CEER-X-184

CEER-X-184

PROCEEDINGS

(Vovume 11)

OF THE

AST PAN AMERICAN CONFERENCE ON ENERGY

AND

2ND NATIONAL CONFERENCE ON RENEWABLE

ENERGY TECHNOLOGIES

PRESENTED AT THE

XVIT CONFERENCES OF THE

PAN AMERICAN CONFEDERATION OF ENGINEERING ASSOCIATION

(UPADI-82)

San Juan, Puerto Rico

Aucust 1-7, 1982

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?E CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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The 17th Convention of the Pan American Association of Engineering Societies (UPADI-82) was held August 1-7, 1982 in San Juan, Puerto Rico under the auspices of the Association of Engineers and Surveyors of Puerto Rico, Included within the Convention's technical program were six (6) Pan American engineering congresses in the following fields: energy, environmental, civil, cost and engineering, economics, oceanic and education. The central, unifying theme of the congresses was ?Engineering as the Keystone in the Development of Nations."

The Pan American Congress on Energy, co-sponsored by the Center for Energy and Environment Research of the University of Puerto Rico, was held jointly with the Second National Congress on Renewable Energy Technologies. The high quality of the technical presentation was widely acknowledged and frequently praised by the participants in the UPADI-82 Convention,

Inorder tomake the presentation on the energy congresses available for future use, CEER is publishing these proceedings. It is hoped that the material contained herein will help expand the technical knowledge of the subject and thereby to promote a better understanding among the Latin American engineering community in the true spirit of UPADI's mission and goals.

Juan A. Bonnet, Jr,

Technical Director, UPADI-82

and Director, CEER/UPR

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FOREWORD

by

UPADI-82

Pedro A. Sarkis, P.E.

Eneray Congress? Director

?These ore the Proceedings, Volume I, of the Energy Congress held

uring UPADI-82 on August 18, 1982 in San Juan, Puerto Rico, The

Energy Congress was composed of the Second National Congress on Renew

able Energy Technologies and the First Pan American Congress on Energy.

The Energy Congress was divided into nine sesslons which included

the following topics:

Planning and Economic Studies

Ocean Phermal

Ocean Energy

Hydro Electric

Energy: ?omens

A (otal of 115 papers were presented to some 400 participants, In

this Volume 11 are Included the sessions on Planning & Economics Studies,

Ocean Thermal Conversion, Ocean Energy, Hydro, Energy Conservation, and others.

The Conclusions and Recommendations from the Energy Congress and also the Puerto Rico National Speakers were published as a courtesy of the Center for Energy and Environment Research of the University of Puerto Rico and can be ordered from them a well as this publication and Volume | oft.

Finally, thonks to all the members of the Energy Congress, the moderators, speakers, and the sponsor and co-sponsores of UPADI-82 who

helped make this Congress a success.

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Estrategias para el Desarrollo de las Fuentes

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Community Issues in the Development of Re- William Ocasio, J.A. Bonnet Jr.

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£1 Financiamiento del Sector Enerofa en

Pmerica Latina para el Periodo 1980-1930 Pedro Vicien

?Arternative Energy Resources and Technologies

for Rural Third World Countries D.K. Sood

?Arrangement according to presentation order at UPAD! 22.

To facilitate the location of papers the following colors have been used for

the front pages of the papers:

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others, golden rod,

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Newton 6, wattis

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UPADI 82

?San Juan, Puerto Rico

August 1-7, 1982

Second National Conference on Renewable Energy Technologies

SUPPLY FUNCTION RELATIONSHIPS FOR RENEWABLE

ENERGY RESOURCES

By

Mindi J. Harber ~ William Steigelmenn

Syneric Resources Corporation

Bale-Cynwyd, PA ~ USA

San Juan, Puerto Rico

August 1982

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SUPPLY FUNCTION RELATIONSHIPS FOR RENEWABLE

ENERGY RESOURCES: PACIFIC NORTHWEST

Mindi J. Facber*

Willian Steigelmann, 7.2.**

vpaDI-82

Puerto Rico August 1-7, 1982

apsTRact

Development of wind and solar energy potential does show promise

in the Pacific Northwest (PMH). Installations of hydro, geothermal,

wind and solar energy conversion systens may approach 12,000 MW caps

sity in the PYM by 1995. However, it is more Likely that these ins

lations will total 1,800 4M, given the current and forecasted state of

the technologies and a host of factors affecting their development and

ues

market peneteation in the cegion. ?Average capacity (ave)

provide far better indication of the actual electricity produced by

these systems, and are the basis of the supply function relationships

developed for each technology. Forecasted prices of electricity in

the cost-competitive range are predominantly for hydro and wind energy.

ernooucrtoN

?This paper presents the findings of a cecent study of supply func

?tion relationships for alternative/cenewable technologies done by

?Energy Analyst/Bcononist.

sevice President.

---Page Break---

Synergic Resources Corporation (SRC) for Washington State university.J/

Supply function relationships have been developed to araphically pre~

Gent threo possible scenarios of development of hydeo, geothermal,

wind, pnotovoltaic and solar thermal electric eneray generation poten

saat show how the price of a given

product" varies a8 the quantity that is produced changes over time.

In this paper, the "product? is expressed as the average installed

in the PNW. These relationshis

© senerating capacity (MMave i.e., defined as the product of

actual installed capacity and the expected average capacity factor) of

five technologies in the PNW, Three distinct five-year time periods

for installation of hydro, geothermal, wind, photovoltaic and solar~

shersal

jeray systens have been

Joumed to illustrate all changes in

?che situation with c

spect to economic competitiveness and available

supply during the period when MPSS nuclear units 4 and 5 were planned enter comercial operation. Three scenarios of renewable resource

lopment are considered: 1) "pessimistic" - high capital costs,

Gelayed mass production capabilities, poor plant reliability, and sig=

nits

sant institutional/regulatory impediments; 2) ?base ~ capital,

costs, production capabilities, plant reliability, and insititutional/

reguiatory considerations are based on logical expectations: and 3)

optimistic" - all factors are somewhat better than the consensus of

predictions

?This study commenced with an appraisal of the phenomena, its his torical development, and current design alternatives. This comprehen- sive survey considered recent manufacturers? cost ata, requirenents for project and manufacturing facility construction lead tines, esta~ lishment of distribution networks to meet demand, and special finance availability. Resource base assesoments included qualitative deter~ ?mination of the environmental, institutional and social aspects in= volved in development of that potential. Synthesis of project economics with resource base assessments provided the basis for computer deter~ mination of supply function relationships for each energy technology. Actual market penetration ducing the 15-year period was considered for

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Gkfferent omership modes ~ utility/governnent, cesidential/tarm/commer- chal, and industry depending uson the system size and application as Getersined by project econonics. Regardless, substantial penetration Of renewable energy technologies (other than hydro) is not expected

before the mid-1990's,

As the study is quite voluminous, thie paper intends to present only the salient features of

ne technologies evaluated in the comuter

ySis. The renewable eneray system chosen for the baseline analysis,

fare discussed in general terms. system paraneters and costs are pre~

Sented and resource bases ae evaivated in Light of capacity factors

and envionmental/institutional/social oarviers to resource development.

A descr

tors of these technologies is provided. The forecasted supply function

relationships and relevant cost of energy are presented in a final

section,

fon of 2

"¢ Financial situation facing potential ovners/opera-

FIVE RENEWABLE ENERGY TECHNOLOGIES

Systems considered for PhW are primarily ?Aispersed? installations = 5-100 MH facilities connected to/within utility grids or facilities with less that 5 MW capacity of which approximately half are {solated installations with minimal storage requirements, Storage facilities are included for wind and solar installations in particular, due to

the intermittent nature of these resources. The actual paraneters of the systems chosen are indicative of the present and near-future state-of-the-art technologies as well as the proven reliability and regional penetration of those systems.

eric Ener:

Hydroelectric technolory is vell developed today and close to obtaining maximum efficiency. Cost reductions have been made through standardization and packaging of all equipnent components. Additional

---Page Break---

cost savings nay come from using puaps in reverse as turbines

and

power provides the PNW with 120 billion <{lowatt hours annually; most

of the Large-scale hydro projects considered economically feasible and

ly accepted in the region have already been daveloped.2/

?The Pacific Northwest Bneray Zolicy Project indicated that the PNW

ic potential, primarily in low-head -

hyéroturbine technology must be improved, especially

far dan/civil works consruction techniques. Conventional hydro-region has a very large hyéroeie

sites. vowshes

Ln terme of reducing the coste of turbine generators for sites with

heads legs than 9 feet.

Several comprehensive studies of hydroelectric power potential in

the PM have been recently compleced. SRC chose to use the J. S. Army

Corps of Bngineers' National ydropower study.3/ This data base pro~

vides 21 existing dams (to be retrofit) and new sites which had been

previously identitied for potential development in the region. The

Corps" active inventory included

tions for each site identified. SRC disregarded these numbers for two

pacity, eneray and cost calevla~

reasons: 1) the Corps assigned more excess capacity than expected since it subsidized hydro projects by below-market fede:
rates, and 2) the economic sizing routine employed by the Corps

2 interest

resulted in smaller sites being penalized by excessive land acquisi-

tion costs which are not always warraned. SRC did use the hydraulic head and mean flow data, as well as the current statue and actual

Anventory prescreening for social/environmental constraints.

Hyroelectric resources in the PAW may be segmented by dam height and flow. Dans less than 60 feet may use bulb, Kaplan or propeller type turbines,
ranges for Francis turbines. Above 200 feet, Pelton tucbines may be considered. The greater the flow, the longer the time needed to design, Procure and install the structure and equipment. Table 1 presents a

ads between 60 and 200 feet are typical operating

watrix of head (feet) ranges and stream flows (cubic feet/second) ,

resulting in the 9 categories used in the PNW analysis, Table 2

---Page Break---

PW RESOURCE BASE SEGMENTATION

; 1

Minimum Development

Py Bead Lead Tine (Years)

« Existing Dame New Dane

eng shan 50040 or tess |

51 to 200

chan $00 20 o sore

co 1000 | 60 or less |

9 1000 51 co 200

to 1000 201 or nore

or more 50 or lees |

or sere | sito 200 |

|

or more | 201 of more

Table 2

SEWERGIC RESOURCES CORPORATION

?SENERGIC RESOURCES CORPORATION

SAPACITY, ENERGY AND COST ESTIMATES AP EXISTING

SAMS_IN THE ACTIVE IWEWORY

SAMS IM THE ACTIVE mwvEWTORY

Nomen meneayra, | crewman | caprmar,

| Ptow/texo or ?capacrty ?Bueno cost

SROUPS stmes 60) (or (s wrut-108W

oral 100 rae

Source: Reference 1

---Page Break---

provides SRC's evaluation of all existing dams identified by the Corpe

active inventory. The ainimua development lead time required for each

project was used to estimate the tine frames for hydro deployment in

the 2a. If the economics of 2 particular type of project (e.., new

dam, sign nead, low flow prosect

ours not take place as shown in this schedule.

) ace unfavorable, their development

Geocnecma! Enersy

Gectnermal eneray provides + hear source of lover temperature

chan anat used in convention: station power plants (typically

300°-500°F instead of 950°-1050°r), and as a consequence, nore hh

input per xih electricity generaced is cequired. Geothermal fluids

Jsonetiner called ?brines*) differ

eatly in their chemical and phys

cat

acteristics from one resource area to another, and even anong

5 within the ame aces. Such ¥:

ations make it difficult to pre-

ct corrosion and deposition ("fouling") effects, and to estinate

power plant emissions prior to obtaining site-specific fluid samples
by well drilting.

Geothermal resources are normally divided into four broad categor-
?vapor-dominated hydrothermal convection systems: Liquid~dominaced
hyérothernal convection systems; hot-igneous systems (including both
hot-dry rock deposits and magma systnes); and geopressured deposits.
The U.S. Geological Survey (USGS) has identified two high-temperature
Liguid~dominated hydrothermal convection systems in Idaho, eight in
Oregon and one in Hashington.4/ Six of these eleven systems have an

?estimated electrical potential greater than 50 MWe for 30 years, {lu
strated by Table 3, Although there are also hot-dry cock geothermal

resources in the region, it has been assumed that these will not be z
fully developed until the end of the century.

Because the identified geothermal cesourcee suitable for commer~
chal exploitation in the PMW are the iquid-dominated hydcothermal 4

---Page Break---

Table 3

SUMMARY OF GEOTHERMAL RESOURCES

?DULTMP py REGION SUTTABLE FOR NEAR~TERM

?ELECTRIC POWER APPLICATIONS

ee OT

rescurce | et i

| rommrace | "aptct | saguence |

ise ae | | see

\ sauna

me

elas

?regen

eae Ee 2 ;

cee Bot Spgs is » :

SRC hi

geothermal resources.

economic assessnent.

Source: Reference 5.

determined this to be the likely sequence of development of

This is the sequence code employed in the

---Page Break---

type, the power plants are assused to be either flashed-stean cycle or

binary-cyete planes. A flashed-steam plant uses geothermal ste:

Sirectly in a turbine to generate electicity. Flashed-stean geothermal

power

and the Philipines. Flashing not water to steam maximizes the electric

generated per unit of vapor /liguid mixture obtained from the

Production wells, prior to reinjecting the Liquid into the ground.

snts have been operating successfully in Mexico, New Zealand

Siver 1-3 identified in Table 3 will use flashed steam vhile sites 4=

AE will use binary-cyele. In binary-cyele, the hot brine from the

Production well is used to heat and vaporize a working fluid (i.e.,

rigecant such a8 ammonia or isobutane), which is expanded in a tur

pine to generate electricity. Regardless of specific plant design,

the power plant will be sized smaller than convention! coa

fand nuclear~

ed plants: $0-110 MW plants have been found to be the sost economic

sné practical. gach well typically contributes the equivalent of 1-10

Mi and should be spaced on the order of one well per 15-30 acre:

Estimates of the installed capital cost of flashed-steam or binary-

cycle geothermal plants range from $800 to $1500 per installed kW capa

city, Cepending on factors such

unit size, quantity of units at

site, ete. (See Table 4).

One of the most significant factors affecting power generation

costs is the temperature of the geothermal resource: the higher the

temperature, the higher the plant's thermal efficiency and the lover

?the bus

bar costs. The potential cost is reservoir and resource owner-

ship-specific. In general, the production cost of geothermal fluids,

including an "appropriate? risk-adjusted return on investment, is

expected to be $1-4/miilion Stu, The actual cost will depend on the

level of development of geofluids by fuel cesource firms and utili~

ties. Substantial development of PNW geothermal resources will depend 4 lupon the availability of Federal lands for exploration and development.

Existing Land management procedures are inefficient.

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?T sovexezoy s902n0s

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Hind Brera

Wind energy is the only solar technology with some actual commer?

ation in the ragion, sostly in the form of 2-10 kW unite

chal pene

for residential/farm applications. Six wind energy conversion systems

(BCS) were chosen to cover the ent:

modes currently existing. The operating characteristics of the WECS

and their forecasted inatalled costs are presented in Tables 5 and 6.

Smal) WECS, denoted as SWECS, include storage at substantial cost a8

re range of sizes and ownership

carta: technologies become commercially available, Portland General

Blectric currently has nine SWECS hooked to its grid and Klickitat

installed 12 SWECS in 2 residential test program. SWECS

produced to date are distributed by ten outlets without strong geo-

County PUD hi

graphic penetration within the PNM. A vast network of distributors is essential for fur

1ec comercialization since prospective owners do

not nave the resources to install/maintain their own units or pay for

said services by a non-local firm.

Approximately 10 MW of wind energy have been developed in the Paw ?theough government programs. Anticipated reductions in Federal wind budget will postpone deploysent of both state-of-the-art and advanced cost-effective models. For example, three DO MOD 2 unite (2.5 Mi each) erected at Goodnoe Hills, Kashington, are still awaiting opera- tion, The start-up of the MOD 5 é-KW unit depends on the reliable experience of its predecessor. While budget cutbacks effectively delay projects and lessen the chances for achievement of DOE cost. goals, testing problens and delayed investigations into mishape have impeded development of the fev large commercial WECS installed in the PWW. Eugene Water and Electric Board, in conjunction with 19 other Oregon utititis

Dareieus vertical-axis WECS.S/ Pacific Power and Light is testing its WIG Systens 200-KW WECS with substantial difficulty. PuW utilities

, 18 awaiting the maiden run of Lts S00-kW Alcoa

fare considering nore purchases and possible ?windfarm" ventures, but

the level of activity in other US regions and poor lead tines

---Page Break---

0

200

500

ee

ane

?Table 5

SSTICS OF MBCS USED IN ANALYST:

Rated

Wind Speed | cut tn/cut out

Winds (mph) Ownership

a 8/80 Uti ity/Government (testing)

Residential/Parm

23 9/60 UeéLity/Government (testing)

Residential/Pare

cy a/s Residential/Parm

30 3/50 Oeitity/covernaent

Industry

38 aayso Ueiity/Government

industry

8 yas UtiLity/Government

Industry

YALL WECS are horizontal-axis WECS except for the S00-kM unit which is a xis, two-bladed model.

?three-bladed aodel.

Reference 1.

?ua

The 200-KW model is the only

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rable 5

RISTALUED MECS COSTS USED 1M ANALYSIS*

(item [es as

some | 26,20 20,075) | 32,300 assavay | 8,000 2,280)

| soe | 35,500 «42,3781 | 28,000 ¢40,230) | 22,000 (33,580

| ann av | 202,000 259,200 13,480) | 220,000 246,780)

500 ew | 600,000 520,000 (679,130) | 490,000 (582,000)

wees costs used in Scenario II.

108 Leas th

costs in parentheses include storage of S hours for

1985+

19908

19958

Soure

sn these costs.

6,400,000 |. #+480,000

Entertech 20 kWh battery $1,490.

Entertech 50 kwh battery $3,755.

Independent Energy Systems 16.96 kWh battery (5 units) $12,275.

Punped storage for all WECS in 200 kWh, S00 kW and 2.5 MW at $245/KH

capacity plus $18/kih stored for 5 hours.

58 cost deer

Se on storage costs in 1985.

108 cost decrease on storage costs in 1985.

Reference 1.

ch ECS.

Scenario 1 costs are 108 more and Scenario 112

---Page Break---

?exsggera'ing rising costs) have effact:vely stymied the secent popu-

7 Of this alternative mode of energy production.

esos

availability is sfvected oy regional topography, land

sequicements for WECS siting, wind regimes and constraints of wind~

hyer Antegration for storage purposes. WECS may be sited along ste

de tops and throughout windy plains, provided that the sites are

sececsible overland. Bquidistant spacing of ¥ECS to avoid wind shadow-

Aa 8 seven rotor diameters in areas with prevailing winds and cen rotor diameters in aceas without prevailing winds. A 3.66-acre pad

say 20 required around each large WECS for safety precaution in poten

S40) theown Blade/toppling incidents. Others include: 1) additional

sights to unobstructed wind flow, 2) purchasing/leasing of Federal and

te lands, 3) zoning issues, and 4) Federal Aviation Administration

?quirements, WECS produce no pollution and present no more safety risks to consteuctors, users, and owners than those faced by a utility Lineman,

Wind regimes prevalent in the PNW are illustrated in Pigure 1. Seasonal wind data revealed several promising high wind regions along the Oragon and Washington coast, in the Columbia Gorge and along ?exposed ridges of the Cascades and Rockies. An abundance of sites located in areas of low population density is supplenented by an equally great quantity of developed and potential hydro storage facii- ties. Wind regime data evaluated with ©:

the six WECS used in the analysis cesult in average annua? capacity factor of 20 to 60 percent.

spect to the paraneters of

Photovoltaic systems

Today's photovoltaic (PV) market is dominated by only one tech~ nology: silicon monocrystal cells, The price of electricity generated by this system is far from competitive with conventional generating facilities, and the cost of the solar cell array is the dominant factor.

a1.

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*L souaaazeq 90205

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ooe-00z ?osi-001 = tt-we a-r

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Wor WW Sav Gia Go

y omprs

oe

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However, as seen in Table 7, the array has the greatest potential for cost reduction and technological improvement while the balance of plant '30P) is relatively well established. The US photovoltaic manufac- taring industey has grown from eight companies in 1976 to the current iS fiems. But PV activity is localized in areas of good insolation.

cee

Pederal PV budget cuts will lessen the curtent momentum, conmer- cial firms are expected to continue in PY manufacture, cost reduction,

and cevelopment of advanced arcays.

Pive sizes of PV systems vere considered in the baseline analysis = 10 XM, SOkW, 300kH, 1Mf, 10 MW. However, these sizes represent gen= eral modular configurations applicable for the residential/farm sector, peimacy metals and chemical industries, and utility demonstrations.

?The potential for eventual PY market penetration in the PNW exists. The najor consideration is the technological evolution of PV systens and it is unlikely that manufacturers will begin mags production until 1995, when the flat plate technology will probably mature. PV systems

?are overdesigned for the most part, and an effort to streamline the models and eliminate unnecessary hardware will complement mass pro- @uction. As for tracking and concentrating PY systems, production economics made these unattractive alternatives for modular flat plat arrays, Basic installation procedures vill become less expensive with time once # substantial distribution network is established.

?The availability of solar radiation varies significantly by region within the PW, Five climate zones, as determined by the Western SUN Solar and Weather Information Series,8/ provide the basis for compari-

son of regional total horizontal and direct beam normal insolation values (Seo Tables @ and 9). Photovoltaic eystems require good total horizontal insolation at relatively level sites, Actual land require

ents vary inve:

ely with insolation values and PY requirements of 4-8 acres/M¥ may result in conflicts of interest over land use. Legal ?Guarantees of uninterrupted solar access must be made in order to

---Page Break---

table 7

2Y SYSTEM INSTALLED Costs

(1980 $m)

oar Scenario T Scenario 1 Scenario 11

1985 rid Isolated cid Isolated cria | _teolatea

Array 7,000 7,000 6,000 5,000 5,000 3,000 pop | __3,000 32,000 7,000 10,000 5,000 8,000

Py | ?25,000 15-000 73,000 16,000 Tora00? | T3000

asso |

arcay 4,000 4,000 3,000 3,000 2,500 2,500

pop | _ 3,000 12,000 61$00 9,500 44/500 7,500

Pv 72,000 15,000 9,500 72,500 7,000 10,000

1995

Array 2,000 2,000 1,400 700 700

BoP. 3,000 10,000 5,000 4,900 7,000

Pv 70,000 12,000 7,400 $700 7,700

ote

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Table 8

-TOEAL SORTZOWEAL INSOLATON

(Btu/ft2-day)

Table 9

DERECT BEAM NORMAL INSOLATION

(Btu/#e2-aay)

ra I

ss mom eee eal Z|

Zone

}?_??___tore______|

Puget Sound/Willamette Valley

cascades

Northern Rockies

Columbia Plateau

Great

in

North Pacitic Coast

Derived from Reference 8.

1897

2000

1500

---Page Break---

promote PY development. Seasonal variation reault in a 25-45-30 per-

cent of total annual energy potential during three hydro seasons:

Capacity factors for PV arrays canged from 15 to 30 percent, while

summer values averaged above 25 percent. Development of PV resource

potential involves minimal dust effects and no pollution. A number of

iasues as vell as other envizonsafety issues do exist; however, the

sental/social concerns are not of major consequence since PV ie a tech=

nology for primarily dispersed applications

Solar Thermal Eneray

Solar thermal electric (STB) systems have more critical siting

requirements than photovoltaic systems due to their reliance on direct,

normal rather than total (@irect plus diffuse) insolation on = south=

facing BV array, lack of geometric flexibility, large construction

support requirements and potential environmental impacts, Table 9

provides the seasonal and regional diffecences in direct beam normal

insolation for the PN. All STE technologies require naturally flat

ding and total area requirements (which

are proportional to plant capacity or cating). A 100-¥H STE plant

built in the Columbia Basin of in Southern Oregon or Téaho would require

ore than 1000 acres of contiguous land at a cost of $750-52000 per

acre. Land at $5000 per acre still constitutes only about 3 percent

Of the capital costs of a STH installation, and minor deviations from

terrain in order to aininize st

ens

wmouint would have a negligible effect on both capital and bu

bar costs of » ST® plant.2/

STE plants have tremendous water cequirents for operation of ?wet* cooling towers, collector washing, etc. the oils and salts used in working/storage fluids of STE plants pose a potential threat to the water supply. Other environmental concerns include air cooling of in collector field, shading effects of closely sited collectors, conflicts Of interest over land use, threat of misdirected solar radiation and fic

and demographic fluxes due to large-scale construction projects.

---Page Break---

STE systems are still in the R&D stage: outside of the parabolic trough demonstration in Arizona, the Barstow project will be the first cei sceiver pilot plant and the Shenandoah experiment will be the

first parabolic dish power plant in

is hindered by Low demand and dizeconoaies of scale. The development

of thermal storage systens will have moce leverage on the expansion of

the STE market. without storage, direct solar conversion syatens are

an

1¢ US. Production of STE units

Limited to a capacity factor of 20 percent of less in most of the US.

"Shas emerged a2 a premising choice for industeial and intec~

mediate load applications in the southwestern US. While Cheyenne, Washington, is veing considered as one of six potential sites for the Smal! Community Solar Thermal Power Experiment, it {3 unlikely that

the PNW site will be chosen, Howe

funded and comercial plants of reliable 30-year Lifetine ace not

1, these projects are federally

expected until 1990. The development of competitive STE systens depends on the evolution of designs for collectors, receivers, power conversion units (cycle turbines) and storage options, as well as continued Federal funding. STE systems have 3-4 year lead tines. Although the costs of parabolic dishes are expected to be lower than those of parabolic troughs, there appeared to be no rational basis for distinguishing installed costs between these systens and those of central ceceivers (See Table 10). The choice of system size also appeared irrelevant since the sodular units maybe combined into any able insolation and Land

number of possible configurations, given a

EIWANCIAL SITUATION

Renewable energy installations are capital-intensive, posing finan~

cial problens for the owner, whether a utility, business or individual.

Individuals ané businesses must either make a very large downpayment

OF find an institution willing to make a loan, The banking community

As reluctant to make loans of this type because of perceived high risk.

Banks have very Limited experience with financing alternative energy

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devices and are uncectain about systes Lif

a5 an investment (i.e., its cost-offectiveness) and the quality of

workmanship which affects all of the foregoing.

and reliability, ite value

Beisting state and Federal tax credit programs are only slightly effective in aitigating the downpayment hurdle faced by individuals

interested in renewable energy facilities. for instance, the Federal

governnent offers calibrated investment and energy tax credits for

Purchases of solar eneray equipment (See Te

fe 11). The energy tax

credit is the principal federai tax incentive for privately-owned solar

faciii

credits, Public utility solar ingtallations may qualify for 4/7 of

the allowable investaent tax credit if covenue does not affect the

base rates.20/ In addition to Federal tax credits, ali states in the

PNW offer sone type of tax incentive for privately-owned renewable

Public utility property does not qualify for energy tax

energy facilities

?The provision for connection to electric utility grid is a key

feature of dispersed alternative enecgy syst:

intertie applications will determine, in large part, their penetration

in residential, farm and comercial markets, tility buy-back cates,

capacity credits and standby charges are powerful determinants of the economic viability of an installation. At this time, all of the utili-

ties in the PNW have yet to set just buy-back cates for electric power

Generated on site, in spite of the 1978 passage of the Federal Public

Utility Regulatory Policies Act (PURPA). In fact, interconnection

Atselt has been very difficult to obtain, one Oregon utility requires

& large anount of Liability insurance prior to interconnection. Since

Utility reaction to

WECS are not certified products, euch situations effectively prohibit

utility interface.

Capacity credits are normally assigned 20 individual generating

a

facilities on the basis of the percentage of tine the unit is

mnie

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maple 11

[FEDERAL TAX INCENTIVES FOR S72 DEVELOE

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pence ox cuit |

|

since 1962

nest -

Limit $25,000 plus 798 Tax

Liapility*

?eeful Life - 77 years = 108

tax Credit 5-6 years ~ 6-2/28

| 3-4 years ~ 31/38

we

198s |

otal Tax Liability |

7+ years - 158

5-6 years ~ 108

Bed years = 58 |

70 increase to 908 by 1982.

Source: Derived from Reference 10.

---Page Break---

able to produce power icing the year. A credit

Per xW per month) is granted to eaca facility on the basis of the capa-

sity displaced, i.e.) tne amount of conventional generating capacity

shat may be omitted from the utility's own aenecation requirements.

Historically, atilities have bec: quise conservative tn assigning capa>

city credits t9 new technologies.

Granted <0 either hydro 2¢ WECS unis

date, no such credit has deen

fn the eM.

PORECASTED SUPPLY FuNCEYONS

fon the basis of the

enecay systems ace fo

Fecoing discussion, quancities of renewable

sasted to be installed during each five-year

Period according to ownership and scenario assumptions. Total instal

Led capa a.

Wnile total PNW installations say approach 12,000 # under the most 'y in 1995 for each technology is presented in Tab:

optimistic conditions by 1995, ie ie more Likely that their market Penetration will be Limited to 1,800 %f, This is apparent from the Preceding discussion of systems, resource base, and environmental/insti~ tational,/financial conditions affecting deployment of siternative eneray systems. However, installed capacity is not an appropriate indicator of alternative energy resource development, since the intermittent nature of the resource, institutional constraints and less than ideal capacity factors will hinder actual use of atl installed capacity.
Average capacity (Mave) takes these factors into account and has been sed as the basic "product

tion relationships.

Hiable in determination of supply func

Foree:

ted installation data are conplenented by the cost data

Presented earlier and other economic variables (fixed and variable O&M

costs, salvage value, lead time, operating Life time, olant availa

bility factors, etc.) The levelized cost of electricity generated from

each resource is computed using a present value cost methodology devel~

ped by SRC. ?The salient features of the cost methodology are: 1) a

five-percent real discount rate is used, 2) a theee-percent cea interest

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rate is used for debt and equity for both public and private utili-

ties, and 2) sunk capita costs are ignored. This cost calculation is

for prioritizing reso

ce options from a broad regional perspective.

Thus, levelized costs co not necessarily correspond to the rates utili

ties night charse.

ani

pated prices of electsicity generated by renewable eneray

systems, quoted in mil!s/kWh, are plotted against average capacity

1d cum:latively over the fifteen-year period. The resultant

supely function relationships are graphically displayed in Pigures 2-6.

Three curves ace presented: P= Pessimictic scenario (I); B= Base

scenario (I) and 0 « Optimistic scenario (113). Depending upon the

quantity of systems installed and the particular characteristics of

the locstion and economics of the installation, #

supply function

cises within any pac

volar five-year period. Between each period,
the curve drops vertically to the most cost-effective alternative
?energy increment to be installed in the next tine frame.

Hydroelectric energy in both the pessimistic and base scenarios
is cost-effective except for very small projects which would be the

last to be installed at the end of 1990 and 1995, The base and pessi-
istic scenario parallel one another for the first 360 MWave installed
fn 1990; the base scenario then continues for another 300 Mwave in

1990 and 250 Mave in 1995. For the optimistic scenario, hydroelectric
facilities are cost-competitive over almost all of the 1,980 Mwave
installed. the price of hydroelectric power generated in the PAW ranges
from a low of 14 mills/kih in 1985 to a high of 162 mille/kim at the

fend of 1995. Most of the capacity to be installed and operating at a
cost below 60 mills/kWh is considered cost-compatitive with other
resources in the PNW.

Geothermal installations are not cost-effective in the PXW ducing any of the time periods considered, with costs ranging from 240 mills/k¥n

in the pessimistic scenario (1990) to a low of 125 mills/kih in the

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optimistic scenario (1995). The poor economics of gecthernal-generated

electricity in Puw prompted an investigation of geothermal district

heating applications in the cegion

?The lover, temperature resource

was somewhat less expensive, however, that application did not fare

much better. Compared to inexpensive hydroelecr ic generation, no

future for massive development of gecthernt

resources is expected.

The price of wind-senerated electricity in the PW ranges from a

igh of 90 mills/k¥h in 1990 to a iow of 25 mills/KWh in 1995 for the

base scenario (11). in the pessimistic scenario, WECS become cos!

competitive only during 1995. Aesidential WECS are cost-competitive

in 1995 base scenario, while installations by other

Dacome economical until 1995. Soth residential and industrial appli-

yetors do not

cations of WECS are cost-competitive in 1985 optimistic scenario.

However, industrial WECS becone

1995, All WECS installed in the optimistic scenario are quite cost~

effective, averaging 32 aills/kin.

135 cost-competitive over time. ay

PY installations are far less feasible. Cost-competitive ayster

are not installed until 1995 optimistic scenario, with cesidential/farm

applications as the sost viable. The costs displayed in Figure 5 are

levelized since incremental cost incraases were too small to be shown

graphically. Even 1995 costs are out of the po:

at 200 milis/ximn,

Able range of PNW

owners, with the Love:

Solar thermal inetallations fare slightly better than photovolt~

ic systems. Only 54 YWave installed in the optimistic scenario (112)

1995 are cost competitive with other energy resources.

As seen by the supply function relationships, st {s unlikely that

sone if any of the geothernal, photovoltaic and solar thermal enersy

Potential in the PNW will be developed for electricity production except

lunder the most optimistic of circumstances. However, hydro and wind

Fesources do show much promise. Approximately 2,000 Mfave could be

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seyrarase ous !30:n05

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generating cost

effective power in the PM by 1995. These figures,

serve as a guide to future development, since any changes in the para

eters upon vhich this analysis is based would ©.

sion of che findings of this paper.

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UPADI 82

San Juan, Puerto Rico

August 1-7, 1982

Second National Conference on Renewable Energy Technologies

ENERGY ALTERNATIVE FOR THE CARIBBEAN

By

Juan A. Bonnet, Jr.

Center for Energy and Environment

University of Puerto Rico

San Juan, Puerto Rico

August 1982

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ENERGY ALTERNATIVES FOR T= CARIBBEAN

Juan A. Bonnet, Jr., Director

?nd Environment Research

University of Puerto Rico

ABSTRACT

Because 21? of the Caribbean countries except Trinidad and Tobago are petroleun importers, they ali have been hurt by the dramatic increases in che price of wetroleum during the last decace. Crude ail production has increased significantly in Latin Anerica during the last three years, and the govern= ments of Mexico and Venezuela are attempting tc control «sales in the Cariobesn y offering incentives for energy conservation and the development of alternative sources. International agencies such as the World Sank and the United States Agency for International Development are now working with the Caribbean Development Bank and CARICOM to develop alternative energy sources.

Many different energy sources can be developed in the Region. Though solar energy has received the most attention, its use 1s still limited te crop crying, water purification, Neatiny and distillation. Hydropower. is, used extensively in Dominica, Heit! and the Dominican Republic and hes. great pos tential in others. The use of Sugarcane and other fast-growing plants. mare biomass @ significent alternative. An experinental farm using the bioconver= sion of organic wastes is being operated successfully in Puerto Rico, Also Geothermal ?power ard ocean thermal eneray conversion (OTEC) are two potential energy sources that are basic to Caribbean geography.

Historically speaking, wind is one of the oldest sources of energy in the Caribbean, and preliminary studies have shown that several Caribbean islands Gould benefit greatly from this alternative. However, four environmental. face tors (noise, radio interference, air disturbance and unsightliness) must Se addressed betore wind energy becomes more widely. accepted,

Finally, in view of the perilous dependence on petroleum, conservation is ber se als0a potential energy transfer source of significant dimension,

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INTRODUCTION

There was sore good news for the developing countries from Geneva at the end of Novenver 1981. "> Organization af Petroteum Exporting Countries (OPEC) agrees to increase world of? prices tc USS34 a barrel, but it also decided to freeze this asic price until ecenber 1962, thus protect ing poorer countries from unexcected anc vrsanegeable urice increases,

Yet, unless long range steps are teken soon, the OPEC action may not be enough.? Kearly 100 develcring countries depend ?on of] £0 meet more then 60. percent of their energy eds. Most of them *nport four-fifths of their otal oti requivenents. ve price of ofl, it infiatton-adjusted terns, has quintupled over the past secade , and many analysts predict price increases f three oercert ennuel!y. This ineers that the oor countries now spending 50 billion a year for frported of? could be paying $110 billion a year by: 1990.

To ofrset znis econonic drain, mary countries are turning to the most readily axsilable alternative supply. Forty percent of the developing world's tinder ?eserves may Titeraliy go up in smoke as households and shall Srgustry substitute firewood for oil. In ¢ number of Caribbean countries eaploitation of wood resources is nct in equiliorium with regeneration rates. ?oo¢ end chercoe! weet 2 large part of Haiti's energy requirenents and, £0 lesser desree, those of countries with forest reserves such as Belize, Vominican xepublic, Grenade, Guyana and St. Lucia

hile developing countries contain two-thirds of the world's populatton, they account for enly one-seventh of worl energy's production. The success tha? developing countries achieve in reducing their dependence on imported energy will determine, in large measure, the degree of flexibility they will have in managing their economies in the future. Since the Arab O11 embargo. of 1974, the debt of developing countries nas more than quadrupled-?to $425 billion, causing more of their incere to go for debt service at continuously increasing rates of interest.

The World Bank estimates that up to 30 percent of the developing world's gneray needs could be eliminated around 1990 by maximizing conservation ef forts and by increasing energy production from fuel sources such as ily 35s

coal, ?hydropower and renewables. It has outlined ways of reducing ?those

eneray seeds by 15 percent without sacrificing economic growth during the

coming decade.

During 1981 there has been increased discussion of eneray.? In Novenber

1981 South and North talked about energy at the Cancu, Mexico Sumit Meeting.

Before this in August there were discussions about renewable energy ot. th

United Nations Conference on New and Renewable Sources of Energy in Rairob!.

For months there have been discussions about a World Bank proposal te set Up

@ Separate energy affiliete within the Bonk, so far no concrete agreements

have been reached.

On the other hand, according to the Interanerican Development Genk (IADB)

crude of] productiongis growing faster in Latin Anerice than. in any other

region of the world.? tts 1980 report on economic and social progress in

Latin Anerica, 45 stated that of1 production in Letin America expanded by

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early 10 percent and the region's share of the world o11 production rose arkedly from 7.7 percent in 1977 to 9.8 percent in 1980, At year end, She total 01] output oF the vesion reached .123 Dillion barrels (337,530,0z)m°) , exceeding consunption ny about 70U mil lign barrels (111,291,106m"),, ah increase o* 100 wit1ion barrels (15,898,729n") over 1979, The rate of growth in production wos the nighust size 19/3, and coupares favorably with the 8.5 percent expansion of .379. Copoired ?production of Mexico and Venezuela accounted for nearly 75 sercent of the region's crude o*] production from 1975 to 1880. Although ?enezueta's shore fel} fron 53 percent in 1978 to 37 Bercent in 1580, Mexico's sroduction rose fron 18 percent of the region's Qutput to 37 vercent during the sane period. Concerning ofl exportation, ?the singie nost important event auring the cast tive years has been Mexico's contrigutvon to the regicr's ircreesce sules of crude to externe! markets, the 1AGS veoert said. Mexican of] exports increased 114 percent. in 1977, 39 vercent im 1978, 47 percen: in 1979 and 89 percent in 1960 when they totaled about 303 ui titon barre':. Production also expanded in Argentina, Breeil, Chile, Peru one Suotemale, but eclineo in solivia, end Trinidad ané Tobago? in Venezueia, rroduction declineg by almost, 8 percent asa result of conser vation messures enforced by the Government.

The Mexican and Venezvelan governments are inplementing an important ot) purchasing financing agreement for the Caribbean. The New York ines eaitorial?zed vccently thet the Caribbean 1s being rediscovered agatn.© The agreement covers up to ¥2,000 barrels for eech country. According to the agreement, & sun equivalent? to 30 percent of the value of the crude purchased by ?the recipient country will be financed by the Venezuelan Investment. Fund sand the Centrai bank of Mexico. The lean wiil be given for five years at a 4 percent rete of interest. If, nowever, money is invested in? development orojects, preferably in energy,? the loan? will be extended for twenty years and the rate of interest will be lowered to Z percent.

The World Gank has 2150 called for an international research program to ?improve ang broaden the use of renewable energy technologies. in developing Countries.? The Genk, in a recent report, "Mobilizing Renewable Energy Techs nology in Developing Countries: Strengthening Local Capabilities and. Res search," particularly enphasizes the role of biomass in. the developing Countries. Although in some countries up to 90 percent of energy consumption

Comes from biowass, the report concludes that ?present research efforts to ?improve biomass production are inadequate to begin to realize the enormous potential of this resource for the longer term. A well designed and executed biomass research progran would inprove the productivity of conventional bio- mass materials such as sugarcane, cassava, and sweet sorghum and identify Species that are potentially more productive. the research should be con- ducted. iq forestry and agricultural Taborstories located tn? developing countries".

The second part of the World Bark proposal focuses on the development of technologies for the production of energy from direct solar, wind. smal? hydro and biomass resources. Because a great deal of research to improve these technologies is already being done in the developed and in the more eavenced developing countries, the progran would be directed at assisting less developed ?countries (LOCs) to ?assess and adapt new technolocies for their own national programs. The aim of such an international program would be to develop reliable data on renewable energy technology performance.

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evaluate experiences in vifferent countries with the adoption of the tech-

Fologies, and meke global assessments of future technological developments

and their implications for developing countries.

The Latin Anerica Plan for Action for the United Nations Conference on New

and Reneueple Sources ot Energy recormendes that priority ve given to the

following:

1. Reaioval

asic Supzort

2. energy planning

bl defor ation an cisseminat ior

cl training

2. integra? Regional Development

a. hydroelectric

b. Hrewnod and charcoal

CL liquie fuel production

2 solar energy,

S vegetable residues

geothermal energy

Btoges

wind power

THE CARIBBEAN REGION

In the Carivbean region the crude petroleum and refined products share of total merchandise imports. increased from tess. than 9 percent in 19/1 to about 4 percent in 1960, Petroleut imports into? the Region. increased during 1972-77 from $150 million to $620 million in. 1980, since ail Caribbean countries with the exception of Trinidad-Tobago are net inporters of energy.

?The Caribbean nations share several energy characteristics:7

1) the subcritical size of most national energy systens precludes a choice

of solutionss

2) there are no organized markets for indigenous fuels;

3) indigenous fuels have not been able to replace the use of inported
petroleum;

4) comercially exploitable indigenous resources are limited;

5) there is a shortage of treined personnel to carry out energy assess-
ments and develop alternative energy progranss

6

national governrents resist considering regional cooperative efforts
@5 the best way to approach energy problems.

In the Caribbean, e large proportion of imported petroleum 1s used by the
glectric utility companies which have peak capacities that range from less
?than ten megawatts to several hundred megawatts (See Table 1 and Figures 1A

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and 18). The commercial sector derands for elect: tc energy in the smaller

islands ?are frequently cuinated by che services industries (tourism and

) unt ing for up te 80 percent of all the electrics

al energy consuned in country. Fesidential e'ectric energy consumption

accounts for approximately -0 pe

To solve the energy problems in ih Coribhean Region the First fact that.

must be recognized is that there are ?arge amounts of natura? energy in the

erea wich ere not being utilized. This situation arises fron cormon geogras

phical and ecological circumstances. ?he potential ?or renewable eneray ta

only tow being recegnized by the Region, ané cone countries are exploring the

sSibITit ies for nonconven-tonal sources chrough rasuarch and dewonstravions

A consultanc for the United Wations Development Pregrasme (UNDP) conclu ced recently that hydro, voothermai, solar uno crarcoal siternatives. should be sevelopec with prioniiy in the Carithean. This? recommendation gpnerally agrees with tne report Envy Resources in tre COcc sumber countries.

9

The Action Plan for the Caribbean Environment Progresme? c:

1s for:

1) Assessment of eajor sources of non-conventional energy and their po- tentials for uti} fzetion,

2) Management will involve:

Cooperation and technical assistance in the application of energy accounting systens which may be used as the basis for the formlae tion and implementation of sound national energy policies and proc grammes,

S

Reinforcenent of regional and subregional integrated non-conventio- hal energy activities with the objective of a fuller exchange and dissemination of all available information and provision of traine ing opportunities.

©) Development of a cooperative programme for the implementation of appropriate technologies and ?practices for waste disposal with Special attention to recycling, energy generation ond? the special problens of the smaller 1slands.

Energy sources considered in the Action Plan are geothermal, solar, ocean ?thermal energy conversion, hydropower, biomes, bioconversion and winds

It is important to mention that the United States Agency for International Sevelopnent (USAID), with the Caribbean Development Bank (C03) and. CARICOM, as implementing agencies, is financing since 1979 a $7.6 million grant for energy development, including energy planning, assessment, design testing and dissenination of alternative eneray technologies. Based on the achieves ments of this exorcise, feasibility studies will be prepared in support of further? financial assistance from regional, multilateral, bilateral and extraregional sources. USAID is in the process of formlating additions! assistance projects totalling about $20 million for simier activities in the Dominican Republic, Guyane and Jamaica and for 2 follow-up project for. the Caribbean region as a whole. Already a USKIO loan of $7.5 millon has been

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approved to help Jamaica establish an eneray program. The goal of the program is to strengthen toe island nation's tility to develop and carry out energy projects, expand energy conservation prograiis and develop alternative ergy sources.

Notwithstarcing these positive situs of joverest and action on aspects of the Caritbean cnergy question, it my ge observed that President Ronalo Reagan's Caribbean Basin i: itiative proposal did vot made signiitcant mention of ?energy, even though Pierto Rico ?hes propoced that the Center for Energy and Eryircnnient Research »* the University ov Puerta Rico become the Research and Development center o» energy in the Corivbear. CEER's twenty five year Dackground of dealing win energy - the lect five specifically on alterna sive and renewable energies ~ ares veluable platform from which many pro- blens nay de identifiec ard solved. An encouraging sign may be recent indications ot awareness shat the CB1 will make impact upon existing energy use patterns within the Caribbean. This my lead to increasing awareness of the need to confront the «nergy question, runcrenewable but more importantly renewable, in ?ne Caribbess: more conprenensively.

Seotherme! Power

The entire Caribbean kegion is part of the Caribbean Tectonic Plate which uccupies ssost of the Yerezuela and the Colorbia basins ané moves east rela~ tive to both the North Anerica Plate on its northern edge, and the South Ane= rica Plate on tne south (See Figures 2 anc 3), The entire area appears to have been extensively intruded by large bodies of basaltic magza which devel- oped deep within the mantle of the Earth and moved upward. Active volcanism around the nargins of the sea and copstant seismic disturbances result in continuous readjustments of the crust.

Regions of geothermal reservoirs are generally located along the margins of major crustal or tectonic plates; the Lesser Antilles is recognized as one ?of these zones. A trenendous waste of eneray in these areas cones from volca= nic eruptions, with large amounts of hot (700°C to 1300°C) magna from the antle being expelled through the crust (See Figure 3).

Volcanos exist in the Lesser Antilles. Martinique has the presently inactive Mont Pelee. in Guadaloupe a vein of steam connecting with La Souffriere volcano has been tapped by drilling at Souvillance off the west coast. This drilling has been capped end, because the pressure 15 sufficient to operate 2 geothermal electricity generating station, the necessary plant and equipnent has been ordered. Reports of potential geothermal energy re- sources in Dominica, Montserrat, St. Lucia, St. Vincent, Dominican Republ iy Grenade, Haiti and Jamaica have been published. St, Lucia is already. plan: ning to? develop its thermal source of poner st Souffriere with 1 to 5 mega watt units. In 1969, 3 United Nations ?study indicated in Dominica where the extensive surface manifestations make the geothermal potentiel quite appa rent. In regard to Haiti and Grenada it will be necessary to determine. the origin of the hot springs to learn whether they are geocherica? or geothermal before any exploratory drilling can be atteupted. A feasibility study of geo- thermal potential is currently underway for generation of electricity in te Ooninican Republic.

Geothermal eneray has some environmental disadvantages because gases such

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28 Cerbon monoxide and traces of nydroyen sulphide are capable of polluting the atmosphere. Honever, his problem can be minimized with the appropriate expertise and resources: It is worth owphasizing that at present, few

gttempts have been made t utilize seotherse! energy for cower generation, ihe major efforts made Seve been iv california, New Tealend, extco and Centrat Ausrica

Solar Eneray

Solar Energy as an alternative source of eneray has received the greatest attention in recent times. Essentia'ly all aur enevgy, except nuclear and ceothermal, is derives sirectly or vectly from? ?the sun. The solar Fadiation in the Carivbear Regios *s on the onder of two thousand kilowace hours per square meter per year. Average air terperature varies. from about °F in February to &3-F in September. ?Nearly Tifteen times more solar Fadiation reaches the ecith's surfaces than the toa) consumption of commer al energy. Presently, solar energy 1: used on a very limited scole in the ribbean| for crop drying, water purification, heating and distillation, fo solar st'lls have been built by 4 foreign rescarch institutes, one in daits and one in St. Vincent in the eastern Caribbean. These stills have been Successfully providing potable water to suail rural communities. Solar Cropedryers have been bul! for drying rutmegs in? Grenada, chili peppers. In Guyana, aué sugar cane in Darbados. The «pplication of? soler energy for water heating has reaches satisfactory levels of development. in Jamaica, Harbados end Puerto Rico, A survey undertaken in January 1962 by CEER, in conjunction with the Puerto Rico Department of Labor and Human Resources, indicated that? there were approximately 18,000 residential hot water heaters in use. The devele opment of solar industrial steam generators and solar air conditioner unite is alse being pursued by the Center for Energy and Environment, Research (CER) of the University of Puerto Rico. A !,100 square meter solar air cons Cittoned factory in Canovenas, Puerto Rico, and a rew 400 square mter solar air conditioned Post Office in Guayama, Puerto Rico, are examples of comers cial installations. In Lagos dei Norte, a 2U3-apartnent condominium tm Toa Baja, Puerto Rico, 3860sq.ft. of solar collectors were installed, with a 2500 gallon hot water tank to supply the needs of the mre than 1000 residents.

In 1961 detatied design for a solar energy system to provide 210°F hot water to the Nestlé-Libby food processing plant at Santa Isabel, FcR. wes completed. The final design consisted of e field of sunmaster tube collecs tors with an active area of §0,600sq.ft. Uetatled system simulation Studies predicted the soler array would provide 10'?sTu/year to three different Processes, mcluding pasteurization, sanitation and boiler preheat, thus Fepresenting an annual saving of approxinetely 102,000 gallons of ¥6 fuel

Also in Puerto Rico a 240sq.ft. shallow solar pond system is currently being designed for hot water generation and storage for a a nigh school io Mayaguez by CER which has 2150 develoned a salt gradient pond computer dee sign. Also in Mayaguez, CEER is currently installing s single stage, cold generator designed to use hot water to reciain refrigerant to sustele ?the refrigeration cycle. Over 300 parabolic trough collectors nade of fiber

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Glass, using boat techno? sy, have bee» built, giving promise of great dura-Dility. in the Domimicen ?Republic an on thi Cyritoean island of Anguitla some applicetiuns of natural satt-gracient pords ere presently being consi-dered for solar emrgy stvrage.

In Garuados passive so or designs have den used, An example 1s the Tech

gical Fnerny Unit (TEU) ouflding ot che Canobean Development Fank (COB).

sting cf this passive system 1s in progress. Also 2 solar air conditioning SySteu nas deer Installec and is being Cested tn the new Barbados Government Analyst \cboratory. USAIZ and the (atin Aneri¢se Organization for Energy Development {OLADE! are ?vancine the desis: and abrication of 8 solar sys em ing ti at a total cost of $5, 6 "ion,

The largest solar hot water system in the Cer *bbean opened in Septenber Regia Hosoite? in Jenaice. The project we? sponsored Energy Corporation.

has almes* everything in its favor to make solar industrial energy ® success. It har an outstanding availab?lity of direct (concentra

ble} sunshine; an incre. sing well-documented insolation data base in Puerto Ricos nign eneryy costs; * large established tourist industry which requires xtensive air conditioning, a well established petrochemical industry In such islands 8 Trinidad, Curacao, the Virgin Islands and Puerto Rico. If one wants to try out a new iaca, one tries it either in the most favorable econo= nic envicarment, or at the location where one has the greatest control over 13 operation. ?The fabrication of inexpensive collectors by unskilled Tabor 1s particular. Solar hot water heaters are already being fabriceted in rnany of the islands. in Puerto Rico, a flexiglass solar concentrator collec- sor for air conditioning systems has been developed and $s being fabricated.

It is ny very persone! belief that industrial solar energy is economi- ly viable in the Caribbean, if it is not, it probably will not be viable anywhere else in the worls.

Ocean Thermal Energy Conversion (OTEC).

As a potential source for comercial supplies of electrical energy, ocean thermo! energy conversion (OTEC) offers another viable answer. {t could become one of the most economical sources of energy yet conceived and is abundantly available as a potential source of power for generating electrici= ty. The ?thermal (including gulf currentsh<eneray potential of the Caribbean is estimated at 182 billion KwHr per year.

Strong ocean surface currents pass through the Caribbean Sea from the Atlantic ena continue with increasing speed through the Yucatan channel. The rain current flows at an average velocity of about ane mile per hour. ?Also, temperature gradients between the ccean surfaces and 1000 meter depths are hore .than 22°C (40°F). Great sources of untapped energy exist in these Currents and tenperature gradients. The maximum depth of the Caribbean See is 6,180 meters about 160 kilometer south of Puerto Rico in the Muertos Trough, However, depths of 1000 meters are encountered two kilometers south east of Puerto Rico. CER has been actively working on the development of an OTEC project on the southeast coast of Puerto Rico, Its floating platform laboratory has run longer, continuously, thon any other similar data~

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gathering stetion iy the world at protenly tre bes! tte for this purpose in

the Unites Stetes.!! Janarea is planning an OTEC camonstretion prosect. in

eonjunction with he gov. mens ne fe, Norway anv Firiand through

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made previuine-y evaluat potenciel and Sarbados, on its

east Cosst, of the wave a1 ca its east coast,

Hyéropower

Hydropower is important in fomseico, att? and the Dominfcan Republic.

Hydropower supi'ies 90 percent of power jevererion in Dominica and. 27 percent in the Dumntéan depudtic. It covld also pray er important role in suyanay Surinam ace Jans i. Sr yang, hydro pocentiet of from 7,200 t0 7,600 mega watts nas beer icentittoo, ana in surinan a hydvopower potential of 3600 tegawatts exists. Beitac is interes: im sini hydro sroteess. A Colombia engineering Fira is groviaing tocknte=! asstscance spy halt ond Domintes th order to Jovelou sna! fe hycvoete:sric resources." ?1 centro 1a Gaviota in Colom 12 hes # som mini hycry technologies suitable for. the regian.

Biona:

Broaciy defined, bivuass consists of terressciai eta aquatic vegetation and its reSiques end wastes, including antral wastes. Giovess. $s essentially a renewable and indirect Fora cf solar energy '= sunlight powering the chem cal reaction wich conver's CO, and water "nto svlid green water end oxygen,

The sub-tropical climate of the Caribbean is ideal for bionass and hes been recognized tor its abundance in producing @ rejor form of biomass in the. Past, i.e., sugar cane,

Sugarcane is grown in many ot tne Car?

Lities in garbados, Cuba, Dominican Repctiic, Guyana, Haiti, vanaica, Puerto Rico, St. Kitts-tievis, Anguila, Trinicee aro Tobago. Sugar factories. in Halts are able to satisty 100% ?their energy reu.irenents fron bagasse and 90 per~ Gent of their energy requirements in Barbicos, considerable use 1s nade oF bagasse as fuel for sugarmills in Guyana, Puerto Rico, Jamzica and other countries. Firewood, charcoal and bagasse provide an estimated 80 percent of Haiti's total prinary energy supplies.

ean countries and in large quan-

The energy content of dry bagasse is about §.15 kilowatt hours per kilo=
gram. An extensive program of more thai 51.50 milion for the development oF bagasse and tropicel grasses for eneray use has been going cr since {978 at. the CEER in cooperation with the Agricultural Experimenta? Statson. In this program the alternative use of sugarcane to produce botn bagésse and the manufacture of molasses and aicoho! has been curcued; also the optimveation Of tropical grasses for biomass production has been studied. A snort ton oF ?ovendry" biomass (6% moisture) conteins about 15 militor BTU of energy. This 4s the equivalent of tno 42 ga'icr barrels of ?residual fuel ote ?tn addition, a significant ancunt of sugar ang high test molasses are also. pro=
duced. it has been estimated by CEE® ccientists that 70,000 acres. planted In energy cane would produce yields rousgh'y dosblng present sugar production,

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eliminate entirely Puert Rican run industry 80% dependence on imported nolasses, and reduce Puerte Rico's petroleum imports by 17°.

Jest that costs would) approximate about $1,000 to 51,100 per acre and yielc fiber and volasses product valued in excess of $3000 per cere. In ?Suu.in spite of inflation end rising labor and other costs, ". iz possible at present to slant energy cane in Puerto Rico and produce it at less than $2.90 per million STU.

Studies currently su

Puerto Rice is geograshically anc historically typically Caribbean and Well positioned to esbark cn a biomass energy industry. Located roughly 18° vorth latitude, its tropical clfrate can sustain plant growth on a year-round basis. Temperatures rarely drop velow 50°F. There are literally thousands ?of plane species, both woody and herbaceous, capable of utilizing this cli- fate for continuous growtn processes. Approxinately 80% of the land mass is ?humid, i.e., ?t receives abundant rainfal?, while irrigation is well devel= cped in? the Tensining aria regions. There are six distinct ecological life rones. The lanes themselves offer varied selection for both research and comercial development. Gt Puerto Rican soils there are 9 Orders, 27 Sub- orders, 27 Grect Groups, 24 Fauril4es, and 163 Series, It thus represents

hearly'al? une Caribbean in all its variety.

Biogas is produced when organic wastes, manure, vegetable matter or human waste are deconposed by bacterial action in anaerobic conditions such as those found in en sirtight digester. The bicoas produced has a composition of approximately 55 to 65 percent methane (Cig), 35 to 45 percent carbon dioxide (Cop), and traces of oxygen, nitrogen and*hydrogen sulphide. Tt is conbust= sbi with a calorific value ?of 20,000 to 25,000 kilo joules per cubic meter, and can be used for cooking, heating and refrigeration. Once the gas pro. Guction has ceased in the digester, the residue forms an excellent fertilizer which can be used to grow algae and the ligquia can be extracted for irriga- tion.

A 1,200 pig farm is being operated successfully by private enterprise in the south of Puerto Rico. All of the electricity at the farm comes from local biogas production, and aiso algae is grown as a feed supplenent for the pigs. It has been estimated than the manure from one large dairy cow could yield 2.5 cubic meters of biogas per day, roughly equivalent to one-third of a gallon of gasoline. It has been estinated that waste from one thousand Poultry broilers will be capable of producing about 10 cubic meters of fuethane per day, energy equivalent to one hundred kilowatt hours per day. If ore assumes 30'millions roslers, the energy potential equivalent to the methane produced will be 3 million kilowat: hours per dey.

Jamaica currently has one unit generating methane from animal wastes and has requested $3.75 million from Kuwait anc Iran for a biogas deronstration unit, Barbados has set up three biogas digesters. Puerto Rico is preparing an energy-integrated farm on the semi-arid South Coast. The farm has # current. wilking herd of 400 registered Holsteins, to be Increased to 500 head during 1982. ?The farm's 1982 average power demand will be about 1,680kwH/day, and 24.6 tons of raw manure will be producec daily. The proposed energy integrs- tion system has two functions: (a) to produce green feed, electricity, and

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high-protein feed substitutes from manure, and (b) to establish » waste Management ?system in conpitance with Puerto Rico's environmental ?quality regulations. The propose: eneray-intesrat ion complex consists of eight sube aystens. These include components for neiire preperation and blending, 3 biogas generation subsystem, a biogss utilization subsystem, a solids de- watering and érying subsystem, ané subsystims for wastewster cleaning and Fecycling. A nonitoring? subsysten 1s inciuced to "assure compliance) wich environmental regulations. Fron 30 to 40 vercent of dairy feed requirenents and 60 to 89 percent of ?arm power nesds wil? be provided by the integrated system. Also in Puerto Vico, the Bacard? Corporstion has installed 4 3.3 million, gation anaerobic digester cark to treat. their distiliery residue:

wastes before dumping the into the oces

Disposal of muntcipa? wastes becomes an tnereasingly serious problem every passing year because of continuing urbanization of Caribbeon countries. Tt may be possible for municioal waste to make 2 substanticl contribution to solving woth the energy and waste problens by converting ihe latter to biogas for energy use. san vuany the capital of Puerto Rico has been investigating the metnane potential Of its present Tans. disposed site.

Winds

?The northeast trade winds preva?! over the Caribbean sea. The winds blow Consistently fron the eas: or northeast more than 70 percent. of the tine ot mean velocities of about 10 miles per hour. Because of this favorable condis tion, 2 200 kilowatt wind power generator wes installed by the U.S. Departs ment of Energy (O0E) on the "island of Culebra in Puerto Rico. this. energy machine has produced 584,990kWHir of energy from 1978 to 1961, despite door Eime to improve blade performance and despite the occurence of a Tabor strike. The project is being continued. A salient finding has, however, been the need to involve the community in such projects. In Culebra, attnough the residents favored wind energy as an alternative, their perception of chev oun wind mill's performance mas largely negative, due to lack of participa: tion and preparation.

Several of the Caribbean Islands show creat suitability for the utiliz Hon of wind energy.? The Caribbean has hed long experience in using wind os 2 Source of energy. Boats have been powered by wind for many years.? Prior to the introduction of machinery for crushing sugarcane, smal? factories were Situated on elevated land inorder to use the available wind for driving windnilts to crush the cane. This is true for Janaice, Antigua, Puerto Rice and Barbados. In Antigua the Rockfeller Fousdation has financed 4 12 kilowase windmi11 generator. " Aiso a proposal for two pilot wind generators (50 to 100 kilowatt) has been sent to the United Narions Interin Fund. The Barbedose based Caribbean Meteorological Institute is an active participant. in colle: ing ?information about wind speeds in the Caribbean Region, "A wind turbine jenerator factory has been installed in Puerto Rico by the Future Energy. RED ?orporat ion.

Because of its importance, some comments about the environmental effects of windmills are significant. " The impact o* wind turbines on the environment can be generally classified in four min areas:

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1) Moise effect. The noise oroduced by large wind turbine generators is ?The most objectione:le environmenta? effect. About 1 percent of the time 2 sound anpl**scattcn or focusing problem raises the noise level 0 velues of up te ?7 decibels. This is equivalent to twigg the noise level experienced at a busy ?rwtropulita intersection. ©* Reducing rator_speed apparec?ly solves the problum, Efforts must. therefore be

-costabie noise levels for these environ=

ts and then to aevelop adequate conputer programs to predict the

roise level of planned wind turbsne generators.

2}, Rualointerference effects. The rotetion of wind turbine blades gener:

Fete radio freque cy nove vich my interfere with TV reception.

ra are varfous solutions te this Sroblem depending upon the local

situation,

3} Air cisturbance aru reduction of wind power in nearby private pro

?Suz. ?Wino Flow sottern 1s aTirea by the presence oF © wind Corbite

Ne. At optimuri operating condition ot the turbine the effect

mht oe felt es for as 15 dlansters of the machine rotor, causing

"wing shadow" av uneventlow 0° air to the blades. For s 300ft, dia

ietey rotor machine the effect would be fel: for a distance of 4500ft
nich could affect she neighbor's wind turbine.

4) Aesth jc effects. Wind turbines can present an objectionable sight when Toceted nearby sophisticated residential areast?.

AV] environmental impacts of wind turbine appear to be insignificant when comparea with other energy sources. Consequently, mong, than 100. United States electric utilities are considering wind projects.?> Southern Cali-tornia Edison is aiready testing wind machines in the San Gorgonio Pass and hnas signed ayreenents to purchase as much as 85 megawatts fron 56 wind tur= Dines.? Hawaii nas signed a contract with kind Farms, Inc. to install 20 wegawatt ving turbines on Oahu by 1985. Wind Farms, Inc. hes. persuadgg

Pacific Gas & Electric Co. to buy as much as 350 megawatts of wind | power.

Also three 2.5 megawatt wing turbines (MOD-2) are ggerating at Goodnoe HiTis

ashington for the Bonneville Power Adninistration? with turbine blades. 300

feet long towers 200 feet tall; and the blades rotating at 17.Srpm. In Ger-

ny MAN is engineering and construgting a Growian (grosse wind energian

Vage) 3 megawatt wind energy machine.

Wind appears as one of the most promising energy alternatives for the

Caribbean Region. Coastal winds could be or significance for meeting. local

energy demands and thereby ?reducing investment requirenents for transmission

and transport of electricity and fuels.

concusions

This poner briefly discussed the renewable eneray technologies, geother=

fmol, Solar, OTEC, hydro, biomass, bioconversion and wind which have? the forge

est? potential for the Caribbean Region. fut let us nor forget. that ayy

activity of man causes sone king of impact on the Surroundings, The ei it

developing renewable energy technologies is to look for socially desirable,

econamically viable and ?ecologically prudent nar-nade production systems,

Paradigratically inspired by the ecosysten concept, and capable of jointly a1.

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supplying nunan secessities. Environment appears in this perspective as a resource potentia? to be varmessed on a custaimable basis ands es much ae possible, in an ecologic '-y benign manner. "he eco development ?approach for

renewapic energy techno! jias utviization including wind power ts pore gules solar

< renewable energies devoioument and potentials are sumarized in fable $s inporten: that these renewable energies be examined in the

Tight of ?cur basic forms of energy use, namely: Tiquid transport svels, cens pralized ciectric power, decentralized cower. and reat. These are outlined. tn

Fable 3, ?sew and Reneweb ie Energins iechnstogies and Applications?, pres

vd for the Unites Natons Contcrence or New and Renewable Sources oF

ong new and revcwable energy tecirolagies, minihydro, staltascale

Solar anc osouethacetion eve aiteady feasible ang aveilable for? rapid protic

feration ane decentralizod mode. ?They can. all be used in the Cariboean,

Region. lacie 4 sumerizes present denonstration projects in renenabe

neruies 1? the Garibuean Tegion. Yore details of some ot thesg projects are

given in Snegy Resources in the COCC member countries reoort.© Large scale

ro, gevtnernal andy tx sone extent, ocean poser will? continue to play

saportant roles in centralized networks which principally benefit, uses

grees. The prospects fur biomass and peat techologies such as the pean

Guction of solic, Tiquie and gaseous fuels are of considerable interest

providing thet there are rc conflicts with food production, Because of their

reat ner term potentia! Table 5 list selected Biomass Energy Systems. for

Jaribbeen countries. Sna'T-scale solar technologies for water pumping snd sistillaticr, low temperature heating, cooking, crop drying, ard power gener gtion are available ard are expected to play a significant rove in the nese future. Small and mediun-size windaills used in decentrelized mode see alreacy cost-corpetitive tr many areas, and medium and large windn'lls are expected ?to de attractive enough for? autonomous and integrated modes ?oF operation in windy areas such as the Caribbean. for given promising areas, SEAS important to determine the wind potential and how soon wind will, besos economically competitive.

Other ?new and renewable energy technologies such as the ocean thermal energy conversion, Geothermal energy, large-scale solar ponds, tar sande ond ott shales are ali very promising. with suitable support for research, devel opuent and demonstration, these resources could energe as significant options within short to medium tine frames.

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FIG I-A 1-8 ELECTRICITY CAPACITY AND PRODUCTION PER

CAPITA IN SOME ISLANDS AND COUNTRIES IN THE

CARIBBEAN

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Figure 2

PLATE BOUNDARIES OF THE CARIBBEAN REGION

PLATE CONFIGURATION IN EASTERN CARIBBEAN

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ABBREVIATIONS AND_ACROKYHS

alo. Agency for International Development

2. BoD British Development Division of the

Ministry of Overseas Development, U.K.

Government

3. 608 Caribbean Jevelopnent Bank

4. crOk Canadion International Developrent Agency

5. CONACYT Consejo Nacional de Ciencia y Tecnologia

Mexico

6. Dor + Department of Eneray (U.S.)

7. EOF European Development Bank

8. EIB + European Investment Bank

9. 1880 + International Bank for Reconstruction

and Development

10, 108 2 Inter American Development Bank

1h, NASA + National Air Space Administration (U.S.)

12. 0as 2 Organization of Anerican States

13. OLADE + Latin American Organization for Energy

Development.

14. PREPA PLR, Electric Power Authority

15. Tey + Technical Eneray Unit of COB

16. WW + InterimFund ~ United Nations Interim-Fund

17. UNDP United Nations Development Progranme

18. UNICA + Caribbean Universities and Research

Institutes Association

19. UNICEF + United Nations International Childrens

Emergency Fund

20. USAID + United States Agency for International

Development.

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UPADI 82

San Juan, Puerto Rico

?August 1-7, 1982

First Pen American Congress on Energy and

Second National Conference on Renewable Energy Technologies

ALTERNATIVE ENERGY PLANNING

FOR PUERTO RICO

By

Ronald C. Scott

Puerto Rico Office of Energy

Office of the Governor

San Juan, Puerto Rico

August 1982

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ALTERNATIVE ENERGY PLANNING FOR PUERTO RICO

1 INTRODUCTION

The Puerto Rico Office of Energy reports directly to me Governor and

has the responsibility to coordinate ané integrate all energy related programs.

Specifically, the Office formulates policy, monitors petroleum and other energy

-¥sagey administers an Energy Conservation Progsapt; develops Yné promotes Altern

Live Energy Sources and Systems; and, in general, assures the availability of energy

for the Island.

Because the Government of Puerto Rico is convinced that alternative energy

can make a significant contribution to the long-term solution of the Island's energy

Problems, the Government has appropriated almost $5 million to be made available

for the development of alternative energy sources for Puerto Rico.

In order to expend this sum most efficiently, it is important to quantity

the potential and the "technology readiness" for commercialization for the various

?Alternative Energy Sources isa term utilized to describe a range of tech=

ology options that would diversify the fuel sources for energy production, Tradle

tionally, this has included the "Solar Technologies" which includes all Renewable

Energy Sources. For Puerto Rico, alternative energy could be viewed as any source

?other than petroleum, since 98% of the Island's energy production is derived from

this source.

Currently, there i a surplus of oll on the world market. Supplies tlow

freely and during periods like this, we tend to forget the fragile balance between

?world supply (production) and demand (consumption).

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?The opportunity exists to begin a steady transition to renewable energy

sources over the next decades, and bring on line those technologies which are

proven and ready for the marketplace.

ce in the form of wind, hydro,

The Island i blested witha great solar ce

bioenergy, ocean, and direct sunlight. What isnot know isthe exact magnitude

of this resource. One ofthe frst steps that must be undertaken before wide-scale

deployment ofthese tecnologles by the private sector will accu isthe quantitica-

ton of the renewable esource potential of Puerto Rice. This is one of the key activities in the Energy Sources Area this fica year

?The overall objective of the progeam is to promote the wide-scale exploi

and utilization of energy sources which are reliable, cost-effective and environ=

mentally acceptable.

Artemelire (2)

?The overall strategy of the Energy Sources Program is to create a favor-

?able environment for the various technologies such that the private sector (with the cooperation of Government) can develop and deploy (commercialize) their products:

?The implementation of this strategy will vary for each technology option.
In some cases it may be policy statements and/or tax incentivess for other tech= nologies, it may include research, development and demonstration. In any case,

if the energy source is environmentally acceptable, economically viable and technology readiness proven;

The purpose of this paper is to describe the methodology we have established

to evaluate the various energy sources and to share some of the early results of

then wide-scale deployment would be expected.

an extended planning activity which will culminate in an ?updated? energy policy

statement for Puerto Rico.

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Hl, CURRENT ENERGY USE AND PROJECTIONS FOR PUERTO RICO

?To understand the "energy problem" of Puer:o Rico, one.must understand

that 9896 of the energy consumed is imported petroleum; however, to obtain a clear picture, the energy use by sector must be analyzed.

In brief overview, the total energy consumption peaked in Puerto Rico in 1979 at just over 350 x 15°? BTU per year. It has steadily declined since then to an overall consumption of 315 x 10"? BTU in 1981. Indications are that a further reduction te approximately 290 x 10? BTU can be expected in 1982. Economic land energy use models predict a continuing decline to around 260 x 10? BTU in the 1983 tumneframe. For the same years, the relationship between energy consumption and Gross Domestic Product has been declining, e.g. (1979 = 78.3 x 107

BTU/GDPS; 1981 - 68.6; and in 1985, i is projected at 56.6).

[As in every story there is good news and bad news. The good news is that we are conserving more and becoming more efficient; the bad news is that several ?energy intensive industries have closed and perhaps we are not living quite as well.

We are not alone; in fact, the U.S. recession, coupled with persistently high interest rates and the overall curtailment of Federal spending is the large

driver in the projections.

If we examine the total energy consumption by sector, in Puerto Rico,

we find the following:

?Electricity production accounts for 439%

*Fuels 5%

sBagasse 3%

100%

?This percentage distribution has remained relatively constant over the

last five years,

1nd will probably remain that way through the mid-1980's.

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[An interesting statistic I that the fuels account for 548 of the total con-

sumption, approximately half of which is gasoline. While gasoline consumption for automobiles declined approximately 12% in the U.S. durin fiscal 1981,

jt declined only 38 in Puerto Rico. Liguid {uel consumption must therefore become

?a prime target if energy self-sufficiency is to be realized.

[At the same time as the total consumption of energy in the near-term

is projected to decrease, the percentage for

trical power generation will remain

significant; therefore, another target of opportunity will be reductions in petroleum

usage for electrical power generation.

til, THE PLANNING PROCESS

?The hierarchy of planning can be broken down into three levels:

Policy Planning; Formulation of alternative goal patterns of functional

objectives for the future--based on alternative future environments--

ina (continuous) comparison, selection and feedback process. Policy

Planning--being concerned with goals--seldom involves technological

considerations in any central way.

2. Surategic Planning: Formulation of a set of goals, together with

1 procedure for systematic comparison and assessment. The strategic options involve significant technological developments, especially when the goals are related to physical (or biological) problems, such 1s putting a man on the moon, feeding the world's population, cleaning vp polluted rivers, developing a defense against ballistic missiles,

?or solving the "Energy Problem."

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3. Tactical (or Operational) Planning: Delineating the sequence of actions necessary to implement a particular strategy. Here the well= defined technological (as opposed to functional) objectives would be at the system or subsystem level.

Using these definitions to differentiate the levels of Planning, relating the role

of Forecasting to the Planning Process, does not explicitly provide for Policy

Planning. It is more adaptable to Steategic Forecasting and Planning, making

sion, and then planning in detail atthe Tactical level. Herein ies a major problem, for what most people thnk of as ?planning? is actually atthe tactical (operational level. There is nothing wrong with tis except.the ?goal is usualy

a "piven goal, and the proces of selection is always viewed as a means to an

end.

11 we invert our thinking process and view Forecasting a8 a means to arrive at Alternative Futures from which we can select desirable goals, Planning then becomes the mechanism to achieve the desirable future through an expression of Policy Statements. Ths inverted thinking process can be translated into @ ?model? that allows the systematic flow of information in an iterative process, resulting in Policy Statements that reflect the selected goals and the required Panning for implementation of that policy. Figure I reflects auch a model.

Let us briefly examine the content of the model. It provides for Forecasting of the various areas by whatever techniques proved most fruitful and allows for synthesis of the Forecasts resulting in an Alternative Futures Forecest. It allows for goat-setting to give visibility to each area (Technology, Economics, Social, Political, etc.) and provides for Planning to achieve the established goals leading

to the Alternative Future. This iterative process allows for the establishment

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of Policy Statements which can be implemented, based on detailed plans. The Performance Evaluation block requires a determination of whether or not the goals are being a

ieved and provides for corrective feedback into the Planning block. According to our definition and thinking, everything to the left of the dashed line becomes Long-Range Planning, and everything to the right becomes Operational Poticy Implementation,

?The Operational Poticy Implementation Process is nothing more than committing resources to the achievement of the established goals according to a de~

tailed plan. A mechanism must be built into the process to measure the effec

tivity of the planss and if substandard performance is detected (Performance Evaluation), then new Planning must be provided for, and possibly resulting in, adjustment of the goals. This allows te dynamic process of change and adaptation to become inherent in the Model.

IV TECHNOLOGICAL FORECASTING, OR "MARKET PENETRATION TAKES TIME?

?The first step in the planning process (Figure 1) involves technological forecasting. All new technologies encounter a limited initial acceptance in the marketplace during the years of commercialization. The Technology Utilization Program created by NASA in the mid-1960's studied over a dozen "innovations" and found the average time from first discovery to a product in the marketplace was approximately 15-20 years. Heat pumps introduced in the late 1950's never really penetrated the marketplace until the 1970's, It could be argued that "Pac-Man".

the electronic game--has violated this law of market acceptance; however, electronic gamed have been around a long time and only the low cost micro-chip and marketing.

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ingenuity have provided the recent exponential growth. Historically, the com=

?mercialization process for new products has followed an S-ahaped curve typical

to the one shown in Figure 2.

The first phase is characterized by an initi

lag in the marketplace

resistance to change and perception of high risk, cost and uncertainty. The second Phase is the "bandwagon" period. The innovation rapidly gains marketplace accept= ?ance coupled with reduced cost; which comes about by the learning curve effect ot increased production volume and refine:nents in the technology. The final phase retlects saturation of the market by the mature version of the initial innova= tion,

In the case of alternative energy technologies, the time for each phase will vary significantly. There are several reasons for this:

|. First, the resource potential (ultimate market share) will vary.

2 The level of technology can vary significantly (solar hot water heaters vs. photovoltaic systems).

3. The characteristics of the ultimate user (individual, industry, utilities, tc) will attect the rate of market deployment.

In order to develop a methodology for use in technological forecasting of alternative energy market penetration, it is necessary to estimate the manner in which alternative energy technologies will replace a petroleum-based society.

To accomplish this purpose, three tasks must be performed.

?The resource potential needs to be analyzed and quantified.

2 The various technologies must be listed and their ?technology readi-

ness" assessed.

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3. And finally, the method, time and rate of entry into the marketplace

for each technology must be estimated.

?With the exception of step functional variations produced by the addition

of large centralized energy plants, all technologies are assumed to follow an S-

shaped market penetration curves with only the time to market saturation and

the percent of the total potential to be anticipated as variables.

?The establishment of the limits of these variables, however, is a most diffi

cult task. Expert opinion and a modified Delphi process may be utilized to establish

?a consensus. With this established, the computer then becomes a servant, allowing ?one to make projections of alternative futures by varying magnitudes of the parameters and the combinations. The projection becomes not what will be, but what is possible should policies be adopted and plans implemented to achieve the market goals in technologically feasible time frames.

The scenario of what is technologically possible must then be subjected to the larger model of overall planning--the "ESP" of the problem, e.g., the Economic Social, and Political considerations and analyses.

?The presentation which follows focuses primarily on the technologically feasible scenario for Puerto Rico. This must await further analysis in the coming period as the "ESP" part of the equation is investigated in order to allow the proper establishment of policies in regard to the development.

APPROPRIATE ALTERNATIVE ENERGY TECHNOLOGIES

The following isa listing of alternative energy technologies considered appropriate for Puerto Rico:

---Page Break---

1, Solar Water Heaters

2 Congeneration

3. Hydroelectric

4, Electricity from Solid Waste

3. Small Wind

6. Large Wind Machines (Wind Farms)

7. Methane from Animal Waste

8. Alcohol from Sugar Cane

9. Electricity trom Bagasse

10. Electricity trom Solar Ponds

11. Photovoltaics

12, Synthetic Fuels trom Coat

13. oTEC

18. Other

?The technologies are rank ordered in terms of their commerical readiness

and anticipated acceptance in the marketplace. The first ones listed are tech~

nically proven and have demonstrated economic viability. As one descends dowin

the list, more time is required for the technologies readiness to be reached. We

are now ready to discuss brietly each of the technology options considered and

the basic assumptions which results in the energy savings that might be achieved.

itiate the first iteration which will become the basis for

It is in this way we i

?the planning process and the generation of policies that are required.

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1, Solar Hot Water Hee

?The use of solar hot vater heaters in Puerty Rico, as an alternative to heating water with electricity, is an alternative energy technology which is eur rently cost-effective, ané which shows promise to continue in this status for the rest of this century. Since 1976, the annual installation of units on residences has steavily increased frot> ubout 2,000 units per year to an estimated 5,800 units

er year in 1981. There are presently about 17,009 units installed in the residential

sector. If the rate of installation is assumed to inerease linearally to 12,000 per year in the year 2000, there will be an estimated 187,737 units in place by that time, which represents about 23% of the estimated 800,000-residences which will exist in Puerto Rico at that date.

1k is assumed that each collector averages 40 59. ft in area, and that the average collector efficiency is 40%. It is further assumed that an average of 2000 BTU per sq. ft. per day is available as solar energy which may be collected, Consistent with these assumptions, a plausible commercialization curve for this technology may then be produced. This curve is shown in Figure 3.

ABTU of energy which has been generated by solar hot water systems, land which replaces a BTU which has been generated by an electric heating element, replaces 3.33 times as much energy in the form of imported fuel if an overall conversion efficiency rate for electrical generation and transmission for central {ossil fueled power station is taken as 30%, and if itis assumed that the power plant is ope ated with imported fossi fuel.

?Ata rate of 5.8 million BTU per barrel, itis possible to predict the barrels

of imported oil which may be saved by the predicted solar hot water heater

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an

?commercialization. This has been done for this case, and the results are as follows,

in terms of fiscal years for the commercialization scenario described:

Year 808182848 BKB 90? 952000

Millions 07.20 30.4050 6S. 90.80 2.20

of BBls

of oil

savings

2 Coxpeneration

Co-generation technology may be defined as mechanical devices which

generate electrical energy at the site of use, and which are designed to provide

heat energy to other processes at the same time, thus replacing imported fossil

fuel which was formerly used for these processes.

A recent study by Energy Research and Associates estimates that approxi-

mately 473 MW co-generation potential now exists in Puerto Rico. Of this total;

150 MW is readily achievable, and could be put in place by 1986. This represents

4x 10!? BTU per year (energy equivalent of electricity generated at a 90% load

factor). A plant efficiency of 60% is assumed,

?The technology is current state-of-the-art. The rate at which the co-generation

?will be brought on line is highly dependent upon institutional constraints and how

the PURPA legislation is implemented with respect to the tariff (stand-by and

payback at avoided cost).

(On the basis of these figures, a plausible commercialization curve for this

technology may be developed. This curve is shown in Figure 4, If the BTU per

year values are converted into BBIs of oll per year replacements as far as imported

fuels are concerned, the increase in plant efficiency, over conventional electrici

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generating methods, allows a credit to be realized. The following savings in imported

cil then results, consistent with the described scenario:

Year(FY) 80 8182838 HBB D8 2000

Millions 0.0 0.0 0.9 0.03 0.86 1.58 3.30 3.78 3.78 3,78

of Bas of

ol savings:

3. Hygroetec

Hydroelectric alternatives involve the conversion of ponded natural rain-

fall to electricity through the use of mechanical devices which are designed to

function under very small pressures differentials, thus replacing imported fossil

fuel which is used to generate electricity.

A cecent U.S. Corps of Engineers report estimates 106 MW potential in

hydroelecteic sources in Puerto Rico. Based on 24 hour per day operation, at

a load factor of 100%, the BTU equivalent of this electrical energy is 3.2 x 10!?

BTU/year. The output currently equals 1.9 x 10!?

BTU/year, and may reach the

{full potential in ten (10) years.

Figure 5 plots this estimate over a technologically realistic time frame.

If it is assumed that the energy output from this alternative i

used directly to

replace fossit fuel produced electricity, then a multiplication ratio for saving

on imported oil which is similar t0 that used for the solar hot water technology results, The resulting savings in terms of fiscal years for this commercialization

scenario are the following:

Year(FY) 80 81 «82885 BKB 80852000

Millions 0.86 0.86 0.86 0.86 0.86 0.89 121 161 184 1.8

of BBls of

oil savings

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B

Electricity from Solid Waste

Electricity that is generated from steam which is created by burning solid

waste represents an alternative energy source.

It is estimated that in the city of San Juan, the first 20 MW increment

of solid waste energy conversion will be on-line by 1988. The introduction of

additional units is under study at this time, and it is estimated that the success

of the San Juan facility will result in another 20 MW increment being added by

1992. The BTU output of these facilities is plotted in Figure 6. If itis assumed

that the electricity produced by these plants replaces imported fossil {uel generated electricity, then a multiplication effect occurs similar to that experienced for

the case of solar water heaters. The resulting savings in imported oil, consistent

with this scenario, are the following:

Year(FY) $0 81 82-8488 BE 90952000

Millions 0.00 0.00 0.00 0.00 0.00 0.00 0.34 0.30 0.69 0.68

of BBs of

oil savings

5. Small Wind Machines

Individual small wind electrical generators (2 to 50 kw) to replace imported

oll which is used to generate electricity for residences in Puerto Rico, is an attractive

alternative energy source. They are marginally cost-effective at this date; however,

with the recent passage of tax incentives and the consumers anticipation of rate

Increases, this technology is ready for commercialization in Puerto Rico. It is

conservatively estimated that the commercialization potential is 1%, or ene home

in 100. By the year 2000, this represents 8,000 units for an annual energy production

equivatent of 0.5 x 10!? BTU/year. Because wind technology uses a free source

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of energy, its rate of deployment could be quite rapid as it becomes more cost-

effective. This could change these projections by an oraer of magnitude, or more,

depending on these socio-economic factors. A plot of the BTU output from the

conservative 19 acceptance scenario stated above is shown in Figure 7. This

produces the following estinates of oil savings, assuming the electricty which is generaisd replaces fossil fuel generated electricity:

Year(FY) $0 81-82 88S BE BB 90952000

Millions 0.00 0.00 0.00 0.03 0.06 0.09 O18 0.17 0.23 0.29

of BBis of

ol savings.

6. Large Wind Machines (Wind Farms)

Large wind machines are an attractive alternative as wind farms or central wind generating plants (greater than #0 MW) to replace imported oil which is used to generate electricity for the residential and industrial sectors of the Puerto Rico energy economy.

?The wind resource potential and the site availablity for large wind farms isin the process of being evaluated. The third generation large wind machines will not be under test and evaluation until the 1984 time frame. A reasonably conservative scenario suggests that the first 40 MW facility will go on line in Puerto Rico in 1988, with a second one being added in 1991, and two more in 1995, {for the combined contribution of 160 MW. This represents a total of 4.8 x 10!? BTU/year by 1995.

A plot of the probable BTU output of this commercialization scenario is

presented in Figure 8. The 88Is of oll per year savings, as far as replacement

of imported oil is concerned, is listed as follows:

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a

Year(FY) 80 81 82 48S 86 BB 90952000

Millions 0.00 0.00 0.00 0.09 0.00 0.00 0.69 069 2.76 2.76

of BBIs of

oll per year

savings

Obviously, the cost effectiveness and ultimate success of wind farms is

highly dependent on the electricity purchase rates established by the utility in response to the PURPA legislation.

7. Methane from Anima! Waste

Anaerobic digestion of animal waste residues to produce methane gas which may be used to replace imported fossil fuels in heating and power generation is an alternative energy technology which is current state-of-the-art, small scale, and highly dispersed, 11 is dificult to estimate the potential, but it appears to be at around 6.7 x 10! BTU per year. A capture rate of 22% would thus yield

about 1.5 x 10!? BTU per year by the year 2000. A plot of this production rate is shown in Figure 9. Because the methane that is produced would tend to be used in applications which directly substitute for imported fossil fuel, the multiplication as far as savings in imported fue! is less than that for the solar hot water technology by about a factor of 3. The estimated savings in imported oil from this commercialization scenario follows:

Year(FY) 80 81 82 8% 886 BB 9095-2000

Millions 0,00 0.00 0.00 0.02 0.03 0.04 0.08 0.12 0.24 0.26

of BBIs of

cil savings

8. Alcohol from Sugar Cane

?The production of commercial grade methanol and ethanol from sugar cane,

for use as a synthetic fuel in gasoline/alcohol blends, thus replacing imported

---Page Break---

{fossil fuels, is an alternative energy technology which may show considerable

promise in the decades ahead.

?This technology is current state-of-the-art. The significant market is in

substitution for liquid fuels, such as gasoline substitution in producing gasoho!

(10% ethanol Estimates have been received that the first pilot plant could be

?operational by 1985 at 1,000 gallons per day for demonstration testing. The production

rate of 8.4 x 10!? BTU/year could be reached by 1995. The success of this alterna .

tive is highly dependent upon agricultural policy (land use) and the overall policy

with respect to alcohol production in Puerto Rico (the rum and sugar industries).

Figure 10 plots the BTU production for this scenario.? The BBIs of oll per .

?year savings which may be produced by the application of this technology in this

manner is as follows:

Year(FY) 80 81 82-84 «85H BBS 90952000

Millions 0.00 9.09 0.09 0.00 0.00 0.07 0.28 0.68 1.65 1.52

of BBIs of

oil per year

savings

?The technology is current state-of-the-art. Realization requires favorable agricultural policy, and a conscious decision to divert land use to the production

of sugar and/or energy cane.

Electricity from Bagasse

The burning of bagasse in boilers to produce steam generated electricity

isa form of alternative energy which may be used to replace imported fossil fuels 4

Which are used to generate electricity. Currently the burning of bagasse consumes

10x 10!? BTU/year which is in the form of electricity and process heat. It is

---Page Break---

v

estimated that 450 MW equivatent potential could be achieved by 1992. This con

verts to a total energy of 26.5 x 10!? 8TU/year, of an electrical equivalent of

8.0 x 10!? BTU/year by 1992, at an assumed efficiency of 30%.

Figure 11 plots a plausible commercialization scenario for this technology.

Estimates of the contribution of this technology in savings of imported

oil are the following:

Yeor(FY) 80 BL 8248S 8G 8B 90952000

Millions 1,72 1.72 1.55 2.01 218 241 295 3.79 5.36 6.03

of BBls of

ll savings

?As sith the alcohol from sugar cane alternative, realization requires favor~

able agric

a! poticy, and a conscious decision to divert land use to the production of sugar cane, and in this case the more prolific bagasse producer, or "energy cane" would need to be instigated. This, however, is fully compatible with require-

iments for the previous alternative, and in fact they each may go hand-in-hand.

10. ticity from Solar Ponds

?An additional alternative energy source with potential in Puerto Rico is the shallow salt-water pond collector which produces hot water or electricity 10 replace imported oil which has been used for industrial process heat or for generating electricity.

Solar ponds are state-of-the-art and are operating in Israel. The potential

in Puerto Rico is inhibited by land values, snd by lack of level terrain, An assumed

?region one mile in width surrounding the island, with 296 of this area, or four square

miles, being converted by solar pond would produce an electrical energy of 0.8 x 10!2

BTU/year by the year 1995. This assumes that the solar pond converts solar energy

to electricity at 1% efficiency.

---Page Break---

1s

A plot of the contribution fromm this resource in BTU per year is shown

in Figure 12. The imported oil which is replaced by this technology, under this

?commercialization scenario is the following:

Year(FY) 89 81-82-84 «83-8909 2000

Millions 0.00 0.09 0.00 0.00 0.00 0.00 0.09 0.17 0.66 0.32

of BBIs of

fil savings.

II, Photovoltaics

Another promising energy alternative from a technological point of view is the use of photovoltaic devices which generate electricity from solar energy 10 replace imported fossil {uel which has been used to generate electricity.

Photovoltaics is state-of-the-art technology, and has been used widely in space and remote applications, where the economics have proved viable. Should the U.S. program cost goals be achieved (70¢ per peak watt by 1986) then wide-scale utilization of this technology could be expected. It is assumed that com=mercialization of this technology in Puerto Rico will be initiated in 1988, with ts full potential of 1.6 x 10!? BTU/year being realized in the year 2000. As ?was the case with small wind systems, this commercialization potential is highly dependent upon cost factors, and estimates could vary by an order of magnitude.

In preparing the estimates for this technology, an assumed conversion efficiency of 11% was used for an ultimate area of photovoltaic cells which was equal to ?an average of 200 59. ft. per home for 100,000 homes.

The forecast for BTU output for this solar energy technology is shown in Figure 13.

?The predictions for BBIs of imported cil savings is the following:

---Page Break---

3

Year(FY) 8 81 82-84 «BSB RB 90952000

Millions 0.00 0.09 0,09 0.00 0.00 0.00 0.03 0.11 0.75 092

of BBs of

oll savings.

12, Synthetic Fuels from Coal

If one defines an alternative energy as one which is alternative to the cu

rently imported fuel oil, the conversion from coal inte synthetic gaseous and liquid fuels, replacing imported fossil fuels, is a viable alternative which must be considered, in that it will provide a transition toward other forms, and a stability to the imported energy market.

Coal may be used directly or indirectly as a substitution for petroleum in power generation. The degree to which this is achieved may be based entirely on capital cost requirements and on the need for reliable energy sources and the

Gesire to reduce cost of production, e.g., economics and security are the key issues.

?Coal may also be gasified and liquitied to a synthetic fuel whic

pacts all sectors

of the fossil fuel economy; for instance, transportation, chemical feedstocks,

and power generation. It may well be the bridge between the existing energy

state and that beyond the year 2000,

11 is assumed that 430 MW equivalent will be produced in electcical generation

by the year 1992, and an additional 450 MW equivalent will be available for absorp

tion into the remaining energy market at that time, The ultimate potential of

900 MW, by the year 2000, will produce 75 x 10!? BTU/year equivalent of energy.

?The energy produced from this alternative is graphed in Figure 14, The

replacement, or savings, of imported oil produced by the introduction of this tech-

nology follows:

---Page Break---

Year(FY) 80 81-82-8485 «8E BB D920

19 0,00 0.00 0.00 0.99 0.00 0.00 8.28 12,93

Millions 0.00 0,

of BBs of

oll savings.

1. TEC

[A developing alternative energy which could have a tremendous potential

in Puerto Rico, by virtue of its geographic uniqueness is the conversion of the

?thermal differences in the tropical ocean to electricity, thus replacing the imported

fuel oil which is used to generate electricity.

Unfortunately, Ocean Thermal Energy Conversion is yet to be proven as

a viable cost-effective electrical energy producer. Further development needs

to be made, but it is assumed that 40 MW may be on-line by 1994, with 80 additional

MW being added in 1998, for a total electrical energy equivalent of 3 x 10!

BTU/year by the year 2000.

?A graph of the energy contribution from this scenario is given in Figure

15. The contribution in terms of savings of imported oil follows:

Year(FY) 80 8182-84-85 «8E BB 9D.?«95-?2000

Mullions 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.57 1.72

of BBIs of

oil savings:

1%. Other

?Other alternative energy technologies which may develop, but which are

ot presently seen as contributing significantly to the creation of an energy self=

sufficient condition before the turn of the century include the following:

---Page Break---

2

1 Ocean wave energy converters

2 Ocean current energy converters

3. Large solar thermal facilities,

Salinity gradients

?The estimated contribution from these sources is shown in Figure 16.

?The contribution in oil saved 1s the following:

Year(FY) 80 818284858808

Miitions 0,09 0.0 0.00 0.00 0.09 0.00 0.00 0,00 0.03 0.03

of BBs of

oil savings

VIL ENERGY SEL!

ICIENCY

The previously described technologies, together with others which remain to be identitied, each possess the capability of contributing technologically to 2 degree of energy self-sufficiency for Puerto Rico, as far as freedom from dependency on imported oil is concerned. though it is obvious that variations ?may exist in the degree and time at which each is commercialized, a summation of the estimates of the contribution does yield useful insights to the composite technological potentials of an alternative energy program.

Figure 17 presents just such a summation for imported fossil fuels which are used in the electric sector, Figure 18 presents the same information for the

non-electric sector,

1nd Figure 19 presents a composite for both. It should be noted that a 1.5 percent per year growth rate in energy consumption is assumed after 1983. This isan ?assumed value to eeflect economic growth; however,

it Could vary significantly, depending upon continued conservation measures and

?economic policies adopted in future years.

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If i is assumed that the forecasts made prev.ously are achievable within ail applicable socio-economic and political constrairts, then it may be said that

major degree of energy self-sufficiency for Puerto Rico is an idea whose achievement is definitely possible. As a matter of fact, it may be observed that with the intro= duction of each new alternative energy technology, savings in imported oil tend

to accurmulate with increasing rapidity. The degree to which this self-sufficiency

is realized is obviously dependent,on numerous economic and non-technological

factors, but such a forecast provides an excellent first step in the identification

of the achievable. The technological forecasts on which this scenario has been

based have been intentional

pragmatic and conservative, but the results appear to be very promising. With sufficient incentives and technological breakthroughs, some of these projections could increase by orders of magnitude, with the result ?of shortening the date to a more self-sufficient state as far as imported energy

is concerned.

vil, SUMMARY.

?The information and data just presented reflect a first projection of what is technologically feasible and has not been subjected to economic and social considerations. The planning model (Ref. Figure 1) is now ready to be exercised with successive iterations which will result in refinements of the energy contributions {rom each of the technologies considered.

Refinements in the resource potential for wind may indicate that only

certain areas of the Island have wind speeds of sutfici

t magnitude and consistency

to warrant deployment of wind machines. This finding would result in a reduced

projection of this technology's energy contribution. Similarly, further analysis

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may indicate that land availability for ?energy cave? production is limited and

the initial assumption will Le modified to reflect the potential contribution of bagasse and alcohol as fuels.

The capital cost of some of the technologies may remain too intensive and never have an opportunity to compete in the marketplace. An example of this is Photovoltaics. The installed systems! cost may never achieve their cost goals. On the other hand, this particular technology could experience a tech notogicat breakthrough in etficiency and cost and our first projections would have to be moditied upward significantly.

These examples are shown to indicate the fragility of technoiogy forecasting and Planning itself; however, not to forecast and to plan is to leave the future unattecteds for the decisions made today determine what path we take into the future.

{ts our conclusion that the methodology and the modeling underway that Considers all elements of the Economic, Social and Political systems will allow realistic uchieveable goals t0 be set and policies adopted which will lead Puerto Rico to a more energy ?self-sufficient? future, and itis to this end that all of

Us are dedicated to serve.

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UPADI 82

San Juan, Puerto Rico

August 1-7, 1982

?Second National Conference on Renewable Energy Technologies

ENERGY PLANNING FOR PUERTO RICO:

?A?SYSTEMS MODELING APPROACH

By

Jorge Haddock Acevedo

University of Puerto Rico

Sen Juan, Puerto Rico

August 1982

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A. INTRODUCTION

wes electric utility in Puerto Rico has had many ai fficulttes in determining

ihe geauirenents for new electrical generating units (10). This mean thor

{uayant ina Ruerto Rico's electric energy network, as well as promoting ates decen-

Toaay ce {5's wen they becone commercially available, will not be an eas) faeke

FoUay we can consider valid options: of1, coal, biomass, OTEC (Ocean Trenecs mrad eocenversion). hydroelectric generation, photovoltaics. (centralised colar), wind poner» and decentralized solar energy. Nuclear eneray can'be glass covonte consideration, even though it has a few political epportustticn

yinen se0e energy crisis struck the world in 1973, the petroleum censuxption in ihe, United States accounted for S0x (55) of the total resoures consumption foe peerteseneration. By that time (as in the present) Puerto Rico dependes on petpojeun for $95 of its energy needs (see Table 1). All the petrolees in puerto Rico is imported.

The main objective of the generation planning at the Puerto Rico Electric Pompe luthordty (PREPA) is to determine the generating capacity: required te

satisfy ithe electrical load in a reliable manner during a given petiod cf cine. mee TTiditional ?criterion used at PREPA in measuring the risk of not berg asi. to Meaiotne, forecast peak denand is the Loss-of-Load Probability (LOL). Ihe Authority found it necessary to complenent this reliebility angigsts with?an ine Sept evaluation of the actual requirements for reserve capacity? to avota avenn building the system.

meganaminal electrical generating capacity of PREPA system is approxtnately 4200 negawatts. |The all-time peak load (Septenber 1978) was 2,057 negevatter? She

Fee eaangin therefore anounts to more than 100 percent of peak Tosd,s margin

fer greater than the 20-30 percent reserve considered adequate in the nator

States to meet system peak demand and accomodate scheduled and unschedules

outages (221,

It is to be expected that an isolated system like that of the PREPA will

qequire a greater reserve margin than a system like most of those inthe wotved

Bo. Tar SeaCamnot, schedule most maintenance, as ?United States utilities custonar! iy

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wesology

Hodels developed to the preaont time to study Yony-range generat fon planning

problems are classified by Cvans °25 as:

(1) Large scate (usuatly linear) optimization sacdels which consider

Sub-problem areas in addition to the electric generation area,

These models require macy approximations which do not permit

studying the specific area of generation planing. (4) U2),

(13), C38}, (32), (33), (34), (36), (423,646), (49), (72).

(2) Large scale simiation models whi:

in addition to the electric gencration plamiing area. These

fodels are capable of outgutting many impacts of @ proposed

energy generation systen, but the feasible region of policy

altematives must be small. (11), (58), (59

can consider other areas

(3) Linear programming, nonlinear programing, and nixed integer

Programing models which require approxinitions (in the calcula

tion of reliability and in tho variable operating cost of the

systen) of the real systen. 8%) 17), (24 25h 376 (ay

(47), (48), (50), (58), (613, (66 >,

(4) Hybrid Linear progranming/sinulation models which do not

Guarantee convergence to an optinal solution. (14%, (26), (27}.

(5) Qynamic programming models vhich can model the real-world

system fairly accurately but are usually computationally in=

feasible for problens of realistic size. Otner models are

Asbedded with specific variations to make them computationally

Feasible. Hany of these models either do not guarantee an

optinun or require approximations to the systen, Even branch

and bound does not present the solution to the ?curse of

dimensionatity? (25) problem in D.P. (9), (18) (24) {25),

MO}, (413, (43), (56), (60).

(6) Multi-objective models that have been suggested by Ecker, J.6.

{26} and Drews, W.P. (15); ?ie have heard that the optimizing models give an'unreatistic simulation of ?real worle? mechanisms because society does not, in fact, pursue single-mindedly the objective function formulated by the analyst..." (15), These models as the LP, LP, and MIP require sone approximations ef the real system.? (7)(15), (25), (63)

3. Data

The demand and supply forecasts are from CEER(39 Jand NAS (23 }. These are gvident on the presentation of results. The electricity generation cost, Table 2, are from CEER. Other relevant costs are presented in Table 3. The coets are gn 1980 dol tars.

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Table 2

Electrivity Generation Costs

Energy Source

Inves tment Cost

Fuel and O8M Costs

Nuclear Energy

sas Plant

Bionass Steam

300 WW Plant

al

30010 Plant

Photovol tates

250 HW Plant

orec

2501 Plant

wes

17 steam

$ 59,600 x 103/year

$ 18,375 x 10%/year

$ 30,662 x 103/year

$108,383 x 103/year

$ 84,382 x 10%/year

$1,400/%01

18,66 mil1s/Kw-hr.

38.81 miNs/Kw-hr.

50.43 mils/Kw-hr.

7.83 mills /kw-hr.

8.22 mil1s/kw-hr.

37.6/Kw-hr.

94.79 milIs/Kwehr.

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Teble 3

Other Costs

Energy Source Cost

Gasoline $ 1.25/gat

Ethanol $ 2.33/ga)

Aviation Fuel $ 1.70/90

ve $ 1.00/ga1

Industrial Water Keating $15.72/108 ety

Residential Water Heating $.0.10/KW-hr.

Industrial Soler Air

Cooling $ 0.29/Kw-br.

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Figure 1 presents the prop.sed meray system for Puerto Rico in year 2000.

Two scenarios are considered: VEER scenario chd NAS scenario.

4.1 Linear Program for Capaci:y Utilization

Constraints,

Energy Sources

Kir Vy o

i

Where Xi = amount of fuel used (coal, biomass, etc.)

Yij = gnount of energy deri vated from fuel i

(coal steam electricity, gasoline, etc.)

Gonversion Systems,

Vig soy

here Vij = electricity generated from fuel i

Cj = a constant representing plant capacity

Final Demand

E yaj2 0,

Brg oy

Where yjj = electricity generated from fuel 4 (base

and peak) and other source of energy to

satisfy demand j.

Balance Equations

There exist balance equations for of] derivatives, for electrici ty

generation, and for base and peak Toad electricity.

Objective Function

Min 25 Gost = Fey iy

Where ?j = cost of energy source

Y4j = amount of eneray from source §

4.1.1 Results

The original models consider many scenarios. These scenarios are: the NAS optimistic and expected forecasts and CER schedule of proposed electricity

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Table 4

Electricity Generation for LP Node! (10° Bru)

(igh Denand Forecast)

No nucrear | AER"

Nuclear Energy | 26,000,000 - -

Biomass Steen | 13,500,000 33,800,000 | 13,500,000

Coat Steen 25,000,000 25,000,000 | 25,000,000

Protovoltatc 13,000,000 - 13,000,000

ore 10,799,685 31,000,000 | 31,000,000

fyaro sei,si0 s2i,si0 21,510

wes - - -

O17 Stean - - 12,188,363

Objective 4,111.37 4,474.19, 5,052.15

Gititions)

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Soother consideration was a 30% reserve margin required for each alternative, This Paper presents the CEER scenario, but for all other scenarios the reader evuld Pyfer te the orginal study!, Table 4 presents the results for electricity generation in this model.

Studies have shown that bionass is technically feasible for automobile conbus- Hon (ethanol) (1,2 band for electricity generation {39 }. However, a consteaioe dn avetlability exists because the sugcr industry 1s decaying. Ethane] from cugar anes is the only alternative to gasoline for ground transportation, However. ty As not cost competitive. Gasol ine costs $1.25/galion (on the average) and ethanal Price ranges from $2.33 to $2.72. the difference is quite significant.

Electricity generated using biomass Tags behind nuclear energy and hydroelectricity in cost teras. The most important contribution (the least costly) ts

nuclear energy. However, nuclear eneray, al though cost-advantageous, te

politically unfavorable.? Hydroelectric power has great limitations because the

Plants are obsolete and?poorly maintained. There $s hiah uncertainty ang disagree.

ent (22,39) regarding the possible contribution of photovoltsics, thoulg faaeable

results be achieved (regarding the possible contribution of photovol tates) ,photon

wolzaics should be incorporated in the systen. The results of this model ghow

Oft fired plants are not cost-competitive, even when these plants are already

Bult and mo investment cost is incurred. The fuel cost is so high that building

nev plants for alternative energy sources presents savings in costs. ?The only

gneray alternative more expensive than ofI=fired plants is MPS (Wind Power systens).

{he results show that WPS are not necessary to satisfy the energy demand (itis

The most controversial cost estimates are for the coal and photovol taics-

generated electricity. The difference (19.33 ~ 19.21 = $0. 12/ 108 BTU) ts not

Significant given the uncertainty of the photovoltaics technology. this section

considers photovoltaics a less costly al ternative, but it is inportent to point

?Out how sensitive it 1s to changes.

The pumped storages en alternative, which has not been consigered by PREP,

to satisty peak Toad electricity demand This pode] Suggest? eset ee feeeee

OF punped storagnsystens is ecamicaliy Teasipie only oh treo ane

Conbidered: ?every consideration shoe be given te oe mee ss et et prices: "Aigner oil Grices would make ponped storage aystens sare nateasive es

the other afternatives, oi)"rired turolne: foreavee?pusped storeee seven

Increase the ult tzet ion of the existing baserioadeleceribiey genset tants

gue the gallon coetFictents of the clifivedtarsines ae Rights or oe

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DatTaeSan FASTER aldo HEPRL ENTS Cetera ats cirecty.

Mddock-Acevedo, Jorge, *Eneray Planning for Puerto Rico: A Syst Mo eling

Foproaci", unpublished?Ph.9 Thesis, Pi due tivers? j

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10

Liguid petroteun gas (LPG) is the best alternative (considering cost only) for cooking.? The solution is not very sensitive to changes in LPG costs. In. sone cases, the cost of ethanol would have to increase fron $10.35/108 BTU to $28.73/108 BTU or 1782 1f electricity were to represent a better alternative economically.

Solar energy 1s cost competitive only for residential water heating when nuclear energy 15 not considered. Solar energy for industrial air cooling and for Process heat 1s not economically competitive. Mid-distillates represent a better alternative than solar process heat, and conventional industrial air cooling is Jess costly than solar air cooling.? For residential water heating, the opportunity cost is from -6.24 to $12.21/1068i. Solar water heating for residential use is

?econonically advantageous when nuclear energy is not considered and when the denand is high. When nuclear energy is considered, the cost would increase up to $6.24/ 108 BTU if residential water heating is forced into the solution. However, when nuclear energy 1s not present, the total cost would decrease up to $12.21/i0® BTU for each extra unit available of solar residential water heating. For? industrial water heating the Increase in cost if 2 higher Tevel is forged would be $6.36/106 BTU; for industrial air cooling between 43.46 and $61.91/108 STU.

?The computer program used for these runs was HPOS (Multi-Purpose Optimization System) developed at Northwestern University. The computer tine used ranged between 1.5 and 1.9 seconds and cost ranged between $0.16 and $0.18.

A common approach in dealing with uncertainty is the use of expected values. These models present uncertainty in demand and in cost. The next model considers uncertainty in denand and cost.

4.2 Capacity Expansion Model

In this section, uncertainty in demand is considered. A Two-Stage Linear. Model, or Stochastic? Linear Prograrming Hodel (73 }, is formulated. This model is also formulated as a capacity expansion model. The first-stage variables determine hhow much capaci ty should be built. The second-stage variables determine how much energy should be supplied when demand is known. Three levels of denand are taken into account; Case A, Case B, the average, and an equal probability of occurrence (pi = p2 = pj = 1/3) 1s assumed. No expansion in oil steam plants is also assuned.

For instance, take a smaller problem as an iTustration: (see Figure 2):

Demand constraints

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NUCLEAR

BIOMASS. ELECTRICITY (D,)

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TRANSPORTATION (Dp)

Figure 2. Network Example.

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Eqs Eos and 5 represent the capacity exgansion of nucTear plants, biomass plants) and oft-fiPed plants, respectively. State T variables (yt y yd.» jd.)

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represent the anount of eneray produced in the case that demand for electricity

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bf ccurs, whjte al ig the amount of Xs supplied t¢,D} occurs. State 2 and 3

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cost of ietlesttay'h Production splits into two components: the capacity expansion

Cost othe investlent costs. and? the operation, patntanance, and fuel (where

Sppticenie) costs, ?Let Ky epresent the capaci ty expansion cost for source f, and

ePPrepresent the © 8'y ahd fuel cost for source se hen the objective function ts, Win Z = cs(pi%s! + p2Xs!+ p3%s!) +era(py%az! + p2Xyp? + p3%23)

+ c13l0p%y3! + PoXys? + pakas) + cra(pyXist + P2Xie? + P3Xi99)

4 Ky Ey tp Ep + Ky

Although this model includes 93 equations and 99 variables compared with 30 equations and 30 variables on the previous one, the conputer tise needed. to run ?this model is not significantly different. The solution for both models is

basically the same, but this second nodel gives more information for the decision making process.

4.3 Capacity Expansion Node! with Shortage Costs

Shortage costs can be introduced to the capacity expansion model. The short= age cost 1s the price that a custoner is willing to pay for a demand which cen be.

---Page Break---

3

Tat; Mis model could be interpreted as meeting the demand which is profitable, These costs are presented in Table 5.

Table 5. ?Shortage costs 70

Sector Shortage Cost ($108 ety)

Ethanol and gasoline 8.91

Aviation Fuel 14.13,

Residential Electricity 10.77

Comercial Electricity 1.22

Industrial Electricity 8.62

Se

ine, inclusion F shortage costs are very significant for the model. In this

Paeteyear cases the prices actually charged are so high thet these ovis on fet

?Significantly change the previous solution.

4.4 Elasticity of Demand Considered

The demand curve (5) sums up the response of consumer demand to alternative

Prices of a product (see Figure 3).

DEMAND

Figure 3. Demand Curve

---Page Break---

?

It shows the relation between denand and price: in other words, what denand will

occur for a certain price. In Figure 2, point A illustrates the denand Dy that

will occur if price pz is fixed and denand D2 that will occur if price py 1s fixed.

Elasticity of demand {5} involves measurement of the response in quantity

demanded, which ean be expected to result from a given change in the price of the

ccommodi ty.

Price elasticity of demand for item X

= = percentage change in quantity of x denanded

percentage change in the Price OF x

== aD. pe -ad.P

?DP PD

PRICE,

DEMAND

Figure 3. Linear Demand Curves

For-each of the demand equations, the model considers three demand curves as pre-

sented in Figure 3, The previous model includes points 8, D, and & for state T

(Yow demand), state 2 (medium demand), and state 3 (high demand), respectively.

Now, for each state of demand the mode] exanines a demand curve and three points

fon each one (points A, 8, and C). Take, for example, demand curve ABC which

---Page Break---

serrereanes to the low demand for a particular demand sector: for instance, an

equation (for transportation) could be

wb tad = (Oy ~ SB) - (05 - 05 = Sh) - (0-9) - 5!) 20

ay

S%Grsbesl +5208 (e01)

where:

B= Oly + oly + obs

Sa ? shortage for demand level A (Sq < Da)

Sp * shortage for demand level 8 (Sp < Dy - dq)

Se = shortage for demand level C (Se < De ~ Dy)

21, Portage gost component of the objective finctfon (the component of Equation

ED1, for instance, is,

PiSa + P2Sb + P3S¢

to ei ase Ene ME are minimizing cost, the model will drive Sy to 0 before trying meentberace gb ongG, MHS 15 because by > py > pyr This meant that bere Before eptnea Oe Une Same holds far Sb? the model will? drive sp fo sent before trying to minimize Sc. The other two equations for this sectst te?

ergrst tse sda,

igs tsbesdang

Among the dravbacks of this model is the inclusion of 99 additional variables Grandad andiZs, Yer IaBley to, represent the shortages." These vortubles pr aie, by Enis acing $9 additional upper limits to the model. ?the comectee thee tay iets Rodel Is not very different, but the extra information ?may noe Ler guceeeh-able in terms of model size increase and complexity.

4.5 Capacity Expansion Mode} with Integer Variables

anis Section discusses a Mixed Integer Program. Integer variables are cose cucee, to, the capacity expansion model with denand elasticities avd shortage fn this cose, eaer Variables are the central station electric plants of each fope. that ny acess «these variables are defined 2s integer (Os), where | reorenens This Bate gratYbe fs EAPAcity k and at site tts considered and is°6 othenstse. pane finition exists because the investnent Pixedjcost. depends on the teen or Polatag 2 2artteuler site) and on the capacity of theses but is not Micerely related, Fixed cost mist be incurred before any output? takes place?

---Page Break---

Where x; = electricity supplied from source

Cj = capacity of plant j

yj * (Os1) variable representing plant J

AN] the previous models are composed of continuous variables only. Unrealistic contributfons. fron glectricity generation alternatives could occur (i.e. a contribution of 1.35 X 10! BTU which is equivalent to a 30 Mi plant, a very unlikely plant size), A fixed cost must be incurred (investment cost) before any output Gould occur. This is not taken into account by continuous variables since the fnvestnent costs are Tinearized. Fuel and O&M are linear costs, but investment costs are not.

Another important consideration can be explained with an ?example. Suppose that residential solar water heating is less costly than conventional water heating. However, after a plant is built (therefore, investment cost already incurred) . electricity for residential water heating could be less costly (for the entire System, not individual customers) than solar water heating because it is competing only with fuel and O&M costs (of generation plants). On the other hand, there could be a certain demand sector which represents a more expensive alternative than electricity, for instance, industrial air cooling. If meeting a certain demand which is smaller than the denand for electricity for industrial air cooling means building an electricity generation plant, it could be better to encourage solar industrial air cooling (continuous variables cannot take this into account). In this case, because PREPA 1s a public corporation, this encouragement could be tax exemptions for installation of industrial air cooling systens. The actual tax exemptions are not presently enough to make this alternative economically conpett~ tive (17 }. In the same way, the inpact of different levels of market penetration of residential water heating systems may be assessed. Studies for alternatives, Such as punped Storage systems where the entire systen is not modeled nor integer variables are considered, could yield erroneous conclusions.

The electricity provided by the TIP node! is generally lower than the elec- tricity provided by the LP. This difference corresponds to the fixed costs (i.e. investnent cost of the electricity generation plants). The previous models, which ?are composed of continuous variables, treat the investment cost as function of the output because the investnent costs are linearized and added to fuel and O&M costs. In reality, independent of the energy output, the investment cost is based on the plant capacity. Previous models do not consider total investment costs where plants are not used at maximum capacity, making the electricity generation costs ower than the shortage costs. Constraints in non-electrical energy sources are relaxed in the next models.

---Page Break---

v

tre gCopPuter program used ¥s based on Bender's Deconposi tion Method and

eveloped at Purdue University, The tine used 1s 31.5 sec, and the eose 051,49,

4.6 Multiple Objective Capacity Expansion Nod

forthe MIP three objectives are considered: cost minimization,

TAGE fas) imports ainiatzation, F3(x):"and pollution level minieryationy f(x).

meanngrnee used for the nul tiple? objective decision analyeis 1s the shival Co cen

Poletios gee qidtaPtis Masel the shortage costs are not consiveree (eles cian

ongh imal vector minimizes relative deviation of the criteria (objective

functions) from the feasible ideal points (38).

The solutions of the following k problens

Hin 50)

set.

(2) < 0,

si) < fed 2, cy m

are defined as the ideat solutions, f(x*), § 3

Then, the Global Criterion Method solves the problen given by

3 fil) - FiO)

Aro)

The constraints, 93(x), are as before,

4.6.1 Objective functions

Cost Minimization

This objective function, f(x), is as before.

Fuel Imports tinimization

Wm Fela) = PyCat + HF MD» bef + x8 « x8) + palxh + x8 + x)

where pi = probability of state i

x1 = coal, of], and uranium

Environnental Effects Minimization

ress sede! gives equal consideration to all pollutants. This can be achieved

by introducing the following constraints. £0 65 (x)?

---Page Break---

18

2 + pa)

Pripyxy + pom? + pK) + ooo. + ARLE ML + Patt

where dj = a slack variable for 1

+8 and Pi = pollutant coefficient.

hax fala) = dy + do + dy + dy + a5 + dg 6 4) + dg sotves for the minima

avount of pollution given equal weights for'all pollutants. Note that because

£308) 15 maxinizeé the problem now 13:

2 fd =) + fOr) = fo

Hin Fs

re

sit. ils) <0 om

5. Trade-Off Analysis

Figure 4 shows the relation between cost and fuel imports, and Figure 5 presents the relation between cost and pollution Ievel (this level is representative Of all the pollution factors). Figure 6 presents the relation between imports and pollution. The relation between jobs and cost and jobs and imports 1s presented in Figure 7.and Figure 8 respectively.

Table § presents the optimal solution for each one of the objectives and the other objective function values at these solutions. The difference in cost for

the three scenarios (aininun cost, £](8*), mininun pollution level, f2(x*), and minimum importation, f3(x*) 1s endrmous.' "The cost for f2(x*) and $3(X4) 15 ?approxi fately 300% nore thin ¥y(x+). The difference for the fuel importation levels and the pollution levels is also great. The solution for fy(x*) is poor in terns of pollution level and fuel importation level.

?These solutions could be characterized using the optimal alternatives for electricity generation. As all the other models also indicate, the less costly alternatives. for electricity ganeration are nuclear energy, biomass steam plants, coal steam plants, and photovoltaics. Biomass is also helpful in minimizing fuel importation. Photovol taics, OTEC, and WPS are both fuel-free and pollution-free (renewable energy sources).

6. The Best Compromise Solution

Table § presents the pay-offs for the Global Criteria Hethod, The pay-off table requires sone explanation. The colums under fy, £2, and f3 present the objective function values when fy, £2, and 3 are optimized, respactively. For instance, the elenent in column I'and'row 1 {§3, 876, 272, 250) ts the minimum cost, (F](2%)) the element inthe Second. row in? the sane column (3975 2465 708) 1 the anount of imports when cost is optinized; and the elements in the other rovs are the pollution level for this solution. The elenent in rov 2 and

column 2 is the optinal anount of imports, f2(x*) and the other elenents in colum Zrepresent the other objective function values for this solution (ty(x) and

falx)).

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?The computer progran used for al! the iuiti-Criteria analysis is MiPZ

developed at Purdue University. The computer time ranged from 16 seconds ?0 23,

Seconds and the cost from $.87 to $1.16. Since MIP is harder to solve. the

difference in computer time is not th? much.

nc us ir

The ten major conclusions are:

1) Biomass (from sugar cane) could help in solving Puerto Rico's

energy needs.

(2) Biomass steam plants are cost-conpetitive and relatively low

in pollution Tevel.

{b) Ethanol for automobile combustion, although not economically

Advantageous, is technologically feasible.

(c) Production of electricity from biomass steam plants creates

more direct and indirect jobs than any other alternative.

(4) The use of biomass as an eneray source could help the decaying

sugar cane industry.

Biomass as an energy source does not require importation. However,

traint in availability exists.

cons-

2) Coal steam plants could help in providing electricity at relative

Tow cost. In this model, coal-steam plants perforn poorly in

pollution level and fuel importation, but extra consideration should be given to these results. Since Puerto Rico is an island, the plants could be placed in such a way that pollution is minimized to the country by diverting the pollutants to the sea. The fuel importation would be from the United States, which means that coal prices will be more stable and the coal availability will not have ?many political constraints. The coal prices are not expected to rise as sharply as the oi! prices. Great uncertainty exists. in elation to coal's relative position in cost terms. Controvers Gould exist as to whether photovoltaics is less costly than coal. ?The models suggest that, independently of this relative position, both sources could help?in providing Puerto Rico's electricity needs.

3) Photovoltaics, if production as expected, is a viable alternative for electricity generation. Although more costly than electricity from bionass steam and nuciear plants, photovoltaics 1s pollution. free and does not require any fuel importation. It could be cost competitive with coal-stean electricity.

4) Although the istand wiNl not be able to fully eliminate the impor- tation of 011, the anount of imported of] could be substantially Feduced. O11'will be needed for gasoline, aviation fuels, and electricity production. The only sector where ite Tevel of consump- ton could remain unchanged is in acrial transportation. Electri-

city generation using of7 is economically disadvantageous, and

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5)

6)

7?)

8)

9)

10)

6

ethanol for auto fuel, al though economically disadvantageous as @ Substitute for gasoline, is technically feasible.

Solar energy for decentralized systens such as residential water heating, industrial process heat, and industrial air cooling could be encouraged. There are cases where investnent costs (and other costs) for electrical plants are much higher than investment and maintenance costs for decentralized solar energy systens. Tax ?exemptions could be created, or the actual ones modified, to make these systems economically competitive with electricity.

Nuclear energy could be the least costly alternative for electricity generation. However, nuclear energy performed poorly in all the other considerations (pollution, inports, and nunber of jobs). The multi-criteria model presents nuclear energy in the optinal solution because radiation is treated equally as regarding all the other pollutants,

Punped storage systems for peak-electricity could be cost-effective, and could help in miniaizing fuel importation if these systens displace ofl-fired turbines. Horeover, the pollution coefficients of the ofl-fired turbines are relatively high. No source of base-load electricity that could be used as input to the punped storage systen is a5 high in pollutants as ofl-fired turbines.

Ocean Thermal Eneray (OTEC) is considered by many a promising altemative, It is more costly than many of the alternative

Sources but could be economically advantageous over ofl-fired plants. Among its other advantages are: it is pollution-free, it cen be operated economically, it requires no fuel, and it ses no land.

Wind Power Systens (WPS) are more costly than oil-fired plants; it

not be necessary in order to supply electricity at minimm cost.

It fs pollution-free and fuel-free, though

Shifting from least costly alternatives, f(x), to more costly

alternative will help in minimizing not only the island's dependence

?on imported fuels, but also the effects on the environnent.

---Page Break---

VITA

Jorge Haddock-Acevedo was born in Caguas, Puerto Rico, on August 15, 1955.

He received a 8.5. in Civil Engineering from the University of Puerto Rico in

Nay, 1978. He entered Rensselaer Polytechnic Institute as a graduate student

?in August, 1978, and was awarded an H.S. degree in Management Engineering in

Nay, 1979. In August 1979 he entered the School of Industrial Engineering at

Purdue University where he received a Ph.D in Industrial Engineering in Oecenber

1981. His professional experience includes research work for the Puerto Rico's

Departnent of Transportation and the University of Puerto Rico. It also

includes consulting work for Management Systens Design and Analysis at Mayaguez,

Puerto Rico, and for Sistema, Inc. at the Citibank, N.A-, San Juan, Puerto Rico.

He is co-author of "The Potential of Solar Energy for Industria? Air Cooling

in Puerto Rico", a research project sponsored by Oak Ridge Associated Universi-

?tes at the Center for Energy and Environment Research, U.P.R. (Co-written by

Dr. K.G. Soderstrom). He is currently an assistant professor in the Departnent

of Industrial Engineering at the University of Puerto Rico.

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UPADI 82

San Juan, Puerto Rico

?Agosto 1-7, 1982

11 Congreso Nacionalf de Alternativas Renovables de Energia

ECONOMIA DE ALTERNATIVAS DE ENERGIA PARA,

PUERTO RICO

Por:

Juan A. Bonnet, Jr. - Modesto Iriarte

Centro para Estudios Energéticos y Ambientales

University of Puerto Rico

San Juan, Puerto Rico

August 1982

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ETRODUCCION

Ua estrecha interrelacién comercial que existe hoy entre los varios pueblos del mundo desenfatiza considerablenente 1a independencia socio-econémica de las varias regiones y pueblos. la distribuci6n, explotacién, aisponibilidad y variacién de pre- cios de 10s recursos del planeta no puede analizarse de forma regional. Estos tienen que verse en su contexte global y de interrelactén.

Por otro lado 1a disponibilidad de los recursos mundiales afectaré en grado sumo las condiciones locales. De ella, de~ Pender en sumo grado la producci6n agrfcola, 1a produceién in- dustrial, 1a salud y el bienestar social en genéral. Los requerimtentos energéticos de un pueblo dependen estrechanente

de su nivel de bienestar socioeconémico, Nuestra primer:

terrogantes por lo tanto serdn (1) Qué cantidad de recursos se necesitan? (2) Qué fuentes pueden supliria adecuadamente? (3)

C6mo nos afectan las condiciones mundiales el suninistro de estos recursos? Una planificacién adecuada debe dar alguna con- sideracién a estos puntos.

POBLACION

Para predecir 1a cantidad de recursos (enersfa) que se re~ Gueriré tendrenos que comenzar prediciendo 1a poblacién futura. Con 1a poblacién futura y los niveles de bienestar socio-econ6- mico en términos de ingreso per cfpita podemos predecir el pro-

@ucto bruto nacional.

---Page Break---

1 protkcto bruto nacional puede correlacionarse con el consum de energfa y esta modificarse con 1a elasticidad de precio~denanda, El estutio © prediccién de cualesquiera de estos parinetros es de Por sf una labor compleja. ZCual es el ntiero de habstantes en el mundo y en especial en Puerto Rico para el aio 2000? Una simple reqresién estadfstica sobre 1a poblacién puede predecir esto con aprocinacién satisfactoria, Fsto serfa cierto si la subestructura secicecontinica y hébitos del Area o pucblo en consideracitn perma reciera inalterable. No obstante este es el problena b&sico ya que 1a sthestructura sociceconinica de los pueblos y sus hibitos estén canbiando répidimente ante los altos costos de 1a eneryta derivada Gel petr6leo. Se requiere por lo tanto desarrollar mitodos de pre- icei6n poblacional basados en parfnetros que se ajusten a los

cmbios vislinbrados, planificaios 0 futuras polfticas a delinearse.

EL informe titulado ?the Global 2000 Report to the President",

Preparado por el Departamento de Estado de IIA y por el Consejo de

Colidad Anbfental contiene quizis 1a Gitina publicacién scbre pre-

@icciones de poblacién mndial, desgloséndose por pases y Areas.

1a predicciGn de poblacién esta hasada en una funcién

Poblacion = f(tasa de fertilidad)-£(tasa de defunciones)

+?(migracién)

Y 1a cunl ee puede reducir nomalnente a una funcién de creciniento

compuesto de 1a formas x = In (Py/P)/t

---Page Break---

onde

= tasa de crecimiento anuil prumedio

P, = aumento total de 1a poblacién en perfato t

poblacién total

Dicho informe predice que para el aiic 2000 1a poblacién muriial

habr& aunentado de 4 billones a 6.35 billones de seres. toy dfa la

Poblacién mundial aunenta a razén de 75 mitlones de seres anualnente

¥ para el aio 2000 e1 aumento anual seré de cerca de 100 millones de

Personas. La tasa de crecimiento, no obstante, se reduciré de 1.60 anual a 1.70 anal.

Esta modelacin de poblacién se presta para introduci 1a polf ttica nacional y los hébitos canbiantes. Siguiendo una modelacién ?similar podrfams predecir 1a poblacién del pas y conpararla con los Pronéstioos realizados hasta 1a fecha,

Modelos Boontni coe

BL infome titulads "The Global 2000 Report to the President" ?contiene analfsis de 1a producci6n econtmica (GP), produccién agri-cola o alimentos, pesquerfa, necesidates de agua, minerales y com bustibles asf com proyecciones anbientales de contaninacién y ?efectos en 1a salu hasta el afio 2000. £1 informe contiene una serie de diferentes modelos socicecontnicos que interelactonan 1a energia con los recursos naturales y el abiente. Tales modelos incluyen:

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a) Modelos mundiales 2 y 3 (alteraciones al modelo 1 del Club de Rema)

») Modelo muntial Hesarovic - Pestel

©) Modelo de Relaciones Internacionales en la Agricultura

oor)

4) Modelo Latinoamericano

©) Modelo de las taciones Unidas

Para dar un ejemplo de las interelaciones que estanos hablando ?en los modelos mencionatos observarenos algunos resultados, cualita- tivanente, que se producen cuardo consideramos el primer modelo.

La Pig. Nom. 1-4, tomada directamente del informe San Juan 2000, realizado por el municipio de San Juan, Puerto Rico,nos ilustra gra- ficmente 1a situacién socioecontimics del mundo.

La Fig. Nim, 1 es el resultato del melo mueiial normal.

Las condiciones iniicadas en la Fig. Nim. 1 concuerdan con los valores histéricos de 1900 a 1970 cuando 1a poblaci6n mundial aumants ?de 1,600 millones en 1900 a 3,500 millones en 1970. A pesar de que os nacimientos se reduoen gradualmente, el ritmo de mortalidad de- lina réipidmente, especialmente después del 1940, y 1a razén del ?crecimiento poblacional aumenta exponencialnente, La produccisn industrial, alimentos y servicios per cfpita también aumentan exporenctalmente. Los recursos naturales tafavia tienen en 1970 com

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Servicios

1900

Figura Nam. 1 -MODELO MUNDIAL NORMAL

Levenoa

ion (nin tale iments pe Capita

?anal ???? Mlopumerpoe psn

Predaccibn Indus per semis pe Capite

Cit (Spor peanaata) (Spor pesonlated

Recursos No Renovables

(Waccibn emanente de

las eservas de 1800)

|. Contaminacibn (tiple

(evel de 1870)

Furnte: Limite 6! Crecimiento

---Page Break---

958 dei valor de 1900, pero declinarfn dransticanente después de
se ao con el crecimiento de la yoblaci6n y 1a producct6n industrial .
5] eomgortaniento del sistena sobrepasa la capacidad de asinilación
Sel anbiente y finaliza en crisis cuando los recursos ro renovables
?se agotan. SegGn los precios de los recursos suben y los depSsitos
80 agotan, més capital debe usarse para obtener recursos alicionales
¥ menos capital quedar& para invertir en el crecimiento futuro. La
inversién no puede mantenerse 2 la par con la depreciactén y la base
industrial hace crisis conjuntarente con los sistemas de servicios y
agricolas que dependen de la prodvcci6n industrial. Durante un corto
perfodo de tiempo, 1a situaci6n se torna my grave al seguir aumer-
tando 1a poblacién con el retraso natural del ajuste social. Final-
mente, la poblacin disminuye cuando 1a nortalidad aumenta por falta
de alimentos y servicios de salud. Suponiendo que no habré canbios
mayores en el sistena actual, e1 modelo indica que el crecimiento
Poblacional e industrial del mio se detendré durante e présim
siglo. .

El grupo investigador anali26 el modelo con una poblacién es?

table. (Véase Fig. Min. 2). Este andlisis mantiene todas las con

diciones idénticas al modelo bésico, excepto que mantiene 1a po-

Dlacién constante después de 1975 igualareio la raz6n de los naci~

mientos con la razin de mortalidad. Mientras tanto, el resto de

las reacciones positivas en el sistena envuelven el capital infustrial

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1900 2000 2100

Figura Nim, 2 - MODELO MUNDIAL CON

POBLACION ESTABLE

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(raecion emanente de

Tat eserves de 1900)

el vl de 1870)

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jae cont inds generando un crecimivare exponencial de la produceién

ndustritl, alimentos y servicios per cavita, Fl agotamiento

uventual de los recursos no venovables causa una crisis répida

vel sistema industrial y el colanso de 1a economta

po investigador analiz6 el modelo con una poblacién

EL grt

el capital estable. (Véase Fig. Num, 3). El crecimiento de

capital se estabiliz6 manteniendo el capital de inversién igual

P 8

ue 1a depreciacién. Cuando el execimiento exponencial se

Gotiene, una condicién temporeramente estable se obtiene, ya que

Jos niveles de pobtecton y capital no son demasiado altos para

azotar los recursos répidamente. Coro no se han tomado medidas

tecnologicas de conservacién de recursos, los recursos eventual-

mente se agotan y la produccién industrial se reduce, Aunque

1a base del capital se mantiene al mismo nivel, la eficiencia

del capital baja al requerirse mayor inversién de capital para

buscar mAs recursos en vez de usarse el capital para producir

productos de mayor utilidad

Al analizar el modelo ahadiéndose a las restricctones de po-
blacion y capital, medidas tecnolégicas de conservacién, se ob-
tiene un estado de equilibrio dinémico por largo perfodo de tiempo.
(Véase Fig. Nom, 4). Las medidas tecnológicas incluyen la recir-
culacién de recursos, medidas de control de contaminacién, aumentos
vitalicios de todas las formas de capital métodos para restaurar
el suelo fértil y erosionade. Los principales cambios en los

valores humanos

---Page Break---

1900 2000 2100

Figura Nim. 3 -MODELO MUNDIAL CON

POBLACION Y CAPITAL ESTABLE

Levevoa

Poblacibn (nm. total de Alimentos pes

er ? (ilogame

Produceibn Industrial per Senicios pet

Chpita (S por personalsho)

Recursos No Renovables

(accion vemanente de

Tas esrat de 1800) Fuente: Limites del Crecimiento

---Page Break---

Prod. tnd.

Poblaciéa

Contaminaciéa ?

seek

1900 2000 2100

FiguraNam.4 -MODELO MUNDIAL

ESTABILIZADO

LEYENDA

Poblaidn (aim, total de Alimentos per Caita

personas)

{Wilogeame granofpersonalaio

Servicios per Capita

(Spor pertona/ana)

Cipita (Spor personals)

Recursos No Renovables

Uaeeion

Contaminscibn (mili

dl rivel de 1970)

Fuente: Limite del Crecimiento

---Page Break---

Aneluyen un aumento en el dnfaisis sobre la pioduscién de alimentos

servicios en ver de sobre le troducidn industrial. ?1 modes

sefiala que an valor estable de ia produccién industrial per e@pita

verfa tres veces el valor del

aredio rurdial del afo 1970.

Siempre ser debatible predecir cuando ser$ que ocuriré ta

crisis mindial, ya que los avarces tecrolégicos han losrado aplazar

este momento, Sin enbargo, los recursos no renovables se agotarén

tarde 0 temprano debido a que el planeta es un sistema finito. Quits

1a falla principal del Modelo Mundial sea haber establecido la can

tidad de recursos no renovables basado en las reservas conocidas.

Hasta la fecha, Ia ciencia y 1a tecnolosfa han logrado deseubrir

huevos yacimientos aumentando extraordinariamente las reservas d{spo-

nibles, Deberi esperarse que la clencia y 1a tecrologfa sigan aux

mentando las cantidades de las reservas conocidas exponencialnente, Bn el 1955 se pronosticé que las reservas conccidas de petréleo se

agotarfan para el aio 1975, pero actualmente todavia queian reservas

para 30 afos ms al ritmo del consumo actual y posiblenente, se des-

cubran 20 6 30 aftos mis de reservas para el aio 2000. Cualguier es

timado de reservas totales del turdo seguixé siendo una especulacién

hasta que se cuente con técnicas de estinados més precisos.

De sumo interés para los paises en Anérica es el Modelo Latino

?americaro desarvollado por investigadores en Buenos Aires, detalles

el cual se enowentran en el infome aludido, No entrarenos por

---Page Break---

1

ahora en més detalles er cuanto a la {nterelacién de ta

nergta como los demas pardmetros socioeconémicos No

vbstante, este breve analysis de nodeiaje nos enfatiza

sramaticamente 1a importancta de tres factores

2) Cancel de fa poblacton

5) Produetividad del capital

La conservacién de recursos representa 1a alrernativa

viable y disponible innediatamente a todos los pueblos

Es imperioso que los recursos no-renovables del planeta

¥ em especial las fuentes agotables de combustibles se con-

serven. Es imerioso que 1a tnaginacién e inventiva ¢el

honbre desarrolle la tecnologsa necesaria para Sintéttzar

recursos agotables. Esto solo puede hacerse econmica-

mente si se dispone de recursos energéticos abundantes y

baratos. Estos recursos estan representados por fuentes atin

no desarrollados tales cono 1a energta de fusién y fuentes

en vias de desarrollo como 1a energta del reactor niciear

reproductor y por las fuentes renovables de energia hoy en

desarrollo tales como 1a energfa solar, oceéno térmica y otros

Pero mientras tanto y hasta que se desarrollen plenamente

estas nuevas tecnologias el puente innediato que une el presente

con que este futuro no my distante se Llama ?Conservactén", en

primera instancia y luego seguido por fuentes alternas

---Page Break---

Mode

Energér Leos

Una vez establecidos los criterios de poblacién futura

Producto bruco nacional y polftica nacional ce conservacién

de recursos, control poblacional. la prediccién del consumo

ee energia puede realizarse bajo ciertas presunciones de pre-

cio de la energfa y elasticidad de precios

EL informe ?Energy in Transition 1985-2010", preparado

por el National Research Council (NRC) de 1a Academia Nacional

de Ciencias de E.U. contiene una descripeton del modelaje uti

Lizado por un grupo de investigadores de modelajes. £1 modelo

ucilizado enple6 métodos econométricos que envuelve el efecto

del GP, niveles de consumo y varios panoramas de descubrimiento

de recursos adicionales

No obstante, para una subestructura poco vartable podenos

cor-relacionar directamente el consumo de energia con el pro-

ducto bruto nacional como lo hemos hecho en el reciente estudio

de "Energy Analysis and Socio Economic Considerations for Puerto

Rico"

El estudio de 1a NRC es muy interesante ya que este discute

escenarios con las vari

alternativas de fuentes renovables de

energia como la energ{a solar

Escenario de Energia

El estudio "Energy Analysis and Socio Economic Considerations

for Puerto Rico" comienza con un andlisis de los requerimientos

energéticos de Puerto Rico hasta el afio 2020.

---Page Break---

a

anflisis se bace a case de una prediccion por regre:

Lineal de 1a poblacién seguido de una correlacién entre 1a poblacién y el producto bruto nacional. £1 pro- duet bruto nacional se correlaciona directamente con el consumo de energia eléctrica Estas simples relaciones presumen que la subestructura del sistema econémico no ha cambiado ya que se requieren afios para un cambio apreciable y medible, No obstante, los resultados se consideran adecua- dos para desarrollar escenarios del uso de fuentes alternas de energia con el propésito de predecir los afios en que dichas alrernativas pueden ser viables economicamente. Otros conbus- tibles como gasolina y aceite diesel fueron proyectados utili- zando una regresi6n estad{stica. El cuadro total del consumo de energia fue desarrollado en esta forma hasta el afio 2000 Esta informacién fue utilizada para desarrollar posibles esce- narios utilizando diferentes alternativas energéticas, Este es un proceso de planificaci6n el cual debe de reestudiarse, anualmente y quizas bi-anualmente y modificarse en sus proye- eciones y escenarios segGn puedan producirse los cambios en la subestructura del sistema econémico, Este primer ejercicio nos dara, con gran probabilidad, una sobreestimacién de la de- manda por energta

Para la evaluacién de las alternativas viables al presente

el estudio primeramente enfoca sobre los costos de produccién

de energia eléctrica en la actualidad utilizando los conbustibles

---Page Break---

de (a) Carbon, (b) Uranio y (c) Petroleo. toa vez deter

minados estos costos para centrales eléctricas para las

proximas dos décadas - hasta cl ano 2000 - estas se ucilizan

como base para competir por Las alternativas de fuentes re-

novables que estén al presente en desarrollo y que incluyen-

sistemas fotovoltaicos, sistemas de combustion de biomasa

sistemas ocedno-térmicos y energia eélica

valuaciones Econémicas Centrales de Energfa

La Fig. 5 nos flustra esquematicamente el modelaje uti-

Lizado por el CEEA para evaluar estas alternativas. Todas

las calculaciones han sido programadas en computadora y re-

sulta sumamente simple realizar estudios de serisitividad. Un

Parémetro que al presente resulta de gran interés son los inte-

reses 0 costo del dinero. Estudios de sensitividad para este

pardmetro y otros se planean para el futuro inmediato

El modelaje de prediccién de los costos capitales o de

inversiOn de la alternativa resultan relativamente sencillos

para lac alternativas que utilizan carbén, uranio o petréleo

ya que estos tienen historial acumulado.

Para las alternativas en desarrollo se tiene que presentar

una curva de aprendizaje que da la relacién de reducci6n de cos-

tos en la fabricacién del equipo segGn se construyen més uni-

dades debido al aprendizaje (desarrollo de técnicas mas econ6-

micas)

---Page Break---

16

Figura 8

MODELO C=EA PARA EVALUACION DE COSTOS DE ALTERNATIVAS

=

ENERGETICAS

DATA

2

Modelo de Inve

Copitel Nominal

he de Ret

(Ae Ret)

Modglo,ae

(Ane de Ret)

[Wetiecion «

linteres dareate

Coste Total

oe 6 Arranque|

Te

Ge tnversion

Anual

jo de Intlacion y

Actuolizacién

Total Actualla

Entre ae de Arrongue

y Terminecién

¥ Teemingcion

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v

Darenos mayor atencién a la central a base de carbon

ya que sabemos que resulta de gran interés

La evaluacién de los costos de una central de carbén

recibié estudio muy detallado y cuidadoso ya? que esta resulta en la alternativa mis económica y viable econbmica y

polfticamente. La alternativa nuclear resulta en los costos:

mas bajos pero ésta no es considerada viable desde el punto de

vista socio-polftico.

La Fig. Ném. 6 nos indica el costo basico de inversién en

Puerto Rico. Estos costos no ineluyen condiciones especiales del

sitio tales como carreteras, lineas eléctricas, puerto y sistena

de manejo del carbén del puerto a lugar de almacenaje, condi-

ctones especiales del subsuelo, Lagos de almacenaje de efluentes,

ete. La central incluye, no obstante, lavadores de gases (Flue

gas desulfurization) y precipitadores electrostéticos.

Los costos de lavadores de ga:

8 sulfuroseos pueden eva-

luarse en términos de délares de 1978 de la siguiente relacién:

$118 Neto

450 mi 100

856 Mw 85

1232 169 7

La inflacién e interés durante 1a construccién y/o planea-

miento de la central debe de tomarse en consideracién utilizando

fGrmulas adecuadas segén desarrolladas en el estudio del CEEA.

---Page Break---

ce

Copita

1978-9 /kw Volor de Inversion

rook

Figuro 6

Equacidn gel Valor de ?aversion Copito! para Centre!

de Cordén con Gesviturizecion de Goses

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Unites Engineers ond Constructors-Estimados Recientes-

Comunicacion Feb. 1979

Gibbs ond Hill- Pout

Je Rienzo Mapla Reunion Marzo 1978

ASME Conterence-1979 Oeaietanis ot ol

PREPA-Jose A Marine Comunicacién Personal 1979,

EPRI-PS- 866 -SR- June 1978

Fuente. CEEA x-72

zoo 385 700 05 730012000

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Costo Promedie sei nude per Compania:

Elects

BTU oe Combustibie

Ceonts/Mi

Corbin Quemado

Dolares/Ton: Costo Promedio de

1972 73 76 78178 tar

Fomte: Power rgineering Reviewmay 1978

Valor Scj0 2a Promedio I Alto Mmm

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ket

por

(milesimos de dolor

Actuatizedo

Coste Tote!

»

19,000 Figura 8 ?

a4 .

4] 450 MWe Centra! Cordén_ con Sisttme ce Onssiterstacicn

! Ieflocidn ae Copia) 1978-85" 8% /y+ |

| Inflccion de Corben "78-85. 71/8 % /y0 |

+ Interen, Duvente. Constraccion: 9% /¥t

: laficerdn de 686 1978-89. 8% /ye

| Tose de tnversion Costa! Phyo. 9 8686 %

Puan CEEA X-72

° 4 dS

a a a Td

Mio de Arrangue

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at

Los costos de comb stible recibieron un detaliado estudio

la Fig T nos ilustra les costos promedio del carhén uti-

lizado por la industria eléctrice en Estados Unidos Hemos

estimado que a base de los precios de 1978 el costo del carbén

ea Puerto Rico podria ser tan bajo como $1.82 por millén de BTU

Estos deben de escalarse adecuadamente segin la inflacién en

costos de equipo utilizado en los mismos, y en la transportacién

y segin discutido en el estudio

Los costes de operacién v mantenimiento de una central de

carbon fueron desarrollados siguiendo una publicacién del Labo-
ratorio Nacional de Oak Ridge. Tenn (ORNL/TN-6467 Jan. 1979)

Los costos de operacién y mantenimiento se. correlactonaron con (a) el nimero total de personal, (b) el personal adicional para operar el sistema de desulfurizacién, (c) generacion anual en kwehr, (d) las toneladas de azufre quenades anuaimente, (e) 1a capacidad de 1a central y (£) un cargo fijo

Los costos de operacién y mantenimiento deben de actuali-
zarse para incluty 1a inflacién en los salarios durante 1a vida de 1a planca

La Fig. 8 nos {lustra el costo de la energta eléctrica pro-
veniente de una central de carbén de 450 MW de capacidad con dos valores diferentes de inflacién

La ordenada de la gréfica indica el costo actualizado to-
Jando un promedio de 30 afios de vida de 1a planta y 1a abscisa nos indica el afio en que inicialmente comienza la operacién

central,

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doiur por kwh?

Costo Totel Actuclizedo (milesimos de

: Costes Totales Actuolizedes de Vorios

Alternatives pro Produccidn de Z|

o Energic Clectrico en RR

Je de Energfe)

© con la Curve

Fuente CEEA x-72

13501835 ?aos aos a a0

Afo oe Arranque

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Figo

DIAGRAMA PARA DETERMINAR COSTOS

Modelo a Prodvecion

Tlerre, Fertilizentes,

Irelgacion, Pesticidas,

Semilias, Combustibi

y Lebor

Modelo oe Recoleccisn

Inversion Copital en

Moquinario,Mantenimienta|

Operacion

?Almacena |

ei

BIOMASA

Fuente

CEEA x-72

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2

Segin podemos observar en el perfodo de 15 afos entre 1985 a1 2000 los costos actualizados de una nueva central puesta fen operacién en el afo 2000 resulean m&s de dos veces de los costos de operacién de una central puesta en operacién en el ato 1985

La grafica Nim. 9 nos ilustra el resultado de las varias alternativas estudiadas

De esta Gleima gréfica observamos, que excluyendo 1a ener-sia nuclear, la biomasa resulta la més econémica seguida por la central de carbén. La central océano-térmica OTEC comienza a competir con carbén para el ao 1995 al igual que los sistemas fotovoltAicos. El costo de 1a biomasa fue determinado a través de una experimentacién acompaiada con un proyecto piloto @ un costo de cerca de $1.5 millones. La Fig. Ndm, 10 nos ilustra el modelo utilizado

La energia del viento aunque resulta atractiva cuando se compara con centrales de petroleo, ésta aparentemente no puede

competir favorablemente con las otras alternativas en el esce-

nario de Puerto Rico.

EL analysis para 1a energta del viento fue basado en obser- vactones metesrologicas de 1a estactén de Roosevelt Roads (10M) al este de Puerto Rico de donde se obtuvo 1a distribucién de frecuencia. Esta fue integrada con la curva caracterfstica de

molinos de 500 kw y 1500 kw,

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Los datos presentados en le figura 9 corresponden a molinos de 500 kw ya que estos resultaron mas econémicos que unidades de 1500 kw, Reconocemos que se requieren ma- yores estudios mete6rologicos para una evaluacién mis ade- cuada. A tales efectos el Centro esta desarrollando una red mete6rologica y ambiental computarizada y utilizando

radiotelemetria para la transmtsién de datos. En el estudio

de energia procedente de celdas fotovoltafcas se utilizé una insola-

cién de 5.451 kwh/m2/dfa correspondiente a observaciones del

CBEA en la parte sur de Puerto Rico

En la prediccién de los costos futuros de modulos foto-

voltaicos se utilizé la informacion mas reciente publicada por

la oficina de Energia Federal

Esta esta ilustrada en la Figura 11. Otros datos y for-

matos de estimacién del costo total de unidades estén contenidos

en el estudio. Tod:

estas variables pueden someterse a analysis

de sensitividad ya que estan progranadas en computador:

Para estimar los costos de inversién, de la alternativa ener-

gética OTEC se utiliz6 un disefo espectfico para el sitio de Punta

de Tuna P.R., realizado por 1a Deep Of1 Technology Inc. subsi-

diaria de Fluor Corp. con un costo total estimado de $5230/kw

(ano 1980). Otros

tudios y estimados también fueron considerados

Para predecir el costo de centrales futuras se utiliz6 una curva

de aprendizaje logarftmica que indica saturacién luego de un apren-

dizaje 0 construccién de varias plantas

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Esta curva es tipica de la industria, Para la generacién eléetrica se presumio un 23% de energfa para auxiliares (comparado con 4% para centrales de aceite y 8% para centrales de carbén)

Los costos de operacién y mantenimiento de cada alternativa fue evaluado mediante el establecimiento de un Staff operacional de cada Planta y correlaciones de los varios gastos con la magnitud del grupo operacional de personal y kwhr. generados.

Conociendo los afios en que pueden resultar econémicas las

alternativas y desarrollando una prediccién de las necesidades energéticas hasta el afo 2000 segin descrito a grandes rasgos anteriormente podenos desarrollar posibles escenarios para satisfacer la demanda, La Tabla I representa un posible escenario para Puerto Rico. La Tabla II presenta los millones de barriles de petr6leo a ser desplazados por el escenario propuesto en la Tabla I.

EL impacto en 1a economfa de Puerto Rico de una fracción
de este escenario en términos de aumento en producto bruto y
nimero de enpleos adicionales se evaldo y esté reportado en
dicho estudio. El efecto de 1a instalación de fuentes renova-
bles de energie reulté my significative, Este incluye los

siguientes resultados

1) Cuando un proyecto de biomasa (una unidad 400 Mi) se in-

troduce la produccién agricola aumenta considerablemente.

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Este aumento induce mayores aumentosen 1a produceién y em-
pleo en el sistema equivalente a $71.8 millones (precios de
1972) y $018 nuevos empleos En otras palabras por cada
millén de d6lares en aumento en la produccién de biomasa
agricola se Crear®? 119 nuevos empleos y 1.6 millones de
aumento en 1a econonta
2. EL establecimiento de dos proyectosuno OTEC y otro
biomasa crearén 58,000 nuevos empleos y un aumento en
$1,236.1 millones

Una serie de 6 condiciones adicionales de no menos impor-

tancia estén contenidas en el estudio

En resumen el CEEA ha desarrollado los modelos econémicos

necesarios los cuales se prestan para estudio de sensitividad

y modificaciones por implicactones regionales. £1 modelo tiene

aplicacién para los demés paises de Latinoamerica y representa

un util instrumento de planificacién energética

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29

maa L

SCENARIO PROPUESTO DE PLANIAS ELECTRICAS A DESARROLLARSE

PASTA EL ARO 2000

Biomasa _OTSC__?Potowoltaico _ Viento cartén

---Page Break---

30

?TABLA IT

MELLONES DE BARRILES DE PETROLED A SER DESPLAZADOS POR EL. ESCENARIO

Biomasa

198084 ~~

1985

1985

1987

1988

1989

1990

1991

1992

3.285

657

657

657

657

657

6.57

657

657

657

657

6.57

657

657

657

PROPUESTO EN TARIA I

(Centrales a 75% Factor de Capacidad)

ome

438

438

438

27446

58.48

548

822

822

8.22

822

13.70

19.20

19.20

2.74

2.74

5.48

5.48

548

5.48

5.48

5.48

88288888888:

a8

ee

?Total:

95.265

101.308

38.36

17

(GT PRSSRT ERS 600 FSB

©

Energfa calculada del

(e) Presume central OTC

236.103

Viento digonible y oaractertaticas ea turbina

?experimental de 40's es retired ae

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UPADI 82

Sen Juan, Puerto Rico

?August 1-7, 1982

First Pan American Congress on Energy and

Second National Conference on Renewable Energy Technologies

ALTERNATIVE ENERGY IN THE CARIGBEAN,

By

Howard P. Harrenstien

Architectural Engineering Program

University of Miami

Coral Gables, Florida - USA

San Juan, Puerto Rico

?August 1982

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Tho island communaties of vas Carinbean and their maintand

neighbors, with th. except .on and Mexicn, are

sufverine? from sscreasu® int of imorted toseil fuels.

the game tame, these jurisdictions a7. blussed with an abundance

f inexhaustible natural sources of energy, including solar,

hormal, wine, ocean, bionass, and in certain Locations. large

wunes «i geothermal energy. his paper repicts on the progress

9 9 peoxect which is currently underway to ivolop the scientific

vt otgsicaring cupabilities of the universities in the Caribbean

reo) san wress of alternative enetay, under funding provided

by the National Science Foundation, the Exxon Educational Founda

ior, tho Caribbean Development Bank, and the Government of

Yenetuela, The project uses a unicue human resource, the mechanism of ?the network of the Association cf Caribbean Universities

wd Research Institutes (UNICA) to endorse 3 cooperative research effort eimed et increasing tne capability of Cariboean institu taons te assist in the intecduction of alternative energy solutions anto the region. An elewent of data coliection and systems analyses of appropriate eneray technology alternatives is included, with results culminating in the preparation ot cooperative

research and training programs to assist in the early impicmentation of the most economically viable alternatives, ?The rescatch workshop formit has been used and provisions have beon made

for the active involvement of & representative network of regional ceneurch centers. With coordination and leadershiy. being provided by the Center cor Energy and Environment Research (CEEK) of

the University of Puerto Rico; the University of Miami, the

Central University of Venezuela, the University of the West

Indies, and the University of Florida are ull taking active

roles in the assurance of the success of this activity.

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NEMGY IN

This paper reports on the srogress of an cngoing project to develop the scicntific and engineering capabilities

of the universities and research institutes in the Caribbean,

in order that faculty, students, and staff at these institutions may assist in the orderly development of 2 ?grass-roots? conversion to alternative energy in the region during the decades ahead. The project is funded primarily by the National Science Foundation, under their Science in Developing Countries program, and by the Exxon Educational Foundation. Additional invaluable assistance has been provided by the Caribbean Develop

ment Bank (COB), and by the Venezuelan Government.

33. BACKGROUND AND NEED

Figure 1 shows sone of the 51 inhabited islands of the Caribbean archipelago which have a total land area of about 90,000 square miles and a total population of approxi- nately 20 million. Only one of these island-states produces fossil fuels. this is Trinidad, which has 1/45th of the total land area and 1/20th of the total population. The size of its foreign reserves places it among the first six of all

?the nations in the British Commonwealth. The other 50

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isiand-communities depend on imported fossil fuels for 99% of their energy requirements

?The Caribbean community includes the collection of geographical entities which occur in the vicinity of the Carib- bean Sea. This sea is the part of the Atlantic Ocean lying directly cast of Central America; north of Panama, Colonbia, and Venezucla; west of the Lesser Antilles Islands (i.e., Barbados, Trinidad, and Martinique) and south of Cuba. The Sea is abour 1500 miles long, 700 miles wide, and as deep #5 22,788 feet. Ships which use the Panama Canal must by necessity pass through the Caribbean Sea, and as a result pass close to many of the Caribbean Islands. Many of thest islands form the West Indies, which, according to adolf A. Berle, former Assistant Secretary of State for Latin American Affairs, is "the most strategically placed, overpopulated, ethnically complex and politically divided archipelago on earth."

Since the 1950's, the Caribbean has made strenuous efforts to diversity its economy by providing more jobs through industrialization and by expanding tourism. As in so many developing countries throughout the world, these early efforts were almost totally based on the use of imported fuels.

By the end of this decade most of the archipelago will

?be @ disaster area unless the dependence on imported fossil

fuels is reduced and the use of alternative sources of energy

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is greatly increased. Four of the major coad-blecks to progress

are (a) Lack of manpower, (b} inadequate ieseurch in the use

of oxisting tachnology and adaptation or nodification of the

various technologies to the social and physical environment,

fe} the lack of 4 grass roots cooperative enersy program involving

the universities and research institutes of the region, and

(a) the lack of investment cupital.

A systen of cooperation is of great importance in

region whose history has been one of fragmentation and of

@ependence on external markets and external authority. The

Project must provide for, and depend upon, the active coopera tion of universities and resoarch institutes from the Spanish-speaking, English-speaking, French-speaking and Dutch-speaking Caribbean. The levels of research work will vary, and this requires advanced centers to provide technical assistance to those which are less advanced. In this way the effort to find viable programs for the use of alternative sources of energy may be shared by al) the institutions involved.

Tes long history of elitism and of dependence on external rulers has left among many Caribbean peoples @ bitter legacy of resentment, even of hatred. The ideological conflicts that characterize the contemporary caribbean and the passionate Litany of abuse are evidence of this, just as the boat-people

from Cuba and Haiti and the illegal immigration into Puerto

Rico from the Dominican Republic are indicators of a growing

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Poverty and discontont, Ald from the industrialized countcies is important, but it cannot of itself provide & solution.

Caribbean development depends, in the last sesort, on the

capability of the Caribbean people to analyze their problems

P:

and, with assistance from others, to find solutions for then,

Cooperative relationships between individual! United states

and Caribbean universities, though valuable in themselves,

do not fully mect the need for transforming donor-recipient

relationships into a large partnership of scholars and scientists.

This is why the project attempts to make full use of a network

of Caribbean institutions, providing a mechanism for training

at appropriate centers within the region, and involving many

Participants in research programs and in the preparation of

@ comprehensive regional program for using alternative sources

Of energy. Through this method, it is contemplated that the quality of science and engineering research will be improved,

and the potential for intellectual stimulation, for technology transfer and for further cooperative efforts will be realized.

?The Caribbean community has a very rich potential in inexhaustible alternative energy sources. In addition to geothermal energy, which is in abundance in locations such as St. Lucia, many feasible inexhaustible solar-related alternative energy sources exist. This is largely due to the fact that the Caribbean, within a latitudinal range of 10°N. to 25°N.,

has a resulting year-round solar insolation of approximately

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2000 BTU y

Sauare foot po: day (about twice as mich as in

Mashingten, D. C.). A few o* the nore comnon of the solar Fclated resources are trade winds, ocean waves, moderate ocean Surents, oxtensive ocean thermal asses, year-round bionasy Prosuction, agriculture, ses tood and mariculture, and many sedsttonal forms of solar thurma? and solar electric options.

?THIS project focuses on the need for practically all She countries of the Caribbean acchipelago and Guyana to achieve ?Sreater self-sufficiency in energy; on the role that Caribbean

universities and research in,

tutes can play in meeting that needs and on the fact that the region has a rich potential 4 Anexhaustible alternative energy sources. we believe it Represents a first indispensable step in using the existing network of research centers, schools of the natural sciences and engineering, and other related university departments 4 2 coordinated program to help moet the region's energy needs, Furthermore, it points the way to an exeiting concept of the region as a laboratory for the development of alternative sources Of energy, in which lessons can be learned and demon Strations carried out that will be of benefit to other countries that have similar needs.

Because of the urgency of the energy situation in the

Caribbean, it is erucial to the orderly economic and cultural

Gevelopment of the region that a degree of energy self-suttie

ciency be developed at an earty date. 12 this does not occur,

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disastrous consequences will result as the prices of imported fuel escalate beyond reach of all but the most well-endowed (or most heavily subsidized) communities, thus forcing them into either a position of complete dependence on those who have oil, or into a position of the deepest poverty, beyond

which economic and political survival may become impossible.

117. UNICA AND THE UNICA FOUNDATION, INC.

?The organization under which this project is being conducted is UNICA, which is supported by the UNICA Foundation, Inc. The Principal Investigator, Dr. Juan A. Bonnet, Jr, Director of the Center for Enersy and Environment Research at the University of Puerto Rico, and the Co-Principal Investi- gator, Dr. Howard Harrenstien, Director of Architectural Engineering at the University of Miami, are both menbers of the UNICA Commission for Science and Technology, with Dr.

Bonnet as Chairman.

In the late 1960s, perceptive Caribbean educators saw the future development of the Caribbean community as a matter of common regional concern. To meet their common needs they created UNICA, a voluntary association of Caribbean universities and research institutes dedicated to positive carefully-directed efforts for Caribbean development. Founded in 1968 by 16 universities located in ten Caribbean countries, the organization now has 45 members representing a constituency of more than 300,000 students and 30,000 faculty. The current list of

UNICA members and officials follows:

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In order to lend: assistance and im

us to the goals

of UNICA, the Association of Caribbean Universities and Kesvarch

Institutes Foundation, Inc., was created. With Dr. Henry

King Stanford, retired President of the University of Miami, a8 President, the Foundation was established as a non-profit organization in Florida, It has been granted tax exempt status a8 a public charity by the Internal Revenue Service and support to the Foundation is tax deductible under the Internal Revenue Code. It is significant that the provision for alternative sources of energy and the improvement of university teaching

and research it

the Caribbean are among the objectives of this organization, and it is this organization which first

agreed to support this project.

1V. PRELIMINARY RESOURCE ASSESSMENT

Demographic and statistical data for most of the island communities involved in the Caribbean region are contained in Table 1.

As may be observed, this table presents data on the language spoken, latitude, longitude, area, population, popu= lation density, highest point, length, width, lateral exposure to wind, kwhr per person per year electrical consumption, and millions of barrels of oil per year required to generate electricity. ?The Table is preliminary in nature, and mast

not be overestimated as to its accuracy, as its purpose is

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only to allow preliminary assessments to be made. Neverthe)

it is hoped that these data ere found useful to those who

would engage in energy analyses ané projections. 1¢ is the

intention of the author to continually update and expand on

these data; therefore, persons who have additional or conflicting

information are urged to contact hin.

Table 1 estimate

total population among all of the

islands mentioned of 18,137,800. ?This figure is probably

Somewhat low, in that 1970 statistics were used for some of

the islands. the combined area of all islands is 42,213 square

Miles, and the estinate of combined projected shoreline which

is normal to the prevailing trade winds is 827 miles. rt

is estimated that 37,950,000 BBLS of ofl per year are imported

by these islands collectively to provide electrical energy

to their population. If the influence of Puerto Rico is subtracted

from these totals, they become 14,961,800 persons, 38,778

Square miles,737 miles, and 16,079,000 BBLS of oi] per year

respectively.

Earlier in this conference, in the paper by Ronald

D. Scott and Howard Harrenstien, a rank ordered list of alterna tive energy technologies which were deemed technologically

suitable for development in Puerto Rico were presented. If

this list is reviewed for possible application to the remaining

islands in the Caribbean, only slight modifications and additions

need by made. The resulting list, in rank order of estimated

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readiness of the technolovy, is the followin

1, Solar Hot Water

co-generation

yaroulectrie

4. Electricity from Solid waste

Small Wind Machines

Large Wind Machines (Windfarms)

7. electricity from Bagasse

lectricity from Solar Ponds

9. Photovoltaics

10. Ocean ?Thermal Energy Conversion

11, Geothermat Energy Conversion

12. Other

A preliminary estimate of the potential of these technologies as far as replacement of imported fossil fuels is concerned nay be produced by assuming (hat the islands in the Caribbean have many sinilarities of character, and that lifestyles will eventually reach similar levels of industrialization and development. One can then take the current estimates of potential for Puerto Rico and use them in predicting the potential for the remaining islands in the Caribbean. ?Tablo 2 computes the values of contribution in BBLS of of1 saved per year for each alternative energy technology at the end of full conmer- eialization by the year 2000, using data which is consistent

with that presented in the Scote-Harrenstien paper of reference.

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u

Tt may be observed that? the combined contribution from the

Sources listed totals 154,230,000 BBLS of oil per year saved.

his assumes that the energy produced by the alternatives replaces electrical energy which has been produced by burning imported fuel at 308 efficiency of conversion.

Fron Table 1, subtracting the contribution fron Puerto Rico, the region imports only 16,079,000 BBLS of oil at the Present time. If a 5% per year growth rate is assuned from

1980 to the year 2000, this total would grow to 42,662,374

BBLS of oil per y

F. Energy self-sufficiency, then, as far as electrical generation is concerned, is achievable by the year 2000, if the region of reference comercializes only 27.66% of the total potential provided by alternative sources that is estimated in Table 2, as 27.668 of 154,230,000 is Precisely 42,660,018.

This is very good news for this region, but @ plan for orderly development and progress must be instigated at the earliest opportunity: to delay is to lose vitel capital which 1s needed for the transition. This capital must not be spent paying for further escalating imported oil purchases, or the energy self-sufficient state may becone unachievable.

As may be observed in Table 2, there are two alternatives which show significant promise for making major contributions in the immediate future. ?These are Wind (Numbers 4 and 5)

and Biomass (Number 7). In recognition of this potential,

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the UNICA Conmizsion on S~ience and Technolagy selected these

for early emphasis. A prourece report on the result of

activity 1s contained in tie following session.

y, JGRESS REPORT

The UNICA project being reported here has to date focused its activities on the collection of material related to the current state of affairs in the Caribbean with respect to alternative energy education, training, research, development,

and demonstration. In order to collect this material and

Ampact the planning process for the acceleration of the introduction of alternatives into the region, it was decided to ask the universities and research institutes which comprise

UNICA to appoint official contact persons who could represent

their institutions, and who could participate in workshops

which were designed to stimulate the production of relevant

material on the subjects chosen.

2. Wind Workshop

?The first opportunity for the contact persons and other

invited participants to convene was at Barbados on December

6-9, 1981, A workshop was presented at that time titled "Wind

as an Energy. Alternative for the Caribbean". Some 50 persons

Participated. After hearing background papers on the subject,

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the participants divided into three workehops covering the

following subjects:

* Education and Training ~ dr. Howard Harrenstien, Moderator

* Research and Development - Dr. Edwin Nukez, Moderator

* Demonstration = De. Mudusto Iriarte, Moderator

It is the opinion cf UNICA that the Dec. 6-3, 1981,

Barbados Conference on Wind as an Energy Alternative for the Caribbean was a success, when seen from the point of view of evaluation by the participants, and from the point of view of providing an opening in communication links on wind energy in the Caribbean scientific and engineering education and research community, Although the three culminating workshops were conducted independently from one another, recommendations Produced by them had some marked similarities and focus. A generalization of the recommendations and a prioritization

results in the following conceptual overall recommendation:

1, A resource assessment should be conducted to determine the existing situation in education and training, manpower, the magnitude of the available wind resource, the avail~

ability of appropriate wind sites, and the existence

of wind denonstration projects in the region.

2, Based on the results of the current ?state of the

art" assessment in priority #1, a plan should be prepared

which would detail the steps (including costs) necessary

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te accomplish an acceptable level of progress toward

est of the recomendations érom

achievement 0

the individual werkstops

3. Sourcos of fundiny snovld be identified which will

enable the continuance of the program which was ini:sated

by this conference and which will assure the timely

completion of priorities } and 2.

With the achievement of these three priorities as objectives.

At is predicted that the scientific and engineering capabilities

of the universities and rescarch institutes in the region will

thened, as far as this form of

be greatly enhenced and str

alternative energy is concerned.

The draft of the proceedings of the Barbados Wind Workshop has been prepared, and copies may be obtained by writing:

Dr. Thomas Mathews, Secretario General

Associacion de Universidades e Institutos de Investigacion

de) Caribe

Apartado 11832

Caparra Heights station

San Juan, Puerto Rico C0922

2. Bionass Workshop

?The second opportunity for the UNICA contact persons

to convene and to discuss the alternative energy situation

29, 1982. The

in the Caribbean was in San Juan on April 2

subject was "Biomass as an Energy Alternative for the Caribbean".

he proceedings for this workshop are in the process of being

---Page Break---

PrepUed, and when completid thoy nay be obtained from br. Mathews, the above source. In ?he interim, however, copies of suite of the papers presented my be obtained dirvctly from:

Dr. Suan A Bonnet, Jr.
Director, Center for Eneray and Environment Research
Caparra iignts station
San Juan, Puerto Rico 0935

The papers which are immediately availuble are listed after

the reference section to this paper.

vr. smmmany

Energy consumption patterns for the Caribbean and alternative energy assessments and analyses are a continuing activity by tho research staff. Results of some of the early assessments were compiled by Dr. Bonnet, and are included in the material

Which follows the reference section of this paper.

It is clear at this stage that a much more detailed Fesource assessment is needed before a realistic plan for education, training, and institutional development may be prepared. in fact, it may be that through the involvement of persons: in

the Caribbean in the as:

sments and plan development, @ sub- stantial level of institutional development will occur by virtue of the grass roots nature of the activity.

What is equally clear, however, is that the Caribbean region is richly blessed with renewable alternative energy sources which are quite capable of providing energy self~

sufficiency to the region in the decades ahead. Whether thoy

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do or whether they don?t-is a matter for rosponsible citizens, from both within ané without the region, co inmediately face;

the conversicn to alternative waersy sources will not happen

without major human and institutional effort, not the least of which is related to education, training, research, develop-

ment and demonstration.

VIT, REFERENCES

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Scott, RD. and H. Harrensticn. 1982. Alternative Energy Planning for Puerto Rico. Presented at UPADI, San Juan, Puerto Rico, August 3, 1982.

The International ic_ Encyclopedia and Atlas

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UNICA WORKSHOP

BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN

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?ABBREVIATION 22D ACRONYMS.

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Caribbean Development Bank

Canadian International Development Agency

Consejo Nacional de Ciencia y Tecnologia

México

Department cf Energy (U.S.)

European Development Fund

European Investment Bank

International Bank for Reconstruction and

Development (World Bank)

Inter-American Development Bank

National Air Space Adwintstratton (u,S.)

Organization of American States

Latin American Organtzation for Energy

Development.

Puerto Rico Electric Power Authority

Technical Energy Unit

Interim-Fund - United Nations Interin-Fund

United Nations Development Programme

Caribbean Universities and Research

Institutes Association

United Nations Internetional Children's

Emergency Fund

United States Agency for International

Development

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UPADI 62

San Juan, Puerto Rico

?August 1-7, 1982

| Congreso Panamericano de Alternativas Energéticas y

1 Congreso Nacional de Alternativas Renovables de Energia

ESTRATEGIAS PARA EL DESARROLLO DE LAS FUENTES NUEVAS

Y RENOVABLES DE ENERGIA EN LA REPUBLICA DE PANAMA

Por

Ramin 0. Argote

Jefe del Departamento de Energia y Tarifas del IRE

y Secretario Técnico de CONADE

Sen Juan, Puerto Rico

?August 1982

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INDICE

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INTRODUCCION

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INTRODUCCION

Este trabajo es un resumen del estudio de las Estrate-

gias para el Desarrollo de las Fuentes Nuevas y Renovables

de Energfa en Panam&, que realiz6 el Instituto de Recursos

Widraulicos y Electriticaci6n (IRHE) y la Comisién Nacional

de Energfa (CONADE) bajo 1a asesorfa del Instituto de Conver-

sign Bnergética de 1a Universidad de Delaware y el Centro de

Estudios ambientales y Energéticos de la Universidad de Puer-

to Rico.

Los objetivos son definir estrategias y brindar recomendaciones para el aprovechamiento de los recursos renovables con miras a sustituir derivados del petrolec y a llevar enerfa a las Sreas rurales en forma eficiente.

Para esto se levant6 informaci6n preliminar y se estiné el inventario de los recursos biomasa, biogas, solar, viento y mareas..

Este estudio, aunque toné 17 meses, no pretende ser £inal, sino solo el primer paso para definir, por primera vez en huestro pafs,en forma aproxinada la potencialidad de las fuentes renovables y su posible participacién seria en el Plan Nacional de Energfa que prepara la CONADE.

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I SITUACION ENERCETICA EN PANAMA

La crisis de energfa mundial repercutié en Panamé no gon una escasez de energéticos, sino con un fuerte aumento

en los precios de los misnos. ?Por tal tazén se han aunentado los esfuerzos nacionales para aprovechar los recursos looeales, esto dentro de una planificacién unergética integral,

los productos derivades del petréles representaron ducinte 1a d&cada del 70 més de] 801 de 1a oferta alobal de saersia secundaria en la Repblica de Panamé, correspondiende esto a aproximadamente ec} 20% del valor de las inportacrones de bienes.

Panama cuenta afortunadamente con considerables recursos hdricos, de bionasa y sclares, en los cuales se apoya su po. iftica para minimizar su dependencia del petr6leo imvortsde, sin descuidar las estrategias para la prospeccién de hidro. carburos.

Bn el aio 1980, .e1 consumo nacional de energfas secundarias fue de 1.5 x 104 Teal o sea el equivaiente de 17,900 miediones de Kwh. De ese total participaron los hidrocasburos gon 62.58, la leha con 20.88, 1a electricidad con 9.48 yo), bagazo con 7.38.

Bn nuestro pafs no existen actualmente reservas conoci-
Gas conercialmente explotables de petréleo. Este se importa en un 1008 ya sea como crudo o en forma de derivades, por 1o gue existe una gran dependencia del petrSleo, que como ener. gia secundaria, graduaimente baj6 su participacién del 678 en 1970 al 638 en 1980

B1 consumo nacional neto de energfa subi6 41.6% entre 4970 y 1980, a expensas casi exclusivanente de los derivados de petréleo, como el diesel y las gasolinas en el sector transporte y el GLP en el residenciai.

Jas fuentes aut6ctonas de energfas, lefa, bagazo e hidro incrementaron su participacién en el consumo desde un 29/08 gn 1970 al 33.68 en 1980, pero la lefia disminuyo su aporte de 268 a 21% on ia década,

Bl consumo de energfa total del pats crecié al 3.58 a-
nual durante el perfodo 1970-1980, 1a energia comercial (ni-
drocarburos y electricidad) 10 hizo al 4.7%, mientras que Las fuentes domésticas lo hicieron al 4.4% anual, crecienda s4¢

en 1a década. tas tasas anuales de crecimienco del consune en los diversos sectores fueron de 1.28 para el residencial, 9¥ Para el comercial, de 7.5% para ei industrial y agropecuario ¥ de 5.08 en el transporte.

---Page Break---

Ante esta situacién se intciS en nuestro pats desde 1972 un agresivo programa de a,rovechamiente de los tecursos hi- Arfalicos cuyo potencial inventariado asciende a los 2500. Mw: de estos se han desarrollado 250 Mw y estan en construccién 300 Mw m&s con una inversi6n de mis de 8/.500 millones. Ade~ mas a fines de 1979 se corenzaron los estudios para el apro- vechamiento de las fuentes sucvas y renovables de energfa.

Esta Gltima iniciativa se concreté mediante el Proyecto de Fuentes Alternas ejecutado por el Instituto de Recursos Hidrdulicos y Electrificacién y tinanciado conjuntamente con la Agencia Internacional para e) Desarrollo (USAID) +

El Proyecto de Fuentes Alternas con una duraci6n de tres afios, cubre dos areas de actividades:

1, Construccién de proyectos demostrativos de energfa solar para calentamiento de agua y aire acondicionado, sistemas fotovoltdicos y producci6n de biogas.

2. Levantamiento de la informacién y definicién de Estrategias para el Desarrollo de las Fuentes Renovables de E~ hergfa a nivel nacional.

Beta Gltima actividad representa el primer esfuerzo en nuestro pafs por cuantificar, localizar y planificar el desarrollo y aprovechamiento energético 6ptimo de recursos de energfa renovable como Biomasa, biogas, solar y e6lico. Esto se ha llevado a cabo utilizando la informaci6n energética y los lineamientos de polftica energética de la Comisién Nacional de Energfa (CONADE).

El estudio para elaborar el documento de Estrategias, se Aniei6 en junio de 1980 siendo sus objetivos principales ios siguientes:

1. Un an&lisis de la domanda de energfa

2: Un inventario de recursos renovables

3. Una evaluacién de tecnologias de aprovechamiento de re-
cursos renovables.

4. Desarrollo de polfticas y estrategias para el desarrollo
y aprovechaniento de energia renovables.

A nivel global, los resultados encontrados de la oferta
de envrgfas nuevas y renovables son los siguientes

1, ba oferta global de biongsa en términos de productividad
anual asciende a 48 x 104 Tcal con un potencial disponi-
ble actualmente de aproximadamente diez veces esa canti-
aad.

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III

rémminos generales, las siguientes estrategias a corto y medio.
yo plazo de las fuente:
nam?:

los recursos aprovechables para la veneracién de biogas
se estiman entre 900 y 1,800 Teal.

Estos son desperdicios cispersos pero su aprovechsmien-
to puede tener un impacto significative en las areas rar
rales del pats.

Las estimaciones preliminares indican que las nicrocen-
trales hidroeléctricas poarfan suplir 10.5 megavatios,
adem&s de los 25 mw en minicentrales-

Los recursos de energfa solar varfan de regién a regién
? inclusive sufren de variaciones estacionales. Panama
euenta con 2100 horas de insolacién promedio anual con
niveles de radiaci6n que oscilan entre un minimo de 194
watts/m2 a 500 watts/m2.

Se ha confeccionado un mapa preliminar de isopletas pa-

Fa estimar la energfa e6lica pero existen pocos datos,

habiendo disponible poca instrunentacién de medicion,

Los recursos energéticos maremotrices o de olas no se

dan en cantidades apreciables; adenis que su explotaci6n

podria afectar la industria pesquera y el habitat mari

ho de nuestras costas, los cuales son una importante

fuente de divisas en nuestro pais:

ESTRATEGIAS PARA LAS NUEVAS FUENTES RENOVABLES

ESTRATEGIAS PARA LAS NUEVAS FUENTES RENOVABLES

En base a los resultados obtenidos, se pueden definir en

nuevas y renovables de energia en Pa-

Promover a nivel nacional 1a concientizacién y 1a educa-

ein técnica tanto en el uso de las fuentes nuevas y res

novables como en el uso racional y eficiente de las fuentes de energia renovables tradicionales.

Completar y detallar e1 invetario de recursos energéti-

cos renovables.

Ejecutar un programa de desarrollo masivo de biogas a

nivel nacional que incluiré la construcci6n de digesto-

res a nivel residencial y comunitario.

Aumentar 1a oferta de lefia mediante 1a creaci6n de bos-

ques comunitarios y programas de reforestacién para uso

en la cocina rural, y promover el uso eficiente de ese

recurso.

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continuar 1

tricas par

das.

hidroeiécectsicida?

Crear servicios de extersi6n rural para diseminar las

tecnologias apropiauas 4 las reas més alejedas de} pats.

Propiciar las invest icaciones aplicadas, en especial en

las reas de enfrian cnt) solar, normas arquitectOnicas

pasivas, secado solar y uprovechamiento e6lico.

Provesr asistencia técnica en el uso de colectores sola-

res para calentamient> de avua o produccién de vapor en

usos industriales, comerciales y reetdenciales, Hacer enszyos locales de especies de rfpide crecimiento para plantaciones fcressales.

mover, medicnte proyectos demostrativos el uso de la energfa para la generacidn de electricidad y energfa mecanica.

Estudiar el uso energético Optimo de residues que se producen en forma centraiizada (basura, cAscara de arroz, rechazos de banano, bagazo, etc.).

Realizar programas de uso integral de energfa con fuentes nativas en comunidades aisladas no interconectadas.

Continuar los estudios de gectermia.

Mejorar 1a capacidad de financiamiento y motivar median- te incentivos o subsidios, las iniciativas a nivel comu= nitario o industrial para?la utilizacién de, 0 produccién de equipamiento para el uso de fuentes renovables de ener- ofa.

IV ANALISIS DE _LA DEMANDA DE ENERGIA

£1 primer reguisito para evaluar el potencial de aprove- chamiento de fuentes renovablee de enere?a en Panané, es una descripcién de sus usos finales para identificar la demanda de energia susceptible de ser cubierta por las diversas tecnolo- gfas de aprovechamiento.

Se analiz6 1a informacién disponible que habta sido pre- viamente obtenida y ordenada en el desarrollo de los Balances Naciona?-z de Energfa. Al encontrarse que la informaci6n no contenfa 1 grado de detaile y el tipo de ordenamiento para este esiudio, hubo necesidad de disehar un plan de investiga-

ci6n para generarla.

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Para los propésitos de oste estudic se necesitaba una

estructura sectorial desagregada donde re pudicran identiei-

gaz claramente los consumo de energia currespondientes a}

Sector Residencial, Comercial, Industrial, Pablico y trans-

portaci6n. Adenas, ?se requerfan ios consumus de energta segdn

Uso final en estos factores.

a. Sector Residencsal Urbano

Se disefio y realiz6 una encuesta para determinar ol con-

sumo residencial urbano de energfa, Se toné una micstre

de 995 viviendas equivalente al 0.5% de las viviendas

particulares ocupadas conectadas a la red de electrifica-

gion en la ciudedes de Panama, Colén, Santiago y Davids

Se valor 1a informaci6n obtenida comparando tos consu=

mos de energfa eléctrica facturados por el iRHE a las vi~

viendas incorporadas a la muestra, con 10s consumos re.

portados por los encuestados y con los célculos elabora:

dos de consumo de energfa eléctrica por uso final. Esta:

Gomparaciones indicaron que las cifras correspondientes

a 18s distintas indicaciones de energfa eléctrica estaban

generalmente dentro de un rango de 10% de variaci6n ents

ellas, por lo cual se consideré valida.

b. Sector Residencial Rural

Se tom6 la informaci6n del Balance Energ&tico en donde el

gonsumo de lefa en 1980 para el sector residencial fue oe

780,000 Toneladas por ano.

Bl promedio de uso de la lefia para cocinar es de 3.25 Kg/

hab. /afa.

La participaci6én del consumo de carbén vegetal ha dismi-

nuido debido a causas tales como:

(a) La disminución en 1a demanda por 1a reubicación de

Poblaciones tradicionalmente consumidoras, como las

de Chorrillo y Maranén.

(>) La lejania dei principal centro de produceién y los

consiguientes aumentos en el flete de transporte.

(c) Los precios no competitivos con el GLP.

Sector Comercial

Una muestra correspondiente al 1% de las empresas comer-

giales incluidas en la Gran Divisién 7 del COdigo Inter=

nacional Industrial Uniforme (CIIU) se seleccionS aleato-

Fdamente para el Sector Comercial. En total se incluyeron

62 empresas comerciales on 1a muestra.

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a. Sector Industrial.

Una muestra similar coLzes,ondiente a) 1% de las sndus~ trias manufactureras se seleccioné aleatorianente de 1a Gran Divisi6n 3 cel Cli. Esta muestra consistfa en 40 industrias. Aguf del Balance Energético se obtuvo un consumo de lefia de 73800 Tcn/aho en dreas rurales.

Sector PGblico

La informaci6n correspondiente al consumo de enerasa e- iéctrica en el Sector PGblico se tond de dos encuestas realizadas en 1979 por el IRIE, sobre los usos de 1a e- nergia.

Los resultados de todas estas investigaciones se presen- tan en tres formatos diferentes que son:

1. Consumo ?To!

La participaci6n de los distintos sectores en el consumo de energfa para 1980 fue de 29.3% para el Sector Residencial, 4.48 en el Comercial, 27.2% en ¢l Industrial, 26.74 en e1 transporte, 2.10 en/el pGblico y 10.4% en otros (ver Figura 1)»

Consumo Total Anual de Energfa Secundaria, por tipo de Uso Final

M&s del 56% del consumo total de energfa est en las ac~ tividades de cocina y transporte. (Cocina con 26.4% y Transporte con el 26.78). Las otras actividades tienen una importancia relativa mucho menor en el consumo. (Ver

Figura 2).

Consumo Total Anual de Energfa Secundaria, por Energ6tiee.

En este formato resaltan los consunos de lefia (bajo el rubro de Otros) para cocina; de la gasolina y el diesel

para el transporte; y de los desechos agrScolas para 1a

Producci6n de calor de proceso. (Ver Figura 3).

La informaci6n asf clasificada, permitié la definicin

de metas de sustituci6n a través de'1a aplicacién de tecnolo-

gias de aprovechamiento de recuros renovables de energ?a. Tan-

bién ayudo a identificar tipos particulares de demanda de ener-

gfa a los cuales deben dirigirse los esfuerzos de conservacién

de energia, de reordenamiento de los precios relativos de los

energéticos o de aplicacién de impuestos u otorgamientos de

subsidios..

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V EVALUACION DE LOS RECURSOS ENERGETICOS RENOVABLES

Se realiz6 una evaluaci6n preliminar de los recursos e-

nergéticos renovables disponibles, presenténdose los resulta-

dos en cuatro volumenes: Biomasa, Biogas, Solar y Oc62no/E61i

Biomasa

Esta investigaci6n se centr en tres objetivos principa-

les: Evaluaciéa de la fitomasa, de su potencial energético

y valoraci6n del potencial de los desperdicios, como fuentes

alternas de energfa provenientes de las plantas.

La estimaci6n del potencial de biomasa, se realiz6 eva~

luando métodos distintos con informaci6n de varias fuentes.

Se opt6 por un estudio planinétrico de mapas y fotogra-

ffa de satélite, conteniendo dates de la zona de vida a nivel

nacional. Del estudio se determinaron las grandes reas de

biomasa existentes en el pafs excluyendo las zonas agricolas,

cuencas hidrograficas, drea cerca de los depésitos de agua y

las reas pobladas.

Se hizo un listado de las especies existentes més repre-

sentativas en el pafs (ver Tabla i) y se determiné su poten

cial energético.

Tabla N°2

Especies m&s representativas dentro del Pats

a. Especies de mayor demanda para Carb6n de Lefia en

Panamé en base al estudio de Duke (1972)

Acacia

Brysonina nance?

Prosopis

Manglar

b. Especies m&s usadas como Lefia en base al estudio de

Duke (2972)

Acnistus

Bursera

Diphysa

Erithrina

Spondias

Tabebuia

10.

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c. Especies Secundarias en base al estudio de Tosi

(a971)

Acrocomia sclerocarpa ?Pacora?

Apeiba tiborbou ?cortezo"

Brysonina Crassifolia ?nance?

Cecropia spp. ?guarumo?

Cochio spermim uvifera ?poroporo"

Davilla lucida ?chumico peoro*

Didymopanax morototoni "mangabe"

Guazuma ulmifolie "guas ino"

Ochrona lagopus "balsa"

Trena sp.

xylopia frutescens "malagueto"

En_base al estudio de Porter 1973

Casearia nitida "raspa-lengua*

Cordia alliodora ?taurel"

Hasseltia floribunda "raspa-lengua?

Heliocarpur popayanensis "majagua"

Luehea spectos:

Muntingia calabura "Pasito *

Psidium guajava sguayaba"

?Triplaris cumingiana nvaro santo"

Veronia patens ?lengua de vaca

Vismia baccifera ?sangre perro

Vismia latifolia "sangre perro

Zanthoxylum panamense sarcabu"

Zanthoxylum setulosum ?arcabu*

La lencaena existe pero no es abundante en Panama.

La productividad anual de biomasa se estimé en 484,700

?Teal. La biomasa en pie existente representa un potencial de

1,100 millones de Toneladas métricas (Tm) secas, que equiva-

Len a 2,700 mitlones de barriles de petroleo. Los desechos

forestales representan 90,000 Tm secas de madera, equivalen-

tes a 216,000 barriles de petr6leo (Ver Tabla 2).

Tabla 2

Potencial disponible de Bionasa

Poente, 10° Tm se teas

Inventario forestal

viv 1,120.00 4,703,517.00

Desechos Forestales 0.09 370.00

Desechos Centralizados

(bagazo, desechos agro-

industriales, etc.) 1.80 7,540.00

Total ?3,421.89 Wao

1,121.89 4,711,427.00

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Se considers coe, administredas co: cactamente, tas plane

feciones de energta podrfan rovecr un Cantidad eonscaeree

ble de energfa rencvable. Cuno wedida 2 corto plase so sune~

san probar diferentes espec.es do plantas para lograr el saat

Dor necaesento de biomass pur hect&rea, asf como también pest

dargiuevas especies do rapide crecimiento y de alte contenae

aiérico que pudieran aurentar el potencial de 1a bionasg ae

Panamg, como son las: Albizuia lebbek, Cacuarina equiscesfen

iia, Eucalyptus camaléulensis, ueucaena Leucsccgheta

La mayorfa de los residuos agrfcolas e industriales ru-
Eales estan demasiado disperscs como para ser considerwion
un combustible utilizabie anpilementes

Biogas

$¢,2na1i26 el potencial de producción de biogas a partir
ge xesiduos animales, de plantas, desechos agro-indeservart,
Y,BOblicos, tales como 1a basura: El informe concluys gue ee
fee 6250 ¥ 348-2 millones de metros eGbicos de bioges Geeaine
Se,bueden producir depertiendo de 1a cantidad recuseraae ae
gatos recursos, representando de 894.1 a 1841.1 Torlenae oo
Rergia. (Ver Tabla 3). Estos céiculos se basan en ios Secur=
f08 considerados recuperables y no en el potencial otai ae
seeuges 2isponibles. ?£1 mayor recurso potencial para la cto-
Gugeton de biogas son los residuos animales y desechos agree

industriales.

En base a la informacién recabada, se determiné que las

nayores existencias de ganado y cerdos estin en ia srevinenn

Ge ,Chiriqut, Prov. de panamd y Veraguas. Las Provincise ae

Chiriqut y Coclé ?tienen las nayores plan

arroz, mientras que Bocas de! Tore y Der

Producei6n tienen de los misnos

ho est4 en Chiriguf y Bocas del 1

(bagazo) en Coclé, chirigut y Pan

dos estos productés agricolas 10

cen para el biogas.

se nzecomiendan tres tipos de ostudios para conocer mejor

©1 potencial nacional para le utilizacién de esta cecnolosey

3+ Un estudio detaliado de los recursos disponibles para la

Produccién de biogas y de la demanda susceptible he? see

Cubierta por estos recursos

2+ Un estudio de biodegrabi1idad, e1 cual analice las dis-

tintas materias primas nacionales susceptibles de sen

ntilizadas para producir bioga:

3+ Un estudio para 1a selecci6n de disefios y materiales a-

Propiados para las condiciones locales ef la sonevence

cién de digestores.

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TABLA 3

b

PRODUOCION POTENCIAL ANUAL DE BIOGAS DE DESPERDICIOS RESIDUALES

Fente

Residuos Animales

Plantas Acuaticas

Desperdicios Agro

Industriales

Desperdicios Urba-

nos y Aguas Negras,

?Total

Porcentaje

de Recuperacién

9-30

50

80 - 100

70 ~ 100

10° a? ?Teal

Biogas Byuivalente

34.1 ~ 132.3 160,5-698.5

1.3 59.8

103.1 - 181.4 545.6-960.0

20.5 - 34.5 108.5-182.6

169.0 348.2 994.4 eat

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En cuanto a proyectos, se revomsencan la ejecuci?n de tres tipos:

1, Sistemas unifamiliares, que provean de biogas y fertilizante a las familias aisjadas rurales.

2. Sistemas comunales y cooperativos, que provean de ener gfa a varias familiac, o a requefias ompresas e institu- iones en areas rurales.

3. Sistemas industriales o gubernamentales que generen su- Hicientes cantidades de biogas para abastecer un volumen apreciable de demanda, ya sea en freas rurales 0 urdanas.

En el informe se presentan los programas y presupuestos para estas actividades.

Las tecnologfas de aprovechamiento que se han utilizado en China e India, son susceptibles de adaptarse a las condi-clones de Panama, siendo generalmente tecnologfas benignas, que requieren una inversi6n limitada de capital, poco mante-nimiento y no resultan peligroras para los usuarios, para los recursos naturales, ni para el medio ambiente en el cual se ubican.

Solar, Térmico y Fotovoltdico

Se prepararon dos informes para 1a evaluaci6n de los re-cursos de energfa solar. £1 primer informe evala e] potencial, de radiacién solar basfidose en los datos de piran6metros en cuatro estaciones meteorolégicas con un minimo de diez afos

de informaci6n. E1 segundo informe estudia las aplicaciones posibles para este potencial, particularmente para aplicacio-hes térmicas industriales de ?baja temperatura.

Se consideré que 1a calidad 4e 1a informaci6n disponible y la ubicaci6n de los piranémetros no eran adecuados para una estimacién global a nivel nacional del potencial de recursos solares. (Ver Mapa de Estaciones de Medici6n). El trabajo

se orient6 entonces a lograr una estimaci6n, utilizando otra informaci6n considerada confiable. Como se contaba con series hist6ricas de datos de precipitaci6n muy confiables, se corre

lacion6 el Indice de nubosidad con el {ndice de insolacién, y

el indice de nubosidad con el de precipitacién.

Los resultados mostraron una correlaci6n de aproximada-

mente 0.64 entre la precipitacién y los datos de insolaci6n

Debido al fen6meno de las lluvias estacionales, la correla-

eign fue mayor para los andlisis hechos a nivel mensual.

an

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mJ EPEELEEEEE

Tio

Hissetittits (2

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1s,

Por tant, los datos de precipitacién se pudieron ut! i-

Bev para ident iticar geograficamente coviones Sond ce SA.

cu obren las &reas con mayor insolacién,

Gono parte de 1a evaluaci6n realizada para estudiar po-

des aplicaciones para la cnergfa soler ce visitaron 16

ustrigs que expresaron interés en el uso de la energia so-

ex y gue presentaban posibilidades de sustitucién. Para

jar una idea del potencial de aplicacién para este recureo,

se consider6 factible reempiazar por energfa solar el 308 del

gcusumo de derivados de petrleo en el sector industrial, con

Je sual les ahorros anuales representarfan aproximadamence

2:8 pmitiones de galones de diesel, mas de 102,000 galones

oe bunker y ms de 12,000 galones de gas licuado,

Se encontré que en casi todos los lugares de la Repébli-
ca es posible encontrar una insolacién minina de aproxinagas
mente 193 W/m?, ?También se efectué una evaluaci6n preliminar
sobre costos de inversién y normas de calidad para ia indus.
trie de construccién de colectores.

En conclusi6n, existe un gran potencial para el uso de
la energfa solar en las empresas visitadas, pero seré necosa-
rio realizar estudios técnico-econ6mico m&s detallados pare
Poder recomendar 1a implementacion masiva de sistemas solaces.

Tenemos interés en estudiar la posibilidad de producir
colectores planos con fines de uso doméstico y otros compan
nentes para las aplicaciones a baja tenperatura,

En Panama, la energfa solar tiene su mayor potencial en
el Area de caléntamiento de agua y Secado de arancs, ya que
por la alta incidencia de nubosidad, la radiacion directa se
jimita a la estaci6n seca, o sea cuatro meses al aio, Sin cee
bargo, el uso del del agua caliente en el sector residenciol

tiene?un mercado limitado.

A pesar de esto, hay posibilidades de usar paneles foto-
voltdicos para aplicaciones de comunicaci6n en repetidoras
xemotas, boyas, @ irrigaci6n. Ya se cuenta con un sistema
de comunicaci6n remota de 360 vatios de potencia. La exten=
si6n del uso de placas fotovoltdicas dependerf de cuan Fapido
decaiga el costo de 1a produccién de electricidad fotovolras.
ca y de mejoras en el rendimiento del equipo,

A corto plazo el equipo nacional de fuentes renovables
Ge energia se dedicaré a intensificar las campafias de concien-
tizaci6n para la sustitucién del gas y de la energfa eléceri-
?2 por energia solar para calentamiento de agua. Ademis, se
continuaré la investigacién y promoci6n de otros usos de? 1s
energfa solar, como el secado de aranos y frucas.

Con 1a experiencia que se adquiera en la instalaci6n de

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Sistemas de calentamfento y enfriamientc solar, se brindaré

en erms continuada a usuarios interesados, la asesorfa tée-

nica necesaria para el disefo y la instslacisn de sistemas

Ge todo tarafo. Finalmente, se ampliar&n los programas de ne-

sici6n ?e energfa solar en distintos puntos de la Reptblica.

droeléctrjca

81 conjunto de 1as instalac?ones de las micro-hidroeléc~

sceas constituyen una alternativa para electrificacién de

Gzeus venotas en Panama.

Se han identificado 200 sitios probables y de éstos, 40 devan todos los requisitos que permiten 1a ejecución de ?un proyecto icro-hidroeléctrice.

A nivel nacional, se estima que se podrdn obtener como sinimo 10.5 megawatts de electricidad de este tipo de inste: laciones.

Existen otros sitios con grandes perspectivas, pero és- tos afin no han sido identificados.

El IRHE ha construido conjuntamente con la Agencia Inter- nacional de Desarrollo (AID) dos microhidroeléctricas con ca~ pacidades instaladas de 10 y 50 kilovatios. Adems tiene en construcción cuatro microhidroeléctricas con capacidades de 30, 35, 50 y 60 kilovatios.

Con respecto a las minihidros, se estima que 1a potencia- 1idad a nivel nacional puede ascender a 25 MW. Por el momen~ to el IRHE, en una etapa de experimentación, ya ha construido 2 minihidroeléctricas; una de 350 kilovatios y otra de 250 ki~ lovatios. Adem&s, se estudian tres proyectos mininidroeléc= tricos que tendran capacidades de 500 Kw, 300 Kw y 200 Kw. (Ver mapas de ubicación de los proyectos).

Energfa Geotérmica

Los estudios para determinar el potencial geotérmico en Panam estén en sus primeras otapas

Se han realizado perforaciones con buenos resultados en el frea de Cerro Pando y Cerro Colorado en 1a Provincia de Chiriqut, y £1 Valle en Coclé. Se estan realszando las evalua. clones con apoyo de OLADE; al'momento ee han estimado poven= Giales de 400 MW. (Ver ubicaci6n sobre mapa de sitios de per- foraci6n). El Banco Mundial ha dispuesto fondos para conti- nuar con los levantamientos geoffsicos.

Energfa Océanica

Del estudio de la energfa del ocfano se determiné que hay

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Pequelios cambios de mareas y velocidades de corrientes en la gosta Atlantica, y lugares apropiados con sisnificantes came bios de mareas sobre el Pacffico, pero Estos estén en 0 core Ga de zonas de pesca, exiaderos de mariscos y rutas hacia e) Canal de Panama, y son freas costeras de poca profundidad.

Se determing que hay poco potencial inmediato para la Gonversién energética de cradiente termal crsanice ban esean= Go Panand en la gona apropiaca para el uss de 1a energta ter= mal oceinica

E1 futuro aprovechamiento de 1a energfa del ocegno en Panam& dependerd de 1a obtenci6n de costos apropiados de equi- Pamiento, y la evaluact6n minuciosa de los inpactos ecolégi- cos que puedan suscitar.

Energfa E6lica

Bl estudio de energfa e6lica resulté més optimista. se analiz6 la informacion del viento existente y se determiné gue resultarfa prometedor generar electricidad del viento Gu- zante la estacién seca en varias regiones de Panan&. La gress Ge mayor potencial figuran en la costa del Caribe entre colon ¥Portobelo y el fea a lo largo del oriente de 1a Costa Atlantica al final de la Cordillera Central (Ver mapa de 1s0- pletas).

Sin embargo, 1a informaci6n analizada debe ser complementada mediante un? programa de medición edlica a nivel regional, ya gue existen pocos datos. A pesar de la falta de informa: ei6n nunérica, tenemos a priori criterios que nos permiten considerar la energfa e61ica como un recurso prometedor para poblaciones aisladas en las tierras altas de Panama,

Como un paso inicial, se ha iniciado la instalación de cuatro pequefios sistemas de conversión de energfa eólica acom-Pafados de anenémetros, en sitios aislados que no disponen ae flufde eléctrico.

VI PRONOSTICOS DE _USOS Y SUSTITUCION DE FUENTES RENOVABLES

BRONOSTICOS DE USOS ¥ SUSTITUCION DE FUENTES RENOVABLES

Contando con 1a evaluacion preliminar de los recursos, y copociendo las estructuras de 1a demanda de energia, se proyect6 ja demanda a nivel de energfa final de 1982 el ano 2002 (aos decenios). A su vez, tomando en cuenta los recursos disponibles, se fijaron metas de sustitución alcanzables para el pe-Ffodo en menci6n, bajo un programa de desarrollo extensivoe intensivo de las tecnologtas de fuentes renovables- Los pard-metros globales para dichas metas son los siguientes?

V.-

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18.-

fio 2002

Demanda Total 29

de Energie 29,618.4 Teal

Sustitucién Total 7

de Fuentes Renovs athidteliiie

bles de Energta 6.48

Estas cifras globales de sustitucién se trabajaron en de-

talle para cada uso y fuente de energia renovable, analizondo-

se las sustituciones gencrales en los sectores residencial,

comercial ¢ industrial, y como caso aparte la sustitucién de

la demanda de electricidad en 4reas rurales. Estos resu)tades

se muestran en los dos cuadros s:guientes. (Nl y N°);

Basado en costo unitarios actuales, dicho programa reque-

rirfa la inversién de B/.1,052.1 millones de balboas para fi

nanciar el equipamiento necesario sobre el perfodo en mencién.

Adicionalmente Panan& podrfa interesarse a largo plazo

en un programa para la sustitucién en un @0t de la demanda de

electricidad de los sistemas aislados generados por fuentes

*6rmicas, por fuentes nuevas y renovables para el aio 2000.

Esto, distribuido en 27% por biomasa, 27% por microcen-

trales, microhidroeléctricas, 13+ por energfa eblica, y 138

Por energfa fotovoltdica sighificarfa gonerar el equivalente

de 24,000 Mwh/aho.

Sobre e1 perfodo de dos decenios ésto implicarfa inver-

tir B/.15.7 millones para la compra del equipamiento necesas

Sumando estos dos program:

nologfa al aio 2002 serfa de:

el aporte total de cada tec-

Aporte de las Diversas

Tecnologias = Aag. 2002 Teals Porcentajes

Biogas 582.3

solar 952.7

Biomasa 180.

B6lico 90.0

Minicentrales 9327,

Total 17899-1?

En conclusi6n, Panam& cuenta con abundantes fuentes re-

novables para satisfacer sus necesidades energéticas. En es=

tos momentos, el desarrollo de estas tecnologias cuenta con

un compromiso implicito en nuestra polftica energética nacio-

pal. De ahf se Geriva que 1a Comisi6n Nacional de Energta

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Gg Panam& ve un futuro en e7 cual, tanto por inieiativa pé-

biigay coma Le priveda, las fuentes nuovas y renovables jos

gardn un papel interesante en la oferta enetgética, para oi-

Yersiticar nuestras fuentes primarias de enersfa, 7 mejorar

la calidad de vida en las areas rurales del pate,

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Ing. Rann 0. Argote

Ingeniero Nec&nico-Zlectricista con un Master en Ingenierfa

Eléctrica y Sistemas de Control en el Instituto Tecnol6gico y de

Estudios Superiores de Monterrey, México.

Ha ejercido 1a profesién desde 1965 on actividades de ins

pecci6n, disefo, instalacién y asesorfa de sistemas electromecé-

nicos industriales, Fue Director del Departamento de Ingenierfa

Eléctrica de 1a Universidad Tecnolégica de Panamf, en donde hoy

elerce como profesor titular de tiempo parcial.

Pasa al IRHE como Jefe del Departamento de Energia y Tarifas

en donde participa en la creacién de 1a actual Comisi6n Nacional

de Energia (CONADE) en 1a cual funge como Secretario Técnico.

Dentro de estos organismos ha desarrollado y dirigido estudios

a

Tarifas y Costos de Energia Eléctrica; Balances, Pron6sticos y Auditos Energéticos; Fuentes Renovables de Energia y Planeamiento Energético global.

Fue Presidente de 1a Sociedad Panamefia de Ingenieros y Arquitectos y del Instituto de Ingenieros Eléctricos y Electrénicos, Seceién de Panans.

Direcet6n Oficina - I.R.H.E., Depto. de Energta y Tarifas

Apartado 5285 ~ panang 5, Panané

?Teléfono 62-0203

Dixecci6n Residencial ~ apartado 1266 Zona 9A, Panané

Tel6fono 26-6050

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UPADI 82

San Juan, Puerto Rico

?August 1-7, 1982

Second National Conference on Renewable Energy Technologies

COMMUNITY ISSUES IN THE DEVELOPMENT OF RENEWABLE ENERGY

TECHNOLOGIES: THE CULEBRA EXPERIENCE

By

William Ocasio - Juan A. Bonnet, Jr.

Salvador Lugo ~ Luis A. Passalacqua

?Carlos Ramos

Center for Energy and Environment Research

University of Puerto Rico

San Juan, Puerto Rico

August 1982

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COMMUNITY ISSUES IN IME DEVELOPMENT OF RENEWABLE ENERUY TECI-

NOLOGIES: THE CULEBRA EXPERIENCE

William Ocasio, Juan A. Bounet, Jr., Salvador Luyo, Luis Passalacgua,

Carlos Ramos, Center Yor Energy sad Savironment? {esearch Univeranty 0

Fuerte

AuSTRACT

This paper deals with an evaluation cf the response of the Culebra Communi= ty to renewable energy resources. The effort was svonsored by the Science for Citizens Program of the National Science Foundation, and undertaken by an interdisciplinary task force ot scientists from CEE that included @ polit Beal scientist, and economist, an engineer, a regional planner anda social anthropologist. Early in the project 2 Conmunity Eneray Committe represen- Ling a cross section of the Culebra population was formed. With the help of the task force from CEER this Committee would provide the vital liaison between the task force and community at large needed to accomplish the Purpose of the project. Te develop the agenda for these workshops, 30 in-depth interviews were made to assess the level of information of? the population on energy matters. It was found that there was a low level of Information on conventional energy sources. Also evident were mispercep: ons about the wind turbine experiment taking place in Culebra, With this background information and the perceptions of the Committee and the tech force about the Culebra situation, plans were mace and six workshops were held dealing with conventional energy technologies, conservation anc renew. able energy technologies. At the end of the workshop phase, 150 interviews were made to evaluate the results of the workshops. The Community ox.

Pressed their views and preferences about conventional and. renewable energy technologies. Through a last workshop with the community the Committee and the task force presented the options available for the Commits tee to continue to be involved with the community in exploring the possioi~ Uties for renewable energy resources. Finally the Committee chose to undertake a wind evaluation to assess the possibilities for the use of the Fesource. It would also undertake a citizens education program on energy conservation using a slide show to be presented by the Committee to difee rent groups in Culebra.

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1. INTRODUCTION

The principal objetive of this paper is to evaluate the response of the Culebra Community to renewable energy resources, This effort was funded by the Sclence for Citizens Program of the National Science Foundation to under tske "Community Workshous to Consiver Proupects for Energy Self-sufticiency for Culebra Island. ?The reasons ior choosing the area for the project were the relative isolation of the piace, the amount of insolation available, the wind resource and the fact that there is an experimental windmill in Culebra. Since this was to be @ grass roots activity, « Community Energy Committee representing cross section of the Culebra population was formed, The objective of the project would be accomplished by six workshops, with the community about conventional energy technologies, conservation and renewable energy resources. Prior to the workshops thirty in-depth, inter= views were made to assess the level of information on energy matters and thus help in the development of the agendas for the workshop. Ae a final stage of the project 150 interviews would be made *0 evaluate the results of the workshop. Also the Committee would determine ?the ways. in which it would continue to be involved in the development of renewable energy resour= ces for Culebra.

CULEBRA

Culebra is the smallest of the 78 municipalities in Puerto Rico with an area of 28 square kilometers. Its 1980 population of 1265 inhabitants, represented a population increase of 72.84 during the decade, the largest for Puerto Rico, It Is located at 18°18'N latitude and 65°18'N longitude or 3lkm east of the northeast coast of the main island of Puerto Rico and clkm north of Vieques, another outlying island-municipality, Culebra reaches a peak elevation of 196m in Montestina,

The U.S. Navy occupation of most of Culebra and its use as a target prac- Hee, occupies a central place in the history of the island, Colonized in? 1881 during the Spanish era, a settlement named San Idelfonso was soon founded. The U.S. annexation of Puerto Rico after the Spanish-American War was later, followed in 1901 by Navy presence on the island. The settlement at San Idelfonso was moved to make place for the Navy, and the Dewey commu nity, named after the U.S. Admiral, was built. 'A second development, Clark, ?Began in 1944.

U.S. Navy's use of Culebra Island for target practice did not actually begin until 1940, Till the mid~sixties the Island was poor and neglected and did hot share in the economic development of the rest of Puerto Rico. Opposi- tion to the Navy presence and maneuvers became a growing concern of Culebra inhabitants and later a major political controversy. This opposition intensified during the late sixties and early seventies and the *Culebra issue! gained national and even international prominenge. This culminated With the cessation of U.S. Navy activities on January It", 1975.

Accompanying the concern regarding the U.S. Navy's presence in Culebra was a concern with the socio-economic development of the Island Municipali= ty. Natural resources in Culebra, aside from scenic beauty and. limited fisheries are almost non-existant. Average rainfall is rather low, thus accounting for a sparse forest cover and an agricultural sector limted to

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several hundreds heads of cattle. The remainder of the economic base consisted of a small fishing cooperctive, government jobs and some commer ial activity until Fomento, the Puerto Kico Economic Development Administra~ on, promoted s manufacturing facility, Travencl Laboratories., for Culebra, The? large number of jobs generated, both directly and indirectly, have contributed to high income and low unemploymnet rates by Puerto Rican standards, To meet the demand for workers, an immigration from other areas in Puerto Rico and the Virgin Islands has occurred. This has caused @ significant housing shortage in Culebra.

A sample of the adult population reveals that 518 have more than 8 grades of Schooling and that 16t have university education. ?The average family income Jn salaries and wages is approximate $500 per month. Twenty five percent receive government aid to supplement their income in the form of food stamps fo social security benefits. An estimated 618 of the households own automo: biles.

ENERGY PRODUCTION IN CULEBRA

?The U.S. Department of Energy has also taken notice of Culebra and it has undertaken a 200Kw-wind generator demonstration -- one of four sites chosen for the Mod-OA machine. The wind generator was. inaugurated on July 21, 1978. | The NASA/DOE project cost approximately $1,000,000 and is operated by the Puerto Rico Electric Power Authority, which cost-shared with approximately 208 of the total,

The wind energy demonstration project met with a problem of faulty blade design. This limited the electricity generated to 54,5/0KwHy during its first Year of operation (July 1978-June 1979). After the blades were replaced with wooden ones in March 1981 the system picked up and 65,S50Kwiir were Benerated during the 1979-80 fiscal year. During 1980-81 the machine generated, 288,150KwHr which resulted in a 47% availability factor. From July 1, 1961 to June 4, 1982 a total of 236,900KwHr were generated. This represents a total of 645,270Kwhir,

Normal supply of electricity is supplied through a submarine Cable 46Kv polyethilene vynil with 13,000Kva capacity three phase operated at 38Kv, The cable stretches from Puerto Rico to Vieques for a total cable length of 2 miles, The electricity generated in Puerto Rico (994) comes from burning imported oil.

Culebra's peak electricity demand is approximately 800Kw. The wind generator therefore supplies approximately one-quarter of the island's? peak demand and if operating, the total electricity load for Sundays. It should be noted that between the date of the inauguration of the project in 1378 and the NSF - sponsored Energy Workshops described below no attempts had been made to inform the community on the progress of the 200Kw demonstra~ fon project. Given the faulty blades, and the subsequent extended down time, 'a widespread view of wind generators as failures and the Culebra Wind machine in particular as @ source of community embarrassment took hold.

The existence of a 200Kw wind generator in Culebra coupled with the then-

Current national energy policy interest in developing renewable energy

technologies got scientists from the Center for Energy and Environment

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Research of the University of Puez

for Island energy self-sutficienc;,.

10 Rico Interested in Culebra as a snodel

CULEBRA ENERGY WoRKSHO

Several years back, the United States Congress and the US Department of

Energy were very interested in promoting the concept of island energy self-sufficient as & paradigm for the adoption of cmerging renewable energy technologies at the national and international seale to reduce dependence of foreign oil imports. Culebra, with its abundant solar insolation and wind Fesource, its small scale, and isolation, provided adequate physical and climatological conditions to explore the concept of energy selt-sulfieney.

At the same time there was a Science ior Citizens Program of the National Science Foundation whose objectives were to provide selentisic and. technical expertise to citizens and citizens groups so that they woulé better under stand and participate in decisions on local or regional policy issues involving science and technology. Thus the situation seemed ?amenable for further exploration and the Center for Energy and Environment Research submitted Proposal to the National Science Foundation for the undertaking of *Work= shops to Consider the Prospects for Energy Seli-su?ticiency for Culebra Island".

The project obtaincd $44,000 in funding covering the period January 15, 1981-April 30, 1982. The? primary objective of the project was for CEER to

Provide the community of Culebra with the requisite scientific and technical assistance needed for an understanding of the technological, economic and socio-political issues involved in the use and implementation of renewable energy technologie:

The achievement of this primary objectives was obtained through the follow ing specific goals

(2) To increase the contacts of the citizenry of Culebra with the scientific community in a manner which demonstrates the importance and relevance of the natural and social sciences and of technology to issues of public interest i.e. ?the reduction of the dependence on imported petroieum through the Adoption of renewable energy technelogies.

(2) To provide an experience of interactions between scientists, citizens and policy makers through a discussion of the energy future of Culebra Permitting the different categories of participants to set the views of each ?other. ?Such an experience is quite uncommon in Puerto Rico and ?canoe transferred to other communities,

(3) To provide policy makers with information on community goals and needs with respect to the adoption of renewable energy technologies. The survey results and the findings of the final report provide the information needed to meet this goal,

The project consisted of three phases: Planning Phase, Workshop Phase and Project and Policy Evaluation Phase. Five participants from the Center for Energy and Environment Research constituted the task force for the project.

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?This interdisciplinary task force consisted of an engineer, an economist, a regional planner, a community anthropslogist and a political? scientist.

A Community Energy Committee (CE) composed o° Culebra citizens was chosen by the community itself. Although the size of the CEC fluctuated throughout the project, on the average there were cin members including the Hon. ?Anastacio Soto, ?the Mayor, who served ex-ofiicio. Ramén Feliciano, the former Mayor also served on'the Committee. The responsibilities of the Community Energy Committee would be to oversee the whole effort. More specifically they were to plan the workshops, to hold ?a final evaluation, workshop and adopt an independent course on action for future activities of the Committee.

For all these activities the Committee count

force members.

4.1 Planning Phase

During the planning phase of the project the Community Energy Committee was organized. Its duties would be the following: (a) to plan and hold five Workshops to involve the community, scientists, and government: (b) to help. ascertain the perceptions of Culebrans about the energy problem and thelr information level on the subject; (c) to hold the last workshop to evaluate the effectiveness of the project and to formulate recommendations for future action by the Committee.

with the advice of the task

As part of the Planning Phase ~ thirty interviews of Culebra citizens were undertaken to obtain information on the community's energy Use patterns the knowledge about alternative energy technologies and the opinions reger

Strategies most viable for the solution of Culebra's energy pro-

?The main findings of the interviews included:

GQ) High costs were perceived as major problems in the area of electricity and gasoline;

(2) Water shortage took priority over energy problems as areas of community concern;

(3) Limited knowledge and great skepticism over past community efforts to deal with Culebra's problema:

(4) Perception that the government, even though ineffective, has the main responsibility for taking action to solve community probleme

(5) Widespread Knowledge of wind as an electric energy source, even though most interviewed saw it as a failure; ?

(6) Surprisingly little knowledge about conventional energy sources;

(1) Perception of wind and solar energy as the most viable alternate energy ?sources for Culebra

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(8) A substantial majority expressed interest in rece

mation about alternate energy sources;

(2) {twe thirds of those interviewed have already taken steps to conserve energy:

(10) Substantial Interest in obtainin

tion techniques.

fore information on energy conserva-

DEEGE, thls Knowledge about the perceptions and of the energy problems

ang the information levels of the citizenry, an assessment was Sade yo ame

prospects for community action efforts ix Culebra. lt was found thee ee

Te be Geeta {3eters and political environment within which the project Sue

Wonk developed was rather negative. There was a lack of s Pacjtat wat

Sroup civic action; & sharp political division, and a distrust of goversment.

Gini backsround information and the interview findings served as a basis for

the development of the agendas and the timing of the workohopa,

4.2 Workshop Phase

Deslened to fill the knowledge gap on conventional energy sources, the frst

Wopkshop has as its theme "Energy Production and Utilisation im Pueny iat

se cccbtas Materiale distributed included diagrams on conventional socee

Sources: also a 30-minute film was shown and three speakers tained need

Convontingefets of energy in Culebra. ?Emphasis was given to explaining ake SeysMenal enerey technologies. Attencance to this activity averages fren 23 fo 30 Persons, setting the pattern for the attendance to the seen yt ae Rorkshops. The Community Energy Committee thought that ?the ember ng Ficassicn mains, a8, high, ?by Culebra standards: There ?was ?a lively Giscussion period and the ?participants expressed a desive? to ?know Oey about renewable energy techologies, especially about the wind forbs.

dhe moet igh, Gonducted at the workshop revealed that (1) direct mailing was se cmaat sffective mean of informing the citizens about the sclvitye Gy hine Tee weted| the ost: (3) a substantial majority found the workstops usciat and were willing to attend the next ones,

Gog Becend workshop was on wind energy and it included a detailed presenta- the cdpinstttf member of the Puerto Rico Electric Power Authority Gadisine

Sebcrinea al mature, A. speaker from the Puerto Rico Oifice of Exergy described the different wind turbines available for ?residectist nec.

sontierity of the participants in this activity had not been to the previous

Bogkghop but they appeared to posses greater prior knowlecge akece whe

subject.

ing {hird workshop was about biomass and bioconversion. The first lecturer TAS ANE OMREE of a cattle manure digestor who described his experlense ain Rie sreeke digestion, The fact that he had a scale model greaty fecilitna dureremention. "The other lecturer talked about biomass snd decribed tea Sifferent ways to get energy from it ranging from wood burning to aicofat

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distillation. The fact that there were many sludents among the participants contributed to an interesting questions anc answers period.

The fourth workshop was devoted to solar energy and to energy conserva~ tion. A lecture wat given on the ?ature of soiar a water heaters and the steps involved in their construction ?a detailed booklet on the subject was distributed), The same lecture included the description of a desalting unit, an artifact in which fresh water is taken out of sea water by evaporation. On energy conservation there was a conference op pessive cooling of struc= ture (cooling without mechanical hip) and another conference on energy conservation in the use of automobiles end home appliances.

The fifth workshop which dealt with the prospect for increased energy self-sufficiency for Culebra was heid 5s somewhat different format. Members of the task force explained briefly the changes occured in the energy self-sufficieney concept, as au expressed policy of the US Congress, the US Department of Energy and changes in the Science for Citizens Program of the National Science Foundation. The results of the 1980 presidenfal elections brought about a change in energy policy, reducing the government support in the search for renewable energy resourecs. However, the heed for Culebra to press for solutions was emplasized specially now that a ceiling had been put to the subsidy for consumers of less that 425 kilowatt hours of electricity per month. The members of the task force stated that the Center would be willing to help financially to the extent that project funds permited, and that it would be willing to cooperate with the Committee after the completion of the project.

The task force and the Committee went on to describe to the workshop participants the possible fature activities that could be undertaken by the Committee :

(Q) Since energy conservation was a well received topic during the workshop and since there is always room for more energy conservation, the Suggestion was put forth to develop a citizens education project. As part of this activity, brochures could be prepared dealing with passive cooling for energy congervation in existing and new structures.

(2) As evinced by the eaistence of a wind demonstration project in Culebra, the wind regime seems to have potential as an energy source. The sugg: tion was made to evaluate wind energy. potential in various parts of the island.

(3) The availability of substantial amounts of insolation provides favorable conditions for the use of solar water heaters. Thus a workshop on the construction of solar water heaters was suggested.

(4) The acarcity of fresh water in Culebra, coupled with the abundance of insolation lead to the suggestion of an assessment of the potential of solar Geslinators to produce fresh water through evaporation. if the assessment Proved possitive, workshop on the construction of desslinators would be held.

?The workshop participants were divided in three groups where the alterna~ tives were disctissed at lengh. Each group reported its preferences back to

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the Committee, which ia turn vould wsseus them ond hold 2 Gal tuilow-wp workshop to lay down the Auture course vi action

4.3, Project and Policy Evaluation Phase

The fst phase of the project, included a 130-person survey of the Culeora population and one worksiop to discuss subsequent activities of the Comment Hi Energy, Committee, | The survey vas designed to document the impact ef [Be workshops on residents of Culebra end to provide slaning date tor the CEE efor WHE JH the Implementation of community based. alternate energy Projects.

A sample of 150 persons was select! trum the 1930 Flectoral Lists of the Munleipality of Culebra. | This source was selected because it provided the ost Fecent and accessible dats, ?With the information on reckdence, ang Kinship patterns, it was Uien possible tne selection of the sample based na Gh Person Per household. | Thie sample rrzresents 180 householus oF spproxi= mately 508 of the total number sf residential unite a well ae ign Pm population,

?The principal conclusions of the survey were as follows: (See graphs)

(2) rb? publicity used was highly eifective in reaching 73% of the survey's

imple. Jn other word, three out of four households knew that alteretes snergy werkshops were offered in Culebra. However, only lit of the tava Sample attended an average of two workshops, All but tne of thece ?tat attended positively evaluated the workshon's rentent,

Lyecihile S88 of the total population vere interested in attending the Treleens last Workshop, previous attendance advised caution, concernine these ?expectations. If suture activisies are to be planned? thet aeane widespread citizen participation, ?they should be organized mindfal of wre Tip Zeason for non-attendance:? work obligations. It is therefore suggested that future activities be held in different work settings

(2), ,The Brest majority of interviewees fee! that Culebra has energy-related Problems having to do with electricity, gasoline and protane gee Howeeee when asked to evaluate the magnitude of these. specific problas in ieee of cost and inconveniences, gasoline is rated as a very serious probleme Protane gas as a serious one and electricity as not too serious, This ehent ging ranking may be due to two factors. First, large numbers of vesidervs Feceive subsidies that offset having to pay the full cost of eleceit ietond. the installation of the under-water cable has greatly minimised pe inconveniences and problems related to electsicicy-

(4 The interviewed population iacks husic information about alternative energy resources. Additional information is principally solicited in the ates gfwind energy, oil, coal, and solar energy. Moreover, the interviewses wae insnpented ip btaining additional information about energy sources, partices nly Information dealing with wind, ocean thermal, and solar energy, aed sented Lery positively to having experimental alternate energy ?orojects [peated in Culebra. They are of the opinion that these projects shoe te financed principally by the Federal government and initiated by" govern cs agencies.

---Page Break---

(5) The sample reported as having information about 4 variety of comunity action groups, but few were informe! about the Cousurity Energy Committee. The Committee will have to correct this situation anc in addition deal with @ population that posite financial and planning responsibilities for such endeavor in agents or agencies outside the commun ty

(©) Finally, the majority of Culebrons believe thet energy should be conserved, and indicated that they personally have taken steps in this direc~ tion. Nonetheless, the overwhelming majority of tie sample ie interested in additional information about energy-conservation measures

There was a sixth follow-up worksho= to discuss and decide upon the future activities in which the Community Energy Committee would be involved. Even though the concept of energy self-sufficiency was not receiving. sup~ port from the federal government the Committee decided to try to get support from local agencies towards this end. It was also decided to take the following steps that, although small ones, they would nonetheless constitute steps in the right direction to try to ameliorate the energy problem.

Whatever the future may hold for wind energy in Culebra, the first step has to be a wind evaluation, which the Committee decided to undertake. CEER would provide two towers with anemometers and odometers; and advice the Committee as to their location for more effective wind speed measurements,

?The Committee also decided to go ahead with a citizen education program on energy conservation. In this respect the task force would prepare a slide show that the Committee would use in presentations to various groups in Culebra.

5. EVALUATION OF THE COMMUNITY'S RESPONSE

To understand the community response, it should be stressed again that Culebra is a relatively small island with a rather dry climate, ?This isa limitation for biomass and for hydroelectric power as energy sources. How= ever, the wind regime seems to be favorable for energy production.

?The formal instruments of the in-depth interviews and the survey question naire and the informal observations obtained through numerous visits, meetings and workshops held in Culebra permit us to gain an understanding of the community's response to renewable energy. These will be used to evaluate (a) the community's knowledge on wind as an energy alternative (b) their understanding of the purpose of the success of the wind demonstra tion project and (c) their perception on the further potential of wind energy for Culebra.

?The survey questionnaire revealed that 858 of those interviewed were familiar with wind as a source for generating electricity and was tied with solar hot water heaters as the best knows alternative energy source. These percent ages compared with 908 for oil, 808 for coal, 508 for nuclear, 558 for hydro, 358 for biomass, 35% for biogas, 348 for OTEC and 33% for photovoltaics, tt can therefore be surmised that the existence of a wind demonstration project in Culebra had a direct influence in increasing knowledge regarding the potential of wind energy.

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Although the majority of those interviewed (56) identified the principal Purpose of the 200Kw wind generator as experiinentat ?ther thats to generate additional electricity (298 identified it as such). the in-depth ?meersiens reveals little knowledge on the nature or purpose of whe? demonstrating project.

Given the operational problems with the experimental wine generator and the jack of community awareness efforis :o explain them i's not surprising thet it was considered as a source of community embarrarsment. The view wag Widespread during the beginning o° the project anc) was ubiquitous m tne in-depth interviews. The second werkshop on wit energy permitted PREPA pliisials explaining the purpose end achievements of the demonstration, prot fect te restore a sense of community? price to those citizens and. commupity Waders who were present. Sill, during the November 1981 survey, elt of those surveyed viewed unfavorably the success of the wind generator. The Feasons given for this response included (a) the very experimental nature of the Project in that certain technical problems had not yet been resolves (op that the wind generator is defective and simply does not functions Ce thee it does not generate sufficient electricity for the island's needs

Somewhat paradoxically, given the community's negative evaluation of ?the succeae of the 200K wind? gener eine es ENS, weauation cnerey aternative with greatest additional potential for Culebra. Over two thank ox those interviewed favor it, compared with 508 or less for any sthee techeolae By. Fenewable or otherwise. But there appears to be a tlooe rank woaer gorrelation between the information available. to interviewecn, on aneern ee technologies and their evaluation of thelr potenti

In summary, the community's response to the 200K wind generator appears ambivalent. The very existence. of the project provides ?indication ?of ake Potential of the wind resource for geserating electriety,

Performance problems coupled with the lack of adequate public commanion Hons on the wind generator have led to disappointmente

6. RECOMMENDATIONS

The levels of knowledge of the community and its perceptions as to renew-gle energy resources and the wind experiment has been discussed. ?Thee is no doubt that wind is favorably perceived by Culebrans. Hlewever, ene analysis of the response of the Culebra community to the 200Ke Medcn Mind generator reveals the need for public awareness programs targeted to quplain the progress of similar demonstration projects fe Inhstihnte oa surrounding areas. This is particularly true for projets located panto fural areas, such as Culebra. In such cases, the community comes ts te identified in the minds of outsiders as the site of the demonstration, Social ?Acceptability is important to avoid political barriers to further development af unconventional energy technologies.

Eig NSE-spensored project on "Workshops to Consider the Prospects for Energy Self-Sufticiency for Culebra Islanc? provided the requisite sommunicy awareness program to accompany the wind experiment. Although nos eeene Rational energy policy does not contemplate future solar and renewable demonstration projects, this may change. In this case we recommend shat,

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(1) The technical and economi project's progeess be

Accompanied by an evaluation of its

cial acreptablity.

(2) That the inhabitants of tne svcrounding community be kept well-informed on the goals and progress of the demonstration project.

In more general cerms there are other recommendations we would like to make for future efforts aealing with the assessment of community response t0 renewable energy technologies uncior similar clreumstance:

(Q) The technical aspects of renewable and conventional energy resources are not an easy subject for the average person. Since the level of informa tion of the participants on energy ma'ters is apt to be low and group parti~ cipation smaller than anticipated, disappointment is likely to develop asthe project evolves. A priority knowledge uf this possible outcome should enable Project staff to take steps to minimize the effects of such disappointment.

(2) As in other group actions, the prime movers at the community level are always a few persons. To keep up the interest of this group, a systematic folow up is needed. | But care should be exercised so as to maintain the expectations of the local people at reasonable levels.

(3) _In dealing with isolated areas, the logistics for the project become more important. Adequate advance planning, coupled with a flexible attitude in the face of adverse results, are a definite plus.

(4) As soon as trends thay may affect project objectives are detected, the local poepl should be informed.

7. ACKNOWLEDGEMENTS

We would like to acknowledge support from NSF Grant No. OSS-8015825. The authors are solely responsible for the contents of this paper.

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ENERGY RESOURCE ABOUT WHICH ADDITIONAL

1S WANTED

INFORMATION

---Page Break---

RESUME

SALVADOR LUGO

Center for Energy and Environneat Kestoreh,

Caparra Heights Station

San Juan, Puerto Kico 00935

Telephone: Office (809) 767-032:

Home (809) 789-49.

BA Industrial Management MA Economies

Inter American University University of Puerto Rico

Master in Regional Planning, Harvard University

AREAS OF CURRENT INTEREST AN} EXPERTISE

Regional energy and land use planning; energy demand and accounting:

economic base analysis

PROFESSIONAL EXPERIENCE

Energy Planner

Energy Assescoent and Analysis Progam

Center for Energy and Environment Research

University of Puerto Rico

San Juan, Puerto Rico 00935

Director, Office of Institutional Research and Planning

Catholic University of Puerto Rico .

Ponce, Puerto Rico 00731

Technical Director

Regional Energy, Model

Puerto Rico Otfice of Energy

Santurce, Puerto Rico

Economist

Government Development Bank

San Juan, Puerto Rico

Planning Consultant

Puerto Rico Industrial Development Company

San Juan, Puerto Rico oops

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?PADI 82

San Juan, Puerto Rico

?Agosto 1-7, 1982

T Congreso Pananericano de Energia

PROGRAMA DE TRABAJO SOBRE. FUENTES ALTERNAS

DE ENERGIA DEL COMITE DE ENERGIA, DE LA

FEDERACION MUNDIAL DE ORGANIZACIONES Dé. INGENTEROS

Por

Manvel MartSnez F.

Instituto de Investigaciones en Materiales

?Antonio Alonso C.

Inctituto de Ingenierfa

Salvador Herrera ¢.

Unién Mexicana de Asociaciones de Ingenteros

San Juan, Puerto Rico

?Agosto 1982

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PROGRAMA DE TRADATO SUDRE FUENT!'S ALTERNAS DE ENERGIA DEL COMITE

DE ENERGIA DE LA FEDERACION ?MUNDIAL DE ORGANIZACIONES DE INGENTE

ROS.

Dr. Manuel Martinez F.- Institu-o de Investigaciones en Materiales,

UNAY. ~ México

Dr. Antonio Alonso ¢.~ tnstiwst> de Ingenierfa, &

(AM. = México

Yoxicana de Avociactones de Inge--

~ Mexico

Ing. Salvador Herrers

- ANTECEDENTYS

Ua Pederacién Ywndial ce Organizaciones de Ingenieros (FMOI)-

decidié a finsles de 1979 crear en su geno un Comité de Energia pa

ra estudiar 1a problenética cnergética a nivel mundial y promover-

el establecis

ento de necanisnos y 1a ejecucién de acciones especi

fiicas que contribuyen a resolver dicha problenatica. Despies de --

luna encuesta entre todos sus miembros, 1a VITI Asamblea General de

FWOE, reunida en Buenos Aires, Argentina, ea Novienbre de 1981, -~

otorgs 1a Sede del Comité a México y eligié como su Presidente al-

Sr. Ing. Rodolfo Dominguez Calzada.

Cono una de sus primeras actividades, el Comité de Energia ae

#inié un Pyan General de Trabajo para el perfodo 1981 - 1985. La -

estructura del Plan contempla cinco capftulos; los cuatro primers

relacionados con 1a situacién energética mundial considerada en -~

forma global y el quinto dirigido a la definicién de estrategias -

generales. En este alt

0 capitulo se definieron una decena de te~

mas que serén objeto de trabajos y estudios del Comité de Energia.

Uno de ellos se refiere al desarrollo de fuentes alternas de ener-

---Page Break---

efa, entre las que se incluyon }as fuentes de energia nuevas y rena

vables.

Por considerar que ésro es uno de los temas de mayor actuali~

{al impacto internactonal, el Comité de Energia inicié-

?e inmediato acciones para 4elincar un programa detallado de traba~

Jo, que se presenta a continuacién.

1. EwrRopuccron

La comunidad internacional est plenamente consciente y apoya el --

ergética, la cual es concebida como el cam

concepto de Transicién

bio ordenadgo, progresivo, intecral y justo, de 1a presente economia

internacional basada en el consuno de hidrocarburos a otra que

fan

capaz de aprovechar y disponer en forma creciente de las fuentes de

energfa nuevas y renovables.

B1 problena energético de 1a hunanidad podria por lo tanto reducir~

se brevenente a dos dimensiones fundanentales, cada una de las cua~

les abre michos otros frentes que podrian repercutir en la sociedad

@el futuro, tanto en lo que toca a los aspectos econéaicos y socia

les como a los estilos de vida.

La primera dimensién est4 constitufda por la necesidad ineludible -

de cambiar e1 actual balance energético de 1a humanidad, altamente-

dependiente de los hidrocarburos, los cuales, cualesquiera pudieran

ser las hipétesis de reservas y costos asociados, tenderén a agotax

Se dados los patrones actuales de consumo, que incluyen elenentos -

de despilfarro, y las futuras denandas provenientes tanto de los

paises desarrollados como de los vaises en vias de desarrollo.

---Page Break---

La segunda dimensién, que incluye también a fuentes cuya aportacién

Porcentual en el balance energético puede ser pequefio, es de carc-

ter mucho m&s amplio y esté relacionada con el concegto misno de de

sarrollo, especialmente con 1a necesidad de profundos cambios en -~

las estructuras econémicas futuras, basadas en las nuevas realida-~
des energéticas, tecnolégicas, financieras y monetarias enmarcadas~

dentro del Nuevo Orden Econémico Internacional.

Durante los Gltinos diez afios, la mayoria de los paises han inici:
do 0 fortalecido actividades dirigidas hacia el desarrollo de estra
tegias en materia de energfa que permitan vislunbrar el panorama f
turo de las fuentes de energfa nuevas y renovables. La tona de deci

sion

hha visto complicada por diversos factores, entre otros: 1a
incertidunbre sobre 1a disponibilidad y los precios de los energéti.

os + el poco conocimiento sobre 1a oferta energética nacional; 1

poca precisién de los datos de denanda energética, tanto presentes~
?como futuros; y 1a falta de datos técnico-econénicos confiables so~
bre tecnologfas relacionadas a estas fuentes.

La utilizacién generalizada de las Fuentes de Energia Nuevas y Rena

vables requiere del conocimiento de fuente, uso final y tecnologfa~

adecuada que los vincule. La determinacién de 1a tecnologia adecua-

da implica la realizacién de diversas actividades: investigacién, -

desarrollo y denostracién, normalizacién, estandarizacién, industria

Lizaci6n, capacitacién de personal, distribucién comercial y movili

Est

zacién de recursos financieros actividades son fuertemente ~

interdependient:

y exigen un alto grado de coordinacién para su ~~

puesta en prictica.

a planeacién energética deberd tomar en cuenta el costo de todos -

los tipos de energia, tanto cenvencionales como nuevos y renovables,

---Page Break---

4

También deberé

asi como 1a-rapidez en el canbio de las tecnolosfa:

estar ennarcada on un enfoque adecuado de 1a planeacién del desarra

Lo económico global. Especiaimente, deberé contexplar el creciente

costo y escasez relativa de los alimentos, asi como el de otros in~

y adquisicién de tecnologia y de -

sumos necesarics: financianie:

Dienes de capital, entre otros.

ba planeacién que se preocupa s6lo de las fuentes que son econénicas

03 centralizados puede cometer serios

hoy para los sistenas energéi

errores de juicio sobre las procpectivas de 1a energia en el futuro

¥ las necesidades de accién en el presente. La potencialidad debe -

ser comprendida como una interaccién entre recursos actuales y futu

?suras, y necesidades de energfa actua

ros, tecnologias actuales y fx

les y futuras.

El desarrollo, evaluacién, transferencia y adaptacién de tecnologia

basadas en principios de colaboracién internacional justa, puede:

ser elementos necesarios para encontrar una solucién a 1a problenati

ea energética. La Federacién Mundial de Organizaciones de Ingenie

ros, a través de su Comité de Energia, tiene un potencial enorme pa

ra ayudar a resolver los problemas planteados.

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IT, Estado Actual y Proyeecién del Desarroilo de 1as Fuentes

de Energia Kuevas y Renovabies.

Con activo de 1a preparacién de 1s Conferencia te las Naciones Unidas Sobre Fuentes de Energia Nuevas y Renovables que se celebré en Nairobi, Kenya, en agosto de 1981, se ilevé a cabo un gran nGnero de reu-- niones técnicas de expertos en ferentes especialidades. Como

resultado de este significativo ssfuerz0 internacional, se elaboraron

informes por cada uno de los prupos técnicos, los cuales a su vez se Tesumen en un informe de sintesis, el documento A/CONF.100/PC/42 "Synthesis of Technical Panel Reports".

KX continuacién se presenta un extracto de este Gitimo documento, pro Poniéndose que sea tomado cone base de discusidn para que en la FNOT se establezca el estado actual y proyecci6n del desarrollo de las - Fuentes de Energia Nuevas y Renovables.

En la primera parte se hace una breve descripcién de las fuentes de energ{a consideradas, y en la segunda parte se presenta una tabla --

conparativa de las diferentes tecnologias, sus perspectivas y aplica

ciones.

2.1.+ ENERGIA SOLAR

la energfa solar est# disponible on 1a mayor parte de 1a superficie terrestre. La insolacién que se recibe en una superficie horizontal es del orden de 1 kw/m? al mediodia, variando de lugar a lugar se-- fin 1a Latitud, nubosidad, hunedad, etc.

La energfa solar es intermitente y variable y est determinada por - Jas condiciones atmosféricas. Debido a estas caracterfsticas, algu- nas aplicaciones de 1a energia solar requieren de sistemas de respal doo de almacenamiento de la energia Comparada con las fuentes con.

---Page Break---

vencionales de cnerg a

energética, pero pucde ser concentrada para alcanzar altas tempera-cnergia solar presenta una baja densids

turas, habiéndose alcanzado hasta 300U°K en hornos solares. Se pue

de convertir a energfa mecSnica y oléctrica con eficiencias razona-

bles, del orden de 251 y 20% respe-tivanente.

La biomasa se define cono toda ?a ratevia orginica cs origen vegetal

ida del poten,

cial de 1a biomesa como fuente cnergética se. puede indicar que por

medio de 1a fotosfntesis se fi: in en las plantas 80,000 millones de

toneladas de carbono per af

ponde a unas diez veces cl uso mundicl deenergfaen la actualidad.

Se puede sefialar tanbién que e1 contenido energético de 1a biomasa -

almacenada en la superficie terrestre, es equivalents al de las re-

servas probadas de combustibles fSsiles incluyendo carbén, y que la

© animal que puede convertirse a enevgfa. Como una

» cen un contenido de energfa que corres

energia total ce las reservas estinadas de éstos Gltinos, s6lo repre, senta unos 130 afios de fotosintesis neta.

EL uso excesivo de bionasa, especialmente lefla, en algunas regiones, ha resultado en desforestaci6n, erosfon, inundaciones y asolve de - corrientes de agua. Algunos métodos enpleados para incrementar 1a producci6n de biomasa son por ejemplo las plantaciones de arboles - de r4pido crecimiento, tanto para usarse como lefia, como para conver, tirlos a otros combustibles por procesos termoquimicos.

ENERGIA EOLICA

1 de la

atnésfera por el sol, y las irregularidades de }a superficie terres. tre. La potencia de los sitemas conversores de energfa e6lica es - Proporcional al cubo de 13 velocidad del viento, por Io que 1a velo

La energfa del viento se deriva del calentamiento diferenc:

---Page Break---

7

cidad pronedio del viento y su distribucién en un sitio dado son fac-

tores muy importantes en 1a econonfa de los sistenas..

El recurso energético es muy variable tanto en el tiempo como en su

localizaci6n. Esta variacién implica que los sistemas de aprovecha

miento de 1a energia e6lica se pueden operar mejor en tres situacio

nes:

Interconectados con o:res plantas de generacién, desde una

Pequefia planta diesel haste 1a red de ¢istribucién eléctri

ca.

Utilizados en conjunté con sistemas de almacenamiento do -

energfa tales cono baterfas o sistemas de rebombeo.

Utilizados en aplicaciones donde el uso de 1a energia sea relativamente independiente del tiempo.

A pesar de que la necesidad de sitios con buenos vientos es inportan. te desde el punto de vista econ6nico, no se deberd sobre-enfatizar fuera de contexto con las aplicaciones particulares; se podra requerir de un sitio con vientos fuertes (por ejemplo mas de $ m/s) para competir con 1a generacién eléctrica convencional cerca de una central eléctrica, mientras que para regiones remotas pueden ser ade-- cuados sitios con menores velocidades (por ejemplo 3 m/s).

2

GEOTERNIA

La energia geotérmica proviene del graJiente térmico resultante de Jas diferencias de temperatura en las profundidades de 1a tierra - (ms de 1000°C), y 1a superficie. En los yacimientos de vapor se- 0 © de agua dominante, estos fluidas son extraidos a través de pozos de hasta 2000 metros de profundidad, y utilizados para accionar turbinas para generacién eléctrica en instalados aprovechando este tipo de yacimientos.

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Las reservas geotérmicas se estiman en 14.5 x 1025

lente a 8 x 10'7 barriles de petréleo, generalmente limitadas a regio

nes tectOnicas, esperdndose que para el afio 2000 1a capacidad instala

da en centrales geotermoeléctrica llegue a mis de 17,000 MW

Joules, et equiva-

Existe otro tipe de yacimientos, los de roca seca caliente, localiza

dos 2.16 2 km de profundidad, oue a pesar de tener la temperatura -

adecuads para su aprovechamienso en centrales eléctricas, no pueden

ser explotados con la tecnologia disponible actualmente, siendo nece

sario inyectar un fluide para extraer e1 calor de la roca. Este re-

curso energético que estd disp:

cimientos de vapor seco o de acua caliente, tiene et potencial para

generar del orden de 10° 1, en e1 futuro.

ible en muchos nds sities que los ya

= ENERGIA HIDRAULICA

1 de energfa renova

La energfa hidrdulica es una fuente convencioz

bale, adecuadanente desarrollada y conercialmente factible en un gran

nGnero de regiones y en una amplia gama de capac?dades, desde las --

muy pequeflas, hasta las muy grandes.

Bl desarrollo reciente de pequefas turbinas hidréulicas ha abierto -

nuevas posibilidades a las mini-centrales hidroeléctricas, en parti-

cular. en as regiones nontafiosas con corrientes de agua.

Se estima que en estas regiones ?se encuentra un potencial de energia

hidrdulica comparable a1 de los grandes rfos.

Aproximadanente dos tercios de los recursos hidrfulicos mundiales --

técnicamente aprovechables para generar energia, se encuentran en -

Africa, Sudanérica y Asia (excluyendo a la URSS), y sin embargo en -

estas Greas s6lo se genera menos de una tercera parte de 1a energia

hidroeléctrica del mundo. En general las limitantes para el desa

rrollo de 1a energia hidrdulica en estas regiones, estan relaciona-

cos, geol6gicos,

econénicos, y de otro tipo, adecuados para llevar cabo proyectos

das con 1a carencia de datos hidrol6gicos, topogré:

---Page Break---

9

para el desarrollo Sptino de los recursos hidrdulicos, asf como con

la falta de personal entrenade y recursos financieros.

Dados? los bajos costos de opersciGn de las cent-ales hidroetsctricus,

fen algunos casos es econémicanonte factible inplonentar proyectos de alnacenaniento por rebonbeo.

DAS

ESQUISTOS ¥ ARENAS ALQUITR.

Los esquistos se definen como rocas sedinenta

ria orgénica s6lida y conbustibie, que es practicanente insoluble en

solventes de petréleo. Los depésitos de esquistos se estiman en 47.5

x 10" toneladas, y dado que 1as exploraciones para su localizacién

son auy recientes, es muy posible que existan den6sitos potenciales

S que conticnen mate

explotables en muchos paises.

A diferencia de los esquistos, 1a materia orgénica de las arenas o1-

quitranadas sf es soluble en solventes de petréleo, pero dada su al-

ta viscosidad (nds de 10,000 centipoises), no fiuyen de su reservorio como lo hace e1 petréleo. Se estima que los dep6sitos de arenas al-

quitranas son por lo menos una y media veces més grandes que los re-

cursos petroleros convencionales, lo que indica su potencial para 1a

Producci6n de crudo sintético.

2,7.- ENERGIA DE LOS OCEANOS

Los recursos del océano que pucden aprovecharse en la generaci6n de energfa incluyen los gradientes térmicos, las mareas, las olas y los gradientes de salinidad. Se estima que no pasan de 40 los sitios en el mundo que presentan las caracterfsticas adecuadas para la implan-tacién de plantas para aprovechar las mareas, 10 que limitaré el in-Pacto de su contribucién a la oferta global de energia. La energfa de las olas es mayor que 1a energfa de las mareas, pero s6lo es de interés en latitudes superiores a los 30°.

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Para aprovechar los yradientes térmicos del océano, se requicren sitios

con una diferencia de tenperaturas de por lo menos 18°C entre tas ages

superficiales (0-100 m) y las aguas profundas (900-1100 m), adenis Je

caracterfsticas adecuadas en cusi

neteoroldsicas y del fondo del ., etc. La pequefia diferencia de

temperatura implica una efic

o 2 corrientes marinas, condiciones

baja del cicto tornodindmico, con

La consiguiente necesidad de bontear cantidade: muy grandes de agua -

de nar.

8.> ?TURBA

La turba es materia vegetal que enpie:

lo que est4 en la frontera

a convertirse @ carb6n, por

re la biomasa y los combustibles £6si

les. Se encuentra en unos $0 pefses en todos los continentes. Las

reservas globales de turba se estiman en 7 x 10"! barriles equivalen

tes de petr6leo, o sea cerca de! SO% de las reservas conocidas de --

gas natural, y su uso actual es el equivalente de 175 millones de ba

rriles de petréleo al aio.

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qe

HE. Pstrates fa Apoyar et Bi.

Fuentes de Chergfa Suovus y Renovables.

s Cererates ps Folly ge les

Las fwontes fe cacty

son todas los yatses y regiones. las condicio

serollo tecnolSsiea, polfticas y culturates de Estas tarhign pres

nuevas y renovables no son ignnte. ate ah

ian wurentas difeceneia,

To, Tus estratesias para el Gera

rrelo do estas Sicates a nist ¥ tegforal seguessente die

fa de un pats a otro y vo wrt regisn a otra. Aichas estatesi pueden ser plinte be gt oleoenta ?ts s woliticas «+

ietales de planificacién unergétiva.

Por otra parte, el estado de desarrollo teeno 4

les fuentes tec

Mes no

rsfaouevas y re

. inifece, Tas inver

sinnes necesarias para su aprovechomiento @ificren cn Grdcnes de -

vagnitud, sus ventajas relatives son distintus seytin el aso final, y 10s posibles problemas ecolSgicos, polftices y culty:

eapleo masivo son aGn tena de discasiGn. Fsto hace muy conveniente

vies de su -

plantear estrategias ospecfficas para cada triada fuente-tecnologia-

uso final.

La energ{a es elemento indispensable para el desurvollo econ6mico,

y las fuentes convencionales de cnergia, en particular los hidrocar

buros no estén geograficanente distribufdos de manera uni forme.

Asi, las estrategias de desarrollo de las fuentes nuevas y renova-

bles tendrin objet:vos diferentes para los pafses industrializados

grandes consumindores de hidrocarburos, los pafses e\partadores de

hidrocarburos, y los pafses en vias de desurrotlo inyortadores de

energia. Revisando los programas de energfa ¢e

1

energsa nuevas y renovables es visto on ellos coro un posible meca-

nismo para la regulacién del mercado de los

s patses industria

dos, puede conjeturarse que e! desarrollo de las fuentes de

rocarburos y que, -~

por otra parte, lo consideran potencialmente una manera de reducir

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1s

Ja eregioute presiGa que ejercen los pafees en vTas de desursotto

sobre las energfas convencionates. fn otras palabras, 1c

industrializados consideran que on 1a medida en que se «

teenologfas je

vas y renovables, Jos precios de los hidrocarburos snfrivin menor

presién a la alza, y que cn 1a acdida en que sean los ,. Tacs en -

vies de desarrollo 1

sarialten

al aprovechaiento de Tas fuentes de encrgfa mie-

S que sdopten 1a explotacién de iets Cucates,

foram estos Jos que cn bucaa parte pagucn Tos costos de detarrolto

wediante 1a irportacién de tecnologia:

fos de desuriotlo, sobretede para Ios no cxpors

nres, as fuentes de caergfa mucias y renevables

Feprescutsn una alternativa, en algunos casos incluso 1a Gnica, para alinentar su proceso de desarrollo ccoatwico.

Cualquier estrategia nacional, regional @ nuadial para desarrolar el aprovechaniento de tus fucntes de energfa mievas y renovables - debe contenplar Ja evaluacign de 19s recursos y necesidates, 1a cla, boracién de progranas de investigacién y desarrollo tecnolSgico, - la transferencia, adaptacién y aplicacién de las tecnologfas econ Micamente viables, la difusién de informaciSn, tanto intra sistema se ciencia y tecnologia como hacia 1a sociedad en general, y la formaci6n de recursos humanos mediante progravas de educacién y cn- trenamiento. Componentes crfticos adicionalos de 1a estrategia de- ben ser los mecanismos para obtener 1a voluntad politica y los re-- cursos financieros necesarios para desarrollar las fucntes de cner- gfa nuevas y renovables.

La planeaci6n energética debe ser el punto de partida para definir las estrategia

para el desarrollo de las fuentes de envrgia nuevas

y Tenovables. Esto no Ucbe implicar que mientras no se cxente con

un programa o plan energético Jeben dejarse de 13do el resto de las

acciones necesarias para el desarrollo de dichas fuentes. La mayor

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porte de los pafses no devarrollides, @ incluso un hucn oc ero

de los industrializados, no hun fermutade adn planes y csteat.sivs

We energta, y venos aGn inteyrado dichos planes y estrate

Fragranas ylobaled de desarro}lo. Para formlar dichos

s de los recursos, necesidades y terng,

legfas, incluyendo estinades tel suministre y denanda enery

necesario preparar inventa

tuales y futures segdn cl uso finil, que permitan identificar fica

de aceign para el conto, rediane y largo plazo.

La investiznei6n y desarrotto serin parte exearint a

enalqniar os-

testegia prra ef aprovechamicato ve las Cueites ge encrgia nuevas y

reaovables. Tfpicsnente las tei

de aaduracién largos (10 a 15 afies mis en alge logfus enerséticas tienen ticzpas

os eens). Fst hae

a scan fnaptacabtes, Pada Ya alta <=

s acciones on esta

incertidunbre sobve cuél de ts nuevas y reasvables sed pa-

ra-cada pais y regiGn 1a mds atractiva en el futuro, parece particu-larnente apropiado enfocar las cstratogias de investigacién y desa-rrollo deben estar dirigidos a croar una guna de opciones tecaol6gicas tan amplia cono sea posible, a reducir los costos de las tecno-logias disponibles, y a evaluar comparativanente a nivel de prototi, pos las ventajas y desventajas relativas de cada opcién.

El acceso #,1a informacién, 10s necanisnos de regulacisin de transfe rencia de tecnologia y 1a seleceién y adaptacién de ésta, son aspec tos delicados en los que, dados los distintos intereses económicos de los miembros de 1a comunidad internacional, seré diffcil definir estrategias que no scan las de nivel nacional, y 93 gional. Cada pafs debera por tanto fijar sus polfticas y estrate-- gias en este sentido, aunque los esfuerzos por lograr consenso a ni, vel internacional no deben abandonarse.

afis de nivel re

La formacién de recursos humanos capaces de desarroliar las fuentes de energia nuevas y renovables sera factor decisivo del éxito de -- cualquier estrategia y debe entenderse como un proceso de largo pla

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zo que requicre iniciar avciunes inudiatas. Para Jos patses on -

vias de desurrollo 1a fornacién del recursos hunsnos alta cate

pacitades es

Pebe, por tonto, reeibir nn tra:

undaaental y un proble

particularncute critica.

jeato preferencial cn aus estra-

tegias para el desirrollo de las fuentes nuevas y renovahles. Los

programas de cducseién capacit

parte, aquellos en Los qu

cin y entrenuniente son, per otra

lencote podeszn cenevitarse weiter

nes de colaboracign regional © jatcrnucional von nayer fecilided.

1a voluntad politica es indivyessubte para el desstvello ve lus

fuentes de energfa s

vas y renuvedles. Mientras estas favntes no

lones de subsidios, polfticas finan-

ciera, estfnulos fiscates, etc, con las cemenciorsles,

quienes tenan 1

dad de diversificar la base de suninistro eneryético, el desarrollo

de las fuentes nuevas y renovables se veré obstaculizedo. Pero la

voluntad polftica no basta. La evalvaci6n de recursos y 1 planea

ci6n, la investigacién y el desarrollo, lus proyectos de denostra-

ciGn tecnolégica y econémica, y los programas de educacién, requie

Ten para su desarrollo éxitoso de recursos econ6micos y financie--

ros. E1 nonto de estos recursos serf funcién de les objetivos que

se persigan y, dado que estardn en competencia con tos requeridos

Para satisfacer otras necesidades, debern ser deter dosamente y administrados eficaz y eficientenente.

conpitan cn igualdad de cond

ajentras

enes 10 recom

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an la isverinneia y

ados cuida-

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22

4

Vv. concLustow

B1 estudio del campo de las fuentes alternas de energia como un pa~

quete integral presenta dificultades especiales. Su disponibilidad,

ain no cabalmente evaluada, propicia en términos generales sistenas

de generacién de energia de tipo distribufdo.

Las tecnologfas empleadas en su aprovechamiento tienen muy diversos

niveles de madurez; en michos casos, su competencia económica puede

estimarse s61o bajo hipétesis gruesas, por no contarse con informa~

ei6n suficiente. E1 niimero de opciones tecnolégicas para cada una ~

de las fuentes es muy grande. Los niveles de inversi6n minima reque
ridos para la explotacién de las diferentes fuentes, y atin dentro -

de una misma fuente para cada tecnologia, difieren enormemente entre
sf. No hay consenso sobre la futura contribucién de estas fuentes ~

en el marco de 1a oferta energética. Existen problemas de acepta-~-

ci6n social y de incompatibilidad entre patrones de desarrollo in-~

dustrial seleccionados y requerimientos impuestos por el aprovecha~

miento de lagunas de las fuentes alternas de energia.

Bl programa de trabajo que el Comité de Energia de la Federacién ~~

Mandial de Organizacion

de Ingenieros se propone desarrollar en -
el campo de las fuentes alternas de energia, con 1a colaboracién de
las 76 organizaciones nacionales de Ingenieros de todo el mundo afi
Liadas a 1a Federacién, se espera contribuiré a una mejor compren-~

ei6n y evaluacién de los problemas que su explotacién conlleva y ~~

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UPADI 82

San Juan, Puerto Rico

?August 1-7, 1982

Second National Conference on Renewable Energy Technologies

EL FINANCIAMIENTO DEL SECTOR ENERGIA EN AMERICA LATINA PARA EL PERIODO 1980-1990

Por

Pedro Vicien

Consultores Argentinos Asociados, S.A.

Universidad de Buenos Aires

Sen Juan, Puerto Rico

August 1982

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TRODUCCION

DEMAND

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carbén

Gas natural

Nidroelectricidad

Nucleo electricidag

Energia geotérmics

INVERS LONES

Sector eléctrico

Sector petrolero

Sector gas natural

Sector carbén

Sector alcohol

INVERSIONES ToTALeS

FINANG LAMIENTO

externas

Resumen

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?ABSTRACT

EI autor, basindose en los resultados de

una investigacién realizada para el Ban

co Interanericano de Desarrollo, presen

ta los resultados estimados para las ne~

cesidades Financieras det sector energta

de América Latina en el perfodo 1980-90.

The author, based on the results of 2 ~

research made for the Interanerican De

opment Bank, presents the results of

the financial needs of the energy sector

of Latin America for the period 1980-80.

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INTRODUCCION

[L,Problene det financioniento del sector energta en América Latina para -

les préximos aos (1980-1990) es de singular importancie. La enerat

tun papel esencial en el desarrollo econsnics de los pucbios

yer desarr

EI desorrollo es un probleme central para América Latina pues su crecimien=

to demogrStico denanda el ingreso en las tereas produc

dad de habitantes; la mayorfa de ellos no puede huceria en? ta

Porque como en la regiGn el agro es en general un sector,

os empleos han de buscarse en industeiss ©

Ssctor Industrial cada puesto ce trabajo requiere inversiones que se. predey
Jo que hace un promedio de inversion de

USS/afo @ 240 x 109 USS/ano para un nivel de 4.000.000 46 necwee

smpleos. | Hay que considerar también que existe un desenpleo disinelony oe

empleo y un franco desenpleo en michas regiones.

faérica Latine mantendré en las préxinas décadas hasta el fin de siglo, un

ce chenass Cemmarético det 2.65 8 se la poblacién econdnicanante sctiva. Ea
fe glevade crecimiento incige sobre las necesidades financieres globules =
{ANE para satisfacer las de crecimiento industrial, abesteciniente ene sge~
Ecos tess como para las de tipo no productive e.g. educacién, recrent oe
asistencia 'nédica, viviends, ete,

Registringiendo nuestro anélisis al sector energta y en procure ¢e visual =
Zar icubles serdn las necesidades de financiomiente vamos? a considera? or ing
seea" composi ign de lo demands, luego las formas en que diche denangs? pare
Gria ser satisfecha, los costos de inversion para satistacerts $ fin tanta
0s componentes nacionales © importados y su relaciGn con las exportecionts,

DEKANDA

Ef eindlisis de la demands requiere establecer supuestos de cree! -

mlgnte econsmico para el futuro. Las bases del prondstics fuecsn 2

Slaboradas con los datos oficiaies de cada pats. Sin enierger an

Gfigrminacién de Ie denanda se ha hecho recurriendo a eritesios que

tienen en cuenta condiciones mundiates de activicss cesnaene?

Le ecuacién de regresién uti} izada es una ecuacién tipo:

Wn Ot = ko + ki In Ye + k2 In P+ KS Int

De Demands Y= Ingreso P= Precio t= tienpo ko ki. k2 43 coeticientes de reoresion

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los andl isis reatizados para el perfodo 1960-1978 indican una rela

Elén bastante vigorosa entre el consumo de energia y el PBI. Es Im

Gortante sefalar que. Tos. resultados, inducan a pensar en el ingreso

Se cada pats como e! aotivador principal del nivel de Tos consumos

snergéticos y a considera? que el precio two menos. Signifieacion.

Este hecho confirma Ia etapa de desarrollo en que se encuentra Aaé=

rica Latina. En Tos Gitios afos el efecto del precio parece haber

enido alguna mayor influencio; sin embargo, las evidencias muestran

ae al consino de enerafa eléctrica est6 generaimente my vineulado

Gon el ingreso.

Huasticided-ingrese 1

= ajo aS Buje alto

Paisas inportadores de

petrsleo 138,9 222,6 2760 1,17 Aas

?exportadores de

96,2 211, 230,58 1,00 aon

?tel pera Aetrica

Latins 23541 4341 $065 113 aan

ida como 1a relacién entre el crecini

eneraia y el 0.

Puente: Estimaciones del 31D.

£1 cuadro 1 Indica tos resultados obtenidos para 1a demands de ener

ata en Angrice Latina y las elasticldaces respectivas en sus 408 p°S

Jecclones. Las cifras Indican el consumo total de energta para |

Fagin. En 1930 sers del orden de los 4341 atep a Tor 506,5 mtep

conparados con los 235,1 mtep en el afo 1978,? Los costiclentes de

Ereclatente histérico de 6,32 pare 1960-1978 han sigo estinados on

Siz ty 6,6 3. Para los paises, inportadores el crecimiento fue pro

yoctado ai 4 iy 5,92. Los paises exportadores tendrén crecinie

foe del 6,887 7.8 8 hegin se refieran al escenario de bajo 0 ato

Le partictpactén relative

los pafses exportadores pasaré del 41%

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fen 1978 al 45/48 % y los patses inportadores disminuirén del 59%

fen 1978 al 52/55 % en 1990. Guatemala, HaitT, Paraguay y la Repi-

blica Dominicans crecerin sor encima del pronedio de los pases im

portadores, y entre los pofses exportadores Néjico lo hard a un

Bui, cifra ésra mayor que Is correspondiente al pronedio de los

El cuadro 2 muestra un balance consol idado de 19 demande y suminis tro de energra para 1s regign en el perfado 1980-1990 y las dos hE potesis consideradas.

La elasticidad de 1a demands de energfa-inareso para el 1aps0 con- iderado nose modificard en forms notable. Cuando Io elasticicad fiere al producto bruto per capita se observa que en los pa Ses inportadores su crecimiento global sers del 342% y en los ex= portadores del #2 2, es decir Iiceranente mayor.? El Consumo to = tal de energia Iegars a 1.100 kgep per capita que represents slo tun 25% de aumento referido al pronedio de 1978.

La intensidad de eneroia, es decir el consumo de energfa por 1000 USS de PEN Tlecaré en 1990 2 630 kgep/1000 USS. ano 19/8 comparado con 10s 600 kgep/1000 USS de! amo 1978, y los 2000 kgep/1000 USS correspondientes al mismo afo en los paises desarrol iados.

Energta eléetrica

Antrica Lavina:

Capacidad (tw) Generacién (Gun)

1978 nsw 281.057

1985 Supuesto bajo 113.532 433.502

Supuesto alco 116.980 487.824

1990 Supuesto bajo 255.362 582.178

Supuesto alto viens 743.007

Eetimaciones del 81D.

£1 euadro 3 representa 1a capacidad de generacién y 1a energia -

eléctrica generada en 60s escenarios, Se puede observar que en ?

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el escenario. nfs balp pl crecimiento se haré 2 un rita del 66

envel"nda ates S18, E'e<"eSoparnds SonPe/ScretTafeets MbeBifck

cl"B4 E para el periods 1960°1978, En el priner excenaris, fa ge

neracién pasaré de 281.057 Gwh a 582.178 Gwh; en el mis alto lega-

F3'0 753,007 Gxnen 1350. Eleseenatto nis alto correspon 6 igs

Sroectativas enpresadas cficialmente por eade batty eehiens setae

Sintnicas optinisean,

1 coefictente de electrificactén posers de 1,2 en 1978 2 1,39-1,47

fn 1990,. dao qoe reflese y confirm te cendencts provoninatee ye

Coabién ?el estuerso realizado: en conservacian de encrena,

Desde et punto de vista de los valores de consum eléctrico per ca~

pita, se estine que en 1990 se llegar a 1.308-1.619 kwh part

de 854 kwh en 1978,

iro

satrica Watina: Produceién de energta en 1978

YsstinscTones para 1983 y 1990

(En willones de toneladas de equivalente en petréleo)

1978 1985, 1990

By Ate ajo aS

Peerdieo 24,0 43,6 393,1403,9 480,2

(cas natural 40,3 ?62,0 76,383,599,

carbén 16,6 25.7 30,0 tad

Widroelectricidad 8 40277 Sue ane

Energia geotérmica al 03 0,3 0s ONS.

Energ(a nuclear Bie 188 wa

Alcohol us siz 7k 8a

Total 31.4 463.1 5363 576.6 683,7

Ta Wao de 0,1.

Ruence: Estinaciones det 810.

EI cuadro 4 refleja 1a producción de energia de 'a regién, proyec-

tada para 1990 segiin os dos escenarios. En su conjunto, la pra >

ducción pasaré de 317,2 mtoe en 1978, 2 576,8 y 68,h mtoe en 1590.

Esta producción de energta esti estimada para satisfac:

Sidedes de demanda con recursos provenlentes de la reg

as nece-

---Page Break---

1.2, Petrdieo

La produecién de petréter ?endré un vigoroso crecimienta en los pai,

os inportadores de pecevlec (Argentina, Brasil, Colombia y Pera)

que esperan exceder en mas ce! doole as cifras de 1978. Los paf-

Ses exportadores proveerin e! 77% de la produccién de ia region,

Valor inferior al del 80 2 en ef afo 1978,? Esta diaminucién prosor

Clonal Se explice por les limi taciones adoptadas en Ia. praduec én

de Venezuela, Ecuador y Trinidad Tobaga, Méjico tendrS, por el =

Contrario, un erecimiente, insortante

Quadro

Aofrica Latina: Minero acumulativo de potos pertorados a/

Mipseesis hipstesia

baja Bitsy

1973-1980 1981-1990) 1981-1990

Argentina 5.465 12.246 13.200

Bolivia 208 638 00

Brasil 2.097 3.975 6.000

Goleabie 533 2057 21400

Chile 390 767 Lease

Ecuador 26 400 720

Mexico 2.917 7.420 8.600

Pers 1.359 euro 51500

Teiniaad y Tobago 1679 1335 2800

Venezuela 6353 soe 107000

otros 60 ?500 500

eat 19.481 Pretrl 52.470

Promedio sual russ 4.020 4.770

TT HaeTaye pores de produccisn y de exploracién.

vent.

World O41 varios nuseros y estinaciones del 810.

Ene! cuadro § se reflejo el esfuerzo de perforacién necesario 08.

ra Negor a las metas. Se debers pasar de un pronecio de 2.435

pozos por afo (1978) a 4.030 y 6.770 respect ivanante.

Serd el pats de mayor

Esta tarea de perforacién que implica grandes inversiones, parece

---Page Break---

1h

haber inducido a 105 gobiernos 3 modificar las teves y reglanentos fara pronover una mayor participacién de recursos privades. nee ona les 0 extranjeros en tareas exploratorias y de provuccién.

De particular interés son ?os esfuerzos de Venecuela para desarro~ Nor los petréleos pesados ie ?a faja del Orinoco que necesitarsn una inversign del orden de 17.000 millones de sélares de 1978,

carbén

La produceién de carbén en Anérica Latina pasard de 16,6 mtoe en 1978 0 41,1/44,8 mtoe en 1990. Los mayores aumentos de produce én Se realizardn en Brasil, Colombia, Venezuela, Peri, Méjico y hile.

a tiene una apreciable riqueza y variedad de cal idades, y #6 ?ue se convierta en un inportante exsortader en 1985.

A pesar de la disponibilided existente y del desarrollo previsto, ~

@l carbén no tendré todavia una participacion que refleje esa eit. =

Gunstancia. Otro inconveniente para la utilizacién del carkéa oF

a falto de faniliaridad con su uso,

2s natural

Le mayor producciGn de petrSieo aumentaré las disponibitidades de =

995 asociado con Ia explotacién de petrsleo. Dicho disponibil ided

Se verd increnentada en razén de lor esfuerios para dismimitr el =

95 ventado a la atnisfere. De la cifra de 1978 de 40,3 moe se

Negaré 2 83,5 en 1990 6 9 99,9 mtor segin el escenario tonado en ?

Proporcionalmente 1 gas aumentarfa su produccién a una tasa mayor

gue el petrSleo. Existen hal lazgos de yacimientos de gas natural =

e importancia y Argentina podrfa pasar de imoortador de gat natu, =

tala exportador neto del tluido » Uruguay, Brasil y Chile o en for

mma de LNG a otros mercados. Méjico y Bolivia también serin expor

Gores de cantidaes importantes.

Hidroolectricidas

Gran parte de la electricidad consumida en 1a regién provendré de -

Fuentes hidr6ulicos; de 14,8 mtoe en 1978 Ilegars a 36.4 y 42,2 m

foe en 1990. En el ?conjunto su participacién pesaré del $ ¥ or

1978 al 6 Yen 1990. £1 crecimiento de esta fuente se hard aun ~

citm de 7,6 % y 9,1 % respectivanente, valores estos nayores que

los del crecimiento de la electricidad anterfornente mencionados.

De esto se infiere que Ia electricidad de este fuente sunentard a

participacién relativa.

Todos los pafses con recursos hidricos tienen planes pars desarra,

Marlos con preferencia.

---Page Break---

1.6.

Sélo Arsentina, Brasil y #jies tienen planes paca e) desarrollo nu clear; Argentine com su I sea de uranio natural, Brasit y Hej ico con uranto enriquecide. ?1 cessrrotlo de esta fuente permitirs cu- brirel 5,7 4, 5,3? de la yroduceign aléctrica ioeis el aha 1990 habiends partido? ae uns eitra Je 05°'

Energia geotérmica

Esta fuente de enerofa tiers desarrollo, en América Latina, en Méji co y El Salvador. Se espera que Bolivia, Costa Rica, Guatemala y Nicaragua se asocien a ese grupo inicial antes dei tin de la décida ¥ que en conjunto |ieguen« producir alrededor de 5,500 Gwh o se9 = lin poco wens del | Ede los necesidades de 1a regida.

WVERS1ONES

Las estimaciones deben ser corregidas en forma continua, pues mu -
chas de ellas estin basadas sobre datos en moneda local 'y se dei9c~
tual izan con 1a inflacién en lo mayoria de los pafses. Sin enbar =
+ al Eransponer todos los valores a délares de 1978, parte de esa
Incereidunbre queda ancrt iguada, sunque de nuevo aqui se oresenta =
el problema de la propia inflaciGn de ta moneda norteanericans

Otro factor diffe!l de apreciar es el efecto de Ie recesién en los
precios de algunos bienes de capital que afectan las correlaciones
con referencia.» moneda estatle:

Adenss, précticomente sélo en el sector eléctrico es posible encon=
trar planes detallados en !9 mayor parte de los paises, Los otros
sectores energéticos no gozan del misno grado de planeaniento y 1a
Informacion ofrecida es fragnentaria

Aefectos de obtener las cifras de los componentes locales y extran

Jeros de 1a inversion se estind, en cada pals, le posibilidad de le

participacién de la industria local en los proyectos, Dada la nag

itud de los programas, dicha posibilidad es un objetivo a lograr y

Dresuntanente posible con acuerdos de transferencia. de tecnologia.

Las inversiones calculades no Incluyen valores para desarrollo de

Fuentes no convencionales excepto el alcohol. Tanaoco incluyen les

necesidades para sustitucién de un combustible por otros, ni para =

Ve conservacién de a enere"s. Hay razones pera elo, tas Inver =

siones antes mencionadas son una parte menor frente si total consi-

derado, su cBlevlo es incierto y no existen referencias confiables.

---Page Break---

Escenario de

?generacién, 90

hase

= Teenie

fuadro NY 6

América Latina: Capacidad de potencia eléctrica_y.

fuente y por oats ¢ inversfones requeridas 1980-1990

N= Wuclear y G = Geotér

alto crecimiento

inversiones

1980-1990.

(106 uss de 1978)

Bs

---Page Break---

Fuente: 810

23100

Inversiones

1980-1990

(308 Uss de 1978)

---Page Break---

snirico Latina: Capacidad de potencia eléctrica_y

?generacién, por fuente y por pais © inversiones requeridas 1980-1990

Excenario de bsjo erecinierto

Inver

1980-1990

(108 5s de 1978)

fae Ye ew

3 a ?a

1 = Widro; T = Térmics

Fuente: 810

N= Nuc

© = Geotérnica

---Page Break---

cuadro NY 7

Cont inwactéa

1980-1990

(108 ss de 1978)

1/ b= Hidro; T= Térmica; N= Nuclear y G = Geotérmica

Fuente: B10

a1.

---Page Break---

22

2.3.

Sector ?

Las inversiones del sector energia eléetrica son las que ofrecen na

Yor certeza dedido a 13 exser'encia acumlada en el BID y en el Sep

co Mundial, a ta pudlicides de las ti 7

tundiai y a los datos de consultores o fabricartes de equiposs Lee

dros 6 y 7 dan las inversiones vara las hipctesis de alto y bese crecimiento respect ivanent=

Sector peteSleo

Las inversiones en el sector petréleo s@ han dividido en dos am ~ plios campos: el de la exsloración, desarrollo y prosuccign, sel el transporte, 1a distribución y la elaboración

Las inversiones en exploración-desarrol lo-producc ién fueron estima das estableciendo vetas conparibles con las reservay tradicionales de cade pats. ?A ese efecto se toni como bases relacien reservar Produceién del ato 1978/75.

los datos acerca de perforaciones necesarias, profundidad y produc tividad fueron tonados de datos hist6ricos. "Se asumié que no po. = arian aparecer yacimientos gigentes.

Los eostos de perforacién ?ueron estinados para cada pats y se en contraron veriaciones de 400.000 USS 9 3.900.000 USS © nds para? =

Sreos costa afuera. También se estinaron les inversiones pars pros

peceidn y exploraci6n en paises sin recursos pecroleros en los Cu

les debertan realizarse esfuerios mucho mis considerabies,

Las inversiones en claboracién reflejan los costos que resultan de

insformar destilerias existentes a eayor conversion, para flex!

Vizar la produceién de destiledos

Las inversiones en transporte y almacenamtento se aprec

ja base de planes oficiales

ron sobre

Sector gas natural

No se estimaron inversiones en perforaciones para gas natural pues fen Anérica Latina, 1a mayor parte proviene de ges ssaclado,

$610 fueron computadas tas inversiones correspondientes a plantas = de tratamiento de gas,2 gesoductos con sus plontas ce conpresién y

a distribucién. La base para las estimaciones del conjunto, foe et

estudio de los proyectos conocidos. Los princios!es proyectos, foc ron los de los gasoductos en Argentina y Bolivie a Srasit. ts diss tribucién en este Gltim pats no fue computads, Potenciaimente, las inversiones en instalaciones para gas natural ~

podrian ser mucho mayores. Ho se han tomado en cuenta proyectos, de

sesoductos desde MEJico o América Central, o de gasoductos y plan =

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2.4,

2.5.

tas pars Ta exportssiém de LNG n Colombia.

Sector carbén

La metovologta fue <imilar 9 ts utitizeda para pezrsleo y gas naty

eal

Sector alcohol

se han considerado sélo cifras correspondientes 3 Brasil

LNVERS 1ONES.TOTALES

£1 cuadro 8 da un balance consol idado de todas las inversiones de!

Sector energia page el perfodo 1980-1950. Dichas.inversiones ol. ~

Gagsan 2 261 x 109 USS de 1978 para ei escenario bajo, y « 282 x

109°3s se 1978 pore el-gscenario alto, con una inversion anual? =

pronedio de 22 2°26 x 108 uss (1373)

Si esos valores se caleylan con un 7 8 de inflacién pare el lor

Tegan 2 W43 y 525 x 108 eolares corrientes durante el perTodo

£1 cuadrg 6 4a tos vglores estinados pare la componente externa ~

139° 108 y 164 x 108 U3s respectivanente, segin sea el escenario

elepido.

El sector eléctrico absorbe casi el $0 & det total, el petréteo el

ne

E sector petrgleo cequiese 98 x 109 y 117 x 109 Us (1978) de_ los

Cuaies th x-108 y-18-x 108 USS 11978) corresponden » exploracién.

para los pafses fin recupsoe patroleros,. Ia tnversién olcanea la?~

rmodesta sumo de 562 x 106 Us (1978), cifra que muestra lo pruden-

fe de las hipStests Je inversion.

EINANCAMLENTO

De acuerdo con estudios real izados por el Banco Mundial para el =

conjunto de los patses ?de desarrollo, las inversiones del

Sector ceberfan alcanzar alrededor del 10 % de la inversién total.

Asuniendo que ?sta oscilla entre el 15 y el 25 $ del PEN, se obtie~

nen para la inversidn en enersia valores entre el 1,5 y'2,5 3. En

el caso de América Latina, este valor leg a 3,3 ¥.3.6 al final

de la década. Es de hacer notar, sin enbargo, que 1a laversién -

anual aleanza valores de 22 y 26°% de la inversion total

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Tw ope

ol

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Conviene volver a recordar que cada kW instalado requiere inversio

nes adicionales en usuarios de! orden de 4 3 10 veces le inversiOn?

fen potencia instalads. Esta consideracin es vSlide para casos

tradicionales de plantas térmicas. En el supuesto de plantas nu =

cleares o hidriulicas, 1a inversién requerics es proporcionalmente

Hay que aclarar que éstos son grandes nvneros y que su uso sin re

Ferentes pude conducir 8 errores.

La necesigad de divisas para importacién de equipos es de 12,60 y

14,9 x 10 USS (1978). Este cifra representa mis de un tercio de

los Ingresos de Anérica Latina por financianiento externo, en 1978.

Los valores mencionados exceden los compromisos financieros de ~

fuentes pablicas y privadas para proyectos de energia en el conjun

to ce los pafses en vias de desarrollo.

Otro aspecto 9 considerar es lo necesidad de divisas

1as_imporgactones de petréleo que pasarsn de 9,2 x 10

23,7 x 109 (en USS de 1978)

66 8 de! PEN al Final de lo década.

SI acumulanos los valores de 1a import:

componente externa requerida para? | evs

16m de combustible con 1a

adelante los proyectos de

fenergia, se necesitarén 413 y 467 x 109 (USS en 1978).? Esta cifras

es en realidad el 6 % cel PBN de Ia regisn para el mismo periodo.

El financiamiento de tananas cifras es en sf mismo un formidable

problena, no s6lo por 1a magnitud de los valores sino por lo que ~

Significs e) esfuerzo de movilizacién de recursos téenicos, econd-

?micos y hunanos.

Si el problema del financiamiento presenta dificultades, et no to-
grar tas metas deseadas incidirs en forma negativa tanto en el pro,
Eeso de crecimiento económico com en el bienestar de los pueblos:
SI, por ejemplo, s6lo fueran alcanzadas las metas de producción de
Petróleo, GN y carbn en un 75 % para mantgner Ia actividad econó=
mice deseada, se deberian importar k2 x 10° t de petrdleo adiciona.
Tes con un gasto de divisas de tu x 109 (USS 1978)

Una premise fundamental es la de que el desarrollo de los recursos
fenergéticos debe ser pagado por los usuarios de la energia,
Dado el alto nivel de inversión requerido es necesario que el sis-

tema genere el mayor ahorro posible y a mayor ve'oeidad que de cos,
tonbres

Tradicionalmente, el sector eléctrico ha sido capaz de crear recur

505 importantes, tanto a través de la tarifa com por medio de suB,

del gobierno. La inf y diversas posiciones pol feicas

o16-

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faa.

han retrasado la actual izacién de los precios del servicio, por le

ue no siempre lo cuote de inversién ha sido suficientes Este vor

Fla de pois @ pais, pero Gitinanente existe uno creciente comsrens

in de la necesidad de obtener fondas genuinos.

En otros sectores, 1a situacién es tal ver peor y los recursos de Financiamiento ha'sido, en proporcién, menores. Esto vale pera el Sector petréleo, dominado por as empresas oficiales, donde labo Fes esenciales de exploracién y desarrollo han sido postergadseca pesar de su vital necesidad

Con referencia a! endeudamiento aceptable para Ia empresa es razo- able admitir el 50% y en casos de excepcién, nayores valores.

sists muestra ia necesidad de poder acceder 2 fuentes de fi- nanciamiento externas 8 !a regién, en canticades inusvales

Las fuentes oficiales de financiamiento internactones 0 podrén al canzar los niveles requeridos de inversién y deseran ser ssistidey ?con financiamiento privedo.

Las iaversiones extranjeras privadas podrfan concurrir al inancii

sniento del sector en Sreas especificas como Ia ds los hidrocarbs

ros, sobre todo si el pais tiene suficiente potencial com para? =

ronosticar exportaciones

La participacién de bancos comerciales privados extranjeros tendré

ue ser muy active, especialmente en proyectos bien estudiados y=

Que muestren retornos suficientes pare el capital,

2 componente interna de los proyectos deberé ser Financiads a tra

és de tarifas y también mediante la creacién Se nercados Internet

fe capital que pudieran atracr el ahorro de caus pats,

bos pafses exportadores netos de petréleo se encontrarén en ta si-

twaclén de poder financiar su desarrollo en mejores condiciones.

La inversién en exploracin merece un pérrafo aparte. Lo modi

El6n de los pautas legisiativas de muchos paises ho pernitias

atraer inversiones de enpresas extranjeras en el campo petrol ifero.

Es de esperar que esta politica continge. Paises con potencial de

frocarburos, tales com Argentina, Barbados, Brasil, Chile, Coe

lombia, Guatemala y PerG, han tenid> éxito a! ?obtener participa ~

cidn extranjera en su desarrollo. Ser?a interesante que ello au ©

era originar también 1a participacién de capitaies nacionsless «

asociados

Paro otros paises, donde existen posibilidedes de hallazgos de pe-

Eréleo, 1a obtencién de inversiones en el sector exploracien es =

grivica pero, mecanisnos de ayuda oficial extranjera, pueden ser

desencadenanies de desarrollos substanctales,

En el desarrollo de ta actividad exploratoria se encuentran facto~

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res que tienden a disuadirta, tales com

1) Falta de conocimiento geoldgic> de formaciones Favorables.

2) Desinterés de tas fuentes con recursos financieros y téenicos

para exolorar Sreas en las que ye hubo trabajos orevios no com

3) Politicas restrictivas de gobierno con respecte 2 !@ porticipa-

cidn extranjera e historia pasads desfavorable en las relacio -

hes entre gobierno y compafiias petroleras extranjeras.

A estos Factores se agrege actualrente 19 coyuntur

eso de produceisn mundiol, pare algunos transitoria. En los dlti

mos tiempos Se ha desarroiiado uns vasta gama de instituciones off

Ciales con progranas dest inados a ayudar a1 desarrollo energético,

ho slo en el area de los proyectos eléctricos sino también en

adversa de ex-

£1 Banco Mundial, tradiciona! financiador de proyectos eléctricos, ha agregaco un nicwo stograms pare e! sector energia. A.nivel mit

Dear oaeee eer tat ae ee

Tor que deberfo novilizar Inversiones de 57 x 169 USS. OPEP het

cPealo un fondo fapeciai con recursos de hx 10° USS destinado al

esarrolvo co recursos energéticos de los pafses en desarrollo. =

tas lineas ge politica s aplicar inéican que la ayudo principals

HE'pare tos pafses menos desarrollados y mis. serfanente afectadors

En nuestra Srea, El Salvador, Guatemala, Guayana, Haiti y Honduras

han sido seleccionades dentro de la categorta.

Naciones Unidas tiene una propuesta para la creaciéa de un Fondo ~

de Exploracién y Pre-inversién destinado a pronover estudios de. -

produccidn de petrSieo y desarrollo de fuentes alternatives. El

Fondo actuaria en patses con un ingreso per capita menor de 500

uss.

En 1a regién ya existe OLADE, y en Ia décima reunién de ministros

Ge ese organizmo se aprobs un fondo especial para estud|

Gos con la energfa, fondo que ain no ha entrado en vigor.

También siguen Implementindose programas de asistencia técnica, ta les como los de Méjico para desarrollar actividades en Costa Rica, y'los de Brasil para ayudar 2 la promocién del uso del sleohol.

Néjico y Venezuela han establecido facilidades de financiamiento para paises de Anérica Central y de! Caribe que se destinan al fi- naneianiento de proyectos energéticos a bajo interés y largo pla =

Trinidad-Tobago ofrece Facilidades

CARICOM,

inancieras 9 los pavses del -

En Venezuela se estudia un Programa Interamericana de Cooperacién

Y Coordinacién Energét'ca que serfa Financiado con e! Fondo Inte

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Imericanc de Enernis a ser <.sado por los safes de Américe Latina,

USK y Eanaes.

Pese 2 todos estos proyectos y reat izaciones, e! grado de Financia

miento oficial ro ha voriade en gran medida y se ha mantenido en

Resumen

Como un resumen de las nacesidades de financiamiento se puede obser

var en las Fig. 1 y 2 un frafico de los valores utilizados. Tales?

lores constituyen un ejercicio que puede ser arbitrario, pero que

pretende ser objetivo

Se tienen en cuenta dos escenarios de acuerdo con lo expresado ante

Escenario de bajo crecimiento: P81 crece al 4,7 % por fo, 1a ener

gfe al 5,23 por ano.

Los requerimiegros acunutados de inversién alcanzan 9 241 x10? uss.

(1978) 53 x 10° uss (1578) serdn en moneda local y 189 x 109. uss

1978) en moneda extranjera. De,estos Gltines 158,6 x 109 uss

(1978) sera divisas y 50,7'x 109 uss (1978) en fondos externos. ~

Existen disponigitidades de 105 x 109 USS (1978) to eval Geja una

suma de 84 x 10 USS (1978) 2 ser Financiada por fuentes desconoe

das. (Fig.1). Se presune que en este escenario las fuentes priva =

a5 y oficiales mantienen sus nivelgs actuales y que el Banco Mun ~

?ot duplicaré su nivel de $00 x 10® Ss (1978) al doble para 1990.

SI se adopta una posicién un poco mis optimists y se hace 1a hipste,

sis de un aumento de la capacidad de financianiento en? % por ator

1a disponibitiaad eracg a 119 x 108 uss (1578) y lo diferencia a fi

ranciar baja 2 70 x 109 USS (1978). ~

En el escenario optinista, el PBN crece a! 6,0 % por ato y la ener=

91g ©! 6,6 % por ato. Las necesidades de inversion serén de 262 x

10? uss (1978). La componente externa ests formada por 163.8 x 109

USS (1978) en divisas y 59,0 x 109 USS (1978) en fondos externos,

lo cual hace un tgtal de 232.8 x 109 uss (1978). fabria ahora dis

Ponibles 105 x 109 USS (1978) y faltarian 118 x 109 USS (1978). $i

de nuevo consideramos un escenario optimista, 1a disponibilidad cre

cea 119 x 10 USS (1978), y el faltante baja a 1"4 x 109 uss (1978)

las cifras puestas a consideracién muestran el trenendo esfuerzo

que significars poder alcanzar las metas propuestas, sobre las cua

les se basan los proyectos de desarrollo econdmico de Ange

Se pone asf en evidencia la necesidad de adoptar ¢ispost

Vistas en las pol ities [as y de explotacién de recursos, to

mando a tiempo las medi¢as propicias para facilitar el desarrol io

e los. programas ?conprone!

El esfuerzo necesario para obtener e! Financiamiento del sector -

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energia de Anérica Latina para e| perfodo 1980-1990 excede por su onto, Jo disponible en las fuentes tradicionales. Los gobiernos Je indica Latina y los divigentes de las empresas de energia, de ben intensificar, en forma constante e Imaginative, le bisqueda Ge los recursos necasarios pars que el defecto en el crecimiento del sector no resulte en un reno al objetivo de obtener un mayor bienestar general.

Es necesario también promover e! uso racional de la energia y ob fener reducetones significativas en el empleo de combustibles tre dicionales.

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y endey

Gésorss) eoysy0d op sepenwme sovereyroliy >

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conde» || t? ?oy)s4n| everan2n3

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Sux ait sertoeyag | @oueery

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woreienendd sp tay gry h rebw ap iptpinese 1g sper sou rowney

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Banco Interamericano de Desarrollo. Leonardo 0a Silva.

?ecesidades de inversién para el desarrotlo del sector energia y

perspectivas te financinmiento para el desarrollo de la energia".

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Industetat Energy Demand and Conservation in Developing Count:

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Buenos Aires

November 22,1981.

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ALTERNATE ENERGY RESOURCES AND TECHNOLOGIES,

FOR RURAL THIRD WORLD COUNTRIES

by

D.K. Sood

Sheladia Associates, Inc.

Riverdale, MD - USA

San Juan, Puerto Rico

August 1982

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ALTERNALE ENERGY RESCURCES AND TECHNOLOGIES

For RURAL THIRC WORLD CoUNTaE

2. K Sood

Shelacia Associates, Inc

5711 Sareis Avenue

Riverdale, MO 20737

ABSTRACT

The development of alternate energy systens is vital for the survival

of many developing economies. Conventional, centralizee and capital inten

Sive energy systems, because of Timited availability and the high price oF

Oi}, the pollution associated with the curning of fossil fuels, the tree

Irendous expense, environmental and sazisi constraints of nuclear power and

a variety of other reasons can no lonaer be counted to supply the needed energy needs. This is espectally trix for rural areas, where the majority of the develeping pooulation lives enc wmich require shall decentralized systems, There are at present many pronising, practical, and economical ly Gombetitive alternate energy options available tor rura) ?applications. These are primarily based on energy fran the sun, wind, wood, nethone gas and pedal power. Each of these options 1s best suited to a particular aoplication. For example, the best application of wind power 15 water Pumping, because of interittent availasility of the wind instead of elec tricity production.

This paper will examine the various alternate energy resources and available technologies to meet the eneray needs at the village level.

An analysis of the state of the art of available engineering designs and their Timitations with appropriate recomendations for developing countries application will be made.

INTRODUCTION

The energy crisis of 1973 and subsequent price rises in imported of]
Caused a severe setback or delay to the already meagre and slow social

and economic progress in rural areas of developing countries. Up to ?0-90%
of ?the population of nan-OPEC developing countries estimated to contain

428 of the worle's population inhabit these areas. Thus, nowhere, except

in developing countries, the eneray situation has becone'a critics). problem.
In developed countries, the problens have not been that acute, as their
economies have continued to grow, albeit at a reduced rate, in the non
OPEC developing countries, the problem has been compounded due to their
rapidly growing populations, growing urbanization, high unenployment rate

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ang recurring food shortages, with the result that these countries face
increasing difficulties resulting fron imported energy. Most of these
countries are exporters of minerals or agricultural comodi ties, whichy
unfortunately historically, have Seen subject te extrene arice instabi ity,
making it harder to hove a? planes crwth

Firewood, chercoai, crop residues and animal dung account for virtually 211 of the energy used {n many rura! areas and for about 2 percent of totay energy consumption in ary geve'sping countries. Africa is mast dependent. Asia sonawhat less, and Latin Arerica Teast dependent on such sources.

Sone tHo billion people, or about 75 percent of the posulation of the de- veloping countries, presently use traditional fuels for cooking. Most of these people have access ta fircwoos, but between 0.5 and on blilion use agricultural and aninal wastes 20 fuel their cooking fires.

Energy for rural areas is very important, especially for agricultural applications, as developing countries are essentially agrarian societies. Agricultural "sector 15 of primary inportance in deterrining econanic and Socia! well being of their majority aonu'ation which resides in these areas. Much of the phenomenal output c* sericulture in the US an¢ other major. food exporting countries can be traced in large part te the massive apptication of power end fertilizer to the lane

Most of these developing countries are blessed with plenty of sunshine that can provide alternative scurces of energy. For village level applica tions, there are many very promising existing technologies. These tech- nologies are primarily based upon energy from sun, wind, water, wood, methane gas and pedal power. Being snall scale and decentralized, they are ideally suitable for most village and rural applications. This, rather than technical inferiority wos the primary reason these technologies were earlier passed over in industrialized countries using large power. Essentially, alternate technologies for rural needs are typically low in cost, relatively Simple in construction and maintenance, made of materials available. in villages and smal} towns and involve Vittie or no environmental pollution or destruction. Moreover, in the long term, nankind will have to depend on

Fenewable. principally solar energy and shotosynthetic processes rather than fon diminishing fossi? materials for energy and material needs.

Each of the alternate energy sources is best suited to particular par-ticular applications. For example, the best application of wind power 1s for water pinping or grain grinding because of the intermittent avai lability of wind. Water tanks can provide storage for the water, which can be used when no wind power is available. Solar energy, initially captured in the form of heat, 1s increasingly being used for drying fruit, grain and tinber. The technology involved is simple, low cost and effective. The use of

small scale water turbines has provided much of the strength to the develop-ment of decentralized rural industry ang rural electrification as is the case in China. In much of the rura! thire world, 80-90: of eneray consunp~ tion is in the form of cow dung, and woot and crop residues. Severs! cook= ing stove designs that can econorically save up to 6C= of this fuel are

iow available. These appear to be the best and lowest cost way to

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immediately improve the energy susply situation in mary rut while

Preventing deforestation. Biogas digesters on the ctmer hand, not only

Provide fuel but also generate furtilizer and rs!uee by-products. using

digestion of aninal and agricuiturs! residues. Sea'l scale gasificrs,

using wood, agricultural residues, etc., nave be-n cuvelgped to supe!)

Stationary?and mobile sources <* ower ior severe! apalications.

ind energy and solar crop dry d Lincs tines ?nnenorial, are getting

a reintrocuction, though now a! ¢ such nroader scale, at the rare! scene

Reda} power uses human muscle +: chs reat effective way while provising

cransportation (the bicycle, se+i-cab or pedailed art), or as easily sovee

able shert-term small cower scurce: (threshers, winrwers, grinders, ete.)

Thus, there are s nunber ot svall scale, dacentra?ized, Tow cust, teche

ically and economically feasisle senewts'e energy technclogies ave) lable

for rural areas of the *hire world. frsng theses thes paves discusses

Gookstoves, biogas, yas ification, wind energy, solar crop dryers. ave pedal

Bower for the rural ress of aavsloying countries

BIOWASS ENERGY

Bionass is form of sclar energy stored in a wide variety of plant

and animal orgamre matter. Woot is the cldest and nest basic fesource for

meeting human needs. The key process in creation of biomass = pratorayn

thesis uses sunlight to convert carbon sioxide and watur inva migner

anergy products such as carbohydrates and oxyger. Forest materials and

Fesidues, grains, crops, anima? vanures ang aquatic slants, and, prinel=

pally, wood, are?the resources of biomass.

Biomass can be transformed into licuid or gaseous fuels and petro

len substitutes, as well as heat electricity and stean., Several biowass

Gonversion processes are available, with direct conbustion of wove being

the most camon. However, the shurtage of wood, especially in rura) areas

of Africa and Asia, and to prevent rapic deforestation causing severe. long

term ecological damage, use of wood 13 being discouraged. in'hilisiaes,

the renoval of trees reduces the soil's sbility to retain wacer leading

to ever ?increasing cycles of load and draught in the tands below, Ae the

same time, rapid search is underway to develop enercy efficient cookstoves,

Detter charcos) production systens, cannunity wood lots ang fest growing

wood species. For the rural areas, a major enphasts in wood combustion

is on the developnent of wood stoves prinarily for cooking, inefticiont

ooking methods and a lack of replanting cf fuelwood trees, particularly

in rural Third World have forced mitlions of the poor to ssend 8 large

part of each day hunting for fue? and cerrying it tong distances om their

backs.

1, Gookstoves The existing wood stoves lose considerable amounts of heat eneray during cooking. Severa? rew wood stove designs developed recently, save this he:t loss by modifications in combustion chambers, chinney, damper, wall and pot hole design. An efficiens, simple, wood burning cookstove should not only confine the Flame to che cookine srea, but conserve the heat produced by minimizing heet loss £0 the surrounding

---Page Break---

areas, such as the walls of the fire container itself. Construction materia? for this include clay, metel, mud ard cement, al) considered locally avail able in rural areas. ?Fuels inc!uc: wood, charecal, rice hull, and other Grop residues. In the rural Third orld, most of the energy used is in the form of firewood and crop residues gathered and ourned in cooking fires.

Low cost, locally buil* cookin: st.ves can greatly increase the efficiency of cooking, reducing the denanc +c: firewcod by up toune half. This would Slow the rats of deforestation snd Tighten the burger of long distance wood hauling.

Matton, ez a1}(197e) surve:

the fellowing inexpensive deste. (13,

dapanese exrthenware? cooker, the fanado, fer use in ri

World, A cookstove consists of five essential conponents

severa? wood cookstoves and recommended

based on the very efficient ancient

areas of the Third

1) A fiveegatlon can and ic, with vent holes in the Tid and the base

of the can tc contra) grat

2) Two ceranic blocks or st.

25 to support the grates

3) A.ceramic grate to supsort tne fire with holes or air passages to

admit air for conbustion

4) A ceramic Viner (or shell), to insulate the fire fron the can

5) Ametal grill or other structure to support the food being cooked

?The ceramic components of this cookstove can be easily fabricated. As

for this application, they need not be fired in a high temperature kin.

The five-gallon paint cen could be repta.ea by a simple sheet metal shell

hich, when rolled, can be used as an open-ended support structure, Many other ?cookstove designs have been develozea and are cons\dered suitable

for domestic use (2,3,¢,5). However, such designs have not been widely

ai sseninated.

2. Biogas Bioges, a mixture of gases containing methane, carbon ioxise, hydrogen svitide and traces of 3 few other. goses te proauced during biological degradation cf organic matter such as animal, agricultural and hunan wastes. Methane, which constitutes about 60 percent of the total ?gas produced, imparts the property of conbustibility to the biogas, thus making it suitable for applications such as cooking, lighting, and running engines. In rural areas, biogas technology reconciles two seemingly conflicting functions = the use of cattle dung and other organic materials, both as fuel and fertilizer needs of rural Third orld countries. The

left over sludge retains its nitrosen and both the useful constituents, namely carbon and nitrogen of the original material, are appropriately used, for fue? and fertilizer respectively.

A biogas plant has two main parts: a digester in which material for fermentation mixed with water is introduced and a gas no'der in which the generated gas is collected. The digested sludge and the effluents come Out at the outlet and collect in a pit. The digestee slucge and the ef-Fluents can be used as a fertilizer either Girectly or a° lowed to drain

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into @ drainage pit for later use.

Standard biogas plant designs utilizing concrete tanks, concrete inlet ang outlet basins and steel covers serving as floating gas holders, con-sidered suitable for rurai areas, have been developed. Anong the Third Worle countries, India is the leader and is carrying out extensive programs of biogas research and plant corstruction. During the past 30 years, such institutions 25 the Indian Agriculture Research Institute (IARI), New Delhi; the Khadi and Village Industries Commission (KVIC), Bombay: the Gobar Ges Research Statior., Ajv2mal; and the Planning Research and Action Institute, Lucknow, have conducted Considerable work in biogas technology.

At the sane time, known technology to produce biogas to satisfy a Significant portion of nuran needs is being approached differently in various countries by various organizations (6).

A typical biogas digester designed and developed by IARI, mostly Using animal waste is shown in Fig. 2 (7), Available varrations include those {in biogas plant configurations incorporating design features particularly to suit various types of feedstocks, construction materials available and end uses of by-products that are produced. A more popular one anong these is the Chinese design, which replaces the expensive and problem causing steel gas holder with'a concrete done. The methane gas is instead trapped below 2 ferro-cenent cover, displacing the Viquid slurry and pressurizing the gas. Moreover, since the unit is built completely underground, savings in and space and improved tenperature conditions for fermentation are said to be additional advantages. However, initial studies by KVIC and the Ministry of Agriculture and Irrigation seem to indicate several problens with the Chinese design. Among then are the lack of provision for breaking ?the scum buildup in the tank, the necessity for using manual Tabor or 3 punp for renoving slurry from the cutlet chamber, the need for periodic opening of the digester to renove the sludge, fluctuating gas pressures and occasional shortcircuiting of the feedstocks. In larger-sized digesters, these problens are said to lover gas production by 30-50 percent.(8) Even in Chinia large biogas units are generally said to be rectangular with flat tops.

Depending upon the requirements of the fuel gas in rural areas and the availability of animals, the capacity of biogas plants can be chosen. Popular sizes of plants? in operation in Incia are village model snali-size Plants (suitable for a family of five or six), producing about three cum, (200 cu. ft.) and usually odtained fron three to five head of aquit cattle; medium size plants producing about nine curm. (300 cu. ttc) of fuel Sas requiring about 150 kg. of fresh dung/aay, usually obtained fron 10 to 15 head of cattle; large connunity-size gas plants producing about 30 cucm (1,000 cu. ft.}/day of gas requiring daily about S00 kg. of fresh dung/day, usually obtained from 30-40 head of adult cattle. (3).

India has over 500,000 biogas plants of all sizes in operation. A significant number of these are not in operation, prinarily due to. the economics and sometime due to technical,ma intenanice, and social difficulties. Unfortunately, only modest attempts are? being made at present to improve

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PULLEYS COUNTERWEIGHTS

SLURRYMIXER f 6 OVERFLOW

CHANNEL

et. I R 7

SPENT SLURRY PIT

BREAKER WATERTRAP

GAS HOLDER

DIGESTER

FIG. 2 BIOGAS PLANT (Indian Agriculture Research

Institute, New Dethi)

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ertorsance ard prospects <# bicgas veneration systers in India.

In order to taprove the prospe:ts for biogas generation in rura) areas Of the Third Worle and to veatize :: ful potentia?, it 1s imperative that not only the technical crot jens. ou: s)so the soci? ~conomic and organsza- tional probles be dealt with ri ently. In Indizy as in severa? countries elsewnere, there have instances where socio-cultural factors, acting alone, fave resu'tec in stoppage cr fa! lure of @ biogas progran?in a rure? area

3. Gasification Gasitre:

. Gasiticatig fers to the thermal conversion of biomass (or coal oF petruteun) ustible gases for heat, power and Chemica? synthesis. The simples: metnad of this conversion is air gasificas tion, producing @ iow energy gas, well suited to eivect heat or engine applications, but unsuitable for piveline use. Oxygen gasification, on

the other hang, groduces @ madiv~-eneray 93s composed prinariy of CO ond Hp which can be used in industrial pipelines for applscat?ons. including power end heat cogeneration, eng cherica? synthesis of methanol or ammonia. Steam for hydrogen gasification are also posstble, but externa) heat and energy sources are required.

lihen air ts used for biomass gasificaton, a low energy gas [typically 5200 k J/nm3 (150 Btu/sc f)) results because of nitrogen dilution. Though suitable for operating engines or close coupling to boilers, it 13 not economical to distribute this gas in pipelines. When oxygen is used for biomass gasification, a "medium energy gas" [typically 10,400 k j/nm?

(300 BTU/scf)) is produced, and this can be distributed in pipelines to

be used for applications such as power turbines or to synthesize chemicals.

In principal, gasifiers can operate on any carbonaceous solid fuel such 25 biomass, coal,?or Tignite. In practice, however, the satisfactory operation of any particular gasifier will depend on its design relative to the fuels used end, in particular, on the fuel density, mossture content, ash, fusion temperatures, particie'size, etc.

?The satisfactory operation of @ gasifier depends on a free and uniform passage of the gas through the fuel bed. Therefore, satisfactory bionass fuels should be relatively uniform in particle size'so that the gases do not form channels. Particle size should be greater than about one-quarter inch

so that there is not too much back pressure, particularly in updraft gasifiers. Dusts and fines are particularly troublesome. The charcoal which forms

on pyrolysis should nave moderate physical integrity to prevent collapse

and plugging of the bed.

For these reasons, wood chips and bark make excellent fuels for the gasifiers. Gasifiers have also been run satisfactorily on shells, pits

id corn cobs. However, other fuels such as sugarcane bagasse, rice hulls, ta ks, wood barks, branches, coconut shells, husks, trunks, peanut. shells: Straw, "cotton gin trash, food residues, etc., may require densification {cubing, pelleting, briquetting, extrusion, etc.) in order to be used satisfactorily in gasifiers.

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Biowacs he. sany atract've Features as fuel, including very tow sulfur, renewability, Tor cost in ?ary cases, and?no Increase in lorgeterm atmospheric 60-. However, bionsss occurs in'a wade variety of Fors ong

$5 often too wet to burr and too bulky to ship. Recently, 2 number of Companies have begun to make aers'fied biomass fue\s, ?OBF," to overcone this handicap anc create a unifor= cormodity fuel (currently selling on

the US for $20 - $30/ton). The cost of arying and densifying is approxi-mately USS6 to $15/tor, and must be weighed against the value Gf the Biomass, with and without densification. In the United States, Sweden and Frances

in particular, 9 number of gasification tests have been runon pellets and they are found to be quite satisfactory. This process may, however, turn outfor many applications, to be uneconomical for rural areas of developing countries.

The research work carried cut on biomass gasification has established its technical and economic viability for several rursi applications. in the Third World countries. Several specialized apalications are being commercialized. good deal cf this work is being done in the Philippines » ere farm Systens Development Corporation (ESOC), the government-nandated lead agency in gasification application, is Tooking inta the comercial production of gasifiers for diesel and gasoline driven vehicles for short hauls (up to 120 kn) in rural areas. Gasifier equiprent 15 also being Conmercialized for irrigation and other farm related applications such as electricity generation, and powering rice mills, driers and farm vehicles. FSDC's goals call for self reliance at a reasonable price,

Considerable attention is also being paid in the Philippines to develop biomass-based gas producers for cars, trucks, and buses. two. systens using Producer gas and Hydrogas are being tried. Producer gas isthe combination of combustible gases from the partial conbustion of dry organic matter Tike charcoal, wood, coconut husk, rice hull and the like inside

2 cylindrical reactor. In'this model, air is used as the gasifying medium. Dry carbonaceous material is fed into? the reactor where it is parsially burned, thereby producing the mixture of combustible devices: this gas

mixture then passes through a series of cleaning devices; first, the eyclone Separator where solid particles are taken aut, then the gas scrubber (ror ® stationary installation) or the condenser (for vehicles)s that Tiquifies and removes the moisture content, and lastly, the wet filter which collects the remaining impurities. The gas is now mixed with filtered air and is fed together with a reduced volume of gasoline vapor. (11)

With gasifiers, Philippine data shows that an equivalent of IAN-Hr of energy is made avalable from one kilogram of coconut charcos!,

Producer gas may likewise be used in electric power generation, water supply systems, ricenil1 and drying operations, and other applications re-Quiring the use of internal combustion engine (12) (Fig. 3),

Hydrogas, on the other hand, is a clean, medium Btu gaseous fuel which an be produced in a gasifier, using charcoal or wood fuels heated to st Teast 1,000°C. A jet of stean directed into this red hot charcos! bed

---Page Break---

FIG PRODUCER GAS AS A FUEL IN A

GASOLINE ENGINE GENERATOR SET

a10-

---Page Break---

its s which reacts wit® carbon to produce carbon 16 oxie= Mometr'clusr Se inductee sy the

steam te cessary ?0 susia!s ?he endocnerme,

reactior

The sydrovas

production: a cycler

@ primary Milter ty 4

catsally of a gas! fier for hydrogas

slarate solid inpunities from the gas:

cole part: p)ssed through

the cyclone senareto: anc wet Filte~ unit to coo) down

the a5 while removing condensibe ceses and very Tine selié impurities:

2 fuel air mixing sox tc snake the 93. conduetible ag -t is sucked into he

engine intake ~anifole; arg s we7%r crein tank assendiy. A hand operates

Blower fo~ starting and 9 foo: are hand-operated Bicycve air gump eo

Pressurize the water tanks are two eusantial accessories 10 complete the

hydrogas systen.

The system can be used solely, as 102 percent displacement of fuel,

in spark ignition angines (gasoline engins). For comaression. ignition

engines (diese? engine}, only a sininal anoust of deere? to prouuee she

spark and conbustion 1s requires,

The system can be used for trarsport vehicles, irrigaton pumps, elece

?tric power eneration, ishing boats and other mari tine applications.

WIND ENERGY

its eneray from the sun's heating of the atmosphere,

has been described as ?the greatest terrestrial mediun for harvesting, hare

essing and conserving solar energy(13) Wind energy has been used for

thousands of years to propel boats and ships and to provide rotary windni1)

power for applications such as irrigation and to run'milis. Evidence

indicates that Persians used vertica!-axis sai mil) wind machines. to. ground

grains as early as 3600 BC. Later, Chinese used the horizontal axis winds

MINIs for irrigation ang grain arinding. Wind mills in China are currently uses for irrigation on smal? holdings, using windn Il eriven seogp bucket systems. These, for local use are always constructed of wood and banboos With minor modifications, the sane device is used to grind beans and rice, and for shelling crops, as well as for pumping.

Wind, often with its intermittent availability, can be practical for water pumping, crop processing and sone rural industries because the energy Fequirenents are spread out over a runber of days. The word, "wind mill in a strictly technical sense refers only to a type of machine that drives a mill to grind flour. Ina more practical sense, the word 1s, however, ?interchangeably used with wind machines.

Wind machines are strongly dependent on the sites furnishing high, reliable winds, Wind speed is very much affected by the topograghy.? The top Of a small hill will usually have much more wind energy available then the bottom of a hilT. Moreover, the power in a stream of moving air 1s Proportional to the product of the cross sectional area of that stream

---Page Break---

and the cube of 4+ velocity, sc the? doubling the wind speed increases

the power aight tines, This? mens trat energy In wind moving at 2 mah
is etght times as much as thera 16 or wind moving ot 19 mph
There are a runber «+ consesuenres of this pecul ?arity; one is that

the designer ond builder must pr.vice sone method of orotecting the wind
mil) fron trenendoss forces of huh winds. Three methods are commonly useé.
In one c2se, a ?feathering? system for moderately strong winds tn which

the angle of the blades 1s changec so that more of the wind is allowed to
pass through the rotor without effecting it, a system which causes the wind
rotor t9 turn sideways out of the wind at stil] higher wind velocities, and
2 break and tying down system for very high winds. On the other hand, sai?
windnil]s in developing countries that have Severe tropical storms may be

?2 good choice; the sails can be casily removed, leaving only a skeleton
that is not easily danaged by the wind.

In determining an appropriace configuration of an array of wind mills, it fs important to assess the interacting relationship between the relative positions, heights, and the energy produces by a number of wind energy col- Sectors ot winanit¥s. Thare wou'd be interference effect, if the individual windni I's within an array are paced very close to each other, thereby re~ Sucing the average energy of the wind across the array - fron?the direction of the attack to the opposite end. Within the array, the wakes of the in dividual wine mills can be regions of increased turbulence, where there would be variations in wind intensity. This intensity, compared to original intensity could becone substantially lower in sone places and higher in others.

However, not a1? the power in 2 wind can be extracted. It has been shown that a maximum fraction extracted by 3 wind mill 1s 59.3 percent. AS a practical natter, horizontal axis wind devices achieve less than 70 percent

Of this theoretical naxinun; that 1s, they are able to extract sonewhat

Jess than 42 percent of the power in the wind.(14) Vertical axis machines are significantly less efficient. The useful? power produced elso.depencs upon

the? ability of the user to use 18 when produced. Otherwise, the usefulness, even of an elegant wind device 1s Severely conpronised.? These foctors, tong with the capital costs have an important bearing? on the economics of & vind mi11 whether operating puna, a generator, or used to grind grain or perform other mechenical tasks.? The cost of a wind systen 1s closely linked to the type end height of the tower on which the machine is mounted, A large Dart of that cost is the cost of the tower, which is dependent on its design and materials of construction. For rural areas, to keep the costs low, it ty be Important to develop desions thet ute Tocal materials, for construction tnd installation,

Many sinple, though less efficient *do-it-yoursel" wind machine designs for rural appiiestions ave. available. Water pimping wind mills usually have 2 Slowly: turning whee! with many blades. On? the other hane, wind generators GsvaTiy nave two or three narrow Blages which turn at vary high speed.

For wind generators, gearing 1s still necced to multiply the number ef Te-volutions per minute (rea) up to the range required by 9 generetor. For txomple, awind generator may be charging the batteries at. 200 rom, but only ?if the gearing has multiplied this to at least 800 rpm at the generator.

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This gearing wo" 45 esceet

Vly where #t can dramatically affect

the entire desige of Qaelain! guauoee

One wine 233 urce 'n #96 38 wi supe'y plans for severst

types Gt ming ats eattanis foe ceseteelag auuntsiec, "ane ater hve

Rerap Susanobs Te Sordi netuatng p seve aches wpieage vagetatee Ma

Seneratonor cHeernatar, ?anes! syelt te almocl ec fseaheel, the blades

OF which fearon automat eed incrosse. anes designed

for local fabrication, vations, the et 'se unit will supply

Fron $00 w to 2 ke: the cost of materials well vary with the value ane

availability cf surep eucamobite parts on the Toca? market. ATT Tabor

for fabrication, assembly. and ate?lation can be cunaited locally. Wind nachines providing less thane Be ines? for use on small ams

of the rural Thre Morte end a ersea sites

DIRECT USES OF SoU

Crop Drying the availability of ample sunshine tn most rural

Ta countrtes favors. the ap2tication o* solar thensal conversion gies such as solar erop drying. This direct use of solar energy 18 perhaps the most anc?ent and wide spread. The customary cechnigue jnvolves spreading the material to be dried in a thin Taye on the ground, to expose it co sun and wind. Copra, grain, hay, *ruit and vegetables are SUIT! dried in this manner in many parts or the world, including the indus trialized countries.

The technology employs solar collectors to heat air which is then

used to dry crops and focd products. Size of the unizs may range ?ron sal) chest-type collectors with 9 few square meters of the ares for use

at the donestic and single farm level, to much larger comerctal-seale units capable of producing severai tonnes or tens of tomnes per day of Gries goods. Simple solar cryers generaily consist of a wooden rectangular box covered with glass. Air circulates chrough vents efther by natural or forced draft. The crying trays are renvable, Materials required for dryer Construction are sinple-steel, glass. wood, sealants, and galvanized sheet. Such dryers coulé be manufactured 103 percent in most rural areas of the Third World. Larger comercia] units may resemble greenhouses,

framed rectangular units with glass roots. Drying plattarms are placed inside the building and air circulates by eitner natura! or forced draft, usually exiting through vents at the pea?: of the roof. If auxiliary fosst? heating is used, as is the case with tow temperature and drying operations, burners are usually placed in rows under the erying trays. The energy output of such units depends, apart from other things. on the amount and intensity of solar radiation, design consigurations and the type of material to be dried. (15, 16) Agricultura? crops should be cried toa moisture content of 12-15 percent by welght. The relative munic:ty cf the air ranges from 8-50 percent for fruits, arain ard hay to be ?r s0u"librium at thet moisture content. The most desirable mo: sture content for corn and peas

is about 60% revative humidity for about 12% moisture content. The corn and pea crops off the field is usually at about 18% moisture content so,

---Page Break---

arying 33 necded <0 avo? degracatic:. Relative humidity, however, cat be adjustes with ratner minal inorece- in air temperature,? The copitaly

operational ond raintensrce costs cf solar dryers 91s0 show extrene varia~

tion, Howevery 2 simple domestic dryer, with carefui selection of Yocally-

available material, can be built ircipensively, and can cost as Tittle as

S1-5/n°. AL the other extrene, expssive and sophisticated collectors may

cost as uch as §14-24/n

Solar crop drying 1s consizored to be the cheapest and simplest way

to dry crops in regions waving abundant sunshine and where post harvest.

season is characterizes by low =:)otive humidity and Tittle or no rainfall.

Solar crap drying is alsc one way of reducing wide fluctuations in the

price of food products. In Equ=t, fer examale, crops and food are dried

fn both commercial and?domestic/farn scales. About 100,000 tonnes of dried

food stuffs are produced comercially each year, mostly by plants of 0.5-10

?tonnes/day output capacity. Use of solar drying can reduce fossil fuel

consumption by up to 160,000 bbi/year or 25% of current usage in commercial

arying (17) and will raise fam incone by improvenent of quality and reduction

of losses in donestic/farm drying

In rural third world countries, solar dryers should be usable by farmers with 2 limited technical skill and sal] capital resources, A"'do 1% yourself? tyne dryer can be buitt with Tocally available materials and labor. However, because of the short term seasonal use, 2 crop dryer may have to be designed so that a variety of crops, maturing at difterent times, can be Gried in sequence, by use of the same equipment. Several designs of solar crops dryers (suitable for rural applications) have been developed, These range from the use of solar-heated air in more or less conventional air dryers to a conbination of direct drying and air drying by placing the materials in flat plate collector-dryers. The Tater have been desi gned and used successfully in India, Janaica and Trinidad. (18, 19, 20, 21, 22)

PEDAL POWER

Bicycling or pedaling is perhaps the most efficient use of the biggest and the strongest thigh muscle (the quadricep) of the hunan body. Pedating enhances the power of the legs which are then relieved of the effort of Standing or supporting the body. A person on a bicycle 1s the most energy efficient moving thing that exists, measured in calories per unit of weight Der unit of distance. (23) A man can generate four times more power by edalling than by hand-cranking. The usual pedaling speed, 60-80 rpm, uses

Jeg muscles at their maximum efficiency and yields sonewhet Tess then?@-1 hp (74.6H). In sone cases, professional cyclists have produced up to one hp for short periods of time.

Pedaling continuously at a rate of 4 hp can be done for only short Beriods (about ten minutes); however, pedaling at ha? this power (1/8 hp) can be sustained for around sixty minutes. Experts feel that the human energy can be most efficiently harnessed using pedal-powered machines, including, but not limited to the bicycle. Pedal power enables @ person to drive devices

ae,

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at the seme rate as that achieved by hand-cranking, but with far less effort and fatigue (e.g. Flour mtil}. Honevs Beda Power, it 12 possible to drive devices at a ?ast-r race than before (2-9, winnower) and ER.BQHET Gevices which wou'd reou'r2 toc much power for haniccranking. (erg. thresher).

Probably the oldest pedal power application is weter pumping, The fraditional Chinese square pellet chain pump for irrigation ands. twe man borehole punp capable of 1:fting water 100 meters, are popular examples Ingthts category. ?At the International Rice Research Institute (IRI) bos Banos. Laguna, Philispines, a siall Tight weight, inexpensive: teste powered punp that lifts large quantities of water severs? fect hae boot Seveloped..

West domestic chores in rural areas -equire a statfonary power source. ThE principle behind the Stationery Eneray Cycle powered generator is simple qhe energy generated by pedaling 15 transmitted bys sumer. takerort nese one S,Conventional chain-and-sacket is used as the drive chain. The input ahaft of the machine or tool to be powered is coupled dractly to the power take off shafts,

However, the use of pedal power in such a capacity necessitates over= coming a number cf problens, inclucing (1) cycle toraue, (2) the neeo for

2 rigid brace between the driving and the driven sprockets. to teke sre ult of the chain which can be as much as twice tie rider's weight,

{3) sone provision for adjusting the chain, and (4) she varying lengths of the Tegs.

A Stationary pedal power unit - Dynapod (Greek for power and foot), G27 be acapted to a wide variety of uses in agriculture, smallescate. ynduse {ria} processes and electric generation. Dynspods usually consict of o Stationary bicycle frame, seat, handle bars, and pedals which drives series £f chains or belts. The ?number of revolutions per minute can be changed By adding or subtracting pulleys or gears. Usually 2 flywheel is necessary fo smooth out the high and low power out of a person's natural pedaling plytha. the use of flywheel assures constant speed and power toa device being driven by the dynapod. | dynapod can be a one person Unie. or a ton Person untt. A two person unit (Fig. ?) can provide » maximum power oF bout 150 watts over an hour; for shorter periods, higher output fs, possibl TRE UNE shown has a frame made of wood and uses woaden bearings. (24): In addition, six bicycle cranks, two saddle seats, 2 bicycle wheel, a cayn Grive gear and two chains are also required. Five otver parts require the use of metal turning lathe, Saddle supports are made of steel tubing ane Bates and require welding. Accoraing to the Tocsi conditions end use, many orsetese Parts can be replaced with wood or simple mete? ones. The designer Sysoests several applications of the dynapod including {1) 9 winch capable cinraising one metric ton at about 15 cn/Second or to power a seationsey

finch for blowing. The dynapod oowers a winch which moves the implement

Ehrough the field; 2) 2 water pump capable of raising 230 glions per

Iminute (gpm) through a 30 cn éistance or 33 gallons Der minute: through

Ehree meters distance (11 gpm through 10 meters gtstance/3.3. gpm? through

?three meters); an electrical generator capable of producing 60-200 waties

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?Other applications of dynapac include cassava yraters, coffee and grain hulling. cracking of of? palm nuts, rolling oatmea! (decorsicating fibres =

sisal, hemp, etc.) and baling. "he Pura} Appropriate Tecnology Center in

Madras, Indie has designed and testes a number of vecel powered agricultural

implements ane small scale equio-er:. A Bicycle paddy thresher fram the

initial date :s shown to have a cepacity of up to 0 tg pasay/nour,

Several new designs of tools teat use pedal power especially for rural

areas are being developec in many countries. Several of these designe are

even s2id to provide a more relsabls scurce of electric power than wind

energy. (25, 26)

(OTHER TECHNOLOGIES.

The renewable techncIogies discussed earlier are, in general, accessible

20 rural comunities in developing countries. However, the Tse "is not comprehensive, There are other renewable nergy technclogies, such ts solar hot'water heaters ?that also have proven their technics! anc econome viability in rural areas of develosing ccuntries, though have net been dis- cussed here. Sone of these technologies, in mary cases, can be ?mplerented using ?off the shelf? equipment or tn other cases !ght recuire some modi fications, A prime example is Jamaica and Columbia where sclar heated hot water in Sone rural areas is being used primarily to mect the needs of smal] scale industry. ?At the sane time, cther renewable tecnnologies,. though

highly practical for rural environments, are as yet unavailable primarily because of their economics.

Photovoltaic devices and microbial conversion of biomass to produce Viquié fuels, such as fuel grade alcohols are among the prime examples Potential applications exist for photovoltaic cells in refrigeration and Vighting for renote rural health clinics, in teleconmunications, and perhaps in water punping. The Republic of Malt has hag extensive experience with photovoltaic. systems, where several units mainly with French assistance have been instalea

The mcrodial conversion of agriculture waste, spoiles grains, ete.

can provide mich needed liquid fuels for numerous rural applications 85

well as protein rich byproduct stillege for feed and fertilizer use.

Direct photovoltaic conversion can be achieved with basically simple

devices that involve no moving parts, no additional sources of energy, and

Little, sf any maintenance, and possibility for modular systens at sizes,

from a'few watts to megawatts. The operation of these solar cells 1s based

?on the photovoltaic effect - the creation of charge carriers within

?materia? by the absorption of energy fron incident tonszing radiation.

This occurs best in semiconductor matertals, with properties between those

of conductors and insulators, Literally dozens of materia's, alone er 4n,

Gonbination, possess the semiconductor peoperties required for high efficiency

(greater than .10) conversion of solar radiation to electricity.? ?However,

a

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for possible comercial apalication: of protovolteics, only three - siticon,

cadniun sulfice ard gsl1ius arser ide, with silicon as the Teaging material ~

have deer: success?ully sca. Otrors ere in experinantal stages of deverop-

In rural areas, the ettractsveness of a photovittaie system will depend fon the eccnone siansficence of ?he avalication, wher current prices are considered, critical neecs, such as renote rural clinic refrigeration appear justifiable, Provision cf refriceretion will allow a wider range of vaccines. and drugs to be keot. This may ?ive =speciaily beneficial effects on infant mortality rates. If and when photovaltaic celi coszs are radically reduced, fnore applications will become economically viable, The on-going research

has so far been quite successful in considerably syproving their economies. The nodular nature of photovoltaic systens permits the users to gain expert- ence with a relatively srall invastnant, This 1s a crucia? aspect of rapid Giffusion of an innovation, Biochenical conversion of bfonass, using fermentation has been used, 817 over the world since tines tmenorial, to produce s?eane'. Currently, agricultural grains and sugar crops have Deen the feecscocks OF choice, Since they are more easily decorposes. Highly abundant lignin containing cellulosic materials, such as agviculiural residues and woody crops must undergo expensive pretreatment to sreak the lignocellulosic complex, thus haking the economics of conversion generally unfavorable, At present post developments for cormercial orcduction of alccho! fuels have been achieved mainly in industrialized nations. Considerable work te eliminate fof mitigate constraints including issues such as "ood vs fuel? characteris= ties of rural areas, is required, before this known technolegy can be. adapted for applications in develning countries.

?conctustow

Renewable energy systems such as bio eneray ranks very high among the possibilities for eventually achieving sustainable supplies of eneray for Fura} third world countries. The snail scale technologies for harnessing alternate sources of energy represent more than a possible answer to the dilema posed by depletable and high price of imported of}. It also re= presents an opportunity for the village to regain ite viability through better economic development and slowing of mass migration to cities.

However, development of renewable energy technologies should be regarded

as a component of rural third world development as a whole rather than

25 an end itself. Thus, any options recomended could be fully integrated in-

Yo the social, economic and physical realities of the rural third world.

Technology at ?the village level due to needs and resources, essentially,

has to be simple. Rural areas, anong other things, lack 1)skilled manpower,

2) inability for capital accumilation, 3) facilities for continued research

?and development and 4) ability to take risks.

?Thus, in each country, @ central organization with a competent development

oriented staff, working through reajonal research and development institutes,

?18,

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entrusted with the capacity to ceveic2 new equipment suited to loca? reeds, sens a necessary first step. ?re sngact of an increased energy supply

could be enormous. It can go a Weng way in achieving incresses im agei=

cultural procuctivity, inprovenent economic growth, ctf farm enployment

and overel) improvenents in the storvare of Tiving for most of the rural

Populazion of the Thira world

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UPADI 82

Sen. Juan, Puerto Rico

?August 1-7, 1982

Second National Conference on Renewable Energy Technologies

CARIBBEAN DEVELOPMENT BANK'S

RENEWABLE ENERGY PROGRAMME

By

JM, Dellimore

Technology and Energy Unit

Caribbean Development Bank

San Juan, Puerto Rico

August 1982

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USAID

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?Warions

Caribbean Developrent Bank

Canadian Internati ona! Development Agency

Commonwealth Science Counci?

Caribbean Techaological Consul tancy Services

Caribbean Technological Information Services

Inter-American Development Bank

Integrated Set of Information System

Less Developes Country (of C08 menber countries)

Overseas Development Agency

Latinetoer

?an Energy Organization

Technology Development Programme

Technology and Enersy Unit

Uni ted Nations Educational, Selentific and Cultural

United States Agency for International Development

University of the West Indtes

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packs? Jno

1. im adaitien so a we sening ba ance of payments rositton attributable, at Teast in part. co the - sing cos? of Imported fos?! fuels. anglophone Caribbean stares face a wc-sening u: aployment probiem. !n 1979, with Financial assistance fron he Unt tac States Agency for International Development (USAID), the Caribbean Development Bank (C08) responded to this situation by enbarking on 3 novel exverinent in development banking, In that year, C08 created a Techno'ogy Infornation Unit, within its Project Design and Analysis Division, for the purpose of promoting development, adaptation

and utilization of techniques which are well matched to the needs and

Circumstances of 15 Conromwea! th Caribbean menber countries. Within a year, with adel tional financial assistance fron USAID, the Unit was expanded Into 4 Technology and Energy Unit (TEU), more than doubled in size, and developed

42 special focus on renewable energy technology.

2. The Technology Development Programe (TOP) administered by TEU is an

Integral component of other, more traditional forms of development assistance provided by COB for generating employment and generating or conserving foreign exchange. TEU functlons, essentially, as @ project assistance unit and is

jst the Bank, the public sector and the private sector In COB

in project identification, project design and project implementation. All assistance under the TDP Is expected to support development priorities of the host country and, in addition, satisfy one or more of the

following eriter

1, Reduce the need for imported of} by pursuing opportuni ties for =

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im

(a) nore efficient use of ofl;

{b) fuel substitution by ?ocal energy sources
wherever the opportunity presents itself as

an attractive alternative: and

(c) a deliberate choice of a less energy-intensive
development path in those countries without
abundant comercial ly-exploitable energy

Reduce the recry!tment of new fossil fuel consumers Into

the commer

al energy sub-sector by using development of

alternative local energy sources to stimulate, facilitate

and promote rural development wherever possible.

Assist countries in addressing projected needs by generating

Firm data on the nature, volume and alternative uses of

Indigenous resources which will be needed to sustain and

Tnerease the Flow of comer:

Hy-ready

westment projects.

Support strategies and actions of COB menber countries for

Improving the quality of life of low-income groups.

Develop mechanisms to organize and mobilize the skilled

human resources of the Region to provide greater support for

the technological requirements of using alterna!

fe energy

sources and other techniques which are wel! matched to the

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circomsrar an. of (08 somber countries, so as to ensure

speeiy inclarensssion nd replication of commercial iy=

see appl co tions

3. The Bank's Ronauahle Ererg: °rograme fs an integral part of this

broader Technology Developne: rome TDP)

impossible to

disaggregate one From she ot

devause energy use Is an Important

consigeration i oracticatty at! ?2° orojects.

PRoGRAMKE 5

aducing the Need for ingorted i!

4. TDP projects concerned with reducing the nead Tor imported of! are

Vsted at Table 1; 50% of al! TEU projects and studies fall in this category. OF these projects and studies, approxinately 852 are related to fuel substitution with locally-availabl> energy sources (such as wind, radiation, biomass wastes and hydro-energy), 10% are concerned wi th more efficient use of ofl, and SE with reducing the energy-intensiveness of industry.

5. In the future, greater attention will be given to more efficient use of of, as opportunities for energy conservation are Identified through country eneray needs assessments being conducted by the Energy Unit of the Caribbean Conmuni ty Secretariat. These assessments are confirming that anglophone Caribbean countries are almost totally devendent on of! as the primary source of commercial energy and that dependence on fossil fuels is likely to continue wel! beyond the end of century. It Is hoped that

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fon the bas!s of averay ~o de sesess ante oad more detailed eneray audits

of the major eneray consurers. inv tment srogeumaes can be initiated in

each country to Increase ?he e/Fici-ncy of energy utilization. Additional

funds ore needee +3 Finance thie -vestnent programmes.

Reducing Recruf tment of Now Fossil Fuel Consuners/Rural Development

6, Rout 17% of TOP projects are directly concerned with using renewable

energy sources to support rural development or to reduce the demand for

fossil fuels or Fossil-fuel-derived energy by rural energy consumers.

These projects are listed at Table 2

Assistance to Countries in Addressing Projected Needs

7. AI! TOP projects may be regarded at fal

ng Into this category since

they seek either to promote new investments or to stimulate growth by

eliminating problens astociated with exts:

19 Investments, However, about

12% of these projects are primarily concerned with developing an information

base on aval lable resources which can be used for long-term as well 9s term energy planning, or generating Information on the limitations and

potentialities of applications of local resources which are not yet able to

produce a favourable ra

of return, but have @ good potential for eventual

commercial success. Table 3 lists five such projects.

Support Strategies and Actions for improving the Qual! ty of Life of

Low-tncone Groups

8. There are a nunb

Of ways in which activities under the TOP can

1 low-Incone groups. Two Important ways

---Page Break---

(2) Ieont!Fieation and dexore cration of enploynant opportunities

For unck! Me and seny-#s Ted workers: ang

(9) Identification and carons-ration of lowcost ways and means

of Inoroving or Increasing the services available to low-incone

groups (0.9. clectrification of rural areas, low-cost transportation systems, Improvenents in drinking water susplies, better ways

use available food materials to eliminate wastage, ete.)

9. About NOX of TOP projects are expected to benefit low-income groups

Elrectly, Tf they succeed In meeting project objectives,

Organtzing and Mobil tzing Skilled Hunan Resources of the Region

10, This aspect of the TOP is the most challenging and, potentlally, the

ost rewarding dimension of CO8's progranme. One of the principal mechanisms

used by TEU to organize and mobilize skilled human resources 1s networking.

?The main purpose of TEU's networking effort Is the estab!ishnent of mechanisms

for the sharing of Information, experiences and ski1!s anong groups of

Caritbean specialists a a means of promoting coordinated approaches to

problens and maximizing benefits to the Region from the scarce skilled

manpower and Financial resources. Networking efforts are matnly concentrated

fon the establishment of two permanent regional networks. These are:

CTCS Network - A Caribbean Technological Consul tancy Services

Network to serve as a means of providing

technical as:

tance to enterprises, govérnnents

and technica! institutions at affordable prices,

?and creating and ¢isseminating the skills and

---Page Break---

CTIS Network = A cariboean Technol

Remwork to s2rve as a means of creati

19 regular

information Flows between Conmonweal th Caribbean

countries ard institutions with regard to the

application of technology and energy to development

and, 2330, as a means of rapidly transferring

technology and energy Information needed in

particioating countries

11, There are cotential areas of overlap between the activities of the

two networks, and the hope is that they can eventually be Integrated. Both

networks were started, on a pilot basis, early in 1982. TEU serves as

coordinator for both networks and, in this role, operates as the referral

?stance from the

centre. It also provides Information and technical a

Bank's information and skills base as 2 network members

12, Apart From networking, TEU publishes a quarterly newsletter that seeks

to maintain an awareness of efforts being made to apply technology and
?renewable energy to Caribbean development prablens. The Bank fas also hosted,
OF cooperated with other organisations in hosting, workshops and sentnars
which can upgrade the skills and knowledge of key personnel In its Comorweal th

Caribbean member countries and address eri

eal problems In the development of

renewable energy resources of the Region.

13, Table 4 lists the major activities which have been completed, or are

in progress, under this category, There are plans to hold other workshops

?and conferences, publish special newsletters and bulletins on Important

developments, and publish select bib! iographies and information packages on

---Page Break---

important problem areas. ?0 cope w' the increasing complexity of TEU's

data base, it is being conouterized. The ISIS Information system developed

by UNESCC has been instal 8 or this purpose.

OVERVIEW OF PROGRESS, P208LENS AND PROSPECTS

1h, The ultimate goa! of C08"s TOP Is to develop capability in Comonweal th

Caribbean countries to identify, acquire and apply techniques which are well

snatched to thelr needs and circumstances, s as to reduce or eli

nate

persistent problens of high unenploynent, scarcity of foreign exchange, and

low living standards arong the majority of the population.

15, Individual TOP projects, per se, being very small-scale, can have

Jects, per se, being very

very little direct or immediate Impact on employment, foreign exchange

35 oF living standards. However, te and

they can be used to Init!

develop programes which can, over tine, transform productive sectors and

increase the utilization of local resources, both human and material. To achieve this, one must ensure that successful TOP projects lead to investment programmes which exploit the technology to the fullest possible extent, by

repeated replication wherever appropriate condi tions exist for doing so.

?Therefore, CD8's challenge is the creation of a system by which deliberate Progress can be made through the stage of technology development/adaptation

fon to successful widespread practical or comercial anp! ication.

16, CDB's role as a major source of investment capi

1 in the smaller
Commonwealth Caribbean countries places it in a unique position to create

and sustain such a system. A strong linkage between TOP and CO8!s lending

---Page Break---

progranme should go a tang way towards

ting this requirement, Three

baste questions could therefore be asked in evaluating the programme:

What progress her oeen made towards =

(QL taking indivieual projects to successful physical

completions

formulating investnent programmes and other linkages

with the Bank; and

GAN) developing tocal capabilities to apply renewable energy

(and other] technology?

sical Completion of Pro}

17, Today, @ little over two years after the first project was approved under the ToP 1/, the situation is as follows, Of a total of 3h projects

?and studies related to applications of technology, nine have been taken to

Physical completion, seven more are near to physical completion, elght are.

Progressing towards completion, and ten are starting.

18, It has been found that the programe, Involving as It does nunerous

small-scale projects and studies, entails disproportionately high operating

c08tS, presents serious supervision problens, and is prone to operational

Problems and Failures. TEU must act in concert with and through Institutions

in ?08 menber countries In implanenting TOP projects, and the capabittttes attitudes, absorptive capacity and learning rate of the institutions and

people Involved determine, to large extent, how quickly or how slowly

/ One project predated the TOP but has now been incorsorated into the

programe:

---Page Break---

projects can be implemen ce was hoped that complete project proposals

would have been suenitted co ?22 For financing uscer ts programme, Honever,

in general, TEY has to design arajecs end orepare project proposals for

£08 approval. It has proved gi ficu # to Keep projects on schedule, and the

smal! TEU technical staff of sever cust also spend 2 considerable amount of time assisting the majority of project executing agencies In dealing with

implementation problems. 1+ can be argued that these difficulties are tn

Inkaoes with C08 Lending Prograome

2. OF nine projects and stucies completed, six have been followed-up by

further activity such as replication, development of » commercial operation,

Implementation of recommendations, ete.

wo were only recently completed,

and one produced a negative result. However, despite sore apparent success,

effective linkages between the lending programme and TOP have not fully

developed. There are nagging problens associated w!th development of markets

which will hove to be solved In many cases before Investnent programmes can

be formulated. When a technology development project Is

9 to physical

completion, the chelienge to apply the technology Is only just beginning,

and developnent of tools, tactics and skills to dea! with this challenge ts

now 2 high priority for TEU.

Development of Loca! Capabilities

20, To the maximum extent possib?e, TOP projects ore implemented by ?oa?

Institutions and Individuals, and a significant process of sk!!! deve?ooment

has been created in several institutions within the Region as a result of

---Page Break---

- oe

the programe. However, a high staf? turnover and a tendency for the few

skIITed persons available to have too many responsibilities to permit them

© concentrate fully on any one aree. is working against countries deriving

?naximum benefits from project implementation, Overall, TOP prospects for making a significant impact on the Region are quite good, If the momentum developed so far is to be maintained or increased, a major Injection of additional Financing is needed. By the end

of 1982, a1! programe funds are likely to be fully committed.

---Page Break---

TALE 1: COMPLETED, ONGOING AND PLANNED PROJECTS CONCERNED MAINLY WITS REDUCING THE NEED FOR IMPORTED ONL cost T

(ussraoo) | vocation |__srarus

1 tneray Audits = Grenade [| cremate | ctor

| (0) Fuel substitution | i

i i i

| 3, tev possive solar suiteing i 50 | sarvados | conpteted

4. Enviromental Moni toring of TEU i

Passive Sotar Building 26 | Sartador | Starting

| 5. Wind Power Demonstration Prograrme i

pO ?antigne 270 | Antigua | Starting

| 6 vine turbine Project = Barbados | 70 | Barbados | Starting

7. Grid-Connected MinieMydro Demonstration j :

|S oomintes | 101 | Soninica | Starting

| |

| 8. Wind-Powered Chi?) Room 45 | St. Lucia] Starting

9. Field Testing of 200 m? Rod Mud Plastic | :

Digester bag | Starting

10. Testing of Solar Collectors | 16 | sartados jequin. instattes

11. Study of Non-Conventional Water Heating | |

in Tourism Sector 9 | Regional !Near Completion

Production Fron Sawaill ing Wastes 6 core | conten

13. Feasibility Study of the integrated |

nergy Pate Concept for state i

Rural Plantation 33. | Sewvincent} Conpteree

14, Solar Drying of Chilli Peppers 50 | Guyana [reer Completion

15. Recovery of Fuels and Feeds from | i

| 1%" Mrronrdoe processing Wastes 46 | st.vtocent|Near Conptetton

| 16. Rehabttieotton Progranse for Existing | |

Wigan ts 55. | Regional { In Preparation

| 17, Pllot Digester for Arromroot Processing | { !

Kastes ; Seven] In Preparation

---Page Break---

Table 1 (cont!

f Cost

[praise Sion | vocation | staue

---Page Break---

TABLE 2: ONGOING AND PLANNED ENFAGY PROJECTS CONCERNED MAINLY WITH

RURAL DEVELOFNENT AND RSOUCING RECRUITHENT OF NEW FOSSIL

FUEL CONSUMERS

[cost

I Provecr {wss-000) |_tocarion sraTus

Streangauging and Hyérotogica!

?Assessment = Doniniea 7 Dominica Starting

Improving Charcoo! Production and

Ueitizatton 20 rontserrat | Starting

Promotion of Simple Oanestic Solar

Food Dryers 10 tegtonat Near Completion

Stand-Alone Hini-Hydro 300 In Preparation

Sanana Transportation by Aerial

Cableway 170 | windward tstands] Melt Advanced

Feasibility Study: Production of Sale 1

?Sy Solar evaporation of See ¥ater 117 | Se, KTeesNevis | Completes

300 - Planned

---Page Break---

TABLE 3: COMPLETED, ONGOING AND PLANNED ENERGY PROJECTS CONCERNED

Wind and Solar Energy Resource |

Testing and Demonstration of |

|

---Page Break---

TABLE bs COMPLETED AO ?_NGOING

PROJECTS CONCERNED MAINLY

NG. ORG NIZING AND MOBILIZING SKILLED HUMAN

" sources

cost

{ PROJECT/ACTIVITY {_(uss*900) LOCATION status

1. TEU Newstecter 55 egionat longotng/Aetive

| 2. caribbean Aopropriate Technology i ij

[OSCR RSET Secs 9 | tostona

| 3. itor Project far Develoment of |

| > "hachaniees for fetect'se and Soote :

| Dissemination of Information 5 71 | Regionat loncoing/Active

4. caribbean Technological consultancy ? |

1» Geartes Netort Bilas projec? | ton Regionat longoing/Active

| 5. sotar crop orying woreshop (with |

|B Soimromen tts selence tounest} fF tate | caste

| 6. sintaysre Workshep | 17 | omintea | competes |

| 5, caribbean electric usitities conterence) ah | tarbacos | conpteted |

| % ust solar Engineering Seminar Ne | rintdat | copiers

| 9, Caribbean Appropriate Technology)

Centre Workshop } 1h | Barbados Completed

10, Regional Vorkshop to Disseminate } |

sporopriave Tecmotony } | se. wucta | cooptetee

11, UCR Seminar on Wind as an Enersy \

Aiterrative. (Poanee for Cot

participants) : roados | Completed

12, WWICA Seminar on Biomass Uti tzatton = | Puerto Rico} Competed

13. Seninar on Finance and Energy (with :

? OLADE and 198) | 5 | Barbados Completed

! i

---Page Break---

TROLE 5: compte?

AND ONGOING NON-ENERGY PROJECTS ADMINISTERED By TEU sh | freionvtesdes] ser eangtetin

isis je | acim oss

|

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UPADI 82

San Juan, Puerto Rico

?August 1-7, 1982

First Pan American Congress on Energy

NUCLEAR POWER IN LATIN AMERICA

By

Marcelo Alonso

Florida Institute of Technology

Florida - USA

San Juan, Puerto Rico

?Agosto 1982

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---Page Break---

NUCLEAR POWER TN LATIN AMERICA

Marcelo Alonso

Blorida Institute of Technology

?The assessment of nuclear power prospects in Latin Anerica requires the consideration of three key factors:

in Latin America and the structure of the national

electric grids .

2. the availability of primary energy resources to satisfy that

demand

3. @ satisfactory arrangenent for handling the complete nuclear

fuel cycle on a multinational basis

Energy consumption in Latin America is on the average of the order of 1ki/cap,

which although 2a

sr than in che rest of the Third World, is smaller chan the world

average of about 2kW/cap. and auch saaller than in the industrialized countri which {9 between 5 and 10 ku/eap. This situation {s compounded by the tremendous

tnequalities in energy consuaption anong the different

sctors of the population;

the contrast is particularly marked between urban (4 to 6 ki/cap) and rural (les

?than 0.1 kWcap) populations. In fact about SOX of the population in Latin Anerica

?has no ace

to electricity and sost of it in rural areas. This s{tuation, combined
with a continous increase in population (330 millions in 1975, 790 aflltons
expected in 2030), an unchecked trend tovard urbanization, expected to increase froa
the present value of about 4OE to the order of 70% in 2030, and increased industrial-
zation, create an ?aportant pressure to increase the production of electric pover.

ra batin Armariien

In fact the total deaand for primary envrsyKis expected to quadruple in the next

psnving trom 10Q/y to about 40 Q/y, and possibly teaching $0 Q/y Sy 2030.

20 yearaA Ta the case of electric pover generation, it is increasing at a rae

larger than 10% tn most countries and for the whole region it

expected to increase

from about 96000 MY in 1980 to about 170,000 Mi in 1990.

?Paper presented at the UPADI~82 Conference, San Juan, P.R., August 1-7, 1982.

---Page Break---

The big question then {s how to aeet that demand for electric power. Until

now oi has constituted the most iaportant primary energy source in Latin snerica,

about 66%, compared with 44% in North America ant 46% wo

wide. For of

producing countries this might be an accentable alternacive, but for ofl importing

countries (the great majority) other options must be exercised. Coal is not expected to replace oil to generate electricity in an apprectable ssount in Latin dmerica except in four or five countries, particularly Colombia, Presently, {¢ accounts only for ST of the prinary energy vhile in North America {t is about 172.

The hydrovenergy potential of Lattin Aneriea {e vast and nore or lese vel. ddatrtbuted anong all the countries, but still aostly undeveloped (less than 20% of the total potential has been utilized and in some countries only 3% to St has deen developed). liydro-energy accounts only for 112 of the total primary energy in

Latin America comparable with 7% for North America and world wide, but is already

of the order of 50% of the total electric production. Obviously hydro-energy {= Sound to play an important role in the expansion of energy production in Latin Averica, This is vhy aost Latin American countries give top priority to hydro~ energy in thetr electric power expansion plans, both in terms of large and snall units. However, hydro-energy 1s not alvays located close to the consumer centers ?and therefore in many instances its large acale developaent may require the construet~ son and/or upgrading of transaisston Lines. ven so it (s expected that hydro electric pover generation capacity in Latin Anerica vill increase from about 30,000 sii 42 1980 to about 100,000 MW in 1990, representing 60% of the total electric generating capacity.

The above considerations point out that in the next decade nuclear eneray

?ight play an apprectabie role in electric power generation in sone Latin

?American countries, although sti21 smaller than of! and hyéro-energy. The

avatlability of urantun (and thoriun) ts not expected to be a critical factor since

both elenente ore relatively abundant in Latin America. In fact ££ energy could

flow freely tn Latin Anertca, without georo

teal considerations, the region would

---Page Break---

sufffeient for quite a lox tire (Table 1). Thus the main limiting

be energy sei

factor for the use of nuclear energy 18 cing co be the size of the electric grids

fof the countries, vhich with che exceptions of etght cou tes, all are present?y

ese that 1000 Mi. This makes Le difficult for those councries to consider nuclear

plants of the order of 600 Mi, which rouzhly is the size of auclear power plants

commercially available. Tt is possible shat nuclear power plants in the range

of 300 M8 to 400 MW may become comerct:

'y available in the ?mmediate future,

(fable 2) but even so, those plants are too big for @ good many Latin American

countr?s

Of the eight countries with grids Larger than 1000 Mi, only three countries (argentina, Brasil and Mexico) have grids sufficiently large as to justify a

comprehensive nuclear program, which includes the construction of several auclear power plants in the next fev years, as vel as all the facilities related

to the complete nuclear fuel cycle such as uranium aining, uranium enrichment,

fuel production, fuel reprocessing an heavy vater production. In fact those three countries have adopted quite serious miclear programs, which are in different stages ?of development, By 1990 the respective nuclear pover capacities are expected

to be: Argentina 1600 MY, Brasil 1200 My, Mexico 2600 Mi. That 1s a total of

5400 M6i or 32 of the total generating capacity for.the whole of Latin America. The

Argentine progras 1e based on HR and the Br

Alien on LiR, The Mexican program is

not yet fully determined. These three programs are described in Appendices

1, 1, and rrr,

For the other five countries, (Chile,

Colombia, Zeuador, Peru, Venezuela) with

grids larger than 1000 Mi the

at that can be expected tn che next decade or so

ight be the construction of one ouclear plant each,vaich does not justify consider-

ing the other aspects of the nuclear fuel cycle. Thus for those countries the

assurance of fuel supply and other suclear services is most ?aportant. Presently of those countries have under consideration the construction of nuclear. power

---Page Break---

Plancs, but ail of thes have reeares rea tors ia operation or under constzu:

However, it is relevant to consider what ind of Interaner ?can cooperation aight be

desirable should those countries decide ¢. go nuclear.

Im the first place the three Latin Anerican muclear coun?

fee my be prepared

to provide assistance and services to the other countries, ts fact Argentina and

Brasil have already helped sose countries for establishing suclear research facilities.

In the second place the United States nay reconsider its uclear policy, as stated (NPA)

im the Nuclear Non-proliferation Act of 1978, and be gore flexible in terms of

Providing miclear services to other countries; Reagan's adainistration has ade sone

moves in that direction (Appendix IV), but the fact 4s that untt! now the United

States has played a very sarginal role in quclear power developments in Latin

america, (while Germany has been very aggressive). In the third place the aull

national instruments have to be reinforced to assure that nuclear weapons are not produced or introduced in Latin Anerica using muclearfue! cycle factlitées in the region. The regional organizations that aight play a role ia thts respect are OPANAL, charged with the application of the Tlatelolco Treatyvand the IANEC, wtehta the OAS. To these t¥0 we must adé the IAEA (and ts international non-proliferation Anstrument, the NPT). But there are ti11 some concerns about the effectiveness of such sechanisne, Of course in Latin Anerica ve have another organtzatton, OLADE,

that deals with energy in general and which aight be involved in the development

of mclear pover without proliferation risks.

Perhaps it might be sore desirable to organize in Latin Anerica an organization

specifically concerned vith nuclear pover and the nuclear fuel cycle, similar to

EURATON in Europe, and that could be designated LATINATOM, under vhose control

dea has already

alt nuclear facilities in the region vould be placed. Thi

deen advanced in some Latin Anetican fora but it has not yet been formatly explored

F Fresently there are 13 nuclear research reactors in tatin Anerica located in Brasi!

(4), Argentina (3), Chile (2), Mexico, Colombia, Venezuela, Peru and Uruguay,

plus those in Cub

---Page Break---

appendix I, Nuclear Power Program of argentina

SAGES AEST ine

Argentina has the oldest, tos: cororehensive}and/aore advanced state of

implenentation. the progran began abo

25 years ago with the construction

of a sali Agonaut reactor and since then ir has progressed steadily as it can be

appreciated in Figures 1 and 2. the bo¢y charged with nuclear matters in Argentina

4s the Nattonal Commission for Atomic 2nergy (CNEA), which depends directly from

the president of the country. The CNEA has six major R & D programs, a6

tndicated in Table 3. but for the specific purpose of the construction of suclear

power plants a conpany, EXACE, has been established vith CNEA holding 75% of the

shares and the German consortiun Kil/Sienens the renaining 252 (Table 4)

Argentina nuclear pover program is based on the concept

¢ natural urantun/heavy

water reactors. Argentina has developed a total capability for the nuclear fuel

cycle for such types of reactors; the details are given in Table 5, The flow

aa

faa of the CNEA progran is shown in Figure 3. In particular the production of

uranium concentrates has

creased appreciable, a8 shown in Figure 4, The first

ructear pover plant of ArgSHEEanpAtucha Ty a the Froviace of Suenos Aires,

?entered {nto operation in 1974 with a pover of 340 Mi, and tn 1977 4e was uperaded

fo 368 mi. It has proved fo be a very reliable untt. the second unit, in Eabalse,

Province of Cordoba, ts ready to enter into operation, The nuclear pover progras

of CNEA appears in Table 6 and Figure 5, The program is being carried out mostly

with collaboration of Geraany, with a substantial Lnvolvenent of Argentina engineer

?ng, construction and sanufaccuring f{fee, tn fact the program Nas had a very salucory iapact on Argentina industry and in the development of sitIled sanpover.

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Appendix IE Nuclear Power

?the nuclear energy program Yepas: fa ths Late 53's with tne

construction of a research re:

or 2s San

ule. A nuclear power program wae wot

initiated until more than a decade _cter. nen after signing tn 1972 ar agreeseat,

of cooperation with the United Stater, a uontract was entoved with Westinghouse

for the construction of a PKR auclear plant of about 600 Mf, at Angra dos ets

«

xy of the Kings), a most scente place sovth of Rlo de Joneizo, The reactor

hhas been finally completed In 1982 buc {s operacing only ac St of its rated

over until there {8 complete assurence shat the heat exchange systen does not

hhave the sane problems found in other sinilar Westinghouse reactors buflt in Sweden fan? Seatn. Ste

Wy after,Brazi? decided zo develop a rather comprehensive ard

anbitious nuclear pover program bases on the PUR concept, and couprising a1! aspects

fof the nuclear fuel cycle. For thts rurpore it entered into a broad and ecospassing

agreenent with Germany, that vould provide equipment, nowNoy and training.

Within this agreement a second quclear power plant ie already under construction

?at Angra, However, the nuclear power progran has been sloved down a bit because

?the parallel development of hyéroenergy and nore efffctent transnission systens

land the reduction ia the Increase of the denand for electric pover.

?To carry out {es nuclear pover program, Brazil has established the

institutional arrangesent shown in Chart I and in Table 7 where the functions of each

Institution are indcated. The progran depends directly from the Minister of

Mines and Energy. Yor dealing with the nuclear fuel cycle as well ae the construct

ion of mclear plants NUCLEBRAS has established seven aubsidtary companies as

?shown in Chart 2, In five of then the capital is mixed, vith participation of

Gersan companies in the proportions indicated, One of thes (SISTEP) actually

operates in the FRG. Table § gives the details of the prograns carried out by

NUCLEBRAS. Reprocessing (an aspect that has vorried very such past U.S.

adaintstrations) is probably going to be postponed because the reduction in the rate

---Page Break---

of developaent of the progrux. Table) gives the scheiule of construction of miclear power plants in Brasil, and ?> Figure 6 the flow dtagran of the fuel eyele fs shown, Brazil ts particularly rich in U and Th Figure 7 shows the sata Aeposies of U. The one most actively erslotted ts Pogos 4e Caldas, Like in the

case of Argentina, an objective of Brazil is to seek 2 subs

antial involvement of

Brazilian industry in the nuclear prograa.

Appendix 3 Nuclear Pover Program of Mexico

Although Mexico has excellent research facilities, {t has moved into nuclear

power at a such slover pace than Argentina and Brazil. At first sight, in view of

eh

vast petroleus reserves of Mexico, that sakes it 4 ai

energy exporter, one

could think that Mexico does not need to consider suc)

sar power ae an energy

alternative. However, the consideration of the nead to manage wisely the oil

resources stretching their life,

ell as other considerations of economic and

political nature, particularly a considerable increase in the denand of electric

power, expected to tacrease from 15,000 Mii in 1960 to about 80,000 Mi <n 2000,

able 109 have convinced Mexican authorities that Mexico should initiate a sound nuclear progran, Sased on those facts Mexico released in Novenber 1980 an Energy Plan that calle for a muclear generation by 2000 of the order of 20,000 Mi oF

23% of the total electric generating capacity, Previous to this plan the Federal Comission of Electricity (CFE) carried out a study in 1967 to appraise the possibilities of nuclear pover in Mexico. As a result Yexico contracted with General Electric in 1972 the construction of tvo BHR, of $50 sti each, in Laguna Verde, Veracruz. Although, the project has suffered several setbacks and delays, {¢ has provided a tremendous experience for Mexican engineers and setentists for the new nuclear program. The first untt of Laguna Verde vill enter {nto operation

4m 1984 and the second in 1985.

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?The institutional str

sre to cer?y cut the Mexican wuclear progras ts shown

im Chart 3 and the funeztons of each {riety rable 2. ie

authorization to go shead with che cuclvar program vas given Sy the Pres:

4m Septeaber 1981, end seven nuclear surplfers from Sour ccuntrtes vere invited to

bid for the frat phase corresponding t» about 1300 Mi a cne or tuo unite. the

Program contemplates not only the cone:ruction of the miclear power units tut also

an effective transfer of technology, a s:adual involvement of Mexican industry

and the eventual developsent of a complete capabiltey in the auclear fuel cycle, Unexpectedly, im May 1982 the new Finance Minister, Mr. J. Silva Herzog,

nounced that in view of the econeafe situation of Mexico and the prospect of zero economic growth in the next 12 nonths the nuclear progran witl probably be post= oned untit the next government, that will be installed tn Decenber 1982, has the opportunity to review the program, cogecher with other investuent prograns. However, {8 seens reasonable to expect that the program will not be cancelled

but considerably reduced in sco}

Appendix 4 U.S. Policies related to Nuc!

?The consideration of nuclear pover in Latin America would be incomplete

Power

without examining the mclear pover policies of the United States, vho is the largest user of nuclear pover and one of the most inportant supplier of nuclear

services, materials and technology. Currently, the U.S. hae 77 auclear power

?or planned

plants to operation and 67 under construction, vith a total pover of 147, 751

MM. Unfortunately, during recent years the U.S. nuclear power policies, both

domestic and international, have not be

stable, and to a great extent doninated

by one major concern: reduction of the risk of proliferation of nuclear veapone.

Tais 18 a very reasonable and sound objective, but the vay it has Seen pushed by

the U.S., especially during Carter's adaintstration, has backfired on American nuclear industry, to the extent that presently the U.S. industry s in a critical

situation with no nev orders for miclesr pover plants placed ta the last

---Page Break---

two years, and even a few cane ations or indefinise do!

(che oscineted

number is 19). This has been iggravate? by the fact that the trend in the growth

of demand of electricity in U.S. is suc: smtller that vine was foracasted five

oF six years ago, resulting nost probab:v from conservation efforts, and byescalacing construction costs as well ae interest cates that have increased considerab:

Reagan's Adninistration has expresved its firm comn?taent to domestic ?energy independence, for which tt 1s considered essential the Long term expansion of nuclear pover and encouraging the health of the U.S. nuclear reactor tedustry. In @ domestic policy statenent in October 3, 1981, the folloving steps taken by the Adaintstration were stated:

1, Inprovenent of the mclear regulatory and Leensing process reducing it feos

the present 10 to 14 years to about 6 to 8 year

Proceed with the development of nuclear breeder reactor technology. A first step 1s to complete the CRBR. Congress has approved the additional funds required for this project.

3. Lifeing the ban on comercial reprocessing and production of Pu (which had

deen established during Carter's adainistration)

One component of this

Program vould be the activation of the Barnwell reprocessing plant. However,

?Ro company has yet expressed interest in taking over Barnwell.

4, Analysis of the obstacles vhich stand in the way of an expanded use of nuclear

power. The report 1s due before September 30, 1982.

Obviously a reverse, in the positive direction, of the domestic nuclear poltey

of the U.S. cannot produce imediate results, and vill sti! be sometine before

ite effects are detectabl

The international nuclear power policy of the U.S. has also suffered several

changes in recent years. The frame of reference for U.S. international cooperation

on muclear aatters ts the Nuclear Non-Proliferation Act (NYPT) adopted by the U.S.

Congress in 1978. This lav was passed ?na bit of a haste ond many of its original

supporters believe it should be revised, Sut no aotion Vas Seen nade yet

---Page Break---

im chat direction, Also the YNPT has been used to put some pressure on other

reduce

countries to place their nuclear facili.ies under strict safeguards or +:

the scope of their mclear prograns,as ?t vas the case of che Carter Administration

with Brazil with no positive results as was to be expected. However, on Jul

16, 1982, President Reagan nade a policy statement for internattonal cooperation in muclear energy, within the NNPT frane,which 1s @ positive step forvard. Its basic elements are the folloving:

Re-establish the U.S. asa reliable partner for the peaceful use of

nuclear energy

No relaxation in the concern about the need to avert suclear proliferation

and reduction of proliferation risks.

3, Isprove international U.S. cooperation in nuclear power withtn SPT/TAEA framework of safeguards.

4, Ditferentiated treatnent of the countries in accordance vith their proliferation risk, expediting action on export requests vhen statutory

requirenents are

5. Enhance international competitiveness of U.S. nuclk

F exports.

The effectiventss of thts policy will depend on the extent to vnich te will become eatable and well supported. We shall review next the status of the co-operation between the U.S. and the three Latin Averican countries vith nuclear Prograns.

In the case of Argentina the cooperation 1s practically inexistent, but in addition there 19 no najor interest on the Argentina side since they have been able to develop their nuclear progran in cooperation with other countries.

Tn the case of Brazil a bilateral agreement for peaceful cooperation in suclear energy was signed in 1972. Right after, Brazil contracted with Westinghouse

for the construction ofthe first muclear pover station, Angra I, which has just

---Page Break---

been completed. Also en agrecsent vas -.gned ?or the U.S. supply of enrichsent services for Angra T, vhich include? av naley Af Brazil decided to obtain che

welesr fuel elsewhere, In 1979 Brazil applied for an wxport License for the first

refuel lead. However, due

adffeultos with NWPA requirements, particularly

TASA safeguarcs, forced the Carter Admiu?seratton to de127 anv action, ta spite

of Brazil's protest and insistence chat Lt ¥.S./Brazit cooperation had to abide

strictly by che terms of the 1972 agreenoat. To resolve, ac ?east cenporariiy,

this delfcate steuation the presest ade?atetration conveyed +9 Brazil the

dectaion that the U.S. would accept the: Brazil obtains

Ne nuclear fue! elsewhere

without any penaity. I think the case of Brazil hows how the U.S. has assed an

opportunity for an effective nuclear cooperation.

tn the case of Mexico, thet o

recently

11) announced an anbit?ous

suclear program, the U.S. has been more active, under Reecan Adnintstrat?on poliete

fo secure a productive cooperation. igh level discuss?ons wi:

Mexican authorities

have been held, to assure that the U.S. is prepared to wwe = couprehenstve come

ent to oupport nuclear exports infttatives related to the requirenents of the

Mexican nuclear program. Also technical exchanges and joint research are contenplated.

?The final decision will depend on the fate of the Mexican progran.

We may conclude this brief review of U.S, policies by saying that the U.S. must

Adopt a sore stable and flexible poltcy in suclear cooperation, and offer stronger

support to the U.S. nuclear industry 1

the U.S. 48 to play an inportant meaningful

international role in the development of nuclear pover.

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TABLE 1

ESTIMATE OF ENERGY RESOURCES

Noreh Centra? ane Wescern

America South America Hemisphere

coal /oii/tar

Sands/Shale .

(Quads)* 30,000, 30,090 60,000

Nuclear (Quads)

?Without Breeder >1,000 2 >1,000

?With Breeder >100,000 t >100;000

Solar (Quads per year)

?Insolation x IZ 450 = 830 = 1,300

?Developable by 2000 8 =5 16

Cnetuding Wind)

Water Power (Qu

per year) 8 =ru2 = 15-20

Biowass (Quads p>

ar)

?Developable by 2000

225 240

Geothermal (Quads

per year)

?Developable by 2000 et 3

1 Quad is the equivalent of: 500,000 barrels of oil per day for one year

10" soute

40 million cont of coal

1 trillion cubic feet of natural gas

293 billion kim of electricity

3

---Page Break---

TABLE 2

Prospects for Smal? Nuclear Reactor:

1. ASEA-Atom (Sweden) aut

2. Rrafewerk-Uaton (Germany) SiR (natural circulation)

3. Alathou-Atlaneique (Prance) PAR (cA?)

Britain) PAR

5. Oldbury (Great Britain) GcNU/aagnox

TABLE 3

Programa of CXEA

1. Nuclear Pover

2, Fuel cycie

3. Radioisotopes and Radiations

4, Radiological protection and safety

5. Research and Developsent

6. Training

TABLE 4

Construction of Nuclear Pover P1

nea (752)

NACE

KRWU/Stemmens (25)

supervision of construction, industrial architecture,

Preparation of specs for tenders, quality control.

---Page Break---

3

5.

rate 5

Fuel cycle Facil! tes of CEA

Uranium exploration

30,000 tons of U0 (aseured)

23

Uranium mining

Five areas presently under exploitation (Cordoba, Mendoza,

Neuquen, Chubut, Salta)

Uranium concentration (yellow cake)

Production of U dioxide (Yuclear quality)

4, Palot plant: 3 ton/yr (Argentine technology)

44, Cordoba (150 ton/yr) (under construction, Geraan technology)

(expandable to 700ten/yr in 1989)

44d. Second commercial plant (900 ton/yr, 1996)

Fabrication of fuel elenents

4, PAlot plane (Argentine technology, S0z of needs)

44, seize plant (for GUA and NE

441. Special alloys plant (zizcalloy tubes)

tv. Ze sponge (Bariloche) (500 kg/yr)

of 100 ton/yr.

second phase will be plane

¥. Testing of fuel elesents (high pressure)

vi, Testing and Assay of spent fuel elenents.

Reprocessing

Experimental plant (1982)

Production of Heavy Water

4. Ptloe Plane (3 ton/yr) (under construction)

44, Planned two gore plants, one of 80 ton/yr. and another of

250 ton/yr (Neuquen, vith Svise Sngineering (Sulzer).

---Page Break---

TABLE 6

Nuclear Pover Program of Argentina

Plane Location Dace of Operation Capacity sie)

2. Atucha T Prov. 8.4. 1974 340

: 1977 368

2. Babalee cordoba 1982 600

Atucha IT Prov. BuAL 1987 692

4. cuye 1 Mendoza i991

5. Noa Noroeste 1994

6. BAS Prov. B.A./S 1997

Total Nuclear Pover Capacity Planned for Year 1990

1650 Mie) 7.8%

---Page Break---

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Ia ccnacion Figure 3

---Page Break---

ARGENTINA

EVOLUCION ve LA PRODUCTION DE DE URANIO

(EXPRESAOO EN'1vydy CONTEMDO £105 CONEEN a Be a0)

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owe

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Jy ona) stusture for Nuclear

Powe: in Srasth

PRESIDENT

Defines wuclear Energy

Povey

Mixistry of Mines

?and fherey

? >

1

National = Brasilien Brasilian

nuclear Energy | Sietear"Encerprises) electric Power .

Coamisston i (oecceas) company ;

cen | (etirommsy |

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cancer for | [paettiay] | comracion

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TANE 7

INSTITUTIONAL FUNCTIONS YR NUCLEAR ENERGY IN BRASIL

Ministry of Mines and Ener sy

4, Planning, Execution and Control of national nuclear energy policy.

2. Natdonal Nuclear Energy Commission. (CNEX)

1, Sets standards and authorizes Licensing of miclear installations.

4£. Sets standards and noras for safeguards and protection for the construction

and operation of nuclear facilities as well as the use of nuclear materials.

Ait, Supervises and inspects all auclear facilities in Brasil.

iv. Carries nuclear research

v. Provides training in nuclear science and engineering.

3. Bragilian Wuclear Enterprises (SUCLEBRAS)

1, Prospection, ataing and processing of uraniun sineral:

At] Construction and operation of ail facilities related to the nuclear

fuel cycle (enrichment, fuel fabrication, reprocessing).

At, controls the trade of suclear materials.

tv. Construction of nuclear power reactors (engineering, design, construction,

financing, as vell as promotion of local manufacture of components.)

¥. operation? of the Center for Developsent of Nuclear Technology (CDTN).

vi. Managenent of subsidiary companies related to the Suclear Progran

(RUCLENON, NUCON, NUCLEN, NUCLEP, NUCLAM, NUCLEI, NUSTEP)

4, Brazilian Electric Power Company (ELECTROSRAS)

4, Planning, siting and construction of nuclear power plants.

44. Operation of nuclear pover plants through local subsidiaries.

---Page Break---

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(Jd 3SAN | ?TON WYTONN: dd TON NITONN NOONN [Nowertoniy

---Page Break---

table 8

Muclear Pover Prograns in Brazi?

Uranium prospecting and exploration

Reserve of 236,000 tons of sO, (1980)

Mining and Refintag

Pogos de Caldas Industrial Complex (CIPC)

1. Mining: 2500 tons of ore/éay

2, Refining: yellow cake, 550 tons U;09/yr

Conversion into Uranius Hexafluoride

Conversion Plant (1984;

500 tons/yr UF,

)

Enrichaent (nozzle proce

Demonstration plant (1984): 24 stage cascade

Expansion to 200,000 SWU/ yr

Buel Element Fabrication

Mamufacturing of U0, pellets and assembly in fuel eleneats (1982)

Reprocessing

Pilot plant (Dortmund, FRG)

Training at German Reprocessing Plant, WAC, Karlsruhe

---Page Break---

Tabie 9

Muclear Power ?alts (Sr:

ALL are °4R, 600 mile)

A, Angra I, Angra dos Nets, coapieced 1982

2. Angra II, same site, begun 1980

3. Angra ITZ, Ponta Grande, A.d.

+ site approved 1980

+. Muclear Unit 4, Sours Sao Pauto, site selected 1980

5. Nuclear Unte 5, sane

Two nore units considered to the general plan. Locations not yet decided.

?Total Nuclear Power Capacity Planned for Year 1990

1200 mie) 22

---Page Break---

---Page Break---

wErosns:

TPLANALTODEPOGOSDE

CALDAS / MG 26,800

2 FIGUERATPA 000

?3, QUADANATERO -

FERAIFERO/ MG 15.000

4 AMORINOPOLIS GO 5.000

'5. CAMPOS BELOS.

Filo PRETO / GO 1.000

GWATAW/CE «122.000

T LAGOA REN 14 ~ 8.000

8. ESPINIIARAS / PB 10,000

?ToraL=SSSSSSSCSC*C« 00

Figure 7

---Page Break---

CHART 3 INSTITUTIONAL STRUCTURE FoR WUCLEAR POWER

Iw Mext00

---Page Break---

Thermal

ost

coal

geoth

Hydro

Nuclear

?Total

TABLE 10

STRUCTURE OF FLECYaxe

ENERGY PRODUCTION

TN MEXICO

(oxpressed in Me)

1980

1990

2000

T emw wm | ccm asl

8000 Me (532) |

1000 me (7)

6000 sw (40x)

15,000 69

20,000 88 (son)

4,000 s8¢ cao8)

2000 88 (2)

12000 (308)

3,000 (82)

40,000 »2

5 46,000 (3139 |

6,000 (72)

3,000 42) |

33,000 ast}

| 20,000 ¢232))

87,000»

---Page Break---

sBLE 1

TONS FC NUCLEAR POWER IN MEXICO

Secretary of Patrinony and Industrial Promotion (SEPAFIM) i, Definition and Coordination of tue National Energy Plan, through the

Director General of Energy.
Coordination of decentralized government institutions dealing with nuclear
encrgy (NIN, URAWX, CMRSN) as sell as the CFE in what refers to polictes and
Amplenontation of the Suclear Progran.

2. Federal Comission of Flectricity (CFE)

1, Public company for production and distribution of electricity.

44, Design and specifications of nuclear power plants, through the Director General
of Miclear Engineering, with the advise of INTN.

Aik. The institute for Electric Research advises in satters related to eneray in
general but ie not directly related to the Nuclear Progran.

The Programming, Planning and Management Comittee participates in the
yas about ?the Nuclear Progran.

we

7 Institute for Nuclear Research (INDY)

3. Nationa:

R&D related to the Nuclear Prograa.

9 CFE in design and engineering as vell as in the trating of

hhuan resources.

4. Urantun of Mexico (URAMEX)

Public Company with the monopoly for exploration, mining and proct

uranium sinerals,

AL, Advises SEPAFIN and CFE in the use of national uranium resourc

5. Nuclear Regulatory and Safeguards Commissions (CNRS%)

4, Im charge of nuclear regulatory and safeguards satters,

Ai, Advises users of nuclear naterials and systens about regulations, standards and safeguard:

---Page Break---

UPADI 82

San Juan, Puerto Rico

August 1-7, 1982

Second National Conference on Renewable Energy Technologies

THE RATIONAL USE OF ENERGY AND RENEWABLE ENERGIES

FOR THE DEVELOPMENT OF CARIBBEAN COUNTRIES

By

Y. Chevalier

French Agency for the Management of Energy

France

San Juan, Puerto Rico

August 1982

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= yetaopceroN

Ss ephasized 4t tho last (uited Vaticns Conferenes on new and renewable

vources of energy Sel? in NAIROBI, duvcloping countries are to solve a

?fold exergy problem in cl foreh-vveing sears ing dependancs

or Gndustey, ceansport

cary ¢0 develop their

Hy Heading

comencia! energy in the teaditionnal sector

aodest sgricvitural productivity and reral

Such » sitvae

in could br greatly endanced through a core rational use she oviseing snergies cnd che developscat of the Large potential chat

erivable enarg-es veprnsent.

Novertheless, it has co energy (whazever solar of classical)

ts sane in ies int achieve & sectoral develop

= Teed 5 ?ordance with the real needs of

foe those reasons, we consider that, for any country of the world the

£0 towing mettodology has tn be followed in order t0 inplenent a coherent

siiey ae the field:

= present nce assessment including aon comercial ensrgies

That Classical ones) in terms o: supply and demand.

dy be cone for ost oF the Latin-azerican countrie:

Such a work has

by OLADE.

tuation of the realistic potential of

?energy emana reduction

2) anergy supply Sy neans of renevable energies technology in terms of

realistic teckn'cat, industrial and financial environeent.

For such an approach, al} the concerned actors, from the Ministries of

wine end Suergy to che ead users (eechnical Ministries such as Inéustcy,

Agriculture, Building, Health, industries, consumers) should be assoc.

fed.

= in function of the priories

defined previously, development projects on

sete prolecton,

can be drafted and inplesenced. Such projects should

From the Beginning the Zegree of possisle appropriation

OF the concerned technology. By appropriate technology, I do not sean a

Stansferable technology, T'rean, first of all, a techaoiozy that will eet

---Page Break---

to its best the actual venand, a technology that vill not need gonthty foreign experts visits ro vork in a satisfactory manner, ?Yard? depen dency (0il for example) should not be replaced by a "soit" dependency (foreign know-how). To meet these goals, formation of scientists and technicians who will adapt, install and saintain these technologies is crucial.

To conclude this introduction, I woul? Like to emphasize the fact that developing new energy technolsgles will not lead by itself to a better development, but such prograss should be part of well defined sectoriat development projects

POTENTIAL OF A BETTER MANAGED (GY_IN THE CARTBSEAN REGION

?The study of the published Caribbean energy balances and statististies Leads to t¥o sain constatations

= Caribbean councries are heavily dependant on oil (up to 91 % of the energy needs of Jamaica in 1980) which is totally imported except for

Trinidad and Tobago.

~ The electrical energy efficiency, i.e., the electricity production/GxP ratio as shown in table | varies froz 0.18 in Martinique to 1.18 in Bananas. Alchough this ratio should only be considered as an indicator ~ it docs hot take into account neither the total energy consusption nor the structure of the desand = it is significance of Large differences in the region. Such a situation leads me to briefly develop, although it is not the these of this conference, che problen of the rational use of energy (RUE).

1 ~ gattonal use of energy

?As said previously and shown in table 1, at comparable GNP/capita (tartinique and Puerto Rico), the electrical energy efficiency can be 6 tines higher in similar clinate conditions, Does it wean chat people in Puerto-Rico have living standards 6 tines higher chan in, Martinique 7'As a aatter of fact, the era of cheap energy from oll is gone, and therefore seasures to ensure that energy is used judi-ciously?and efficiently should be adopted.

Energy denand management is equally important as energy rerource development and eanagenent of the supply.

Activicd

= Phased reduction in the utilization of petroleum products

to manage energy deaund should focus on +

~ Energy auditing and retrofitting for the purposes of identifying

?energy wastes and increasing energy efficiency in the public and

private sectors

= Fiscal measures vith the objectives of +

+ rationalizing the pricing and marketing of petroleum products to

?encourage conservation

+ encouraging investment in energy efficient equipment

---Page Break---

?TABLE |

ELECTRICITY CONSUMPTION PER GNP

epee)

sland oF country 5 cnPrc

(GNPPC) (US8/perton) (evh 088)

anrtcua 950 0.75

AIUMAS 2,620 has

BARBADOS. 1,940 0.6

cuss 810 0.96

(CURACAO-ARUBA

oMENECA 440 0.47

?GRENADA 530

wart, 260

smutea 1,150

MaRTINTQUE 2,900

MOnsERRAT 920

?PUERTO RICO 3,172

DOMENTCAN REPUBLIC 910

St. KITTs-EviS| 660

St. wocra 630

st. vicewt 380

?TRINIDAD & TOBAGO 2,910

Reference i The energy alternatives for the Caribbean - Dr Juan A. Bonnet =

Deceaber 7, 1981.

(1) Energy Production Per Capita,

---Page Break---

= Public education, designed to

educate and ingore the public on energy issues celevant to

government plans and projects

- potivate greater energy s2vings consciousness.

Finally, Lt should se pointed out that euch aeasures mainly concern the "aodern sector? inclucins rhe heavy consuaing induscey (cenent= plants, ogro-industry, etc...) transports and energy losses for the production transpoccation and distribution of slactricity.

According to a recent study ssonsored by the French Ministry of Research and Technology, table 2 shows what could ye the impact of conservation seasures for the world comercia! energy consumpt ion in developing countries.

TABLE 2 = Developing countries : possibi

comercial energy conservation in 1990%

(CmTEP/year)

SAVINGS

[estimated

Taxes [Subst icution)

price | T8G* | technica Se>stit Total

poticy| regu- | up-grading| scale | savings

lation econeay

Electricity | 323,7] 5,0 | (9 24,9 5,0 49

Agriculture mrt or fo 5,0 o 5,0

Residential 293,8] 14,9 | 5,0 5,9 19,9 46

Transportation] 373,5] 5,0 | 5,0 29,9 10,0 49,8

Industry 433,31 10,0 | 10,0 54,8 149 89,6

Others 29 | 5.0 | oO o

20,0 | 19,6 49,8 | 2264

4 utilisation rationnelle de "énergie

ARES, CTRED, SEMA ENERGIE, TRANSENERC,

* From "Energies renouvelab!

dans les pays en développenent

june 82.

(a) Production, transportation and distribution losse

---Page Break---

Ae appears that che gost oroaising benefits of a strong conservation policy could be obtaines from the industry and residential sectors,

Last but not least, RUE should also concern the teaditionnal rural sector which largely depends on renevable energies, In HAITI, firewood, charcoal and bagasseprovide an estimated 80 percent of all pri supplies, and they gee scarce as population grows, leading to a situation where they could not be "renewable" any gore, I conder whether deveio-ping countries should not consider '?:t RUE is not only a developes countries prodlen ! Saving energy is the problem of users and conse quently of all of us.

~ Renewable energies

?Renewable energies" are already widely used in gone Caribbean countries as seen previously in the case of HAITI, Thearieal potential is

considerable : solar energy is - sonetines too much = present everyshere while hydro, biomass, wind or geothermal are available in most countries

2.2.1, Direct solar energy

High solar radiation in the Caribbean region leads presently to 4 high electrical energy consumption for air-conditioning purposes. These contradictory situation appeals the following Tesark : before using solar, ve have to learn, of re-learn,

how to build houses and buildings allowing a good thereal confort. Western architecture, developped before the energy crisis is definitely aot adapted to tropical conditions. Fassive solar designs are to be promted by the eentibilisation of architects and builders while strict regulations should be implemented.

Active solar energy should mainly aim crop-dryers and solar ater heaters in the sediun-tera and solar industrial steax generation in the long-tera. All these technics can and have to be developped locally in the frase of regional progeanmes

Photovoltaics is a different problem. Often considered as an expensive and sophisticated technology, I nevertheless consider that it represents one of the most appropriate cenewable eneray. Actually, a photovoltaic generator can be considecer as the pace aker of rural community in bringing an answer to its fundsocneal needs (vater, health, telecomsunication, Tights). Still a large part of the rural areas of the Caribbean countries do not count vith electricity. The sodularity, the absence of maintenance of 4 photovoltaic system certainly represents an answer to their problems. Photovoltaic rural electrification should be seriously considered by public utilities while formation of technicians

able to design, install and maintain such generators should be

developped.

energy

Steady and strong vinds prevail on gost east and northeeast

coasts of Caribbean islands. Windmills and wind-generarors can

a

---Page Break---

supply sechanical power direct; to flour-mills or water-pueps They should be used a5 videly as possible under local manufac ture. In order to convert this Jarge potential into electricity, ost specialises now consider that small is really beautiful in this case. Large sachines (2300 kM) save not accually demons trated to be acre cos effeczive than soaller ones ; ferthermore they require a highe> aaintenance and technica? eavicongent.

Large hydro-pouer have been used in Caribbean countries up co now (90% cf the electrical power generator in Doninica). Miai~ hydro-power which is sighly feliable and easily appropriable could play an important role in developing the hilly regions not reached by the electric grid. An occurate inventory of the sites is evertheless required before planning a generali- zation of their use.

2.5.

Bagasw is already Largely used in Caribbean sugar-cane factories. A becter energy efficiency of these factories could allow them to convert their bagasse excesses into electricity.

?The upgrading of plant vaste by gasification, production of biogas or ethanol, has already given rise to perfectly competitive technologies. This applies to the production of biogas for heating and Lighting, and to the gasification of certain agricultural wastes. Depending on the quanti

uc yea Lean-gas

oto, thus providing echanical or electrical motive power.

Ih some Caribbean countries, the scale of wood consumption wakes it imporcant to preserve its renevable character. Hence it ie necessary to stop the process of degradation of the forest and to assist reforestation.

Geothermal _enerey

Constant seisnic disturbance and active volcanisa is significant of the potential of the region. Nevertheless, excepting the ?Gouillante? plant in Guadeloupe, Little have been done in the region up to now. The necessary evaluation of the potential and identification of sites is being perforaed in aost countries. Wether for electricity generation for power supply networks,

or the use of steas or medium tenperature heat for industry oF heating, the use of geothersal energy requires Large investaents but say?be an alternative energy form wherever it exists and wherever energy needs are relatively high and concentrated-

---Page Break---

AN EXEMPLE : FAME PROGRAMME WW FRENCH Ai

HLA

Martinique and Guadeloupe are situated in the heart of che Caribbean sea.

The islands are soncaneous and volcanic. [n spite of their high density

Of population (180-300 hab/la2), 50-00 hovses are not yet connected t0

the grid,

ML the previously described reneveble energies are avaitable but Litete

sed while gost of the consused energ: coms from oi! (280.000 T in 1980

in Mareinique) -

3.1 = Consunption and energy seeds

The oil consuapeion is presently 48 follows in che case of Martinique +

= Road transportation « ast

= Air transportation Li9e

= Sea transportation be

= Electricity production «. seceeseeses DER

= Industry (wedium and high conperature heat) .. 3

= others on

This balance does not take inco account the bagasse used in the distilleries which ensures their energy autonoay. The growth-rate Of the energy desand is around 7 Z/year in Martinique, while it reaches li in Guadeloupe.

taportant sensibilisation campaigns on energy conservation and renewable energies have been realized in the past years.

various installations already exist +

= Large solar water heaters at the "Club Méditerranée? (800 52)

and-an hospital (350 22).

Tele-detection of voles

generators.

Je activity equipped with photovoltaic

Wind-generators for celecoumunications, se:

beaconing.

= The geothernal ?La Bouillante? installation.

3.2 = Renouable energies programme

The objective is to substitute 35.000 TEP/year of oil and to elec~

trify 10,000 houses by 1990 in both islands. The main sub-programmes are as follows :

---Page Break---

fed_ingo the gria

A detailed study of the existing sugat-cane factories shoved the possibiticy of producing electricity froe bagasse excesses, The exanpic of a plant in the island of Reunion ehicn wll Produce £2 We at the end of the wear (one third of che installed capacity in Martinique) shows the importance of such an approach. Other studies concersing the possibilities uf OTEC and gecthernal ate being perfor?

3.2.2.

Areas that vill ust Svan reached by tue grid within the next ten years have been icenzitied. The design of photovoltaic and/or wind generators avapted to the needs of the concerned houses as under Jevelopaent. The first instaliations will be opere tional in ?la Désirace? island next year,

sional _sppl ications in isolated

Uation of wind ané photovoltaic zenerators will be gene~

satized tor ali new celecoumunications or beaconing equipeent,

apglications

Sutorous existing public buildings will be equipped with sola

water heaters white nev ones will be built witha solar passive architecture sometines coupled with an active climstisattes, Two projects concerning raverse osmosis water desalination powered by photovoltaic and/or wind generators are presently considered.

= Regional (French Antillas) evaluation of the resources

~ Regional evaluation of demand and identification of project.

= Information campaigns,

= Training, in particular for solar water-heaters installer:

conctustoxs

Rational use of energy has been since 1973 in the hands of economic planners while renewasie energies vere aostly in hands of researcherss It ts foee {han tine co act to concretize our papers. Acting needs everybody especially hen refering to decentralised energy souices (conservation of teneeetley

ie should spend such more tine :0 prepare what tomorow can Se (1985) thon the long ters sight be (2000). the energy problem exists now in the Carcebean Fegion. Tf it could not Se solved in the forthcoming years, many roureeiee Wilt definitely not afford the future promising aysceas, Ue stocld we ante

---Page Break---

sither for decreasing costs, otbervise they will not ?appen. Funding always

exists when good projects, in the brouiue sense of ti teray exist. tee we

promote and prepare then

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---Page Break---

UPADI 82

?San Juan, Puerto Rico

?August 1-7, 1982

1 Congreso Nacional de Alternativas Renovables de Energia

USO RACIONAL DE ENERGIA EN EL DESARROLLO NACIONAL

Por

Sergio Arkhipenko

UADI - Argentina

Sen Juan, Puerto Rico

August 1982

---Page Break---

---Page Break---

USO RACIONAT, D2 ENFROTA FN EL DeSART?

Ingeniero Sergio Arkeiverko = UADY - Argentine

? ?ACIO

Pore contribuir al lena: INGENTSNTA: PIS ORA .

TAR EH EL DESARROLLO D8 10S PUEBLOS ce? eeu Pauamericn=

0: de energia, = reslizarse en Puerts icc os ite ke

fosto 42 1982, el Ingentero Sergio Arkiiven?s dy! vem.te de

de VARI presenta le

Tnergfa en el Desarrollo

arciones eleboredas en el Congreso

ae

Nacional argentine, ¢

Necional

biendo une

Ingenierfa en 1977 en Buenos Aires, 2escr neto¢ologfa pare implementar el cumpliniente 4s retus crisnts

des hacte el bienestar de! hombre en e! presente y ene) fae

ture.

Aunque el tema se seserrolle en oo) ares

culares de la Argentina, como se nutre de exsers valver-

val, se espera que su experiencia verndcula ~

6 también para otros paises: por semejanz

---Page Break---

1 IntRODUceTe:

II MODETC EYERG:

IIT APLICACION

onal y conservacién

Polfticu Energstice

Fe y perseverancie

kedios

Comviceién

Epoque mfltiple

tmo del URE

Seméntica energética

Bifequeda

a

NACIONAL

Prfoque euférico

Enfoque erftico

Uso Ractonal de Snergfa

Desgloses

VEL ALCORITNO DEL URE

Forma

Blenestar individual

Premisas del bienestar

Mternativas del modo de uso

Blectrificacién

Sento dencerétteo

erefa no regi

Tir Agrieusture

<7:2 Znergfa no convenctons?

Venta de combustidves

---Page Break---

IV USO RACTONAL,

V NUEVOS RUEBOS

3.9

4.9

Notelo general

13.9.1 Representacidn gréficn

9.1.0 Genera?

9-2-1 Alternative &

+3.9.1.2 Alternetiva 3

Directives para URE

Pactibilidad de cambio

Balance Alternativa &

Balance Alternativa 3

Conclusiones

ENERGIA ELECTRICA

Inportencie de medides

Diegrane de cares

Importancis productiva

Desgiose y factor de carga

Factor de potencie

Factor de transfornacién

Bnpuntaniento

Los factores tfpicos y e2 URE

-8.1 Factor de carga

+8.2 Factor de potencia

18.3 Factor de transformacién

Potencial Nacional de Ahorro Energétice

19.1 Factores de generactén y tet:

bucién

19:2 Factores de te uttitsactén protug

Representacidn de? eszuene functone?

de cambio

Ejemplo Argentino

Neces:

Nuevo enfoque

---Page Break---

I. TNtRoDUccION

1.1 Defintetén

Requiere te sccién pare lograr e] Uso Racional de Ener-

gfe: "un conjunto conerente de medidas tend?entes ? la utiliza

eign, con el nfnimo de pérdides recursos energéticos, en pos

gel bienestar, Ie seguridad, la libertad y el progreso del hon,

bra en el preaente y en ei futuro, en un ambiente litre de con

?aminacicnes nocivas y con la minima aniquiac:én de reserves;

naturales no renovables.?

2.2 Uso zactona? y conservacién

Freferinos ie denominacién de! "uso racionai" frente a

da ge Neonservactén?, agocianio egte tino témino en el "man

tenintento en buen estado" de cardeter casi essdtteo, mientras

gue le misma naturelere diadnica de Ia energie puesta al servi

cio del hortre ze relaciona con su uso.

Le energie debe ser usade en forma juste y ldgica, 0

goa "ractonal", pera producir et progress Se !a"inlitad dev

Ga" del hombre:

Cbservamos que en algunos paises se trata 2 tena como

"conservast én" eniéndonog al

concepso 3 7 ce ja? conservactén

spor medica artificialnente introducidos- Ge avg que por su

propia navuraleza es imperecedero, cone 10 el Ter.Prin

cipio de la Termodindmica de "Conservactin rata.

El II Princinio de ta "Irreversidi2ided de los procesos naturales", noa indice que el flujo eneraético svenpre desras da su celidad at producir los efectos que neces: anon parse) bienestar dei nombre, por lo que debenos aprovechario gt méxt no aientres recerre du camino hacia 1a mayor ceotizactén 0 ef Hropia. Asi que no interesa simplemente suerder 0 conseever Joa recursss, sino usarica adesuadamente para que inpalsee el desarrollo del bienestar de ls comanicas.

ie amplitud de conceptos contenidos en Ie definicién gel URE requiere un trateniento muy heterogénec, no obstante de mantener te misne orientacién del progreso 22 hombre, ind co destinaterio de esta accién.

1.3 dedete

Nuestre condicién hunana,que requiere ta ayuda de los medion natendticos para coordinar mentainente =ée de dos ase menciones, nos obliga de resurrir 2 ioe novels Se sols tise pare preseniar 2a mitifecéiiea reali¢ad ce. mnie.

En concreso: 2a problenétice ¢e le Snergévica (ctencia de 2a energie) por se conprejidad no permite t gnfogue sinp:iete, construids en base a una cadens tonada por je rigidn conexiéh entre causa y efecto ce muchoe suvconiune tos, sino requiere usar un enfoque universal con relaciones

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en varios planos (Modelo Pestel-Mesarovic) y, ain asi, no po-

demos ufanarncs de haber podido llegar a la perfeccién de nuestra tarea de construir une imagen de la realidad.

No propicianos realizar una tareu sencilla y fictl pa-
ra captar el cuadro del universc, que jands se encuentra en
estados cussi-estdticos durante un considerable lapeo, sino
que cambia continuamente con rumbos de marcedoe antagonismos,
propulsados por "disparatados? eriterios.

1.4 Polftice Energética

El modo de estructurar, cono el resultado de une con-
ciencia, Zija 1a conducta de la comunidad que aceptanos cone
une "poiftica", 1a que eg: tanto més definida y estable, ou
fo mayor e¢ le" éifusién de los conocimientos espectficos en
Jes eafergs llamada @ asunir la responsabilidad de goberne:
En le polftica energética Juega el rol prezonderante le co}
chencia enereética colecsiva, dada la inporcencia de le ener=
Staten rode Tes Gvetetiadse ce te comunicets sor Je que eu
Togro es le condicién de méxina importancia para el URE.

En nuestro ambiente nacional no se ha formado atin le
conctencia energética colectiva por lo que los planes enersé.
rigor sectoriales ee presenian con poea, o ninguna, coordina
cigs entre af.

1a energfa'de 1 Industria, en 1s Agricultura, ef el

?Transporte, en la Defensa, on la Educacidn, on la Salud, etc.

ete. no se'trata con un enfoque integrador, observandose sien

pre mayor, ttinero' de divergencias que colncidencias de tos ort

terios utilizados.

Tas nunerosas inteiativas: en forma de proyectos ~nacen por doguier, sin suficiente justificacién, pare realizaree so doen contados casos, y estos no siempre en versiones née ver tajosas vara el conjinto. Su ejecucién, universalnenteracole= cede strasos, michas veces mayores de lo eanis:bie-

1.5 Fe y perseverencta

Pare indagar sobre las razones de este situacién, vie~ ne bien el caso el relato de Herodoto sobre le conatruceién Ge le pirdnide de Cheops. Dice este historiacor griego que, para arrastrer las piedras desde las canteras nesta los bor- Bes del Nilo diez veces diezm!] hombres te~daron tres meses pare que, luego, la misma cantidad de hombres eon e) lapse i- gual las'colocata en la pirdmide. Pero previamente durante Lez afios toda dotactén en conjunto ha preyaraco "oe camsnos para hacer factible el arrastre.

Le decisidn de construir la pirdmide fue baeada en le

fe de los egipcios en la innortalidad de ?os faraones, 10 que

he llevado a realizar la obra sin vacilacioncs y cambios de

criterio. la perseverancia ce denostré con cedicar inreoe aflos

---Page Break---

para le preparacién de le infraestructura sin le cual la obra

no podrfa realizarse.

En questros tiempos, muchas veces reclaman la falta de

construceién de grandes obres, olvidando que sin la fe y per=

severancia ninguna obre: grante o chica , util o né, salutes

ble o maligna, puede ilevarse « cabo. Nuestra diffeuliad eo

gue carecenos de estas condiciones por cuanto, es mucho mis

Complejo motivar @ nuestra poblacién a lo que'lo fue para los

egipcios

Pero si no podemos contar con la fe, no tendrenos la

perseverancia de la fuerza creadora que neces! tamos pe:

ver las montenas.

1.6 Medios

Muchae veces se comenta que le posibilidad de obras "farednicas" radicaba en el uso brutal de las mesas de escla- YOS en cantidades siderales, Seguranente este treto no ere na 8 guave y caei tan brutal, como, cuatro mil anos despues, je observanos en los campos de concentracién de nuestra época, pero el esfuerzo muscular que ee disponie 2% taba my lejos de lo que nosotros podenos cisponer ahora,

Por ejemplo para le construccién de esta pirdmide lo gre equivelente @ la enerafa eldctrica de una central my no- desta de unos 10.000 kilovatios de potencia, Ia obra para Construir cualquier represa gasta més enereZa que una pirdmide.

1:7 Convicetén

legamos @ le conclusién de que nuestre capacidad de

realizar grandes obras no depende tanto de ios medios mates

Figles, coo de le fe y de 1a conviceidn que vancs por el ca~

mino correcto para llegar al fin que anhelance

No bastan las motivaciones econdmicas epoyades en las

fórmulas matendticas sofisticadas; el aval moneserio de tae

mejores inetituciones mundiales del crédito; tos proyectos

perfectamente elaborados por las mejores instituctones de in=

genierfa,.. ta fe y perseverancia no se fabrican con "rutinas",

© con procediméentos, por mis avanzados que fucsen.

La Ze y le conviccidn aparecen como resultante de o-

tres fectores; cuando ©] sentir del hombre 25 "teva a la con=

giencia colectiva compartida ce que la enerrfa lo protese con

tra le mseria y lo defiende en ou afdn de supervivencias., Asi aparece 1a voluntad de actuar y 2e conflanza en

gue ?2 camino elegido es e) que corresponds, siensre due

Fesponsables de le conducción, as? lo pusden ienossrar,

1.8 Bnfoque multipre

Henos fijado le meta de preparar ur modelo m

tiple pa,

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a poder reflejar la realidad y tratar de proyectarle hecta el

futuro.

Nuestro presente tiene ou raiz en el pasado, tal como

e1 future ge nutre en el presente. £1 pacado es innévil @ m=

posible de ser modificado, no obstante de que muchos ain asf

2e insisten! 81 presente? pasa cono una flecha y colo el futy

ro se espera con cierta chance de poder modificarlo.

~,Ai decir del poeta alemén del siglo 19 ~ von Schilles

?tome @1 futuro por tu consejero, pero no como le herranienta

ae tu gcoién; no elijasal fugitive presente por tu amigos ni

al innévii pesado como tu enemtzo"..~

1.9 No lanentarse

Lanentarse frente a la realidad del ps

los responsebles de sue males en el innovi

eva ? nade positive.

gente y buscar

pasado ~ no nos

Mds vale prender 1a vela que lanentar 1a obscuridad"

Hee un viejo proverbio chino que elegimos cono nuestro lena

Gon este espiritu hemos orientado le busqueda de solu-
cfones pare In problendtica que nos ocupa. No eceptamos le cimplicidad ce tos slogans, i la sofisticac:én ce los pocos qiigiades, no sratanos justificar @ la iceclosias, ni apoyar elgunos plenteos, ni metodos, sino tratar de aunar los evar lies del'mundo en que vivimos para plasmar un modelo que ten-
ga la mayor probabilidad de simular correctanente los efectos ?elas acciones que podemos proponer para e! logro de la meta del Uso Racional de Enerefé

1-10 Algoritmo del URE

Bi mandato contentde en la definicién del URE nog ayy Ge"preparar un @lgoritmo (método y anotacidn del célculo) pet

ra poder anglizar varias alternativas con proced!mientos al-
fa-nunéricos.

De esta manera podemos enfocar tanto las medidas ope-
rativas pare el mejor manejo de lus instalaciones existent, como evaluar las propuestas de cambios estructurales en los equipos y procesos productivos.

Tembién pare e1 pleneaniento le posibi2idad de simular qi futuro con un mode! de razoneble confiabilidad tiene un ve tor nada despreciable.

1.11 Senéntica energética

Para llegar a le éifusién de una informacién coheren-
se y comprensible, concordante con los conceptcs que evoca,
8 de imprescindible necesidad 1a aplicacin correcta de 14
"eignificacién de palabras? o sea de la senintica-

La confusién, que nace de la indefinicién y que favo-

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rece al increnento de a entropia (caotizacién), es solo con-
batible por 1a claridad de los conceptos que son ecpecialmen-
te vulnerables en el campo de la energfa. in efecto: les ene.
gies pueden figurar expresadas en cierto minero de unidedes

Ssicas (KWh, TEP, etc.) que indican le misma cifra, pero s0-

jo. con ello no significan que estas energies tienen? la miana

calidad en 10 que.a su posibilidad de uso se refiere:-un mi-

ign de kilocelorfas contiene un tangue de agua de 1000 metros

cildicos calentado a 1°C, como los 150 litros de nafta en el

tanque de nuestro auto.Bsto debe ser entendido como una condi,

cién bdsica para la accién pro URE "no debenos gastar le ene®

gia de "alta calidaé? en 20 que se puede obtener con la "ba

3 Como ejemplo: no quenar un bosque pare celenter una pa

ya de?agua o hacer funcionar una central eléctrice con 20002

Coen su horno para luego celentar, con la electricidad asf ge

nerada,el-ague para e: bafio a 30°C, 0, como se ha dicho, no

cortar un pan de manteca con un cuchillo eléctrico.

1.12 Bisquece

Gon los conceptos generaies que acabenos de exponer

nos proponenos realizar une busqueda de le metodologfa que puede ser aplicada al conjunto energético para formar la con

Giencia nacional de la problendtice energética contri buyendo

8] logro del propéaito que nos henos fornuledo: ?elevar el

bienester delhombre de muestra comunidad?.

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Digg.

Banta:

ay Ie

jescaser?

Jagotamiento?

sexplosign?

---Page Break---

I1 MODEIO ENERGHTICO NACICNAL

2.1 Bafoque euférico

Hace algunos pocos silos exiot{a 1a idea de que el mode

do energético se obtiene como un conjunto matendtico de muchos

batances parcieles de los nrocesos que se realizan en un cone

torne nacional y que es tanto mds confiable, cuanto még comple

to y detallado se le puede elaborar. Unido a la informatica,

cada vez mils sofisticada, ce legaba esf -par io menos en men

fe- a la conclusién de cue cate artificio serfa capag, con so

lo formularie alguna pregunta, producir una respuesta ajuetes

dea te verdad.

Actualnente le implacable realidad relegé esta idea al

mundo de la ciencia-ficcidn al que efectivenente pertenece.

2.2 Enfoque erftico

Mids se acerca a 1a reelided 1a propuesta de los profe-

sores Pestel y Megerovic, ce leo univereidaces de Clegveland y

Rennover, de usar'ia representacién en "mur:tplanos? cone? MO

delo, {iuetrado en el Diagrana 1, con ous principales varie-

bles'definidas como:

Ecoronfa

Poblecién

Energie y

Recursos naturales.

Sstas variables se estudian en sus mitues inter rela~

clones en diversos plahos como ser:

Nature?

enoldgico

Econdntco

Pobieciona?

Sanided

Seguridad ete.

Para les situsciones fortuitas se introducen les "ca-

tdstrofes" que afectan a lac principales variabl,

Inflacién a la Econonfe; Explosién a la Po>lacid:

cimiento a le Energfa y Agotaniento

E1 tratamiento en"multipianos" con las téenicas de ia

"programacién" permite le eliminecién de las alternatives "im

posibles? que no pasan le prueba de "restricciones? en cua=

suiera de los planos asunidos.

Con este criterio se pueden elaborar toe modelos més

confiables, sin por ello llegar a cer infalibles.

2.3 Uso Racional de Energfa

evaluar las medidas pro e2 Teo Recional de Ener:

etmodeo de mult!iplanos en for

ma iterativa.

06

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Comenzar con ©) plano ?eccnémi

ternativas al, por e,empll

© las mejores resuitantes paca

o? para trasiadar ue al

seguridad social? y 2

natura?)

rar"lae alternatives

panos legen las versiones gue me

ae ser aceptebles perk el conjunto.

chance tienen

Enpeznr por e? plano econcmétriso tiene e) sentido préc

tice de no perder el tiempo con elgo irrealizeble por falta de

2.4. Deaglo:

Cade una de las principalce variables, es @ su vez, le

resultente de diferentes componentes. Por ejexpio a la Energfe

podemos desglosar de digtintas muneres: pore? destino de su

aso: T Tranoportes y Nesidencial, Comercial y Serv.

Piolicos; por la forma bajo la .val se presente: Calor, Elec-

trichdad: por el proceso de sv generacién: Sicto Térmico, Apro

que represents a la Economfs ée) conjunto, se

war tunte por les actividades productivas que

como por las componentes de ia Snergfe que parti-

cipan en su creacién. No se puede pretender el fogro de una

perfecta exectisud en este desgiose que por lo tanto tiene el eargeter orientativo, ya que siempre existe cierta copartici~

pacién entre diferentes formas de la energfa, de manera que los

indicadores cefalen mis que valores absolutes a la preponderen

cia de unos frente a! conjunto.

Por ejemplo,vamos a considerar la componente del PBI,

devide @ le Shergfa Bléetrica quo indicanoa con la "partici pg

cién W" que alguna forma relacionamos con le "electrificacion?

Pare 1a tiuetracidn henos usado una relaciéa:

Ke

diicamos su significado.

Los desgioses pueden realizarse tans? éa con las resten

tes variables acquiriendo asf el modelo siex>rs mayor versati.

1Mdad ecercandose asimptoticamente a la realiced- sin aleanzer

2a janési

y en un "Modelo General -3,8"

III APLICACTON DEL ALGORTTMO DEL URE

3.1 Pome

El algoritno ¢e1 URE debe permitir te wequeda de sc-

luciones pare obtener con el minino coneuno de Snergfe e! né-

ximo del Benestar, cuando se io formule pare e- plano eccno-

Sirtco.

Lo eseribimes con:

\

xin | (PBT)!

sue

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Fara ou empleo debemos considerar que podenes contar con la re

lacidn de ?EX PEI) con cierta confiabilidad que puede ser aco:

tada, a le yer que disronenos de "coordinadores" 6 "factcres,

ge correceién" para ajustar ects relacién a ios estados de.

contexto Bj: tanto nacurales como dependientes de la yoluntaé

Gel hombre, de: estado y manejo de equipos ete.

Ia relecién entre ©! conouno de 2a Bnarefa y el Produg

to Bruto Interno (PBI) tiene 1a complejidad que ea imposible

Feconstruir por lm integracién de todos los procesos inter=

Vingenteg en "as cadenas que tienen como lo: necos finales a

la Bnergfa y ¢: PEI. Con muchos procesos de? Spo input-Output"?

"ge sabe como funcionan, pero que no son reproduet bi

en base a la ontesis ce gus elementos.

Pare este caso eiempre se opte por te obs

recta que luego se presenta como

cided,

tice para

inero de

o. Este es el pro.

ne. valides

Ia relecién que extate entre el consumo ce 1a Pnergfe

en un eonjunto cue, al incorporar la energfa produ

¥ servicios, se cuantifica con nardnetros de) uso

ifico de energfa por unidad del producto" .con kWh/ke,

KEP/ke, cd /unided, otc., etc. y se puede considerarlos como la

expresién de los aspecios :éenieos Ge fabricacién:

El producto elaborado tiene su "precio" de modo que se

puede referir n la enerafa requerida pore) producto evaluade

con sy precio con KWh/$, XEP/$ ete. que expresa comunmente en

energfa en el costo "standard" de diferentes actividades productivas.

nego el producto elaborado particiva en former su com ponente ds Froducto Bruto Interns, ?levande ceneige a la Ec hergia" que requirié pare sv eluborecién, consorme el modo y sector de Is activided que representa. Evaluaco oi PBI en und, dades monetarias (nornalmente en dolares de 22 UU del valor sonstante) y el consumo energético en unidades que le corres~ ponden (nor ejemplo TEP- Toneladas Equivalentes ce Petroles

Gente Entenaidad energétion gue se exprece cose:

= pp er otesten ete,

es condiciones do cata contexto y 10 "soecie? Ze pre

ceeon, ofan CSotghe aporte? gus contsslones $8

posible de

: ?otesis de ce

ign de in ?elasticidad?, cono relucidn de variectones de

BI) resu? tanto

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Spe

PEL

PET

tor y por lo tanto SeK.PBr®

Para ou repres

dodle logaritnices, so

eréficn, usando lac eoordenadas

anecrbe como:

in Bek +e tn PET

lo que es sunamente convent:

linearidad que adquiere.

3.2 Blenestar inéivicual

Bn le definicién det URE eros asumido ge oe requere ase

gurer el cumpliniento de le meta dei bienesta~ del gue en el vieno econdmico se pondera con 2! Pal por ¢

fa variable en su valor absciuto no tlene tanto eignificads

como zor su cambio cone! tienps s pares ca uación +

piciel. tretandose de un indicador ?eonpues sc?, depenciente de

condiciones Se cade contorna, lo que: nds es su e~

nue su valor ebsoluro,nara ce !f2

neater individual del pais.

Existe une bestente difundida préetica de usar como ¢?

Dienester a? Consumo Energétice sor cdpita,

@ cone un objetivo del planeaniento de! ?ecarroile,

proceder no puete ser recomendad>: muchos paises "pobres" sor

baje caliaad de vida al exportar la "enere?a? (venia de come

buptibles) tienen un alto indice de consumo, cas! a nivel

paises "deserrolledos". Por otra parte entre los paises de:

Erollados y con similares "standard" de vide, existen algunos

fndsces altos muy por encima de otros, dedido al uso Mireacte

nal" de energfs, rayano con el "despilfarre?.

Anelizade cuidedovamente, el {ndice del PBT per cépita

#iene gran importancia para e2 enfoque, siempre que se deri

nen adecvadamente los alcances.

Dede hacerse notar otra nds. B1 valor det

PRI de un conjunto normalmente se exprese en su valor acumi-

lado nnual con dolares de EE UU correspone:enves al

un determined eflo. Si ae

indicarge el fnéice de intlacsé: Sos valores a una ase uniforme, cue en este tra! ea coo USA

Gel afto 1960, "pare tener 1 nparecién ene}

Plan Oficie:'de le Argen'

3 Premises del dienestar

En este trabajo los velores"inicisles" se~a

eign B(PET) han sido referidoa a: ato 1980, con ta pr

nte para su renresentacién ser te

indice

veces or

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Como promis

Pat /edptta "inte

clepar

eraio que el

4s se puede calouler e? PBI del ato

in tase denogréfica ser neceserio lograr

Lperfod. consigersio.

éel ae

El algoratmo dei URE se ubica en el Modelo General(3.8)

dentro de ciertos fsites de eu "factibilidad?, de manera que

enté poaibles de

vazones obviag tene-

Hencs considerate

derance cul

det rétode.

natives que const

nificwtives para una demoatracté

aciona Ja con PET con la e-

0.87 tai como 1o hace e?

lo hace con la eleaticidad e = 0,3,

ieée como un valor "deseado" con 14

oaibilidad de alcanar en base a las

experiencias de otros paises.

Pore 22 Alsernativa 3 el cambio de le elesticidad de

su valor "niotérico" de #=0,87 a! "finel? de ex0,) no pued

Tealizarse en forma immediate y esto debe tenerse en cuenta

#1 Racer ?ou edloulon mis exactos. Lag Alternativas A'y 3 eon

leranos cue Gelinitan el sector de "pos: ble" ubicactin de

28 caracteris*.ces, curante el perfodo ce los préximos 20 @~

Rios, © saa: ne "pes: que A? n! ?mejor que B

35 cactén

is relecién de le Bnergta Bléctrica y la Energfa Glo-
Bel, que dencminamos como ?electrificaci én? pensanos que en
nuestro contexio diftciimente poarfa superer en los préxinos
20 aiios ?2 valor de? 40% mientras e) valor de? 50 % puede
consideraree cone mite generel, caivo a:gunae excepeio-
Bes muy particulars

La impertencia de ia electrificac!én se hece presente
a] obeervar los datos estadfstieos mundsa ?es cue t:enen ee)
récte> resresents e2 Diegrane 2 de intencidad ne vers

sus le electrifiención E+ 22 que muestre que con la srectente

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electrificaciéa se geners més bienes y servicios por cada uni-

dad energética

3.6 Crecimento denográfico

Para este perfoco fue acumide en 1,67 % anual acumula~

tivo.ta incidencia de in tasa demográfica es muy significati-

va por cuanto afecta oi PEI/cépita y la "olasticidad".En la

Argentina no ea ce tino "expiceivo", lo que sin embargo suce-

Geen muchos otros paises donde requiere una consideracién muy

particule:

3.7 Energia no registrada

3.7.1 - Agricultura

La intensided energétioa definida como

n = on KEP/USA

Par

y,para la componente del PEI debida a la actividad agro-pecua

Fie en le Argentina es notablenente baje ce manera que ia 6

ticidae parcial es practicanente mula, 5! procucto sgropects

rho recive una insignificante "subsidio eneraéice" fe ta ener

"rez que eu generacién se debe principal

teu la Nenergfayresiairada? 6 sea le que le asorta en for-

Fa natural el sor ye suelos A su ves le "sereiclpactén? del

agro es de orden de a= 12 %, de modo que dede ser contempla-

Ga en ie caracterfstica en su parte econdmica.

Le particular situacidn de la Argentina merece ser a~

clarad: le energfe sienpre se encuentra presente en todo pro-

Geso productivoy pues sin au aporte ninguna ectividad puese

desarrollarse, pero, en ie Argentina, le enerefe neceseria

re el crecimiento y la manipulacidn de los productos elimentt

clos (energfa metabolizabie) en cu mayor parte es proporcions
da por le energfa solar y los nutrientes fe! sueion ae modo
que le parte "registraca? (o sen le labor, lon pesticides y
fertiligantes) es considerablemente baja con respecte al con-
tenido energético de los dienes producidos ene: sector agree
pecuarso.

Esta parte de energfa, que se lana e) ?subsidio ener-
gético? es en la Argentina caracterizada por el hecho que por
cade kilocalorfa del "subsidio" aparece en el producto 5, 5
kilocalorfas, en EEUU la relacién es de 1: 0,87, en Israel e
Inglaterra 22 1: 0,5, en Australia de 2: 2,07, etc. Zeta situa
in debe ser tenida'en cuente al querer hacer las comparacio
Res entre log paises por cus pardmetros eapecificos. con e)
?subsidio" energético muy bajo en la Argentina es posible con
tos momentos, le elasticicad pereal con valor
silo, 10 que por supuesto no sueede en otro: paises donde 2a
ngensiva" produccién de bienes agricolas insune muy conside-
rables montoo de energfa, tanto en el labores como en produc~
tos elaboredos en base a los combustibles cono los fertilizan

---Page Break---

tes _y pesticidac, y los elementos de avarcada tecnologfa que se necesitan para'increnentar los ringes. in le Argentina ef aports energético pura *! viego pore: sombeo del agua tiene por cierto si signtficncsdn ~neionnl ©o que correaponde coneL Gerar en los entocuce nis ievnstneon, Dero para el eran con Santo nacional no ee cus Geno pees. lo es pare

3.7.2 Bnergfe no convenc?onal

Dentro del concepto de in ?enerefa no registrade? de

ie caracterfstica (FEI) caten totos lor azories de la energla

en formas no convenc!ona?es o sea las que 20 figuran en el fn

ventario de Recureos (combustities fésiles, nuciéares y los ti

cursos hidroenergéticos). As. bienes y servicios que se

generan en la energie solar ce,geotérmica, ete. al produ-

cir su componente cel PEI, no registran la encrefa que emple-

an.

Desde e1 enfoque econonétrico se comportan como los re

cursos agrepecuarios c sea zienen dai o practicamente nula

elesticicad y por lo tanto = ea le optinize

cién de le caracter?ssice global, reduciendo pare el consunse

el requerimiento ce la energie "registrace?.

Aunque en estos momentos ?@ incidence de le "parti-

gipeciga? ée,20, snerefe no convencional es. practicanente me=

Bisgible, esto no significa que puede ser ignorada gu crecien

?te imporsancia en o) futuro. El remplezo que se acentia con Ta

energia solar, de las demsndas convencionalss para la calefac

gign y secado'es un ejerplo de esta afirmac:én. Los recursos

"no convencionales" participan en la reduccsén de la elasete:

dad y por lo tento responden a la meta de! RZ, que propicie

su difueién

3.8 Tenta de combustible:

B1 contexto nacional hasta el presente no tuvo la nece

sidad ée contenplar las consecuencias de is venta de combust?

Bler fuera de eu contorno, que sin embargo corresponde mencid

ner por le posibilidad dee: ocurrencia exe! futuro. Para

ceracteristice energética general, la venta de combustibies cae censro de 12 relacién de le Shergfa para 21 uso Directo,

donde los bienes vendidos se cuantifican cono 1a Bnergfa R

gistraca, y le"participactdn" en el PEI o cea) como la com

nonente due se produce por tal razén comb

Con diferencia a otros casos de te relecién entre te

snergfa y 21 PSI, donde e1 costo ce energfa cenzro del costo

sel produeto representa solo una parte bastante redjeida en

~@.mayorfa de procesos productivor o gen i crsensidad "nes

aia, le venta directa Se Snergin en forme ce combuss

conveneionaies se caracteriza po= Sa inzenc/cad tense

ta, cuanto menor valor egregacs ne requiere-vender e? ?crude?

significa operar con ?n" alta, pero otra s:tuacién se estable

=~

---Page Break---

) PBL

Sain 2, PB!

partictpacién ?i

---Page Break---

ce con combustibles refinados 0 de tipo no-convencional como

Peej. nucieares, inclusive trensformadce en productos para u-

08 diferenciados, cono fertilizantes, pesticiaas, ete.

También puede considerarse Ia venta ce la Energfa Bléc

trica fuera del contorne naciona?, lo que recuiere un andlists

nds profundo pare establecer su incidencta final sobre e! bie~

nester individual.

Dado el cardeter polémico que siempre sucita el tena

Ge le exportacién de conbustibles, cabe agrecar la siguiente

reflexién:

B1 plano econo

rico, ta: como lo henoe seflalado repe

fidanente, no es una forma catogdricanente cecisiva pera fors

gular une'conclusién sobre les bondades de medidas propueatae.

Dede ser complementada por eu consideracién on otros pianos

donde pres. e] polftico puede impulear nacie tes soluciones

que no Feeulten convenientes en ¢2 econdnico. custamente en eg

te proceder radica la venteja de "multipiancs?

Hecemos esta refiexién con respecto 2 1

ey a2 fctrica fuere

+ que faciimente puede coneiderarse con =a Gs

gan preparado para satisfacen los intereses ce tipos éiame=

jralnente opuestos. La ventaja del modelo "maltijerarquico"?

que heros asunico para eate trabajo ae hace expecialenente pro

Yechosa para el andlisis sereno ée este prob-ema de indudabie

3 nacional

3.9 Mode2o general

Reviste un interés especial poder confeccional un Mode

to general de le caracterfstica E(PRI) donde pueden tener cy

bide lee reiaciones entre las componentes parciales de distin

$05 particizantes. Un modelo de este tipo nernite "simular"

los Feaultados pare las variactones de (aco dea ta BE), de

Wa (debics al egro), de la electrificacién ?, elesticidad

gidba e (2 yo 252); "de Ia einwsiciada egy co Ja BS ve PEs

de elastieidac parcial egy de le ZEvs componente parcial

PEI y algunas otras nés.

EL astudio de este tipo de modelo se decarrelia en los

Sentnerios sobre 1m Computacién en el Uso aacsensl de Euerere

1 Centro ée udios de Computecién de 1s Universided del

Salvador en Suenos Aires, de io que mencionarence elgunas con

sideractones de tipo orientativo:

3.9 1 Representeciér gréfica

3.9. 0 General

En e2 Disgrane 3 en coordenadas doble togarftmtens,

2@ representa un modelo simplificaco de la caracterfstice BP

BI) con prenieas siguientes.

---Page Break---

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(Eecats ¢otte

---Page Break---

1° la Enerefa Global

léctrica y ED ca Ia

29 ta electriftescsén S

nereia ©

mite supe-

Her E+ 40s ye

3° La participacién Wi indica ?a componente del rue se

x

cen su estado actual de

fede a la SE - Puece ser expresado como

Bl coefictente k depenie de 1a elect,

ma 2) y adends de la estruczy-a de cade exe

4° Durante esta etape entre 1a situacién inielal y fine?

las elasticidades rarctales ge mentieaen invarialbles,

© sea no cambia e2"rodo"de uso.

5° Las elasticidades parciales eps y eg

y nfs

Bn el Diegrama 3, mientras el PB!,cre

5 3g,

y la Energfa Global incrementa del BS %a1 {oy

ites velorer dentro 421 90

8 partictpactén en

Lencién (Diagra

ena.

sus valores limttentes de méximo

> pag (2)-(5)

componentes

one 12e8ne~

Wt29)

Gono ce yé 1a caracterfstica de la EE (PSI) representa

da con 3-¢ no ofrece informaciones significativas para su de=

Tinkeiéa, sino se indiean loo valores GeWs,) 7 (ye) Dare

un caso determinado, formando caracterfsticas (7)-(16)-(4) de

un caso especffico. Obeérvace que Ja 25 vs FS! vara todos los

casos sienpre serfa la misna?(2)-(6)],aunque encierra todes las elternativas posibles, de manera que no es una ze?acidn sufi-

definitoria

3.9.2.1 Representactén de le Alternative 4

En el Diagrams ¢ ce resresentan Ica caracterfsticas

en los puntos "iniciales" y " fingles" de la alvernativa Ay

para las prentsas cel Sienestar 1, iI y iii.

"ara esta representacién ve asum!é e!

techo de electriftcacién de! 40%.

Gon premisas ge observa quo 1 elasticidad

parcial de la Energfa Directa ég seria cerca cel 0,61, mien=

tres que para le Energfe Eléctrica su elasticicad varcial é,

vaFierfa entre 0,9 a 0.92 pare les premisas I a! III.

Confirmando 20 ya expresado la elasticidad eparen=

entre la Energfe Bléctrice ye! PSY o sen eyz varce ce ma-

ra tal que hace evidente sufnlta de aplicacién.

Bl consumo de la energfe eléctricn para ia crentee

0,5 ¥ et

20-

---Page Break---

III desde si yalorMizicie!® 6 8,67 ¥T

e1 congumo total acum

ée 1426 UTEP.

sube 4 42,2 KTEP, con

o ds le" energfa gtoba: on? los 20? ahoe:

ie Alterna!)

se encuentrs Ia renrcsentacién de

ouest2 cue

Bn e1 DMegren

la caracterfs:ice sajo ¢:

se lograrfa bajar le eloatic dad "e" a ©

eate caso 20 chserva que is Snergfe Directa ha

mentenido st elasticicnd ep. = 0.61, mentzes se eg, se encien

tra entre 0,77 @ 0,57 pare ?a9 vrenises

Pare le

ria de 23,4 YTEP/ano

energfa globe! acum

Se saca le conclusién que, arn sranteniendo el mis-

mo modo de consumir = ?s Energia Directs, xsecs:tamos inple-

menter mayor econonfe ene! uso de le Eners?e Eléetrice y oon

esto podomcs ahorrar, 9 a1 se quiere dec var, el 30%

de la energie globe:

10 Dérectivas para 02 URE

ga Ill le cnergfa oléctrica "final" se

entre de! 70 alos, cen e: consumo de le

2a de (026 WEP.

Estos dos 2jempioe, que se ubtcan como ciertos extre-

mos, en el Modelo General, 'nes permiten formuiar ia direct!

ves? para le inplementacién de medidas "pro 7P=".

Yimos que debe incrementarse: la electri icactén para

lograr mayor remplazo de} uso de recursos no renovabiesy a

ie vez optimizer el "modo" de emplear la enezgfa eléctrica con

le dismimucién de su elasticided parcial. Al cunplirse estos

objetives los regultafos serfan Tuy atractivossson ln energra

global pare cl mdximo beneficio (Preniea I17'-losrerfamos ba~

jer de SSOOuTEP 2 1000 MPEP pare ei consunc acumslado de 20 a

Ros SIM A7ZOTAR SL PROGRESO Ze] bienestar + ir cesta le mitad e2 consumo final ée la enersfa eléct=

Ccusesuentemente esto perait:

te les invereicnes ée] capital en las es!

Vig les exizoncias ectuales de? capital er futuro.

Queda le pregunta: ;Podenoa realmente lograr un cambio

de elesticided de ta! magni tua?

3.11 Pecttbiitéad ded cambio

Como en otros paises se hen producido los cambios que

queremoa introduetr en e2 $ro, poderos or Sorma may sim-

ple, pero no cen otros tan~

eign le herence

También podenos preguntar:

¥ seguir en adelante cong p-anenzo

breocuparnce por cambiar?

> considerabiemen

lo que el

fence no cambiar

caso,para que

?23+

---Page Break---

osm ortaps soreraeeieog

AL Uli

on a

ee ATEPTUT Sasa

V vValavuianty soNvIVE 9 wR

---Page Break---

BE nn 4

Yrussoaayy |

|

25 LUMI

|

i

---Page Break---

Analicenos rrativa "AT que corresponde a lo pla

neado y tratemos de ectatieccr mu factidilivad y, si este es

negative, tenemos que cert en ?orzosamen:a!

Dos aspecton funtarentaiee cond

ée le Alternativa "4": ta exietencia

ios para asegurar ?+ ofirta y Ie posto:!idad de ampiier

jetures para la devun!: de ln enery?n . éovrica ce tal

megnitud que puede ser akesr>: sa por el ucierio or 10s 20 ales

para esegurer e! desar: Oe

n le factibiliaed

sos energéticos

Aunque no disponenos en estos momentos 72 suficientes

informaciones sobre le magn? tu! real del Inventerts ce Recur=

908, podemos tener la esvenanzs del descubr'nento de nuevas

fuentes o del cambio coyuntura? que inerenenza ia provieldn.

tes,

pero si estarfanos frente e le imposibili?ac ce aprovechar 78

Gionalmente a la energfa e7éc-rica por faiin cel "mercado" de

Semafo apropiago la Alternative "A" pierde ou ?actibiliged.

Bn e1 estudio del Zulance energético d> la Alternative

NAM que hacemos seguidamenze, veremos ?2 imnos:b2

q Ge 20 stios de elevar le ekvensién de> mersato

iéetrice al tanafo que se reoues

mo un imperative eatend:

tes,

3.12 Balance de la Alternative A

Recowdemon que cesde e2 consumo "inicial" de 8,67 MEP de le Energfa Ziéctrice debencs liegar a los 42.2 ?TEP'*fina-les" dentro ¢e ios préximos 20 afos. Bn Diagrena § presentanos el Balence Inicial y ex Disgrana 7 el Belance Pena. do eatos custros en un trabajo sobre: "Rol ce ciéa en el Uso Raciona? de Energfa" llegamos a 12 conclusién gue 21 creciniento de la denanda solo serfe faciible si, con Fespecto # los valores presences, se increnen:a-"1 ? das sector: R Comercial y Servicios Pibii= cos en 2,5 veces, ansporte'en 2 veces ¥ de 1a Industrie en cai 5 veces laiet!)-De los actuales 6 UTE? ce 1a Energfa Eléctrica consumide inicialnente en la Indus*-i: se deberve llegar @ 30 UP3P/aio, lo que constituye una neta de tipo "gi-ganveaco" con practicamente ninguna chance de. cumplintente sungue sea por le necesidad de llegar a le inversién fuera de nuestras posibilidades.

Fero sin esta condicién no serfa posible absorber "ra cionalmente? a los 42.3 NTEP/ato y por lo tanto desemos bus: car otras alternativas:

Baste solo la consideracién de que los 20 NTSP/afo en le Industria equivalen a unos 120 TWh/ano er forme é eléctrica que, con 4000 hores ce utilizacidn, serfan absorsices gon una denends media de 30 GW (o sea mas de'50 Cl inatacados)

Jo que exige facilmente una ?nversign de cerca de 50.000 Muse

Flo tante tebenos, eo

co, lograr un cambio te la carnelert'

---Page Break---

en in ampliacién de eguin

te ios prdxinos 20 afas,

trinlizacién de magni tud

Fire veces avperior >.

gue no se paste con

Prosegulr con ta

Tacneta adopt ads

2,13 Belence de le Alternative 3

En eota alternative

Enexgfa Biéstrion de Sh,2 Wt

sie dei Balance Fine? con esta alternatives requ

grenentos, en todoe los sectore, alrededor de dor veces at

gopemo tical, io que no cerfa"inpoaibiony tends Setuce no

Dlenente se momma ce nuee eretico. Pare oer

factible requiere sin erbargo un notable ease ex ta Cheetieh

Ged total, produotde ccain c2 Deprane § 1 cenblo de le

ectiei2ad parca! ene! uso de fe En éctricas

Cbeervaremos que ei no logrese este cambio de elasti.

due, eeguirenoa con ei ge actual, 0 sea con ta corestentetted

gq fa Alternative A-'y sf 2in!tande ef apsrce de ce onereiice

2éesrsca e ton 23,2 uPEP ei bieneatar dete sostactée mess oo

fe 2000 ee mantendrfa a: nivel actual (Presia)

3.24 Conetuszén

Con ins coneideraciones precedentes estenos en condi=

stones de formlar una reconendacién para cocnblecer el cortege

Ze comtno nacke le meta del URS, con el envocue cus recaser ae

objetivo principal: el bienestar Jel hombre.

ZoEs,Png5s"9,cortorne podmen eotableces eiglteghot ae

poder adsorser una cierta "oferta" de ig_enersfe eléctrica en

un determinsdo momento en base a las daiiie sees ee seeeetel on

¥ Gistrimetén y'del iso que pata aque! tense sofente sonsers

Gen esta oferta de 1a Ene~gfa Eléctrice\?eplicando 1a

slasticided parcial tog factibie de ebtencs, sacontrancs GOg(?)

PRI © nee ie partictpactén on o1 PRE que lp corresponde.

Asumimos cierte electrificacién ? t1 podrfamos lograr

ene} mazento conatderado y por lo tanto encenssarence la fe

rerefa Global que gerfa requeriia en

ee (3-8

E = y por 10 tanto EDWE-BEjcon 1a en 0 see In

Slastictee péSeta? de? Yeo Directo encontvence el valor des

PEL tote!'y hor lo tanto. nee

De esta manera tendrenos te infornectén sobre e} view

que podrfance eoperar con e! mode ce sen~ vesnesier tee)

227+

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Diagrama 8

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que stsponemoe. si

nesorario tenemos que nodiftear

TY USC RACT:

inportenete de nedtée,

Hemos sefaledo 26 tno: erste eobr>

co de la energfe elée:

le argentine ¢o las fuenses

ane slempre mayor "elecsri fs

Por tet rexén in ace

cha en esto sector lo que, ps

un enfoque muy partiensar:

4.2 Diagrams és Cerca

eléctrice

en e2 moreno de gu ro.

condiciones de "calicec"

(voltase, y frecuenc!a cone:

tib16 Gon otres fneunos, S. 2 cee

momFectars Se 5) os

el Palnacenamtento?,

ene co20 le postin: sid

presente po> 20 7

ha tmportan

es, merece

cove ger gy

gniZicante-ha-

2° son resgos

3tro Eléctrico

?practi cament:

1 deeazrol. oral lo repre

carga, normaines! as "cotencia? ver=

sue ?tiempo?, que merece une ave : ler. Bn el

Diagrana 8 ge carga,

agregenc> un 3 valores de

y enerefas

seat baset y oonia?. con la retncteo

Heéia}, Carga dfzice y Wntne.

4.3, Dnpertaneta srotuetive

Bi deeglose nencioneco tiene une si sx12tcgcién para el

ggtudie de ies reiectones "parcia?es" ze fa e-wvgta eiéeset=

cay ie produceién,

oo sectores det

* Factor de Gar

Za "base" atiente log servicios esone

Suainistro ¢el agus, d2 conse~vectén =

(eros y gran partes ce los nrocescs intus?

oras/cfa. Te? "semi dace? co:

rarsportes é> les

mertando o: valor

---Page Break---

claramente qué polftica de fonunto debe seguirse para conZor-

mar los propésitos que han sido seflalados: xayor suministro

ce "base" y "senibase" y menos de la "punta"

4.4 Desglose y Factor de Carga

Bl nomograna del Dingrama 8 indica 1a relacién entre el Pactor de Carga y la proporcidn ¢e la ?energfa de punta", que por lo expuesto debe tratarse de reducir #1 mfnimo posible, por medidas de "buena" adzinistracién tarifarie que lleva a ios usuarios al auto contro! en el requeriniento del uso, re= eibiendo como el prenio la revaja del costo de este servicio, por la mejora de su Factor de Sarge.

Para la Denanda mfnime de) 40% de le Méxima, el aunen vo del Pactor de Carga desde 0.55a O.JOreduce 1a potencie de punta de 40 a 10% de le udxina, y baje la energfa de punta Gesde el Gal 1% de la energfa total.

4.5 Pactor de Potencia

La energfe eléctrica es "autopropulsade? sor los condue tog de su tranemisidn y dietributén y ademic posee la condi 46n de transformer su tensién. Estas operaciones generan las pérdidas por el efecto Joule cue son inversanenie proporctona, tes al cuadro del Factor de Potencia que exprece e° destasaje entre la tensién e intensidad del circuit eléetrico. Dismi?

suir el Factor ce Potencia, significa reduci~ in pérdida entre

ls energfa onviada a la rod y consumida por e2 usuerio, le que

Puede adquirir valores bastante considerable:

4.6 Pactor de Transfornactén

Ie energia eléctrica por su naturales de "exergia?,

que puede transZomarse directamente en el "trabajo" con art

iietos aproviedos, para su generacidn en base a la ener=

gia contenida en'los combustibles, pase por el estado térmico

sufriendo una transZornacién segin'e! proceso clezide y de ea

manejo operative. Zeta relecién conocida cono e! factor de

Tranaformacién Fes sueceptibie de mejoras, santo operativas,

como estrucsureles,

4.7 Susesteniente

E2 proceder Iégico es tratar, por todes 10 medios, trang

formar la curve de carga hacia menor empuntaniente a le ver

que reductr la energfa generada, sin disminuir su entrega al

usuario en forma tal que, consuniendola con menor elastictded

sosible, produzca e! méximo beneficios

Sin embargo, en a2gunos caso:

Ge algunas enpresag de ?correr detras" de loc acontecimientos

yen vez de reprinir la punts ,increnentar su ofersa con e:

?Gmpuntamionto? de sus plantas generadoras hitroeéctricas Nt

te tamafos gigantescos de su potencig instalace-con sractica~

nente insignificance aporte de energ?a.

© observa la tendencia

=30-

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Son ta: plant

lo pueden cunfniecrar

perfodos Ge tienpe.

Bate s~oceder ves

mente incormovih? »

tal como ne nresente

primir le puate"

cia de punsa?

el valor, so

te pare le "punta" gue so

a2 sistema ep muy cortos

puntaMes un ele-

gue Gebe sem atend!do

punta" y no de "re

oasiderable "poten:

N naUidas eproviedas ge

51 URE demucetra que

gosamente evatunie, =

te tipo de aprovertan

nificativor y evitabie:

4.8 Loe factor

expuntamiento"debe cer cuida-

tna "gobreinversiéa? en es

que ceracterizan

hectrificastén? con

ra forma, importancie ~elativa

Se estos factores yr:> 2m economia real de: suadre eneredtieo

?aremos una ostina: Dy pere no por ello menos con=

Vincente.

4.8.2 Factor de Corze

Bi Factor ce Cara, cuanto més alto, tanto menos ener-

gia eldctrica fiuye coo ia'"punta? 22 bajo efecto produetios

¥ por lo tanto a commonente de: Pal, serd mayor paca un alswo

Consumo total, gto sigaifica ia a'eminucidn de 1a slagidolies

parcial y por ende de a global del confun

Como 22 ejem

9 nunérico te cerdeter orientativo, con

gigeranos, conforms 2 2iagrans 4, que requerinos para ia? ef tia

cién "final" los 42.2 WEP en vnensia Eléctrica con te *oartie

sipacidn® de 13,2 x"20/ MUSA en cf PAL y que eate consumo n

TeaHizarfa con ei Factor 42 Caren del 0,6 gue (Diazeana 8) sig

nifice que el 415 % eo la snecvia, por ger de tpunta?s pratt

Gemente no consiituye a! TST. Si'noloremos el Fastus de Cares

© 0,F solo 1% deja ce ser "punta?.

Si asunimos que In enorg/a de

contribuye gl PBI necesiteremos cone:

cnevut le aisme participacién de

Bengs_enere{e eléctrica para

17y 34k 10? HUSA (0 -aen 45,7 MED y ?a elesticidae serelal baja

ria del 0.92 a 0.5. Considerands que pera el Uso Directs seach

Zymog con le misma elasticidac narcial del 0,6 requitarfa que

et consumo de ta energ{a stoma? on arfa cells une? a6:

con que,con la mejora del 2a.

ita precticamente no,

Pactor de.Jarga de 0,2

rie CArea del 0.92 0, lopra-

rfemos ina econonfa de 5,7 KTEc/ahc ni Sina! del persoaoroee

Fepresenta ei £,4 4 ax el requotimento de ia energia glosel.

---Page Break---

4.8.2 Factor de Potencia

Br eate trabajo imputanos @ las fuentes 4e1 conguno

g toda le nergta *priman/a? ueais gara le generacién de la e-

legtricidad. La expresanos scuivalencie", con la re

cidn esumida en les plen.zs 9 de? confunto naciona? en

2,9 unidades térmices por niga eidetrica generada (a

Sfegada en log boraes de i> central para ger ?enviada e la red")

Esta colaracién debs tener conparer los resul,

tados con ciao estinasicn heches con otro

criterio:

Entre le energfa "reneri

gada el usuerio media 12 nércnda

medio ge acume en un 13%,

no se contempla el modo >

1a incidencia de ie aut

Con esta supoeic!4r te nérdide de ln red en eu momen

to "final" con el coneuns de? 42,2 MPEP serfa de 4,9 MTEP en trariamente que cl 50% se debe al

onal al eua~

" ys "consumida" © gen entre

je Te red, cue en su gran pro

fre gue es volo orientative pues

duir la energfa, ni tampoco

efecto soul

Seago del

= de Potencia es de

On7 y Logregenon. ser 2 QoS cegutterde gue Se. Stemi-

?ste te pérdida Gel dy 44,0 «2 sstual a-2,i y per

Zo Tanto haere una Aisnisacsts de as en 0,65 SEP/aro,

ae mane: 2 fine Ja ensrefa

a elasticidad parcie? Cz, dajarfa de 0.92 @ 0.91, mi-

entras que el consumo tote! de energfa de 105 MPSP a 102 UTEP

decrectendo le electicidad total de 0,87 a 0,82 - la economfa

de 3 MTEP/ato sign 2,85

4.8.3 Pastor ce transformacié:

El factor R = 2,2, odtertds cono un indicador en ba-
se al pronedio del consuno?de lcs contusvibles para le sene=
racién'de la enersla electrice, en reeiiand es un ei?r> come
puesta de los restitados de varias fuentes de genezacién de
diferente tipo y de forma del uso. Depende para un cenjunto
exietente de caracterfsticas bésicas de cade uno de los centros
de generacién y de eu reletivo empleo, weorde @l "Despacho B-
condmico de Cenza

Existen dos pos!bes 2<neas ee accidn: para 1a opti-

mizacién del R: por medidac opezstivas y por los cambios ea-

tructureles - anbos son de ran inportancia mientras que lee

apreciaciones untversaics atri

ambos.

Con las medidas operativae, coneistentes

lancia del estado y manejo v su permanente a.

To vigi-

te,las experien

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ciag en nuestro medio han denostrado 1m posibilidad de una me

del %, por lo gue ha-enos 1a eatinecién con uns

"a observer su incidencia.

Para la venta de 37,2 MTEP a los usuarios requerinos

42,2 MTEP como energfa generaia con % = 2,9, asi que con una

reducción de 4% Im denange seria de 10,5 UTEP para la miam

participacién de 13,3 x 10? Muge que se traducirfa en la dis-

minución de le elasticidad vercial de 0,92 a 0,90, mientras

que el consumo de la energfa global bajarfa de'105 RIEP & 99,6

MPEP, con la elasticidad de 0,8 en verde! 0,87.

Is econonfa total de? SA uTEP significa el 5.1 4.

4.9 Potencial Fectona! de Ahorre Energétice

4.9 1 = Pactoree ce generacién y distri tuetén

Podemos presenter un cuadro

us variactones de ios parine:ros por

Surgen de lo indicado y que contizman

Gerla edvertencia core el carder

estas indicaciones que deven ser 2

80 por caso.

le las implicancias de

medidas "pro URE"que

viabilidad. Cave Sa-

netarente informasiro de

dadosunente anglizados ca

POSTBLES ECONO¥IAS EN

GENERACION Y DISTRISUCION

Energia Global

Ahorro Tota: Sn BE

Acci én URE Consiste

De Energfa Eléctrica

«1 Factor de Carga cambiar de 0,600,7 54% 3.6%

«2 Factor de Potencia " "0,70 0,8 28% 1,6%

+3 Factor de Tranefo-mecién * "2,98 2,78 5.1% 4,0%

Aplicados sinultaneament> a2 podrfs estinay ose el

consumo totai de Enersia mejorarfa en un 15 %o se es ver de

gasta 105 MTET ce ie snergfa total bejarfamos a 9C on el

?a0 2000.

Para la onergfa eléctrica se dieminuirfa la genera-

eign en un 9% 0 sea Ilegarfa w un 38,4 TEP.

. Aunque sstos son logros importantes se

aun estén bastante slejados a la seta que henos ee?

Diagrama 4 con 58 ?a Clobal y 23,4 NTRP en

ta Bnerafa Eléctrica. Esta brecna debe ser salvaca con 1s ac=

46n gosre e2 procs ugtive que debe pode> lograr una e=

sonomfa adiciona: de orden de? 25 UTEP, ene: c

nergfa eléctrica por el cambio de! mode de utili:

ayor parte en el sector de la Industria.

4.9.2 Pactores de la wiilizecidn productive

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ado ene}

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enerefn tiene aserurn'o un

IB

eutu misién.

(2) Control Operative en Plantes te Vapor

INGENIERIA X° 933 1965

(2) Control Operative Sinplificats

5° Congnec Ingenierfa 1966

(3) Manual del Contro? Plantes

?Ay3E 2969

(4) Investigactén Oneretiva en Serv, Pilbl. de Zlec~

trieddad

Universidad Tucumin 1969

(5) Un Bnfoque sobre e2 Suministro de Energfa EB1ée+

trice

Rev. Blectrotéenica 2972

odo para actualizar las caracterfeticas

ntas

Universidad Le Plate 1975

ificncidn Energética de? Pais

Sen Cuan 2975

(8) Reflexiones sobre e! Uso Racional de Enerafa

car 1978

(9) Recursos Hidroeiéctricoe Argentinos

Rev. Blectrotéenica 1979

(10) Empleo de Silogismos en e1 Uso Racional co

Enerefa

CAI Informa 1e7°

(12) Uso Racional de le Energfe Eléctrica

Seninario Conservacién Ener-

gfe 2iéctrica - SSEE 2980

(22) Computacién en e1 Uso Racional de Energve

Univ.delSslvador INTER:

(13) Computador en el Control Operative

Univ.del Selvador I

(14) Ingenierfa Energétice

Centro

(15) Consi¢eraciones sobre e2

Puerto

(16) Energfa en procesos produ:

idea ~

(27) Aspectos teoricos de Mod!

Semina:

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UPADI 82

San Juan, Puerto Rico

August 1-7, 1982

Second National Conference on Renewable Energy Technologies

ENGINEERING: KEYTONE IN THE DEVELOPMENT OF NATIONS

AN OVERVIEW ON ENERGY AND THE ENVIRONVENT

by

Paul Cho

Health and Environmental Risk Analysis Program

Office of Energy Research

U.S. Department of Energy

San Juan, Puerto Rico

August 1982

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Topaeat of Katt

send the Environment

URcneme: orem o ve vamionem or narod er

NOHMENT. By Paul

iS Gravis oN Brena Mo Te TE

oy Ovtice of Energy Research, Uy 8. Deparcee

; Toetay, Neastagton, 9. 6.20805

This saper covers a brief htatoricel perspective, ve

eoenay Covelopanat ample, to ittustrate how angi |

?baring Sas beiped pations to econoate growth ent techee. |

Selcel advancenats Ansccdated with the deveopasne gf) | 253 |

nations, there are, hovever, many teportant tseuee wuch ae] =o Ses TS

| population, natural resources, f00d, eovironsentel polls | |

|

ton and potential health impacts witch ate idestified asd

| dcscussed in this

Ltenging cake th

Fat individuals, and engi

} continue the application of our engineering tngenuitier ?

| the developsent of nations im an effective ant'a balanced

jw.

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aper. Yioally, ft exanis

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NSN UGRIR. SOWSTOS 7 TRE DEVELOPMENT ot wartONS

POF eH AND 7

Ie TRON

Poot Gio Me ASIE

?The Webster's New Ioverratton:! DieeLonary [1] defines engtoeering

ss follows: "the actesce oy which the properties of eater and the

sources of energy in nature are mace ureful to man {n structures, machines, products, aystens and proce Sietlartly, the Landon House College

Dictionary [2] gives engineering the folloving definition: "the art oF

sckence of making practical application of the knovledge of pure actences,

fas physice, chenietry, etc., as in the construction of engines, bridges

butidings, wines, chesteal plants, and the like.

Kt tn feportant to tscinguish betveen sci

Poqeer fs ?know-vhy""; the Latter fe "know-how",

ridge; enginenring helpe to produce weelth.

Science produces know

The material weaith of # country depends on the oraductton of goods

and services through the planning, designing, construction, wrilization, fenc management of the available supplies of human ekiile, capital, and, machine ?Just ae civilization of the world Se wmrrked by advances in the arte, Literatures, sciences, ete-, to the Gevelopnent of nations {6 characterized by econoate growth one technica progress which a manifested by making practical appsication of the ai

Economie grovth and technical progress, {n turn, can sten from greater production through the use of more Tesources, and from greater productivity through the more efficient use of resources. Engineering, is Keystone to both aspects, through increasing the stiiity Ladle xesources -- as for exanple in alloving the productive use of land pre- iously considered infertile, of by discovering an economic wae fore Fav paterial previously thought valueless -- and sy productivity teprove- ents through increased skills, better methods, better machines, and effietent marketing and service infrastructure

?The scope of this paper covers a brief historical perapective, using energy developsent as an example, to illustrate how engineering has helped nations in economte grovth and technical progress. Tt {4 then folloved by a élscusion of issuer and concerns associeted with econonte growth and technica! paent in industralized nations, Finally, this paper provi Tecomendations vhich are brace on lessons

Ekscused previously, to afd engineers and ackentiats through their

Gincoverter and innovations expanding the range of choice open to nations

land the(r people in the world.

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ELSTORICAL PERSPECTIVES

In looking back the recordes hisiory, we can aee that the efvilize

tien of mankine {4 replete vith efforte ané atroggler "2 ?naure ele-

monte of simple survival, progrersing tovards creating ané maintaining

fro amviroment suited ?- mar's ectsctent performance, end the enfoyment

ef life.

Our ancestors, motivated by their instinct to survive, moved into caves, built other more peraanent shelters, utilitized fire, and made tools and veapons. Thence they began to multiply, and replenish the earth, and subdue other living things on the earth. Man's survival rate war enhanced by his primitive engiseering ingenuity vaich set the first Stage of the development of mankind? civilization. The use of energy, for exazple, hi factor to the supply of fo0c, to physical comfort, and tn improve the quality of life beyond the rudimentary acti- Sitter necessary for aurvival. The utiltzation of energy depends on t¥o Fectore: available resources and the engineering, tecsnical skiile to sources £0 useful heat and work. hile energy ©

Later, with the advent of agriculturel development, men and women in wveral aajor regions of the vorlé changed from a prizitive hunting-and-gathering level of existence tovolving every menber of « nomadic froup, to an agricultural society where only « part of the population fould raise enough food to feed the vhole society. A sedentary mode of existence, raising crops and Livestock, presented fever hazards £0 ?aan than the forner sigratory vay of life. Food production through the deployment of tools, frrigation and flood tion achenes decane more efficient, Water pover for drrigation purposes, Zor exexple, vas developed in about the first century B.C. By the fourth century, the vertical vatersheel had been developed for grinding cereals and sisilar tasks, By the sixteenth century, the vateruheel var by far the most important prime mover, providing the foundation for the industrializa, tion of western Europe. The windeill f{ret appeared ir western Europe in the tuelfth century. It vas used for grinding grains, for boisting materiale from mines and for pumping water for irrigation purpose. With the development of roads, watervays, bridges,s butiding, it becane bute food anong villages and nations.

drought

?Of those pover sources. The development of the stem prime mover is

relatively wodern compared vith the vatervhee! and the vindstl!.

---Page Break---

?not untti the widdle of the oinertenth century, chy cteam engine decane

4 principal prine mover to provide bari: mobii?ty, unconstrained by eve

geographic Mescation as inthe tise of vatersser!. for ehe sanutectun

ing sndurtry of the Sestera & Since 1992, a siecckly groving

vartety of poerscon: rater Sevicvs anv -ectnofogtes ave atcelereted

ano'a throst 15 pears cf Ave Toeay, many Anduetri-

alized pation: in the verl4 Savt covetuned nuciear youet to eect hel

Anereasing electrtet=» dena?: to austacs healthy ecctoie growth. Tn

e United States of ?erica, engeere ant atone its are continuing.

their research and developne": elorta es advance! cuergr technologies such as coal gacificozten ans Meo tartiony aweleat ?salons Bapnecee

hytradynantes

Beginning about 3,000 8.¢.,

dotts sycenids, forteatio:

(609 #.C,- 400'A.9.) Rom:

> noginsers and architects

By the tine of the Christian era

rs completed the conscruction of the

sand bridges in Europe and Asia Minor.

In the 3ré century B.C, 8)

Huang TL, who styleé himself as the

untfier of china, ordered ruction Of highways Linking the entire country to the capital near Stan. The writing system was etandardizes, as vere weights and measures, coinage ond the care-rar. Ageinat the

alvays dangerous nomads to the ners ens the west, one enperer Linked up walls built earlier Sy the incivigua? states {nto the Greet Well ae & solid barrier about 1,500 miles (2,4}4 tn) long whics sifetehes from the sea to the desert slong the mountain: that sarced off China's northern Limits, tm the weet.

Around the 2nd century, Chinese invented pepermeking and printing, which vere introduced later'to archer countries wien she Arabs Degen 0 te with China, In the 12th century, Cheneve deverones the magnetic compass and black powder (gunpouder) Arch nave Brought about srofeund departs on areas germane to the civil engineering ant military eechnologies,

Following the development of more advanced technique of printing, the revival of science by means of this node of tnfcrnetion transfer. took place in 17th and 18th centuries. During this perios, significant advan Eenents vere made in communication and transporta:?en, Canals and locks vere built for inlané water travel ané docks end hardors were improved for ocean commerce, Advances tn thin cesign and covroved method of navi gation peraieted » vide sprese oF unouiecge th

Sed in certain

ia

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because of ths development of printing and the improvements in

?areay of communication an traveportation,

Farly in the 1th century, tk developments provided an tapetus for further technological disci ove, developed by Henry Cort, was the refining ison for mechinery, snd tie other by Janes Watt vas an efficient fitean engine for powerplants to op-rate the machinery. Meanwhile modern Erensportation systeas begen to develop, both by water and by land, @

network of railroads and highvays were bu!lt to tie together the major Cities in Europe and in the United States. During th!s period, schools nd colleges began to teach nore courses tn sctence and engineering. It Wee the training and educatins procerses that set che stage for an explo- Ston of discovery in the tuersieth century.

As the 20th century came into being, a auaber of inventions energed that vere destined to have far-reaching effect on our civiltzatton. The utonobile began to be more widely used. The taventions of Edison and DeForest of electrical equipment and electron tubes started the wide: Spread use of electricity and comuntcation netvorks. Folloving the uoserations by the Wright brothers that wan could bufid a machine that would fly, aeronautic engineering developed rapidly. Within fairly Fecent tiwes, several engineering developments have produced profound Changes in our vay of Life, These developoents are nuclear power, the electronic computer, and aerospace technology.

Frog the {Ilustrattons given previously, it is fatr to say that the beginnings of civilization and the beginnings of engineering are coincident. Down through the ages, the engineer has been in the forefront as a maker

of Mstory. His accomplishsente have had as much impact on world history Gs political, soctal and econonic developaents. Sometines, his accomplich-nents have stemmed from the pressures of need from evolving civilization, dt other tines, bis abilities to produce and meet needs have led the vay for civilization to advance. In general, the engineers do the thing: Eequired to serve the needs of people and thet culture. It 1s plausible that engineering vill continue to play « Key role, as it alvays has since the dawn of our civilization, in applying ectence to the optiaum conver~ ion of the resources of nature to benefit man,

ISSUES ASSOCIATED WITH ENGINEERING DEVELOPMENT

In view of the success which nations have had in applying science land technology to econonie development, though not without considerable Adverse tmpacts or side-effects to the industrialized nations, it sens Useful to review this experience to see vhat lessons can be learned which may be of value to developing nations.

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Population: Associate! -dth Cadusrrfalieation, medica? knoviedge and peblic beslth and sent ary pract?ces, the live birth rate bas been ved; the death rate decreased siqntfteantly, table T shows birth ratec dp several regiors during 2970-1975.

Table 1 BIRTS AND DEATH LTRS, AREA AND DENSITY

_ mS 23 =z

sence nowratn ons "

inca um » mae ?

asa ree ?

Source: World Stattatice Brief, UN Statistical Pocketbook,

th Edition, UN Publication, New York, N.Y.

?The unprececedented grovth in human population is occurring in

thts century, In 1930, the world's population stocd at 2 billion, but

by 1975 - only 45 years later = it Mad Coubled to ¢ billion, Table shows population statistics of varfour regions ?= the vorlé during

1965-1878, according to the sane UN publication cited sbove.

Table IT ROMAN POPULATION

(An millions)

=o =e

a rr rr er

roy meek

enc HOUTEN Mees

awenca, us mom te

a vee nokta

enor us wet

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The worldwide race of popu? stion growth has declined from about

2 percent in 1955 to 1969 to soneching under 2 percent at present.

Nevertheless, overs? populstior continues to rise, Because most of

the population to the world are young and have cheir childbearing

yeaa ahead ;¢ then, chere 1s 4 bulle-{a momentua toverd population

Brevth, This meanc ?that even ?/ {t vere possible to obtain within

The next fev decades a vorié fertility level that would merely replace

the parental generation, populetion would continue to grov for 50 to

70 years thereafter {4

tion picture ts the great disurity between growth ret

loped countries, which average 2.? to 2.4 percent, wie:

loping countries Nave graven races veli above 5 percent (5). This

ea severe drain on resources in developing countries. More=

over, men's burgeoning numbers are not restricted to the Astan and

other developing countries of the world. The United Sti

now has some 230 milli

sin, Phoentx-Tucvon art

corridor, for example, have been bothered by enviromental pollution

and other problenr attributed to the high density of population living ural resources - matertals and

?energy. Viable sources of energy include fossi: ?uels (coal, petroleum,

?oll shale and tar sand), hydro-pover, vind, sunlight, geothermal, and nuclear fission, The bounty of fossil fuels, witch are believed to have evolved from burried organic matter over the courae of ailltons

of year through a conbination of chemical changes ané Zatense pressures from the earth over it, i8 limited, and aot renevabie, Once « barrel of of] te burned, it 1s gone forever.

In 1980, the primary energy production of the world vas extis 0 be 286.65 quadriliion BT's, Coal fAlls 27 percent of the wudget - 8 rate of use that would not deplete known mntury. Crude of supplied about 125.55 te that would exhaust present reserves in of south Asta, and vast interiors of Africa ané South

eople, are energy starved. The

hovever, have been little explored yet. The industrialized regions to

the north, rich in coal and uraniua, are also comparatively well off in

oll. As energy resources Tike in value, they gravitate to the developed

fations, mostly in the ports, where only # quarter of the vorld's popu

Tatton enjoy some 80 percene of its vealth. The qroving d{sparity

betveen these aactons and the poorer ones to the south has created &

Mnorth-south" éichotony in vorié politics.

heats 7

the denand of energy consunption, we confront other {1

be discussed next.

conmumption of energy ts still groving. Aasoctated vith

er = on which will

---Page Break---

ral Resources: At stated previoosly, engineers #140 use

because of their properties = their strength, dura!

fabrication; their ability to tnavlat

Physical and chesical characteristics.

Tt te {mportant to recognise that sources of most mineral mater-

are great and vith nev Glsccverien, e.g., aiotep of ocean nodules,

vastly increace the auovly of several metals considered vital to

Andustry today. For those waterials vaich are vite! and do shore so.

ply in the near-tere, initta? «forts vill focus om recycling, conser

vation through increased prices, and search for syacheticn and substio

foil

people began to recorntze both the eco-

nomic and environsental iapacte of resource explofsstion, angineere

and consumers alike have given a great deal of attention to the peed

for long-term conservation and such a

and, forests, vater and minera: resources, to provide sustained soca

Acondate and enviromental benefit

ver the vext 20 years, ax human sunbers and sence face

rapidly, che enreh'g taretasee, teaberts

fy ane fresh water, aeasapiers nal state®

?plot and antes! species cost? be aesil wate aeveriy seeeeee.

Evol recent studies, ose prepared for the Presiaess sf tie taiten

Stace and the other for'the United Nations Roviczaseneel fait tame

(OnED), warned of » decline te the anrthie empin eee Hee

sould bacone progressively woree unless eatioer a2) Ser ee Pnenae

presene treadh. ?Both The Clobel 2900 Report to toe Seeataese Tt,

Sae'the World Conservation Serstegy [8] eaphesties een teeed

Ssoditton of many of the earth's teneeasle Pesseetons steetee se

Sources essential for haan aurvivel aad urtereis. destteert are

Enerensingly being destroyed or depleted. cs the iaeeela eeeetee

£2 support people ts being trroversibis reduces i> So0h ate eeey

cod" developing countries.

Food: Tt appears that the world has adequate land, water and fertiliser fo grov food to feed ite people, Hovever, tnadequete dietrivurion of food hes eceounted for malnutrition, hunger and fanixe tn many parte

the world. Regtonal fasine ts primarily « probien of resoeree allo= cation and public policy. In the chronically food-ssort countries, vith the assistance and cooperation of the develope nations, sheeid formulate policies that allocate resources to the cevelopeent of agri gulture technology, provide incentives to farmers to increase profes

?thon and create an agriculturel infrastructure, which tecie

portation, irrigation, education, storage facilivis

credit.

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Baviromertal Pollution: As a res 2t of rapid growth tn husan population

See, signe of devertorated physica? environment and

eur) Tegources ?ave become a grave concera, Eaviron-

?zental probless of various spat'a! scale, of 4ifferent nature and

magnitude have been known ?or vars, On? local comunity scale, pho-

Tochemical smog rerulting from "ydrocarbons and nitrogen oxides

exhausted by automobiles, and some stationary sources, exacerbated by frequent and intense sunlight, geography and meteorological factors, hhas been plaguing nary metropolitan areas, e. g., Los Angeles, Mexico City, ete. On a regional scale, the Colorado River system, the largest in the United States, flows mainly in arid regions that have chronic water deficiency for cultivation of crops. In recent years, the pattern of econonic grovth of the basin has gravitate to mining and manufacturing activities from farming. To the extent that lands are irrigated and drained, or that cining, manufacturing, ané municipal vastes fare discharged into the etreans, the vater quality ts affected.

Between ite Grand Lake islet {n'Colorado and Iaperia! Daa, the point of last ator diversions in the Unired States, there vas a 21-f01d increase {9} in the dissoived-solids concentration in the Colorado. Below the mouth of the Gila, the calinity reached unusually high concentrations for several recent years, causing Mexican Government

in 1961 to express concer about the deteriorated quality of water being delivered to Mexico.

?an energy-related {sve celled "acté rain", of sore correctly

actd deposition, has exerged recently as a concern of regional scale to United States, Canada, and nations in Scandinavia. The problem of acid deposition, vhich encompasses dry as well as wet acidic substances, Starts, most experts agree, with the vorldvide burning of fossil fuels. Az pollutants such as sulfur oxides and nitrogen oxtd g vith other combustion products, are dispersed, transformed, and transported With afr masses that form our weather systens. Governments of the United States of America, Canada and Scandinavia, end research institutions in these countries have launched research programs to Adentify, and evaluate the cause-and-effect relationship between acid deposition and {es potential impacts on biotic (both acquattc and terrestrial),

14 abiotic eystens. Once the cause-and-effect relationship 1s ascertained, we need to develop a feasible strategy for mitigating the potential environmental impact,

Another large-acale environmental {enue {s called the "oreen-
house Effect". The earth's tenperature te detersined in part by
thermal balance betueen net incaaing solar energy and heat radiated
from earth's surface into space at longer wavelengths. Water vapor,
ozone, carbon dioxide, and other polyatomte aolecules in the atsom-
here ?affect this heat balance by capturing and radiating back some
fof the long wavelength radiation, ?Therefore, in the atmosphere carbon

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EQUIVALENT FRACTION OF 1

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ciated cut Prop the sat og some of A back ?0 the

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Tre sarch!

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fron foseti foeie earsestie: Nas

Eavhon nince soout

cent pee 1.

atrogpheric curdon

Carnae 3

rei Line the tues

+ ve tnerensine

yee

pnp

"380 1980-2000

(Coy PRODUCTION AND ORSTRED ATMOSPHERIC

(CREASE (ASEIMED 1860 ATMOSPHERIC CONCENTRATION =295ppa)

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Aithough the global carbon budget (4 poorly understood, 46 Bates fit) thie a doubling of atzoepheric carbon dioxide may {nan increase in globally everaged temperature by probably 1-5°C to 3*C, The potential inpacts or regional variation of temperature through a shife in atnospherse efceulation patterns, and on food pro- @uction are dmportane {eaves which require further research.

Nuclear energy say help solve some of our poilutton problens

Aiacussed above, but 1¢ acy give us nev ones, The health, environ~

mental and safety ecves of nuclear energy have entered a field of

Taging controversy since 1970s in many countries. Controversy seems

to focus on the porsible risk of lov levels of radiation exposure

joeiated with the nuclear fuel cycle (uranium i

over generation, vaste aunagenent, transportation

Ing), the low-probability/high-consequence reactor

threat of hijacking, sabotage, and nuclear blackaa:

opening the vorld to.

cidente, the

?bat ve are

?The other concerns over frustration resulting from econoste

?and technological developaent in our modern society may include

and prononie eiscore eteming from the gep Setween the tepacts

Of technology on man on the one hand, and the lazsing capacity for the

Society as 4 vhole to astimitate, adjust and control of the use/misuse

Of technology on the other, At the time when so many novelties are

available to serve the material needs of people, sen feels al

Insecure, and overvhelned by hie technological achtevenents, as tf

trapped on the horns of a dilems, In brief, negative side-effects

of technological changes have posed the menace of personal insecurity

solescence of Knovledge, the rapid devaluation of skills,

on of experience, external diseconomies [12], aod

environmental pollution, ecological disequilibrun and dismmenitie:

2,

THE TASKS AXEAD

So far this has discussed the consistent, practical and rs sourceful role of engineering as keystone in the development of nations Gnd civiltzerions, and identified major {ssues and concerns associa Mth the development in the context of the modern society. Now let Guanine sone entiphtening aspects of the challenging tasks ahead for

(). engineers, vhose functions range from research, developnent, design, construction, production, operation, and managenent, and;

(I1). enginesring societies, associations, institutions and organization, fo carry out the folloving Fesponsibilicie

(2). For engineers as professional people -

A. To prepare and tuprove knoviedge and skills in spectalized fields,

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To accept overs:

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«For engine

. To tmprove means for utilizing these rei

. To explore means for promoting coos

The future engineer muet etily actences and their

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To exercise sound discretion and judgment.

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+ OF the engineer and employer.

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ing soctety as a vhote -

fe means of assessing the constantly changing needs of

2 an the technical resources that can, and should be

applied to then. Assesunent methodologies mes inetude Techno

Jogy Assessment [13], and Benefit/Risk Analysis [16].

To encourage engineering research and development, atsed at

discovering and conserving natural resources of materials, and

forces including the human,

es vith minimal cost

?and vaste, and vith maximum useful results.

ration tn engineering through

the process of transferring technological xnov-now from

culture to another, and specifically from inéustrialized nations

fo loss developed nations, vith a view to aie their fellouen £0

exanine their nation's needs, dts relation to quaiity of life,

the feasible alternatives for meeting their needs, and the social,

econonic and environmental consequences of there options:

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UPADI 82

San Juan, Puerto Rico

August 1-7, 1982

! Congreso Panamericano de Energia

PROGRAMA BRASILEIRO DE ENERGIA NUCLEAR

Por:

Marisa V. Ballariny

FEBRAE, Brasil

Sen Juan, Puerto Rico

Agosto 1987

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PROGRAMA BRASILEIRO DE

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clo do conbustivel, devendo sua execucio levar o Frasil a completa autonomia na reracac de energia nucleo-elétrica.

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upabr 82

San Juan, Puerto Rico

Second National Conference on Renewable Energy Technologies

OCEAN THERMAL ENERGY CONVERSION
RECENT OCEAN ENGINEERING
DEVELOPMENTS IN THE
UNITED STATES

BY

JONATHAN M. ROSS

GIANNOTI & ASSOCIATES, INC

ANNAPOLIS, MARYLAND, U.S.A.

San Juan, Puerto Rico

August 1982

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ABSTRACT

The development of Ocean Thermal Energy Conversion (OTEC) into a Practical source of energy is one of the wost exciting precent day challenges of ocean engineering. OTEC could significantly contribute to the develossent of @ nation; tt would be aa attractive eource of encvay fora macsee oe Bechnical and econoaic reasone

?The United States is one of several nations actively tavolved in the techatcal developsent of TEC. Of particular taportance to the United States? efforts io this field ie the OTEC Ocean Engineering Technolesy Developaent Program uanaged by the National Oceanic and.? Atasopheric Adaintstration (NOAA) under the direction of the Department of Energy, The orc aystens under developzent by NOMA include. the platfore, ?ooriag/foundation, cold water pipe and the sea water syste

Recent developments of the platform systea include totttal designs and Sodel tests of two innovative versions of OTEC Plants: Mooed PipelMobiie Platfore and the Shelf-vounted Platfor=.

Progress in the area of the mooring/foundation system includes studies on anchoring, foundatton-so{l interaction, aooring systea éynantcs analysts, mooring line hydrodynanic loading, and tnepaction, asintenance and resale of nooring eystens.

?The major cold water pipe work ts centered around the 1/3 Scale At-Sea Test.

In the area of the sea water systen, an analysis of an exteting computer code has been accomplished.

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IwrRoDUCTION

The evelopment of Ocean Thermal nergy Conversion (OTEC) into a practical source of energy 18 one of the most exciting present day challen of ocean engineering. In the following pages, receat accomplishaents and ongoing projects of one major contributing program will ve described. This program is the OTEC Ocean Engineering Technology Developaent Program.

DEFINITION OF OTEC

OTEC ts a means by which energy can be obtained from the ocean by taking advantage of the temperature difference which existe between ware surface water and the cold vater at deep depths. This temperature difference te used a heat engine in which the working fluid ts a substance such a

?The heat engine in turn rung an electric generator, and the resultant electricity ts etther conducted ashore by means of a pover cable oF

is used on-site to produce an energy-intensive product such as ammonia or aluntnun.

RELEVANCE OF OTEC TO DEVELOPING NATIONS

OTEC represents an engineering advance which could stgatfteantly contribute to the development of a region which Le geographically situated 20 that it can take advantage of the ocean's teaperature differential, OTEC is an attractive opportunity for # oumber of reasons

© It provides the pover needed by developing industries and exanding communities while reducing their seed for imports such as of)

© The GTEC plant can be constructed where factlities and a tratned Labor force already exist, then toved to a less-developed site for actual use

© The OTEC plant (floating platform versions) can be moved to a alfterent location ae energy needs change

© The source of the energy, the tenperature differential, is free, non-polluting, renewable, and plentiful

© Many developing countries can theaselves bufld all or such of the OTEC plant, thus providing employment for ther own {dustry and avoiding the noed for foretgn {aportss

Figure 1 (lustrates the extent of the estern Hemtsphere's oceans vhere juftictent Cenperature differential extate to support an OTEC plane te the near future. Tt is readily apparent chat much of the potential for OTEC 18

Jecated off ?the coasts of today's developing nations.

THE PRESENT SCOPE OF OTEC DEVELOPMENT

OTEC ts fast approaching econoaic and engineering feasibility, thanks to substantial efforts by any nations, including Japan, France, the Netherlands, land the United States. The focus in these pages will be on work within the United States? OTEC progran.

---Page Break---

Temperature Differential Between Surface and 3,000 Foot Depth, °C

For the Western Hemisphere

OTEC Thermal Resource

---Page Break---

?The vest sajority of the United States? OTEC development ts carried out

through funding from the U.S. Department of Energy. In particular, the

National Oceanfe and Atsospheric Adaintstration (NOAA) aanages the design, and

Research and development projects which together form the OTEC Ocean

Engineering Technology Development Progran and which are extending the

?engineering state of the art into the realm of practical applications

STATUS OF THE NOAA OTEC OCEAN ENGINEERING

TECHNO! xl PROGR

Scope of NOAA's Tavolvenent

Before defining the exact scope of the NOAA OTEC Ocean Engineering

Technology Development Progras, it {@ useful to gain e perspective of the

entire OTEC effort as viewed from an engineering standpoint. The OTEC plant

is normally thought of as consisting of a number of interactive eystens.

Figure 2 shows these aajor systeas for a soored floating OTEC plant and for a shelf-nounted plant. These aystens may be described as follows:

© The Platfors System consists of a hull for the floating verston of ?GHEE, She Telly te fn ehe. shape of 2 ablp, Senaent spars ouase subsersible, or sphere. In the case of the shelf-sounted version, the platfors consists of cupporting structure and enclosures, both above and below the vater. In all cases, the platfora provides support and protection for OTEC machinery and personnel. The platform ay be constructed of steel or concrete, depending on design constraints.

© The Mooring/Foundation systea holds or supports the platfors at its

Hirigned site. and asst Fantion dering have operactonel gon enteses weather conditions. For a floating OTEC plant, the mooring lines may be of wire rope, eynthetic#, chain, or a coubination of these. The sea floor anchors aay be of the drag exbedeent, deadweight, or pile type. In the case of @ helf-mounted plane, the supporting structure may be constructed of steel or concrece.

© The Gold Water Pipe (CWP) 1s a long pipe (or several pipes cosbined) Which transports col? tster up Tow deep acean depths to the ONG platform. The Cx? may be free-hanging, as in the case of the moored Floating plant, or it may be supported by the ocean floor, as fa the case of the shelf-nounted plant. Candidate materials for a GP Anclude steel, concrete, fiber reinforced plastic, and a nusber of elastoners,

© The Sea Water Systen (SWS) 1s comprised of the piping, pumps and

Tea aren a semesant of he pling, rare end

plant. The heat exchangers are particularly important, and thelr

design sust ensure an efficient use of the tenperature differential

detween ware and cold ocean waters.

© The Power Transmssion Systen consiste of one or several cables

Which traienit the electric power of the GTEC plant to a shore

grid. For the soored floating plant, the cable must withstand the

---Page Break---

5

MOORED FLOATING PLANT

SHELF-MOUNTED PLANT Power System

Figure 2

Major OTEC Systems

---Page Break---

6

dynamic loads induced by vaves and currents acting on the platfore

and directly on the cable.

° Power System includes turbines and electric generators and

?Converts Te sneily of the vorbing?elutd go wheter

Of these six systens, the first four have been addressed by the NOAA OTEC

Ocean Engineering Technology Developsent Progran over the past flve yeate and will be discussed in the following sections. Table I sunartzes the current

and recently completed projects which are aimed at soiving critical technical lwaknowns and reducing the technological risk associated with the OTEC syste

Platform Systes

Two sajor design projects tavolving the platform systen have been Kecently completed. They were started in the second half of 1981, and were aimed at tavestigating specific new concepts for OTS plants ?through combination of design work and sodel tests. A systens analysts approach was used in both studies which {nvolved al1 the major OTEC aystens currently under Anvestigation by NOAA; hovever, the major innovations tavelved the platfora aystea. The fret of these OTEC platfora concepts is referred to as the Moored Pipe/Mobile Platform (MP-Squared) and it ts a hybrid of a noored floating plant. The second concept is shelf-nounted platform with discharge 4nd cold water ptpes sounted along the ocean floor slope dow to depths of 3,000 feet and at slope angles of nore than 30°.

Moored Pipe/Mobtle Platform Project

MP-Squared ts an OTEC concept in vhich the CYP is permanently moored at the working site but the platform {2 gobile and aay be disconnected fros the GHP during etses of severe storm conditions or in order co proceed to a shipyard for maintenance or repatr. Two versions of MP-Squared were developed: the platform of one ts ia the shape of a ship, while the platforw of the other {8 in the form of a sent-subuersible catecatan. They ave Allustrated {a Pigures 3 and 4 respectively. The former provides an econoale Platform, and in large sizes gives good stability; the latter provides excellent stability even at snall sizes, albeit at a prenius in conseruction and maintenance costs. A range of platform sizes was considered, as shown tn Table IL, with overall lengths ranging from 399 to 662 feet for the chip version,? and from 369 to 631 feet for the sent-submersible version. Both versions were connected to the CHP by means of a transition platform. The Eransition platform acts as an interface between the surface platform and the (HP; provides buoyancy to support the CWP when the eurface platform is Aaconnected and off site; and is the platfors to which the mooring systen te attached, For the ship-type version, the transition platfore was connected directly to the surface platfore. For the sent-submersivie, a trassition Cu? Linked ?the two platforms. This link was to help ieclate the CHP from the surface platfora motions, but in practice did? not provide signiticant teolation.

Models of both versions of MP-Squared vere tested 4n an experimental wave

facility. They were subjected to operational and 100-year store wave loadings

representative of a Puerto Rico OTEC site. The seas were represented by

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RECENT ACCOMPLISHDANTS AND PRESENT PROJECTS OF TIE NOMA OTEC TECINOLOGY DEVELOPMENT PROGRAM

---Page Break---

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Figure 3

Moored Pipe / Mobile Platform (MP-Squared) Ship Version

---Page Break---

10

Discharge

(omer 2° omaltted for clarity

Riser Cable

Figure 4

Moored Pipe/Mobile Platform (MP-Squared)

Semi-Submersible Catamaran Version

---Page Break---

?_??_??

Surface Surface orec Plant

Platfors Platfors Net Electrica?

Dispiacenent Length output

(long Tons) (Feet) (tie)

?___ a

68,200 398 40

136,400 500 100

SRP

220,800 578 265

333,200 662 460

a

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147,000 465, 100

SEME~SUBMERSIBLE

238,500 549 185

354,100 63 240

Sane

TABLE IT

YE-SOUARED PLATFORY SIZES CONST

---Page Break---

Bretschneider vave spectra. The odele were instrumented to provide easurenents of platform motions and eooring line atresses. The teat resulte Geferences 1,2) indicate that both platfora types would survive the storm loadings while moored and while disconnected from the moor. The shtp-type Platfora operated well for large sizes, but in enaller verefons its notions Were at tines too large for OTEC plant operations. The seat-submersible operated vell at all sizes tested. In sum, it vas concluded that the HP Squared concept holds promise for application to the design of a practical moored OTEC plant.

?Shelf-Mounted Platform Project

?The other major platfora system design project involves the shelf-nounted platfora (References 3-5). This project had at its goal to review, anelyze ?and compare ocean engineering aspects of past and new conceptual designs applicable to the shelf-nounted type of OTEC platfore. Included were considerations of platforms, discussed here, as well at considerations of GWP's, discussed below. The project addressed a generalized site rather then @ specific site, and vas concerned with the areas o!

dei

Construct ton

Deploysent and Installation

Operation

Survivability Loading.

?The study included a comprehensive look at applicable offshore petroleus technology and the development of Inittal concept designs for eight verstons of shelf-wounted platforms. A model test program ?= presently planned for the second half of 1982. Plant size 1s 4) Mia net generating capacity, the size of a exall commercial unit.

Examples of current applicable offshore technology, shown in Figure 5, Anclude designs presently in place or now in the design evages

Conceptual Deepwater Articulated Drilling/Produetion Platform

Ekoftsk O11 Storage Platform

Malt{ple Tover Production Complex

Condeep Type Gravity Drilling/Production Platform.

The eight initial concept designs of OTEC ehelf-nounted platforas were taken through to an equal level of development, {ncluding ?a Listing of advantages, disadvantages and applicable eite water depths. Limited space prohibits 's discussion of all eight concepts here, so two concepts are Presented as representative of the study. The first concept, Wultiple Towers with Submerged Power Pack, 18 chown in Pigure 6, For this concept, steel is used for platform construction. Deployment {s in three steps: base structure

te Launched and set in place with piles; the tovers are Launched, lovered and

connected: the platfore 1s then lifted into place or mated by a subeersible

barge. The advantages of this concept are:

© Easiest system to expand capacity

2 Seallest vater plane loading area

© Straddied transfer of heat exchangers and supplies

---Page Break---

WATER ARTICULATED

(G/PRODUCT ION PLATFORI

MULTIPLE TOWER PRODUCTION COMPLEX

Figure 5

Examples of Offshore Technology

Applicable to Shelf-Mounted OTEG Piants

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15

w completely topetce for safety

© Conventent seavater purp changeout

© ?-Méntaus foundation preparation needed.

ages of this approach include:

© Subsea heat exchanger connections

© Long and costly at-sea installation

© Ror relocatabie.

?The other representative example ts titled Gravity Structure with Yoon Pool Power Pack and is shown in Figure 7. This version is construcces oe Concrete, towed to the plant site, then flooded, bailasved. and grouted Ia Place. ?Advantages of the concept are:

No eubsea heat exchanger connect ton

Heat exchangers and pumps are pulled/tnse!

Flow channels are incorporated tate the structure

Lttle at-sea construction

Excellent inspection, eatntenance and repetr qualities

Jerlan wall acts as Gave absorber and vara uaver intake, fed in a protected

?The disadvantages are:

© Reavy foundation load

© Extensive foundation preparation may Se necessary

© Relatively poor adaptability to various sites.

?The Shelf-Mounted Project, {n susmary, gave a engtncering state-of-the-art applicable ta OTC aystens; produced a noaber at Posoible concepts for shelf-mounted OTEC planta; and identified avantages and disadvantages of the vartous concepts which were considered, | The ahekte ounted approach is currently considered quite viable sy the ?Departaene of Energy, a8 evidenced by its recent avard of tvo OTEC Pilot Plant comertust design contracts for such a plents

Mooring/Foundation Syste

Recent progress in thie area te represented by several studies dealing With anchor-seaftoor and foundatton-structure tnteraction;, aooring Line behavior; and inspection, matatenance and Tepaits

spective of the ocean

Anchor-Seafloor and Foundetton-Structure Interaction

In [the area of anchor-seafloor and foundation structure interaction, these studies have been carried out. ?The fLrst was an aesesvaent of anchor holding ?capacity and bottom stability daa (References 6.1). The objective ws to develop an analytical toot to evaluate the certs of vartou anchocs os gystepiag sea floor. Major findings to date indicate that oftchore Ravatt the ost promising anchoring procedure would be drilling and. grouting of piles. Offshore Puerto Rico, gravity eabeduent anchors seauatd of the OTEC Platform could be used in ?deep vater vhere heavy tedinetation extsces alternatively, drilling and grouting of piles would be required aeseshae

---Page Break---

ew x

?Seale in fast

Figure 7

Gravity Structure With Moon Poo! Power Pack

0

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v

Riera the Dottos is prinarily vock, Another finding inéteates that the cost!

Setting ety Large gravity anchors aay be essentially che ease cs eee

SRIIZIRE 22 Srouting. "A second study in thie area consists of tnvestieatiog shelfsounted platform and cold water pipe foundation-sot! interaction ane objective {3 fo Adentts; 18 and geotechnic da

Fequirenents for deteraining the interaction effects between foundations, he Geaflocts and sub-botton strata, Included in thie etudy 0 she development of design procedures, the selection of s viable slope-rounted GP foontariog Concept. the performance of a prelininary bathymetric eurvey of one candthare OUEC site, and establishing a model for the interaction becueen foundering wea feafloor. | As of chis writing, the protect is in progress and fiadicne are expected by the end of 1982, The third area involves the geophysical melyere Of eight sediment cores obtained near Kahe Point, Oahu, Haweils inclodes te an fssensaent of the geophysical properties and the bottom conditions fee siting floating a shelfmounted OTEC plants. Te analysis ts

fand the final report te in preperation.

Mooring Line Behavior

behavior, two studtes are noted. The first

ics analysis and component daca base ase

The ?study calls for a deteratnation of the capability of ?che

Engineering Laboratory Deep Sea Ship Mooring Analytical Model to stectate tec

dmnantc response of cored OTEC platforms. In addition a survey aed teckntee

aesessnent are being performed of candidate OTEC sooring ?couponente eat

gautpeent, and a data base ts being developed to mae ?this tctecaaten,

available in an orderly and up-to-date manner, A second study ta ths meena

Concerned with mooring Line hydrodynaste loads analysis. In this) stady a

Rethod was developed which could be used to predict integrated wave and

current hyérodynanic loading by the ocean on OTE mouring ?lines wink

particular enphasis on the drag increase due to vortex shedding: Ustag nin

faghod, docunented tn Reference (8), drag increases that are cacsed by voxseee

induced vibrations can be reasonably estinatod, Inspection, Maintenance and Repair

ebird area of ooring/foundatton eysten technology developaent favolves inspection, watntenance and repair. Two studies are telated to chic area. ett, {its study constees of determining undervacer iaavectesy guldelines, Anstrunentation, equtpaent, aad data retfieval systens vhick wllt be giaguized for inspecting and nonitoring the structural, and operarteast conditions of OTEC systens. This etudy te vell undervay; a iterators seeney wereclamPleted. early OTEC studies reviewed, and typical example aysteas eae eet for evaluation. In a conplenentary study, an asscesuent {a belay gade on tools and techniques which are applicable for tnepection, maletereace and repair. | These tools and techniques are for underwater use, mal ace SHEET Presently evatiable or would be avatlable in che aest futures. They yould be directly applicable to the Inspection, watacenance and repatt ey large underwater structures, vessels, and work platforas steitar to thene thor way be used for OTEC systens.

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Sold Vater Pipe,

?The OTEC CHP is a aystem which has received a grect deal of attention within the SOAK OTEC Program. Both the free-hanging and the shelf-mounted versions have undergone study and continue to be focal points of technology developaent efforts. Although in past years various types of OWP's have been ?studied ~ steel, concrete, flexible, and fiber reinforced plastic ~ the recent focus has beea on only ont ?a sandwich construction eonolithtc fiber reinforced plastic version. Ir is felt that hte version holds the best potential any OTEC applications, based on techateal and. cost Considerations.

?The five recent GHP efforts - some still in progres

completed - include computer studies, conceptual de

materials studies, and the desiga, construction and deployment of a large scale test pipe.

CHP Laboratory Test Progran

?This was a comprehensive progran which consteted of an in-depth study of the OTEC ?fiber reinforced plastic OKP. The effort, now complete and documented by References (9-11), obtained inforaation on:

0 Matertala behavior in an OTEC environment,

© Platfora/CiP response

© Towing and deploysent procedures.

To obtata information on materials behavior, @ Literature search was conducted and an extensive static and fatigue testing program was initiated. Because of cost difficulties, che full testing was not accomplished; however, information vas obtataed on resin foreulation, core saterial composition, and core material structural properties.

Platfora/CHP response {nforaation was generated through the successful execution of model basin test and data analysis effort. Model CuP teats Were conducted using a ship-type moored platform with s suspended CWP in a. odel basin equipped with a deep sea testing pit. Using an interchangeable internal stiffoner arcangenent, rhe pipe'e etiftness was changed to nodel not only the fiber reinforced plastic version, but also a cable reinforced elastoner GiP and an articulated steel shell Ov. 183 test rune were performed, and there vere 60 instrumentation data channels. Model results were compared to the NOAA/DOE and NOAA/ROTECF frequency doaain computer codes ?and the NOAA/TRW tine domain computer code. It was found that the NOAA/ROTECF ?and NOAA/TRM codes closely predicted the test data; NOAA/DOE was consistently Conservative in ite prediction by up to several orders of magnitude. Also it

found that the articulated pipe confines most of the otions to within the first pipe section with only slight motions in the lower sections.

Towing and deploysent procedures were aleo {nvestigated by model testing, thie tine simulating only the fiber reinforced plastic CP. Data was réing tov stability, towing resistance, heading Tinttattons, ptpe saneuvering characteristics, and deployment loads on the pipe during its swing dovn at the OTEC aite. Three towing depths were tested: afloat, avash, and fully subserged. Major findings include:

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© Phpe stresses during towing teste folioved expected trend:

however, signiticantiy lover peak stresseo than predicted were

observed

© Pipe stress levels during coving were highest in the awas

condition followed by afloat and then fully submerged

© Uending of a positively buoyant pipe results in high bending

stresses at the water surface interface.

Fiber Reinforced Plastic CWP Materials Test Plan

In view of the incomplete material testing fron the CHP Laboratory Test

Program, it vas decided to

jan and carry out further material testing. The {iret step was the present program, which involved the preparation of a plen

for testing fiber re{nforced CvP asterial. Reference (12) presents the plans

which outlines testing requirements and also pointe out that fiber reinforced

Pl

te sandwich structures

y require cyclic weakening teste {na sea water

This effort, coupled with that described in the previous section, lead

Logically to @ program presently in progress, which is described directly

below.

Te

1/3 Scale At~Sea Test

W/3 Scale At~Sea Test 1s the largest ongoing effort presently

Supported by the NOAA OTEC Progran, The 1/3 Scale At-Sea Test objectives are

The effort te divided into three pha

L

2

© Design, fabricate, and deploy at sea a 1/3-ecale fiber

Feinforced plastic? model CWP of a 1,000 foot long, ?30 fost

Alameter prototype CHP required for a 10 My OTC plant

© Demonstrate fiber reinforced plastic technology for large scale

o's,

Design the CWP, develop test plans, obtain permits, and conduct

natertals testing

Deploy and monttor the CWP, suspended from a moored vessel

Deploy and monitor the CHP, inetalled on a steep underwater slope

Phase 1 has been funded, is in progress, and prelininary reporta have been gompleted (References 13-15), The design of a 10 foot dlancter, 1,000 fost

long pipe is well undervay; ttt

2 1/3 acale (in diameter) ?model of a

40 Mie OTEC CWP. This model ts show in Figure 8, and detaile of the structure are given in Figure 9. The structure ts of a ?sanduich? type construction, with a syntactic foan core placed between tamer and ovter layers of fiber reinforced plastic. The fiber reinforced plastic layers provide

strength,

and the foam ensures a constant separation of those layere and a

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UPPER TRANSITION

(STEEL)

Sdamo CIRCUMFERENTIAL

SO FRET (TYP) SPLICE JOINT - WET LAYUP.

20 FEET (TYP)

CIRCUMFERENTIAL

10 FEET (TYP) STIFFENER RINGS (FRP)

FRP SHOULDER (FRP)

BALLAST SYSTEM

STEEL BOX BEAM

WIRE ROPE

CHAIN

BOTTOM WEIGHT

Figure 8

1/3 Scale Cold Water Pipe Model

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Tesultant increased bending modulus. Circumferential etiffener rings are Placed every 20 feet along the pipe, sad the pipe 1s manufactured in 40 foot Seguents which are spliced together prior to deployment at se

An overview of the suspended at-sea test ts showm in Figure 10. For thie test, to be conducted off the coast of Oahu, Nawalt, the pipe will be assenbled fron 40 foot sections on shore, launched as one unt: into cala waters, toved (supported by floats) to the mooring wite, swung dom, and then attached to the supporting barge.

?There will be a comprehensive suite of instruacatatfon to monttor the Wwipaent and the environment while the CWP is being deployed aad during festing at sea. Equipment instrusentation vill be placed on the pipe. the gimbal, the moor, and the platform; measurements will be made for strain, acceleration, pressure, deflection, load. and angle. Bavironnental instrumentation will measure ocean waves and currents, and atr temperature, wind velocity and baronetric pressure. Monitoring of ¢ critical group of

signals (e.g-, gimbal load, gimbal aagte and pipe axial etratn) will eave place during operatio: ALL instrument data vill be recorded for test Gocumentation and analysts, and a certain amount of data analysts will be performed on site between active testing periods. The data acquisition systen (recorders, sonstors, tntcomputer, printer, etc.) will be in an ate conditioned van on the barge for the duration of teeting.

Pindings to date for thie progran are:

© Material tests indicate that the fiber reinforced plastic lantnate strength properties meet or exceed thelr design values. The Hlatwise tensile tests produced an average value of 1,087 psi in the laninate ~ a safety factor of 2

© Gore and core-to-face honda provide stab{lity to the lamtnates up to full face sheet strength capabilicy

© Matertal tests of Joints indicated that all proposed Joints have

goo! strength characterteticss

Shelf-Mo

eed CUP Study

A stentficant portion of the Shelf-Nounted Platfora Project, described earlier in thts paper, concentrated on the CMP, which in this case fs teself ?wounted on the sea floor. In the case of the shelf-xounted platform, direct contributions could be expected from offshore technolosy advance; however, this te true only to a small extent for the CAP, as ptpes of the required lengths and dianeters, Installed on slopes of over 20°, have never deed attempted. Eight GiP concepts vere developed. cach ?with a etfferent foundation desig

1. Noncircular Heavy Jointed Pipe Resting on Hotton

2. Flexible Buoyant Pipe With Anchor-Gulde Ra??

3. Segmented Rigid Pipe Supported on Files (deep water installation)

4. Seguented Rigid Pipe on Botton ?rack (shallow water installation)

5. Segmented Rigid Pipe on Raised ?Track

6. Rigid Buoyant Pipe With Anchor-Culde Ratl

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7+ Heavy (single or stockade) Pipe Resting on Botton

Tunnel.

For each of these, consideration vas given to construction, deploysent, and installation; all? were compared by Listing the?r respective advantage and disadvantages. ?Sketches of the concepts are presented in Figure 11,

Validation of NOAA/TRY Code

This study tavolved a computer program vhich te # three dimensional thin shell analytical model for use in analyzing the CHP. The object of the

to validate the code using experimental data obtained from
8 of the CHP Laboratory Test Program, described above. The
NOAA/TRW code was found to be within 10-20% of che experimental data, which 18 considered acceptable for design applications,

Recent work on the SHS consists of an analysis of the S¥S Analytical

Yodel. The SWS analytical model is computer code which sofels the OTEC SvS im steady state and transient conditions, and is design tool for use on conceptual and existing OTEC plants. Included in the analysts was @

documentation of the theory of the model. Also a partial validation of the sodel was carried out by comparing numerical analyses with nodel predictions for 11 steady state and 4 transtent cases at the component (subsystem) level. In each case, the sodel compared well vith. the sumerical calculations. In addition, the aodel vas applied to the OTEC-I SWS and the results provided a quantitative picture of that syste in operation.

?concwustons,

From the foregoing it can be eeen that the NOAA OTEC Technology Development Progran ie continuing to contribute in a dynante and meaningful way toward OTEC from the concept stage to the real of technical and econonte practicality. As OTEC matures, it offers a most attractive option for helping fo fulfill the energy needs for the development of suitably-located coastal nations.

The experimental data, analytical odels and design documentation

Atscussed in ehis paper are avatlable for use by the OTEC community of the

United States. Requests for any of this taforeation say be directed to the

NOAA Office of Ocean Engineering.

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Fégure 11

Shelf-Mounted OTEC CWP Concepts

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?August 1-7, 1982

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DETECTION OF OTEC EFFECTS ON OCEANIC ZOOPLANKTON

By

Paul M. Yoshioka

and

Daniel Pesante

San Juan, Puerto Rico

August 1982

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ABSTRACT

Zooplankton in the surface waters were sampled at the OTEC

nchnask site off Puerto Kico at binonthly intervals over

fone year period. Zooplankton components analyzed were biomes

najor taxonic groups (copepods, chactognaths, lervaceans). and

four representative copepod species. Sampling variability for specific zooplankton categories ranged from 1-18 fold to ¥.00

fold with a median value of 1.56 fold. Power testing indiceced,

that a pinimum OTEC effect of 1.25 fold could be detected with

the present sampling effort. Purther consideration indicaced that gexpling resolution would be more effectively improved by Setemining factors underlying microscale dispersion patterns of cocplankes Father than by increasing sampling effort,

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Estimates of the abundance of planktonic organisms represent an important aspect of biological oceanography research. The reliability fang utility of such estimates ie often determined by its associated variability. For exanple, the ability to statistically discriminate temporal ox spatiel differences in abundance ss largely dependent

pon the magnitude of sampling variability. In a more specific case,

an Ocean Thermal Energy Conversion (OTEC) plant hias been proposed for the oceanic waters near Punta Tuna, Puerto Rico. The ability to detect the effects of an OTEC plant on the oceanic environment will be eapensent fon the magnitude of its effect relative to sampling variability.

During 1980 the Marine Ecology Division of the Center for Enezgy and Environment Research conducted an intensive physical, chenicel, and Biological survey of the cccanic ecosystem Off the south coast of Fuerte Rico. Biological measurements foceset on chlorophy!l concentrations, primary productivity, and ooplankton abundance. Ro isportant eo0 of the program as to determine the effect of natural environmental factors 5 seasonal changes and day/night effects on zooplankton abundance.

In this paper we discuss the Implications of this progran with

Fespect to statistical detection of OTEC effects. Although the Guali- tative effects of an OTEC plant are largely unkown et present, the sanpling variability measures in this program permits an evalustion of the direction and feasibility of future OTEC zooplankton studies. Fer example, the sampling effort required to detect O7=C effects uf given magnitudes can be estimated with conventional power testing technigues. Also, features of an optimal, cost effective sampling program con be determined by examining the role of various factors on the sarpling effort required.

METHODS

Zooplankton were sampled by oblique tows from the surface to 100 m with a 75 cm net equipped with 202 1m mesh. The volme of vater filtered was estinated by 9 digital flowmeter mounted off-center in the net routh ow duration was about 20 min. The CTEC site (17" 51.3°R, ?5* 51-5"") was sampled at binonthly intervals in 1980 beginning in January. ?Three replicate day and night tows were taken during each sampling period.

Zooplankton biomass was measured by volure Gicplacenent (xhistron and Thrailks11, 1963). Counts of the remaining zooplankton catesaries Were besed on subsamples obtained with a Stenpel pipette. Pasor soo.

Plankton categories examined were total biomass; tovel copepods; eoval

chactognaths; and the dominent copepod species Clausocalanss furcatus,

Qithona plunifera, Calocalanus parva, and Paracalsias parva.

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Date vere enalyzed principally by parenetric analysis of variance

(200VR) techniques. major assimptions Of ANOVA include normality of

@istribution and equality of variances within groups. The data were

og transformed to conform to these assumptions. in ANOVA totel vari~

ability (in the form of sums of squares) is partitioned into fixed

or random effects, interaction effects, and error terms. Statistical

Significance is based on variance ratios of fixed, random, or inter~

action effects relative to error. In this study error would be equiva-

ent to sampling variability, fixed effects to day/night and seasonal,

@ifferences, and interaction to the interrelationship between Gay/night

land seasonal effects.

Fower testing procedures were bated on the formita given by sokat

sna reba 3a)" A

me?

2

(ag ae t Ep -P)e ee

where n= # of replicate samples

© = sampling variability in standard deviations

& © magnitude of (OTEC) e!

@ = alpha (Typex) error

af = degrees of freedom

(1-P) = power of the test

RESULTS 4

tp Result s of the analysis of variance are given in Table 1. with

?the exception of Paracalanus parvus end Oithona plun: bignly

Significant differences in zooplankton abundance are evident anong

cruises suggesting seasonality in the zooplankton community of the 4

Caribbean. ?This conclusion contradicts the classical view of little

Seasonality in tropical habitats. fio strong evidence was found for Gay/night differences indicating that the zooplankton categories examined do not aisplay diurnal vertical migration or have migrations confined to the upper 100 m. Also, no strong evidence for interaction between season~ al and day/night effects is apparent.

Sanpling variability expressed as error sidan squares ranged fron 2.0051 (total copepods) to 0.0905 (Paracalanus parvus) with a nedian value of 0.0373. When transformed to a proportional scale these mean squares (or variances) are equivalent to standard deviations of 1-18 fold to 2.00 fol with a median of 1.56 fold (e.g., 1,18 fold = antilog 4 10.0052) ®-5)).

Estinates of sampling variability are integral in estinating the number of samples require? to detect OTEC effects of given magnitudes: For instance, how neny samples are needed to be 90% certain of detecting fan OTEC effect of 1.5 fold at the 0.05 level of significance? The 2V 4 probability constitutes the intended power of the test and is detuned

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as 1,0. 8. where B is the bete or Type 11 error (0.10 in this example). The 0.05 represents the more familiar Type I or alpha (a) error, Ioeslty, both types of error shoulé be minimized. Under the conditions staves above and with sampling variability of 1.18 fold, 1.56 fold, and 2100 fold, tho number of replicate samples required are 5, 26, and ¢2 sen spectively, (Pigure 1).

?Toe megnitude of the alpha and beta errors represents subjective eriteria chosen by the snvestigator and will affect the sample size required. For example, in the ecologicél literature alpha levels gre selected for statistical significance usually range between 0,01 ana 0:20 with 0.05 a5 the most comonly chosen value.? Fer instance, given senpling variability of 1.56 fold, an OTS¢ effect of 1.5 tela, andy Poter of 9ON, the nimber of replicate samples required for alghe jecels Of 0.03, 0.05 and 0.10 would be 37, 26, and 21 respectively, eimelen Yariations in the number of replicate samples required resuit if the intended power of the test is modified,

an inspection of Figure 1 reveals that the ratio of sampling vari- ability to OTE effect has the greatest inpact on sarpie sire Tosuirewent. For instance, for an elpha level of 0.05 an? a 2-25 seid olse crinee Feduotion of sampling variability from 2.00 fold to 1.%6 gold sorseapords to a decrease in sample size requirenent from 202 to 03.

DiscussioN

Processing of zooplankton samples is costly, tine consuming, and Requires tho skills of highly trained personnel. In esvence, eaepie processing traditionally constitutes the limiting factor and boreieveck Am zooplankton survey and monitoring studies. For eanle, each seen Plankton sample in the present study represents roughy 30 misstes of

ship and field personne) time and costs sbout £100 to acquire, Ia com Parison, approxinately 3 man-years were spent procescing these seaples

for an average cost of about §200 per sample. ?Thus, an inportant criteria 48 designing an optinal sanpting program would be to minimise the numer of replicate samples required in view of the expertise, time and monetary constraints involved.

sampling strategy whorein sarple size Fequirenents are minimized is largely determined by the interselacion ship between alpha and beta errors, sanpiing veriauilsty, and ore affects, OTEC effects represent the unknown element in this ansiysie and is robe Diy not subject to elteration by the snvestigator. Both alpha and Leve errors represent criteria chosen by the investigator and have only @

noderate effect on sample size requirements. Thus, the resvsee relia bility of data interpretation resulting {rom a relaxation of siphe end Bota error would only be accompanied by a moderate decrease in eosphe

size requirenent, This trade-off is probably ineffective and uvieeirable. Alternatively, a reduction of sarpling variability represents the most Prenising means of optimizing sespling stratery. ?concequentiy, at ie

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of utmost importance to define the various factors contributing te ?anpling variability.

When arranged in a hierarchical manner, sampling variability can be daconposed into several components ranging from (1) counting or measuring error, (2) subsampling error, (3) net tow errors, and (8) natural variability (* dispersion pattern). The first three factors Yepresent the commonly accepted concept of sampling variability as

unan or experimental "mistakes". An examination of the laboratory methods used in this study indicated that cubsampling and counting (measuring) error constituted only a small fraction of the observed sampling variability. Thus, concentration of effort in these areas would only result in a moderate and ineffective reduction in the sampling effort required. The role of variations in field techniques (including mechanicel sfficulties) has been traditionally @ifficult to determine An biological oceanographic research. However, it should be noted that, the variability observed in this study is comparable to results from other areas with net caught zooplankton (Kiebe, 1971).

?The natural Gispersion pattern of zooplankton probably constitutes the greatest source of the sampling variability and consequently repre~ sents the key to an optimal sampling design. in camuon with other marine environments almost without exception, the zooplankton off Punta Tuna are dispersed ?patchily". Patchiness, in turn, is reflected an high sanpling variability. Although patchiness arises from natural environ mental processes and is not subject to experimental manipulation, it must be noted that the same is not necessarily true for neasurencnts

(of sampling variability. Meacurenents of natural sanpling variability Fesults from an interaction of the scale and intensity of natural dis~ persion pattern with sanpling technique (e-g., tow length, volume Hltered, net mouth size, ete.) For instance, it may be possible to minimize sampling variability by taking Jong tows which ?average out? Snall scale patchiness of gooplenkton. The optimal conpromise between the number and size of samples would consequently be highly dependent upon the details of couplankten dispersion pattern. Once such details are Known, it may be possible to design a sampling strategy optimizing

the trade-offs of tine, personnel and corte involved

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ankton Copponents at Benchaark.

SQUARES

Degrees of

Source Freedon Copeneds tarvaceans chactognaths Sue Eis Live

Months 5 s120"*" ?agzn"** ?.2610"**

Day/tight 1 0502" .9a7e"" 0059) ozs w3aus"*

Interaction 5 0142 .0072 0362 0658 «130.218.0705,

Error 23 .0119 0081 0251 0361 "0905 .0530 .0384

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+1 =p oo

see = p £0,001,

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LIST OF FIGURES

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UPADI 82

?San Juan, Puerto Rico

?August 1-7, 1982

?Second National Conference on Renewable Energy Technologies

CCEAN THERMAL ENERGY CONVERSION (OTEC) HEAT EXCHANGER

BIOFOULING AT PUNTA TUNA, PUERTO RICO

By

Donald S. Sasscer ~ Thomas 0. Morgan

Center for Energy and Environment Research

Thomas R. Tosteson ~ B.R. Zaidi

R. Revuelta ~ 5.H. Iman

Department of Marine? Sciences

University of Puerto Rico

Mayaguez, Puerto Rico

San Juan, Puerto Rico

August 1982

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OCEAN THERMAL :NERGY CONVERSION (OTEC) HEAT EXCHANGER

BIOFOULING AT PUNTA TINA, PUERTO RICO

Donald S. Sasscer

?Thomas 0. Morgan BR. Zaidi, R. Revuelta

Center for Energy and 8-H. ?Iman

Environment Research Devartment of Marine Sciences

university of Puerto Rico University of Puerto Rico

Mayaguez, Puerto Rico 00708 Mayaguez, Puerto Rico 00706

ABSTRACT

?The Center for Energy and Environment Research has conducted two in situ studies of biofouling of simulated heat exchangers at a potential OTEC site off the southeast coast of Puerto Rico.

?The first study was of 13 months duration, while the second study was of 6 months duration, On clean surfaces, fouling rates were initially slow, but after a coupje months exposure fouling cates were approximately 0.25-0.30 £t*-hr-°F/Btu-day. Fouling rates Were the same for aluminum and titanium tube-and-shell-type heat exchanger elements and for a rectangular cross section element from a compact heat exchanger developed by The Trane Company. During the second deployment, one titanium unit was chlorinated for 28 minutes daily at the level of 0.5 ppm. Fouling resistance of this unit remained near zero for the duration of the experiment. All other units had to be cleaned at 2-4 week intervals in order to maintain the fouling resistance of th

biofouling Layer within acceptable limits. Brush cleaning did not reduce fouling resistance to zero, indicating the development of a hard bottom layer which adhered strongly to the metal sugfaces. Fouling resistance of this bottom layer was 0.5-0.9 fet-ne~°x/atu.

INTRODUCTION

Ocean Thermal Energy Conversion (OTEC) is a promising system for using solar energy to generate electricity for countries which lie in the tropical zone of the earth. One of the major difficulties which OTEC technology faces is the reduction of heat exchanger efficiency due to the development of microbial communities on heat exchanger surfaces exposed to Seawater. In order to better understand this phenomonon, the Center for Energy and Environment Research (CEER) of the University of Puerto Rico has undertaken an intensive in situ study of biofouling of simulated heat exchangers at a potential OTEC site 2.1 mi (3.4 km) Off the southeast coast of Puerto Rico (figure 1). "The investigation was conducted on board a modified Landing Craft, Utility (LCU) which was moored at the site. The

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LCU was deployed on :wo occasivns: the first deployment began on 29 January 1980 ano was term nated on 19 Maren 1981, and the Second deployment ran from 25 May 298] to 28 November 1981. Presented here is a summary of ?esults of experiments to quantify the effect of biofouling on weat transfer in seawater heat exchangers along with result: on tne effectiveness of some biofouling countermeasures.

MATERIALS AND METHOD:

A schematic of zhe flow system is given in figure 3S Seawater was drawn irom a depth of 55 £t (17 n), passed at a rate of 6 ft/sec (1.8 m/s) through 4 experimental nodules which simulated tube-and-shell heat exchangers, and was discharged Overboard. Modules 1 and 3 tested aluminum and modules 2 and 4 tested titanium. uch experimental module (figure 4) consisted of four parallel fiow loops. One loop contained a device for monitoring heat traasfer (HTM) (1) mounted on a 1~inch (2.5-cm) id, pipe (5052 aluminum or grade 2 titanium), and the remaining 3'loops had sacrificial tubes (1-inch i.d.) of the same metals, which were used for biofouling and corrosion analyses.

For the second deployment, a special beat transfer monitoring device (STM) was mounted on module 3, and an electrolytic chlorinator was installed between the pumps and module 4, The STM monitored heat transfer on a sample, rectangular cross section water passage from a zinc-diffused, 3003 aluminum, compact heat exchanger developed by The Trane Company (2).

Heat transfer in the units was measured at regular intervals. Fouling resistance (Re) was defined as the normalized inverse heat transfer coefficient (1/h) measured on a given day minus the l/h measured on the first day of the experiment (1/h9)- A more detailed account of the experimental set-up can be found in an earlier publication (3).

the Em's and STM vere cleaneg mapually with nylon bristle brushes unen Ry exceeded. 5 108% Fresh Oryaeu.? bucing the First deployneht, nIN's were cleaned with 40 brush passes in an attempt vo redvce Ry to zero, while during tne secord Seploynent. four beugn pgsoce, were used to cleanvthe unite to approximately 1.x 10" fe2-nr-°r/atu. Unit 4 was chlorinated for Berminutes per day at the level of 0,3 ppr during the second deployment, and it was never necessary to brush this une.

---Page Break---

RESULTS AND DISCUSSIUN

?Throughout each deploymen:, uninterrovtes flow through the modules was maintained. Figures 5 ana 6 show the results of the fouling resistance (r;) measure In ai. cases, there was an

initial induction period duri

zero. During the first deployz= period for the aluminum units was approximately 4 weeks, e the induction period for the titanium units was 2 weeks. For the second deployment, all units had an inducticn period of about 2 weeks with that of the titanium unit slichtly shorcer than the aluminum units. ?Shorter induction pericas for the second deployment may reflect the warmer water tezperatures 3 eginning of the second deployment as compared with the oyment (figure

ne

es temained near

Following the induction pericd and {ollowing each

Rg increased approxinately linearly with tim ne fouling rate

was lower initially, but aftec a few cleaning cycles it

stabilized at approximately 0.25 to 0. 2 nr °P/beu-das

There was no significant difference between fouling rates on the

rectangular,cross section element from the Tiane seat exchanger

(unit 5, 298 deployrant) and the other un!

Leaning,

Excellent correlation was found between the fouling resistance and the wet thickness of the biofilm found growing on the tube surfaces. The calculated coefficient of thermal conductivity for the film was 0.34 Btu/ft-ne-OF which is, approximately the same as the thermal conductivity of sea water. Thus, the insulating properties of the bictilm appear to be due to stagnant water entrapped by the microorganisms (4,5) +

In late April of the first deployment (between days 80 and 90), Re for all units decreased to a value close to zero. NO intentfonal cleaning was performed at this time, but tnere was an inadvertent 50% increase in flow velocity through the ATM's of approximately 30 minutes duration on day 86. This drastic reduction in fouling resistance indicates sloughing of the biofilm which, at that point, was only loosty attached to the Pipe surfac Subsequent tests of the effectiveness of increasing the flow velocity 5y sees (performed before each brush cleaning during the first aeploynent and daily on unit 3 for the first 76 days of the second deployment) resulted in only modest reductions of Rr. Though not as Pronounced, there was also sone evidence of sloughing from the titanium units in late May of the first deployment and, during the second deployment, in mid-September on unit 5 and in early August on unit 2.

---Page Break---

The effectiveness of brush cleaning is illustrated in figures 8 and 9. Two brush passes were sufficient to reduce R, by?tworthirds, and 10 passes reduced Ry by approximately 906 (Ligure 6). However, only in the early stages of the experiment Was it possible to approach an 2; value of zero by brush cleaning (figure 9). This suggests that the fouling resistance was caused by two distinct biological layers: an upper layer which was removed easily by brushing, and a hard, bottom layer (possibly extruded polysaccharides) whicn accumulated slowly and could not be removed by brush cleaning. The thermal resistange of the bottom layer stabl:Ized at between 0.5 and 0.9 x 1074 feé-hr~ Sp/atu.

Intermittent chlorination proved to be an effective method of biofouling control (figure 10). The Re value for unit 4 Guring the entire 5 months of the second deployment renained at essentially zero.

conciusroNs,

In an in situ study of biofouling of simulated OTEC heat exchangers, the fozling resistance of the exposed surfaces {hereased at linear rates and stabilized at approximately 0.25 -

0.30 ft2-nr-°F/Btu-day, Fouling rates on a rectangular cross

Section element from a Trane compact heat exchanger were the same as on other units, The insulating properties of the biofilm appear to be due to stagnant water entrapped by microorganisms. Asa means of controlling biofouling, intermittent increases in flow velocity were not effective. After brush cleaning, a layer Of biofilm remained which had a fouling resistance of 0.5 ~ 0.9 ft2-he-°r/atu. Chlorination for 28 minutes daily at the level of 0.5 ppm effectively controlled biofouling for the duration of a six month experiment.

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Figure 1, Map of Puerto Rico showing the location of the test

site.

EXPERIMENTAL

TUBE MODULES

Sr FraME

DATA ACQUISITION HOUSE]

P

ROTEE

INLET AND EXHAUST wena ~ LEAD WEIGHT

Figure 2. Cutaway view of the LCU modified for use as a moored

research platform,

weet

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SUPPORT FRAME

Figure 3, Schematic diagram of the four modular flow loops of

the hydraulic system.

cMu HEAT

TRANSFER Hf

MONITORING) COUPON

DEVICE TUBES

FLow

i, METER,

Figure 4

T

eS

PUMPS,

Support frame with one of the flow loop modules in

place.

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Figure 6. Measured fouling resistance for the four unchlorinated

heat transfer monitors during the second deployment, May

1981 ~ November 1981.

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© 2nd DEPLOYMENT

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MONTHS

Pigure 7. Water temperature during the first and second

Deploymen=s.

REDUCTION IN FOULING RESISTANCE

WITH BRUSHING

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@ 50.

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& 30 2D TN sosen

8 20. : 8 Stan

5 10 BAL 3003,s7u

$+ ++ ++ 44

0 5 10 15 20 2 30 35 40

BRUSH PASSES

Figure 8. Per cent reduction in thermal resistance by cleaning

with manually operated brushes.

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Figure 9.

FOULING RESISTANCE AFTER CLEANING

he UNITS 1.83 (AL 5052)

F 06:

os UNITS

Roz

Ol ehhtatatatatstotntetytetat

MONTHS

FOULING RESISTANCE AFTER CLEANING

Le UNITS 204 (TITANIUM)

3

°

Rpxio'FT?=HR-PF/BTU

° °

MONTHS

Fouling resistance of aluminum and titanium units

after brush cleaning during the first deployrent.

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FOULING RESISTANCE

UNIT 4, TL GRADE 2

INTERMITTENT CHLORINATION

znd DEPLOYMENT

8.

7

6.

5.

4.

3

2

?1

%

?}?} + + ++}

yoy ase

MONTHS:

Figure 10. Measured fouling resistance for the KTM chlorinated

Suring the second deployment.

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UPADI 62

San Juan, Puerto Rico

August 1-7, 1987

?Second National Conference on Renewable Energy Technologies:

BIOFOULING AND OCEAN THERMAL ENERGY CONVERSION

IN TROPICAL MARINE SURFACE WATERS

by

Donald S. Sasscer - Thomas 0. Morgan

Center for Energy and Environment Research

Thomas R. Tosteson ~ B.R. Zaidi

R. Revuelta - $.H. Iman

Department of Marine Sciences

University of Puerto Rico

Mayaguez, Puerto Rico

San Juan, Puerto Rico

August 1982

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BIOFOULING AND CCEAN THERMAL ENERGY CONVERSION

IN TROPICAL MARINE SURPACE WATERS

?Thomas R. Tos:.eson Donald S. sasscer

B.R. Zaidi, R. Revuelta ?Thomas 0. Morgan

8.8. Tman Center for Energy and

Department of Marine Sciences Environnent Research

Mayaguez, Puerto Rico 00708 Mayaguez, Puerto Rico 00708

ABSTRACT

?The OTEC biofouling study reported here was conducted during the first deployment of the CEER-OTEC facility off the southeast coast of ruerto Rico, from January 1980 through February 1981. For the first 143 days of the experiment, the initiation and accumulation of microfouling on aluminum and titanium surfaces was studied. Following this, the microfouling on the test Surfaces was analyzed during seven cleaning cycles covering an additional 239 days.

Microfouling was assessed by determining the surface residue weight, the organic carbon and nitrogen contents of this residue, and the wet film volume. The increase in thermal resistance (Rg) of the aluminum and titanium heat exchanger tubes during the period of this experiment was correlated with the increase in wet film volume associated with the test surfaces.

There were differences in the microbial populations that golonized the test surfaces. During the second phase of the study (cleaning cycles), there was a marked seasonal variation in the quantity of biomass associated with these surfaces. While there appeared to be differences in both the processes and the extent of microbial accumulation on aluminua ?and titanium surfaces, similar increases in thermal resistance (R,) were observed for both test surfaces during the cleaning cycles. Thus, it appears that these processes, while different for each metal, both result in the formation of a layer of immobilized water adjacent to the test surfaces, providing an ?insulation' capable of increasing the thermal resistance.

INTRODUCTION

The oceans comprise seventy-one percent of the earth's Surface, Eighty-eight percent of the ocean volume is found at depths greater than 1000 m. the average temperature of this subsurface volume is 10°C." at the end of the last decade, the National Academy of Sciences and the National Academy of Engineers reviewed the known resources of the sea but failed to note the abundance of cold water (1,2,3,4). The ocean is a natural collecting sink for the radiant energy of the sun.

Absorbed heat is circulated and stratified due to the earth's

rotation, winds, and the resulting (due to density gradients)

ocean currents. ?The result of this stratification is the

1

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The frozen SR simples were transported to the laboratory

(Marine Station of the Department of Marine Sciences at La

Parguera, Puerto Rivo). In the laboratory, each ring and its

contents ?were thawed and sonicated. The suspension of material

obtained in this manner was freeze-dried, and the powdered

material recovered and weighed.

IIL, Isolation of Bacteria from the Test Surfaces

The methods employed to isolate the bacteria associated

with the test surfaces have been reported elsewhere (7). A

series of tests were performed to classify these bacterial

Strains and compare them in terms of numerical taxonomy (8).

RESULTS

Sample Collection

During Phase I (0-143 days), the 12 test surfaces were sampled 11 times. ?This sampling Schedule is outlined in Table 1. ?Test surfaces were sampled 9 times during Phase Il. The sampling schedule for Phase II appears in Table 2. On 4 October 1980, the tubes were cleaned but no samples were taken.

1. Sample Analysis: Phase 1

2.1 Total surface Residue (SR)

The surface residues associated with 388 samples were determined during the course of this study (Pigure 1). In general, the accumulation of material on aluminum was higher than that seen on titanium surfaces. During the first ten days of the experiment, the accumulation on both test surfaces was, Linear with time, the aluminua surfaces gaining mptecial at a rate of 1.6 ug/em?/day, the titanium at 0.4 ug/em*/day. This

Table 1, Sample Times

Elapsed Time

bate Sample Sample Interval DAYS

January 29 0# = 8:48 9:20 pm 0.00

January 3001 8:50 pm 0761

February 32 4:15 Bx alg3

February 8 = 3 12:25 pa 3271

February 15 4 = 10:13 pm 16:63

February 26 5 9:34 pm 27.62

March 7 6 12:13 pn 37.65

March 20 7 9:50 pa 50.62

April 16 8 1100 PR 80.63

May 3 3 9245 Pa 95:59

June 20 10 9:20 Pa 14256

Experiment initiated.

---Page Break---

Table 2. Sample Times

Elapsed Time

Date Sample Semple interval Mean Time DAYS

June 20 10 am = 1:45 pa oF

July 25 Al 8:32 am - 12:55 pm 35

August 30 12° 9:10 am - 12:30 pm 36

October 4 13 No biological samples 35

November 1 14 9:00 am - 11:00 am 28

December 315 9:35 am 11:35 am 10:35 am 32

January 9 16 9:30 am = 11:00 am 37

January 16 «17-9353 am - 10:53 an 7

January 2316 am = 11:17 am 14s

February 1s 19 am = 11:45 an 10:33 am 36 teleaning cycle experinent initiates

?*experimental tubes samples, and not cleaned

accumulation corresponds with the establishment of measurable

wet films on the test surfaces. Subsequent to this "file

initiation? period, the amount of naterial associated with both

Surfaces decreased. Throughout the remaining period of the

study, the SR increased linearly with time, at a rate of O6

ug/en*/day on aluminum and 0.1 ug/on/day on? titanium. During

a

no

Figure 1. Surface Residue, Phase 1.

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the period of approx mately 17 days through 143 days of exposure to flowing seawater, the SR on aluminum increased eleven-fold; whereas on titanium, the SR increase was slightly more than double.

2.2 Organic Carbon and Nitrogen Content

Figure 2 illustrates the changes in the organic carbon content of SK during this phase of study. Following the initial period of wet film establishment, the organic carbon contegt of the SR increased linearly with time at a rate of 0.7 ug/ca*/day on aluminum and 0.3 ug/em?/day on titanium surfaces. Prom approximately 20 through 143 days of exposure, the amount of organic carbon found on aluminum increased nine-foid, and on titanium surfaces it increased approximately seven times. Thus, the extent and rate at which organic carbon and total sR accumulated on the aluminum and titanium surfaces was similar.

2.3 ATP Content

The ATP associated with 300 samples of the test surfaces was determined during the course of this study. The average amount of ATP associated with the test surfaces does not express the frequency with which ATP was found on those Surfaces. The average frequency (the average number of rings per tube that gave significant ATP readings) of ATP occurrence

was higher for titanium than aluminum (3). This frequency

reflects the patchiness of the microbial biomass on these

?Te (oavs)

Figure 2. Organic Carbon, Phase

---Page Break---

surfaces. Figure 3 shows the average quantity of ATP (pg) in terms of the area of the cespective surface times the frequency (f!) Of ATP occurrence on that surface (log scale) as a function of time of exposure. The expression of surface associated ATP in this exp-time manner correlated well with the determination of viable aerobic heterotrophic bacteria associated with these surfaces.

The amount of ATP associated with the titanium surfaces increased exponentially with respect to time throughout the course of this study. On the aluminum surfaces, there was an exponential increase in ATP through 51 days of exposure. Following this, there was a sharp decrease in the ATP on the aluminum surfaces through 96 days of exposure. During the

period from 96 through 143 days, there was another sharp

increase in the ATP associated with the aluminum surface.

© TITANIUM ?

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TIME (pays)

Figure 3. ATP Content, Phase I.

---Page Break---

awe

ALUMINA

CARBON 69}

28

ee

?SAMPLE: BEFORE CLEANING.

Figure 4. Surface Associated Organic Carbon, Phase II.

III. Sample Analysis: Phase II

3:1 Organic Carbon and Witrogen Content

A total of 382 analyses of the organic carbon and nitrogen contents of the surface associated residue were done during the course of this study. The results of the organic. carbon analyses on the test surfaces prior to cleaning are illustrated in Figure 4, The data suggest considerable variability in the carbon contents of the surface acsociated material from sample to sample. The average interval between the samples taken in the course of this study was 34 +/- 3 (sp) days.

The average amount of carbon associated with the aluminum surfaces prior to cleaning was significantly greater than that found on titanium. The carbon/nitrogen ratio of the material

found on the aluminum surfaces prior to cleaning was

significantly greater than that seen on the titanium (Table 3).

---Page Break---

Table 3. organic carton

Before Sieaning After Cleaning

Organic Organic

Test Carbon Cazbon

surface ug/eR2 cy ug/em2 c/n

Aluminum 81 4/- 8 9.9 4/- .5 20.0 4/- 3. 16.2 4/- 2d

Titanium 55 4/- © 7.2 4/13 BB HL 83 4/- 008

3.2 ATP Content

The preponderance of carbon oa the aluminum surfaces both

before and after cleaning as compared to the titanium is the

Feverse of that seen with regard to the biomacs (APP) associated

with these surfaces (Figure 5). During the course of the second

phase of the study, the ATP content of 360 samples of the test

Surfaces were determined (in duplicate). Figure 5 shows the

average amount of ATP associated with the test surfaces prior to

gleaning on the respective sample dates. These data suggest.

Significant seasonal changes in the biomass associated with the test surfaces. In September and October, the surface associated biomass significantly increased, I: is of interest to note that the temperature of the seawater passing though the experimental tubes reached its peak value (29.25°C) during this period of the study. This is also the season when precipitation is at a maximum, which means higher nutrients in coastal waters.

3:3 Bacteria Associated with uhe Test surfaces

A total of 14 bacterial isolates were originally obtained from the test surfaces on samples 17, 18 and 19. The similarity index indicated that there were ?five distinct strains of bacteria (848 similarity in test characteristics). Of these five strains, thro were exclusively associated with the aluminum surfaces, and one was found only on the titanium, The one bacterial strain which was found associated with both test Surfaces differed from the other strains isolated in that it did hot form colonies when plated on agar media, instead it spread over the entire surface of the plate. One of the strains found only on aluminum was luminescent.

All five of the isolated bacterial strains were gram Regative, oxidate positive, motile, and they oxidized and fermented glucose. All of the strains isolated belong to the family Vibrionaceac. The luminescent vibrie 1s possibly ff0n the genus Lucibactyerium. This strain very actively produced

9

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HyS. Most of the strains were able to grow on inorganic salts with citrate as ti only source of carbon.

The distribotion and sequence of appearance of these bacterial strains on the test surfaces are illustrated in Table 4. The five strains were arbitrarily designated A, B, C, Dy & B, with strain D being luminescent and strain £ being found on both test surfaces. Bacterial samples were not taken from the titanium surfaces on sample 18. Bacterial strains found on the titanium surfaces on sample 17 were the same as seen on sample 19 at the end of the study. On the aluminum surfaces, there was @ qualitative change in the composition of the bacterial population on samples 18 and 19 as compared to 17 (strain E was

Present on both surfaces at ail sampling times). ?Thus, the test

Surfaces differed in the bacteria associated with them, and the

aluminum surfaces showed some type of succession in the

appearance of bacterial populations.

13) ram

Lon mL

SAMPLE: BEFORE LEANING

Figure 5. Surface Associated ATP, Phase II

10

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© Surfaces

Sample ay 18 13

crime, ?da. oe (36)

7 . sanpie ag

aL Bs ot made) DE

Strain A only on Titenivs

Strains 8, C, D only on alumn

Strain F on both materials.

During Phase this stue st 143 days) the thermal resistance (*,) of chs -o1) naterials increased to average values of 10.6 Sn che cluminm. The Re values did not appear to systematicaily incress= vni.\ approximately 17 days of exposure, following the initiacior of wet fiims and the. first appearance of biomass on thes» suriaces, The Rp on the test surfaces increased steadily ftom .; through ?: days of exposures rising to values of between 4 und ?, Arun 20 days of exposure, the Rg Spontaneously fell to values comparable to those seen approximately 25 d Feer tne 1 1itcazion of the experiment. During the subsequent 90 dye, the x; ir tne aluminum monitors rose to a value of 10.6 and fr tne Vicaniun toa value of Sls At the termination of phase I 0° cco experiment, approximately

26 days later, the Ry vatues oxcze%ed Shose seen at 61 days exposure, The relationship o: the iomaes found on these Surfaces to their respective wet fim volumes also appeared to differ. Following i7 days cf exposure, the biomass. (ATP) associated with the titanium surface increased exponentially until the units were ciesned, This increase was unaffected by the decrease in wry soon and 96 days of exposure.

The biomass on the alum! co increaseé exponentially through 51 days of exposure, decraasing between days 61 and 96 and recovering to a nigh v 43 Gays. The steady increase in the aluminum wey dur reriod was unaffected by the cyclic change in the evan .< mass associated with this surface. Thus, while fil ve was lost trom the titanium surface, the biomass reneinec. Conversely, on the aluminum Surface while WFV s<ead:2) ?acceazec, the quantity of biomass. associated with the surface went tnrovgh » cyelic change.

These data suggest that the m.crobtal populations selected

by the test surfaces might nay n different at the onset of

the experiment. Changes on lationship of the biomass to

film stability during thie period m cht wel! nave determined the

increased rate of fiim cevelopnen: seen nesween cays 96 and 143

of the experinent.

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During Phase 11, the aluminum and titanium test surfaces

appear to have been different with respect to the relative

Proportions of biomass (ATP) and organic carbon associated with

them before each cleaning.

?There were peaks in the quantity of biomass associated with the test surfaces during August and October (samples 12 and 14) and then again during the winter months of December and January (samples 16 and 19). These peaks in surface associated AT? correlated well with peak values in total surface residue (Sk) and organic carbon during these periods.

Average ratios of organic carbon/ATP in bacterial cells have been reported to be around 500 (9), Based on this, an average of 518 of the organic carbon on the titanium surfaces prior to cleaning was microbial. These values are to be contrasted with those found on the aluminum surfaces which were 8.4% before cleaning, The quantity of material remaining on both test surfaces after cleaning does not correlate with the observed thermal resistance (Re) of these surfaces. On the test Surfaces prior to cleaning, R¢ correlated well with the WFV on the aluminum surfaces, and with the biomass (ATP) found on the titanium surfaces. The lack of correlation between properties of the biofilm found on the test surfaces after cleaning might well be related to a patchiness of material on tne "clean® Surfaces. The observed Re might have been reduced by the turbublence of the water flow across these roughened surfaces. Such a circumstance would obviate any correlation between the nature of the material left on the ?clean? surface and the observed Rg.

There were differences in the bacterial strains associated with the test surfaces. Similar strains were found on the titanium surfaces both at the beginning and at the end of the experimental period. On the aluminum, there appeared to be & succession of bacterial populations, culminating in the appearance of a luminescent bacterial strain that produced #25. Bacteria of this type have been reported to be associated with metallic corrosion processes (9). While the aluminum and titanium test surfaces shared the presence of a non-colony forming bacterial strain, they exhibited differences in the accumulation of biomass (arp) during the cycle period, These differences may well be associated with different bacterial Strains found exclusively associated with each material.

?The accumulation of biomass on the titanium and the growth of the wet film on the alumnium surfaces, while representing different processes, may result in the formation of a layer of immobilized water on both the test surfaces. Increases in thermal resistance on the test surfaces during their exposure to Funning seawater have been attributed to this phenomenon (6)

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UPADI 82

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OCEAN THERMAL POWER-THE COMING ENERGY REVOLUTION

By

J. Hilbert Anderson

USA

San Juan, Puerto Rico

August 1982

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Ocean Thersat Poxer=The Beyulution

by a. wither:

The mistory OF man sd Ais domingncs Ln veth, eng ms aUiTity to expand he population has Leen very closely t So eb bity te consuer the forces of

nature, and to utilize those forces for his cu and

Theray 15 probably

the most rmportant factor in man?s doninarce «ver wet

First man Vearned to use fire and burn mod. The use of fire permitted him to keep worn and expand hts horizons to cover a large part of the earth's surface. Eventually, he? elso learned to use wind to ransport him over the oceans and te find fnew horizons to conquer. ne also Fearned to use wind to punp mater from the ground, and to enable him to 1ive in many places wich atheraise would have heen inpossible. With the incustrial revolution and the tnvertion of the steam engine in England in the Sixteenth and Seventeenth Century, he began to use energy on a wider scale, and s00n caused an energy shortage because all cf the supplies of wood were being used wpe TMS sts probably the First energy crisis

The next Stef u2s 0 use coal to poner tre stear engine. This enabled man to increase nis industrial output, and provide vany usable #

rs that were previ-

ously wanufactured by mane, It fostered he iron and steel revolution end becan
our modern society.

Mong with the industrial revolution and the production of metals, we mere
able to develop water poner with its rany uses on a sma?l scale throughout the world.

The discovery of huye quantities of 017 and ges perm

ed us to produce energy
at a much lover cost than ever before. This reslly promoted our modern 20th Century
soctety. how we suddenly realize that oi! ane gos are not in unlimited supply and
that their period of trenendous use is already alnost over. This tells us that we
?need a new revolution in energy supply: we must Took elseuhere for our next source.
We have developed a nuge appetite for energy, and the lack of it would undoubtedly

?Set back our standaré of living to much below that which we have all become accustomed

---Page Break---

For 8 fem years we decane enanored with nuclear poner. It was touted by

rrany as the answer to all our energy problens. we were told thet electricity would

becone too cheap to eter. nis perhaps lulled us into a false sense of security

about our energy supply, and when the OPEC countries suddenly realized the vietual

onopoly that they held over the limited supply of ofl, this shocked us al1 into the

we agein have energy cris*s, and that nuclear power at tne sane tine

realization

has not become too chesp to eter, but 1s actually becoming more costly, and more

dangerous.

nere de we go nent? Solar enthusiesticsstel? us thet solar energy covers. the entire earth and there 1s plenty of it to 30 around. Therefore, we should use solar erergy to supsly all our energy needs. This sounds good, The energy is there. Unfortunately, it is there only curing the caytine, and it 1s there in very Gitfuse arounts. Therefore, by any calculation, it becomes necessary to build costly collectors, and tc use a lot of material and space to collect and utilize solar energy. If we renenber that solar energy in useful arounts is only evaileble for about eight hours a day, and we need energy 24 hours a day, then it becomes obvious that we must collect and store enough energy in the eight hours to supply us for tne 24 hours. This means that if we went 109 kilowatts of power for 26 hours, we must build one plant that wil? develop 100 biTonatts during the daylight, and two plants to supply 100 kilonatts for each of the other two eight hour periods in the day. The reason we rust build two plants instead of one for the other eight

hour pericds is simply that the energy must be stored in order to reke it usable at.
night. Since storage devices are only about 50: efficient then we must senerate

200 kilowatts to get back 100. This means thet any combination of solar energy

plants mvst use approximately five plants for every one usable unit of energy
throughout the 24 hours, They: also require the storage facilities. this is obviously
very expensive and 1s the basic reason why direct solar energy 1s not a very satis
factory source for our huge energy needs, and probably can never be hoped to supply

a11 of the energy that we would Tike to have, nor can it supply it at a reasonably

acceptable cost. ?oe

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heat, Tet us Took ar tne possitit-ties for geothermal poner, or power from

the heat of the earth i:sel'. It can easily te calculated that the earth has enough heat stored therein to supply us with all of tre energy me need for millions of years.

The problen is really not »

her the heat 1s available to generate geothermal poner,
but whether cooling 1s avaciable. Every heat engine generates power by using some engine cycle to transfer meat from high terperature source to 8 low tenperature Source. In orécr to generate power we need toth the high terperature and the low terperature source. The chart on Fig. 1 shons the relative ancunts ef heating and cooling needed for different types of power slants. The bars on the Teft show the amount of heat requtred to produce 100 units of power outbut. shown by the center bar. The bars on the right show the amount of heat that oust be rejected to the cooling systen.

The upper ine shows the case for « rosern of! Tiree plant, with thermal
efficiency of £0-. 250 heat units cust he suoptied to produce 100 units of power.
The reraining 159 units must be rejected to the cooling system. In this case pert
of the heat is rejected thru the flue ges, ane approximately 100 units to the cooling

systen. The heat rejected 4

?the cooling system 45 spproxinately the sane as the useful poner output

As we decrease the available tenverature difference for the poner source and, therefore, decrease the plant efficiency, more heat must be rejected for each unit of power produced. For exuple, in a typical geothermal plant, roughly six tines a5 much heat output to the cooling systen is required as for a highly efficient fossiT~ fuel plant and nore than twice as mich as for a nucleer plant. When we realize that it ts very difficult to Find sufficient cooting mater sources to supply our nuclear and fossil-fuel plants, then we begin to see how difficult it would be to create @ very large geotherma power industry. The cooling water supply Just sinply 3s not there, and particularly it 1s not generally there in areas which have nigh geothermal activity.

?The problem becomes even worse in trying to use direct solar energy in a solar

<3.

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thermal plant. The solar the val plant car vary greatly tn efficiency depending on the type of concentrated coll-ctors usee, hut in eny event » very large cooling source fs requires. The 1750 units er 100 units of yower might be typical for 8 solar sett pond plant.

Now let us turn to the ocean. The occan covers 705 of the earth's surface and {
by far the largest naturel solar collector that we have, and me don't have to manufecty it,

In the tropical oceen the water is heated by the sun. hen water fs heated, ft

expands slightiy, and raises the level of the ocdan slightly. This causes the ocean in effect to overflow toward the poles wnere the water density 1s higher and the level 4s Slightly loner. As @ result we have the Gulf Stream im the Atlantic flowing north from the tropics. In the poier regions the water is cooled down at the surface. This dense

water sinks and lows along tne bottom of the ocean back to the tropics. There is @

continual circulation created by solar heating of the vast areas of the tropical ocean

As a result, me have surface water in the tropics such warner than at the botton of the ocean, The temperature difference between the surface water and the bottom ocean water can be converted to energy by 8 heat engine. Typically, the water at the surface in the tropics is opprosinately 60°F, ang the mater at depths of 1000 seters end nore 1s approximately 40°F, This meers thet we have a tecperature difference of sbout 40°F aveilable for generating enersy.

Theoretically, it is possible to convert the energy at a 40° temperature differ-fence into useful electrical power at an efficiency of approximately 78. tn actual prac tice it is possible to do this at an efficiency of slightly nore than 32

To show how much power can be generated, we can take 8 simple example of the Florida Current, which is the portion of the Gulf Stream that flows past the tip of Florida. (Ref. 1) the Florida Current continually carries approximately 28 million evbic meters per second of warm water. A well designed ocean therral poner plant requires

Ind of warn water to generate 100 negenatts.

approximately 248 cubic meters per si

Based on this the potential generating capacity in the Florida Current alone would be

9.7 million megawatts or nore than 20 times the total capacity of the present power

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Senerating network in the entire United £:atex. (Ref.2) This gives ane seme ieee of the enormity of the poner geveration capeuility in the oceans

Figure 2 shows a rap ceveloped by the".S. Devartment of Tnergy showine where

?the warm mater sources are located throughout the world. It 4s obvious from this that practically al¥ tropical nations in the world have access to huye quantities of ocean therral power potential

Not only is the ocean thermal power an enormous source of power, but it 4s

self-generating. and cov sunply energy a: Tora a: tne sun continues to siine.

Given the huge heat source at 80°F and below +t a heat sink at 40°F, how can we generate wechenical and electrical power frar this? The answer.is that this can work on the sane principles es most other heat engines. In order to generate power,

yOu mist have the heat flow fron the hot source toe

cold source. During the

How of heat from the not scurce to the cold source power can be generated mith

suitable mecranism. Ocean thermal pimer operates no differently than an ordinary steam Plant where you heat and bofl water to produce steam, which then expands thru 4 turbine or reciprocating steam engine, and condenses in 8 condenser which operates at loner pressure corresponding to the boiling ur condensing pressure of the steam.
?An ocean power plant can operate in the sane way. The warm water can give up heat to boil a fluid such as an orcinary household refrigerant. the vacor boils

at a pressure corresponcing to the saturation tenpereture, it then flows thru a turbines giving up poser to drive 8 generator. and at the condensing end it condenses at low pressure back to a Tiquid. The Viguie cen then be pumped back into the boiler and the cycle continues. Me can actually do this using the water
boiling Muid- This was actully the first type of ocean thermal power plant that was attempted. Sack in the 1920"s, George Claude actually built @ power plant in which he pulled @ vacusn on warm water, 1t then boiled into vapor, was passed thru a turbine, and the exhaust steam nas condensed on cold water punped from deep in the ocean. This 15 a simple fons of an ocean thermal power plant, and 1s commonly callee

the open cycle, becouse it uses the mater itself as a working fluid. Originally

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in 1881 Jacque Arsene D'Arsor val suygested tne sone basic principle, but proposed to use the warm water to boi? asmonta, which wis!d pass through a neat engin to generate poner, and then convense on cold water sunped from deep in the ocean. To

day there are many reasons wiy the original or <losed cycle proposed by O'Arsonval

15 the one which appears to ne rost practice! art economic, While this cycle ree

quires neat exchangers to transfer ncat frum the warm water to bet] the working
Mute, ane to transfer heat fron the concensing vapor to the cole water, it hes
any advantages in being much aore compact, and avoiding the need for very large

for conplex and costly degassing

and costly turbines. It also eliminates tne ve
equipment to renove dissolved gases from the water

A simple form of the closed cycte ocean thermal power plant is shown on Fig. 3
?The warm water from the surfece ef the ocean fs pumped through @ boiler at the bottom
of the diagram. This boils Tiguid into a vapor. A typical liquid 1s the ordinary
household refrigerant designated R-22. The vapor from the boiler passes up through a
turbine driving generator, anc from there casses up to the condenser which 18 cooled

by cold water pusped from deep in the ocean. The condenser is pleced high enough abov the boiler so that the liquid will flow ty gravity from the condenser back to the boiler, thereby requiring no purp to force tne tiquid into the boiler, which is at higher pressure than the concenser. This cycle with sone vartations in detail to inprove efficiency is the one thet apuears vost favorable for generating power at. the lowest possible cost

Fig. 4 shows picture of an actual cevonstration poner plant that mas first demonstrated by the authors fire in 1975, and which works on exactly the sare prin- ciple shown in the diagran. At the bottom of the plant is a tank of warm water with a boiler submerged in it. The refrigerant. R11, is boiled end passes upward through the pipes to a turbine at the middle of the plant, which in turn érives a smal? ermanent magnet generator and generates approninately 100 watts. The exhaust from the turbine flows vertically upward to the condenser which is submerged in the tank Of ice water at the top of the plant, The Tiquid condensed from the condenser flows 1

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Srevity through a small tube returning to tre boiler. This plant proved to many

skeptics thet power could indeed be generated with tonperature differences that are very small, and the sat? turbine was actually run with tenperature differe!

Now as 37.

Since the ocean 1s by far our greatest resource, it appears logical to think

that if we can generate power in the ocean, then this power can in turn be the key to

Utilizing many other potential resources in the ocean. Let us now look at sone of

these possibilities.

The first possibility to think about is ?God production. More and nore we

eed to turr to the ocean for the fooa surply for our increasing biN1ions of people

Veing or this planet. Ocean themai power provides an important means for doing this.

It ts fairly weli known that the seep water in the ocean contains a

much higner percentage of nitrates and

osphates than are conta ined

fn the upper warm layers. It has also Tong been known thet where the

?01d waters are brought up to the surface by what 15 called upwelling the fish

Production is greatly increased. ks a natter of Fact it 1s reported that 44% of the

fish produced in the world are produced by one-tenth of one percent of the world ocean

?area.(Ref.t) The most important Fish producing area in the world is off the mest

coast of South Anerica where the Husbolét current brings deep water to the

surface.and supplies the fertilizer to produce millions of tons of Fish annually.

Since an ocean therms) power plant necessarily pumps up cold water to be

utilized in the plant, and since the process marcs this water in the plant, then it

is natura? to think that we can discharge this nutrient rich water

?nto the surface zone where sunlight can promote plant growth and the entire chein

of ravine food production

This has been cenonstrated by Roels (Ref.2) ané the group of setentists working

St. Croix, where they have demonstrated ?uge increases in shellfish production by

Purping water from approximately 800 reters devy to surface fonds where the sun

=?

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Droncted algae gronth ant food for sme* Den,

Roels and Laurence have reportes vat £1?,000 pounds of shellfish neat

could be produced from a flow of 1 cubic vwter (or second of cold water. On

this basis a 100 Megawatt power plant reguirir3 136 cubic meters per second of

cold water Mom coule produce @ yiels of 26.°62.000 pounds per year of shellfish

Feet. At @ nominal price of ene dollar par vouns this would produce an incone of

$56,862,090 yearly. Woste it 15 tov early to say that the efficiency

of 8 large scale food procuction systen would equal the efficiency of the small

systens ceronstrated on St. Croix it 1s still quite apparent thet huge production

©F food 15 possible from on ocean thermal poner plant. From this we can see that fo0d production from ocean therral plants coute be just as injortant or maybe even

Pore important than power prods

In addition to foot production ocean

have the capability to produce another of san?s vital needs, sacely

fresh water. The process for producing frech water from salt water is rather simple

25 iMustrated on Figure 5. First the gases divsolved in seawater must be removed

by a compression process. After the gzses are reroved the water can boil at @ very

Jom temperature ané high vacuur and produce water vapor, This water vapor can then

be condensed on @ condensing surtace cootes ty the cold water leaving the poner

Plant condensers. This process can produce lerge quantities of water utilizing the

heat enersy in the seawater itself, anc with 9 pruperiy designed plant requires very

Little purping and conpression power. Figure ? s1iustrates how much water can be Produced per pound of cold water entering the system. Referring to Figure 6. if we havea 30°F temperature aifference between the warm seanater and the cold water leaving the poner plant, and assume # 3°F temperature difference across

the yield of fresn water would be .0227 Tbs./1b. of

ach evaporative stage,

cold water. Using the figure of 136 cubic wetors/sce. of cold moter

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required for a 100 megawatt jower plant and assuning 0: yearly capacity for the Plant then the potentiat procuction of fresh water would be 87.6 milTion cu. weters/ year, MCA price of $1/1000 ga. oF 26c/cu. cater, tne yearly value of the fresh eter product would be S42 mil}ion. Currently sn the Caribbean and other places where fresh water is scarce, the cost of producing fresh water from seawater is as uch as $6/1000 ga). or S2/eu. meter. At this crice the value would be S175 Bi1Tion er year.

Oryer usable and conveniently produced products are those that can be produced directly fron electrolysis of sodtun, chloride water solution.(Ref. 5) Electrolysis of a sodium chloride solution produces three products, nanely, caustic soda, chiorine, and hydrogen. AN are in leege derand, and are basic chemicals that arc requiree throughout the world, these can not only be very useful and profitable Products from an ocean thermal plant, but also have the advantage that they require Po production or transmission of electricity for producing these chenicals on land. The next products which are conveniently produced from an ocean thermal plant are oxygen, nitrogen, and carbon dioxi¢e. The percentage of oxygen dissolved ?in seawater 1s 355 of the gases, whereas it is only 294 in normal air. This means that the gases removed by deseration during the fresh water production process contain 2 higher percentage of oxygen than norral air, and thereby become a convenient source for a gas separation plant which can produce carbon dioxide, oxygen, and nitrogen: Since poner 1s conveniently available for this process, and cold water is also available to rake the oxygen separation process more efficient, it scens obvious that an ocean thermal plant would be » logical source for these valuable gases.

Hydrogen and oxygen can be produced from pure water by the electrolysis process and several industrial processes have deen developed for this purpose. For

this reason, an ocean thermal plant is a convenient source of hydrogen, which cannot

only be used as a fuel directlysbut also can be used in chanical conbination for

other useful products.

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The farst product that co:es to ?wna using hydrogen is erwonta. The

Gemand for ssvonta for fertsTizer and ottur turn ses exists throvghout the world,

and the need for amonia fertilizer ts particvler'y mmportant to ihe trepica?

food hungry nations of the world. Areunia iz produced by the direct combination

of nitrogen ang hydrogen, ard cany studies have snoun that ocean thermal plants are

2 most logical source for producing ecmerie. tre Janns Kopkins University Acalied

Phystes Laboratory has nace extensive studies of she econcnics ard practicality of

Producing auonia im an ocean therma! plant. Pf. 6

Once hyorogen and carcon dioxice have ?ven produced fron seaneter the next

step possible is to cosbine ther ine catalytic ;rocess which produces methanol

Methanol is a valueble Tiauig fuel wich con Se used directly in automobile engines.

for can be contined with g2soline to proc.ce ive fuel canmonly knows as gesohol.

Further processes are also availanie wnich can convert *ydrogen and methanol into hydrocarbons. Therefore, hydrecarson fuels are also a possible product from

ocean thersal ptents.

Since seanater is reatly whet mignt Se called a chemical soup, it fs

possible to extract many other chenic

s from seawater, the key elenent to producing these chenicals is tne aveileoslity ef sven. Te is evident from these few examples trat oceen thermal power can untock the doors.

toward making tne ocean by far the fost valuable resource on earth.

If the ocean can te the source of so neny important berefits to ranking, hy aren't ocean plants in operation? the answer is simply a combination of human apathy and natural skepticism. Every new pricess or product that 1s ever proposed {5 favartably set with disbelief. There ore elmays et least 100 csople who say ?it can't be done" for every one who says ?it can be done". The story 1s told about the first locomotive to be built in Enoleng. Yury people standing around waiting for

the Toconotive to start were saying, ?it will never run. After the loccnotive started

rerrily down the track, they all saidiehey"I) never get her stopped? £0 it 5 with

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?ocean thenval power. There are many difficulties botn real and fancied, and any one of these diffieuities serves to cake people cisbelfeve, and have no confidence fn the eventual success of such plants. Let us now carefully analyze the various Problens surrounding the building and operation of ocean thermal plants, whether they be real problems or fancied ones.

The first and often quoted objection to these plants 1s their tow effi-
ciency. Me are accustoned to thinking of power plants with thermal efficiencies of 30 - 40%. hen one proposes a plent with only 3 efficiency , most engineers are shocked, and immediately discard the very idea. This has been made even a worse obstacle by early covernnent sponsored studies which projected estinated efficiencies as low as 1.5%. The truth of the matter 4s that thermal efficiency 1s

not 2 good neasure of the value of an ocean thers

1 power plant. Since the cost of the fuel itself 45 zero, then thermal efficiency neans nothing in terms of the fuel used. The real measure that must be made of the value of a power plant 1s the capital costs and the time anc eneray required to butld a plant.

To show now riciculous thermal efficiency can be, let us consider driving a 3,090 Yb, automobile up a 12 grade for one mile. The actuel theoretical work output to THft the autosobile 52.6 ft. is 158.000 ft. Ibs. of energy. If we use gasoline

at the rate of 15 miles/gal. then the actual thermal efficiency of driving the aute-

mobile for one mile is 2.4%. Despite this, we are all perfectly willing to drive automobiles in our daily Vives.

Up to this tine many analyses have been nade of the potential cost of ocean thermal plants. Almost without exception, al1 of these estinates show that these Plants do produce sufficient energy output to pay for all of the energy and materials required to build a plant at @ much more advantageous rate than is the case with most

?other power generation sources. This {s clearly brought out in Ref.

Along with low efficiency, pessimists about ocean thermal power plants Tike to

point out the trenendous quantities of waters that is used by such a plant, Ref. 9.

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mate OUT plete wget reauire wp oweh a 30,900

For exanple, trey point ost

cu. ft/sec., which is stians'y onre rman vane flew of the Susqueranna River.

It sould be pointed out ist 2 weil Gesigres ¢ an tterms) olant should require only

136 cu. neters/sec. of cold water anc 2¢8 cu. ow ters/sec. of warn water for a 100 Hee

Flant, Ref. 10. Corpared to this on the Suscusninna River the York Haven Power Plant operates at a nead of only 20 ft. or meters ent requires Five tines as much water

ermal plant, Ref. Vi

flon/b generates as the efuramntiorsd wean

arse scale develonment of oceen thermal power

+ 1s pretty obvious ¢

Bust depend on builеing Moating plants in the sep ccean. There are relatively few

Places in the workd where steep enoush slopes The close encugh to shore so that Tend de Built. while Teng sases slants can potent?aily be quite useful

based plants cc:

land economic on sany islares, tue Tenge toa e chuetoment OF ps

industrial natfons cust depend on Mating eiacts

AAs

ntities of warm water

fing plant nas iorweiate aice:s to large au

and also to large quantities of cold water within 1,000 eter gestne in the ocean.

A floating prant has one disad.antage compared to @ tand based plent, ano that $s that. it requires suspended cadie Teadirg from the plant to the shore to transmit elee- tricity to the shore, This 1s not true of cresiesl process plants, but is true of plants wich are designed te furnish electricity to the shore

Floating plants mst be sesnorthy uncer al) stort conditions, land must be positioned sufficiently closely an one spot so that a cable can be

attached thereto. They also must be capable of deployment fron tre plant building

site to the operating site in the ocean,

Ref. 12 discusses and evaluates sore of the problems in seakeeping dehavior for ocean therral plants. These protlens are very similar to those required of floatir Of] driN1 rigs,of which there are today many in service throughout the world, many of wach are in the North Sea, wiere storms are tracitionatly the ost violent

fin the world. Ref. 15 shows that by the yeer 1972 there were sav 319 ocean drilling

sie.

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rigs tm service throuphcu. the world, ?ince chat time, rary more have gore into

Service. References 13, 1 and TE describe sone specific Mosting dri}? rigs of

the senfesubersible tyre wich approxsiate in size that ef an ocean themal plant.

For example, the floating srill rig desceites i Hef, 14 aisplaces 28,000 lung tons

which 1s approximately the same size as tne 100 Ye plant described in Ref. 10.

Since floating semi-sutnersible aril] rigs are azproxinately the sane construction

25 that of 9 semi-subrersivle ocean thermal power plant, it becones obvious that construction of such plants is possible. ang ceploycent to the operating site is also sossible. It Should be pointed out that many sub-ersible drill rigs have been built fn the United States end transported as far as Alasia, or to the North Sea, or to Sites off the coast of South Anerica

The cold water pine for suoplying cold meter to an ocean therzal plant

from deoths of 1,000 neters or more presents ¢ serious engineering challenge. The Problens involve not only the construction of the pipe to resist ocean currents, tou

but alse the problens of construction, deplayrent, and suppor

Hoating plat

fors. Nuserous designs have beer proposed for cold water pipe, most of them Geserived in Ref. 19. It appears fron that report that a munber of designs are feasible for construction, and the prodler resolves itself to choosing the sost economic and reliable of the designs available. Hore recently even more effective Gesigns have been proposed so that it appears that the construction of the cold MoLer pipe and its deployment are quite feasible.and can be made quite reliable. The attachment or suspension of the cold mater pipe from the platform is a difficult problem. Both References 20 and 21 indicate that this support had better be designed to be flexible so that the pipe is not rigidly attached to the platforn,but allows the platform to move during storm conditions without the Joint between the platform and the pipe being too seriously affected. Designs

for such attachment between platform and pipe are already in cormon use in the

Gri11ing industry, where drilling pipes must be kept stationary while the platform moves under sea state operating conditions Similar heave compensation

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---Page Break---

devices are possible for use in cormecting the o'4 mater rine to tne platfors of an ocean thermal plant

The underwater pense transwission ceble presents another series of problems. There are already many poner Cai!is unter the sea in service in various

vod cuepest cable is that referred

Farts of the world. The most recent, 137

to in Ref. 22, where a cable for trarsnission of 250 megawatts in $50 meters water Gepth has already been in service for sone sears. Standard Telefon & Kabelfabrik

211 large power cables to Floating

have assured us that they can manufacture and

plants at sea. Their vast experience in his eld seens to assure that this can be

done with good reliabs1 ity

Many papers nave deen written to point out that the resor Key to economic

success of an ocean thermal power plant lies in the heat transfer equipment. Since the plant 1s necessarily inefficient, then it requires @ large quantity of heat input and output to produce @ given anount of power. The heat input and output mist also be transferred across a very small tenperature difference. Therefore, the heat transfer problem is proportionately much greater in magnitude than in @ high temperature power plant.

Mach work has been done.and cary papers have been written on the sudject Of heat transfer for ocean thermal plants. Much progress nas been made. The progress might be suwrerized by comparing the original work described in Reference 23,in which calculated expectes heat transfer coefficients were approxi rately 200 Btu's/sq. ft./hr./*F for Doth condensing and boiling surfaces. AS conpered to this in the Tatest development described in Ref. 24, the corresponding heat transfer coefficients have been increesed to approxinately 2,000 Btu's/sq. ft./he./°F.or 10 tines as high as those originally expected. Much other work has teen done on heat exchanger development, and the results indicate thet heat transfer in an ocean therral

plant can indeed be efficient enough to make such a plant econoricelly and commercial:

practical

-14e

---Page Break---

Not only rust the vest exchangers !e highly offictent, but they cust be able

to maintain thet efficiency ever e long period of tine. The first problem +o think

about 1s corrosion of the materials in the heat exchengers. Since heat exc gers

are alreedy being used ir almost all of the 105,002 ships at sea, and ere muintained

Successfully in those uses, it seems safe to assume that heat exchangers can also be

operated in an ocean theras] plant, The rost acceptable rateria! today for resisting

Seamater corrosion in neat exchangers is cupro-nichel. This has withstood the test of

Lime and proven itself to be a very satisfactory material for heat exchange surfaces.

Ref. 25. It is not compatible with acronia, wich 15 one of the working fluids nest.

frequently susgested for ocean thers} plants. Monever, st 4s quite useable with the

halocarbon materials such as the re?rigerant R-22 which can be used in such power plant

Other racerials sugested have beer alusinum elioys, which appear attractive from

?the standpoint of having very high heat trarsfer efficiency end having @ fair amount

Of successful enplications in marine environments. The low cost of aluninun alloy ex-

changers cekes them appear very attractive, but there 1s sone question as to the life

Of such exchansers. There must necessarily be a trade-off betacen the low cost of

alusinun exchangers and the possibitity that the lifetine of such exchangers nay be too short to be practical. However, there is an increasing anount of evidence that aluminum alloys will be @ satisfactory material for heat exchangers. Ref. 26.

Marine fouling of heat exchanser surfaces is @ problen that must be dealt with in an ocean cheraal plant. There are thousand: of heat exchangers alreedy in service at Sea both in ships and in shore installations. and in harbors where mater conditions are almost certainly worse than those thet should be encountered in the open sea environment. However, the important thing to recognize is that a given anount of dirt fon @ high efficiency heat exchanger produces @ greater percentage deterioration in performance than the sane amount of dirt or fouling on a low efficiency heat exchanger:

Therefore, the heat exchangers for ocean thermal plants are more sensitive to fouling

---Page Break---

than those used in other <pplications at ses

There are tuo important types of foulinu that must be considered in heat ex=

changers. The first fs mcrofouting, which 1s the result of attachnent of larger

sea organtsns such as barnacles to meta! surfaces. In neat exchangers this type of

fouling can be controled norwally by mo intaicing high velocities across surfaces,

?and also by reducing the oxygen level in the mater, which literally deprives such

organisns of their means for living It does not appear that racrofoul ing need be

snd fn general this is @ problem

considered # serious problem in heat exchangers.

?that has been coped with satisfactorily in marine heat exchangers for nany years.

The second type of fouling is wicrofouling, which generally consists of a Slime that is buflt up by minute bacterial organisns of many types. This type of foul-fing has been sliown to be rencvable by mechanical brusning, and more recently by

slurry cleaning. Other types of fouting prevention means are the use

Of chlorine injection in the water, or possibly ozone injection. with the Successful developnent of slurry cleaning it is probable that infection of fouting inhibitors would not be necessary.

Much mark has been done at sea on experinental measurements of fouling and the methods of cleaning fouling from the surfaces. Some of this is sumarized in References 26 thru 28. The experience shows that fouling should really not be too serfous a problem for heat exchangers

?An ocean thermal plant must handle large quantities of water and must pump the water through the heat exchangers at high efficiency so thet the parasitic power osses are small. Pumps can be rotor driven or turbine driven by turbines operating on the sane working fluid that power the turbo generators. Turbine driven Pumps appear to have many advantages in being sraller, lighter, easier to maintain, more flexible in operation, and more efficient than motor driven pumps. the size of bumps involved in a 100 Mxe plant are well within the range of sizes that already have

been built for other purposes, so that pump design does not appear to be a serious

obstacle to the design of such plants

16 -

---Page Break---

Starting a power pient is a serivut orcslen. in ceder te develey poner

?fron the working fluid. it 4s necessary to susply warm and cold water to the

boilers eng condensers. Fur this reason, ramps ust be started im order to start

the plant into operation. If the pumps are electrically driven, then starting

can be accor

ished by providing a Targe gas turbine or ciesel turbine generator to supply electricity to drive the starting suns. for turbine criven pumps, it is

necessary to provide working fluid to power the pungs during the starting period

This can be cone by using a gas turbine te drive a compressor and

supely the working fuia to érive the punps

Turbine designs and generator designs cezend sorextet on the working fluid

thet is used in the cycle. If a hish éensity working {uid such as a halocarbon 4s

used, then che opera:

conditions for the turbine are such that very on wheel tip

Speeds are recutred and oniy one or tuo operating stages are needed. If a helocarbon

$s used for e wcrking {uid, then the generator can also be heretic and cooled by

the working fluid itself, so that there are no problems in designing shaft seats to

retain the working fluid in the turbine. On the other hand, if arwonia is used as

2 working fluid, then a hermetic generator cannot be used.and it 1s necessary to use

Shft seals to retain the working fluid

the turbine. Anonia turbines also gen-

eraity require more operating stages than halocarbon turbines. In either cese, the

snall-tenperature difference involved oroduces smal? available work/1®.

Of operating fluid, and the efficiency of the turbine can be quite high, generally

higher then that of a conventional steam turbine or ges turbine, The characteristics

of the turbines are much Iike those of water turbines.

A nucser of

ferent working fTuids have been suggested for ocean thers

pants and nany studies have been mide on this subject. sevanta sas the original

?ute proposes by O'Arsonval and was actually the fluid used in the wini-OTEC pant

wich operated successfully off the coast of Mowatt.) Various studies have Indleates

thet ammonia is the best theoretical Mule from the standpoint of thermodynamics.

?1.

---Page Break---

Hydrocarbons have else beer propeses. ?ropane was provosed by the

euthors originally in Ref. os

More recently the writer has prop. seo R22, the commen househo

halocarbon refrigerant,as the nost desirable wor+ing fluid. The Japanese have

elected to use this working fluid in the land-nased plant of a 100 kw capacity

that has recently deen started on the {siand of Nauru, #2f. 30. Re22 appears

to have many advantages over ammonia of a practical nature, such as being less

corrosive, environmentally safe, non-explosive, and compatible with copper alloys
fin the turbo generetor and heat exchangers. Ref." 10.

From the foregoing discussion it appears that the technical probtens for ocean thermal plants cen be overcome. This is confirmed by any different published reports sponsored by the U.S. Oepartment of Energy. The real question then is: can actual floating plants be designed and built that cen successfully cope with the technical protiens and at the seme tine be eccronically competitive with other sources, of power?

In evaluating a plant design we need to keep certain fundamental objectives in wind.

1. Survivabitity. The plant must be buit to survive in the ocean environment.

2. Buildability. The design should be such that it can be constructed in existing facitities.

3. Transportability. The plant should be conveniently movable to the

operating site.

4. Positfonabflity. The plant should be able to maintain its position without the costly problem of moring in deep water,

5. MeintainabiTity. Design 2 plant that can be maintained and repaired at

sea, with equiprent that is of convenient size for use at ses.

---Page Break---

6. Fleasbitity, a standaraizec plant derge, easily aéeytable to dif ferent operating condition: such as water temseratu re or aepth 15 very aesirable.

7. Environeental safety. The pant shovtd cinimize harmful effects to the environment and to pent operators.

The second Set of objectives is 10 design 9 cost efficient plant. The fuel for the power plant is the werm and cols weter. ?ince the water is free, one ts terpted to think that efficiency of plart comnene? ts doesn't matter much. Nothing Could be further from the truth. Since this plant is capital intensive, 48 48 ime

Portant to obtain the highest net power output far the minicum investrent by de-

Sgming a cost efficient plant. This is important to assure that the plant wil?

be competitive with other sources of power

The following are design objectives for e cost efficient plant

1. Efficient Heat Exchangers. Yost agree that heat exchangers are the most costly item in the plant, It is essential to design efficient heat exchangers with Iinirum surface area, Tow friction Tosses, and low poner required to punp the water thru the exchangers.

2. Minimize water Tow. Kater supply accounts for the greatest mass of material in the plant and sost of the perasitic power. Reducing water flow reduces Size of pipes, pumps, and platform, also pucping sewer. Improving plant. themal efficiency decreases water consurption, but it is even more important to use the wextrun hect capacity per pound of water:

3. Minimize material. Since the cost of eplant 4s étrectly proportional to ?the anount of material used, it pays to reduce this by efficiency of design.

4, Maximize efficiency. Turbine, generator, and punp efficiencies have & Gtrect effect on plant output and cost per kilowatt.

The effect of several parameters on the output of a plant 1s {1Tustrated on Fig. &. The vertical scale is shown as ?F tenperature difference, which 1s directly proportional to the theoretical poner avasteble.

Starting at the left, we assune thet the temperature difference across each of

the boilers and each of the condensers

19.

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35 10°, Veaving 20° avatiatie for ect! power conversion, If we assune

?hat the power conversion «fficienty 1s $', then ?re grass power arops to 15 out

Of the available 20. If the porasstic suing poms i 1/3 uf the gross, rather

typical figure, then the net power is rvuces to 10 gut of the original 49,

On the second bar we keep the sane enount c+ heat trencfer surface but

double the overall transfer coefficient, this reuces the

Sifference across each

exchanger to 5 insteed of 10. we now have 20 of the 40 units aveilable for conversion. 75: of this Insvos a gross poner of 22.5 compared to 15 on the first bar.

Subtracting the sare perasitic power leaves a nctsoverof 7 5, which is 75% higher

fet output produced by <oubling the heat transfer coefficient

a

one

se ronte Li | ty

Figure 7

RELATIVE NET POWER OUTPUT

- 20+

---Page Break---

On Bar £3 generation efficiency is increesec ?o 90% with other factors

the same es on far 42. The sross output increases ?0 27. Subtracting 5 this leaves

net of 22. Note that a 202 teprovenent in effici-ncy has increased net power by

a

On the Yast bar we keep conditions Iie Bar #2, but have reduced the parasitic

power {0 2.5. This increases the met poxer to 24.5 oF 2.48 tlees a8 much a8 shown

on the first ber.

Mile the bar chart is oversieplified, 4% HVlustrates how vitally important

it 45 to tnprove the efficiency of heat transfer ond gover conversion, and to reduce

Parasitic losses. Note that in the above exazples we assuved the sane quant

ty of

paser flow. or aporosinately the sane 23:0 of the plant. If the plont is the sane size

FOE Brogpess (2.43 Lines as Much pewer, shen the welje? and cost per kw. is useced bees

ST Gh Sn'etual plent we would not tabe acvantage of these improvenents exactly

a shown on the bar chart, It is sure effective to optimize the combination of

individual effects to minimize the cost of the plant. For example, it may be wiser

to reduce the water flow and size of the punping equipment, end reduce heet transfer

area, rather than reduce the tenperature difference across the heat exchangers. In

our design work we optimize the design parameters so as to produce best overall plant

economies. In actual practice it turns out that maximus plant thermal efficiency is

fot as important as minimum heat transfer area and mininum weter flows, which largely

Getermine the size and cost of the plant.

The many years of development, analysis, evaluation of the problems, end

experinental work have enabled us to meke many inprovenants in plant design. These many improvenents are incorporated in the latest conceptual design of @ 100 Me plant, shown on Figure 9. This plant incorporates many inportant features designed to accomplish the objectives outlined above.

The plant shown on Figure 9 operates on the cane principles shown in the cycle diagram on Figure 4. These principles are basically the same as proposed in our original paper Ref. 32. However, the many improvements have resv?ted in a more effi-cent, more practical, and much lighter weight plant.

- a.

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The plant 45 a seni-submersible design constructed prisarily of ordinery shippuilding materials, such as, stee?, ciumrun, nut fibergiass reinforced

en

plastics. The depth of the platform is 2: oroxinate! vrs, and tne length

120 meters. The total dead weight, inciuinge Ici. ?eter long cold water pipe, and ?the working fluid 1s approxinately 28,490 etric tors

The warm water enters thry the screen surrounding the plant at the aster

Vine, and some of the vir 1s resoved fren the wazer vefore it enters the turbine

Griven warm water punps located 10 meters below the sea surface. Revoval of sone of the air from the mater reduces the possibility of cacrofouling and corrosion:

The warm water is purped down thry the larce vertical pipes to a pienum chazber fron where it 4s éischarged thru the boilers to the oven sea

The R-22 working fluid $s evaporeted in the boilers under 8 pressure that is nearly the sane as that of the seamater surrourding ?ne boilers at the totton of the plant. The vapor flows usward from tre boilers to the turbines located Stightly atove the boilers.

The turbogenerators are a patented hermetic design that operate at extrenely high efficiency. The turbogenerator housings ere in the open see; but the working parts are accessible for repair and revoval inte the generator access room on woich they are counted. Transformers, controls, and accessories are contained in ?the generator access room.

The exhaust vapor from the turbines flons directly upward to the condenserss

where it is condensed to Miquid by cold sea water purped thru the condensers to the

?open sea. The condensers are located at approximately 25 meters below see Tevel, where

?the vapor pressure is nearly the sane as that in the seawater surrounding them.

?The condensed Tiquid R-22 flows by cravity to the bo!lers Delow, so that no

'd. Since gravity feed 45 1002 efficient. wherees

boiler feed pumps are requil

Punps and drivers are not, this feature iscroves plent efficiency

~ ae

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The cold water pipe, which may te JU to 1200 meters tong, is suspended

from a flexible spring support im the center well It 4s free to swing in any

Cirection, end free to move up and down on its contretled ny support system,

The cold water pipe ?s what say be called © stockade construction,

originally described in Reforence 53, with numerous inerovenents later incorporated.

Essentially it consists of » circular ran of hollow tubes, nich form the mall of

the large pipe. This provides @ thick. insutating wall, which provides strength

and stability against collepse, and persits contro) of buoyancy. This construction

is also easily code from the platform at sea, since individual pieces are easy to

ship and handle. There is, therefore, 0 probler: in transporting the cold water pipe

from shore to platfore

The cold water Mons from the top of the pipe into the center closed well,

from where dissolved gases con be renoved befcre the water enters the turbine driven cold water punps, which discharge the mater doxrmard to the condenser plern chamber, and out thru the concensers to the open sea

Dynavic positioning thrust forces are produced ty the water jets issuing from the boilers and condensers thru directionally controlled lowers. These jets troduce avple thrust to position the pleat euring normal operation. during storms, when additional thrust is required, the turbine driven purps can be seeded up, and additional Tcuvers can be opened to produce the necessary high thrust. The auxiliary engine sterting systen can also provide power to the punps for producing thrust when the main power plant is not operating, and for transporting the plant

It is interesting to note in Reference 18, wnere a very detailed study of deep water mooring systens sas sade, that a dyramic positioning system wes proposed 46 a safety measure, in case the mooring systes failed. It 1s also interesting to rote that a floating moored of] drill rig in the North Sea mas saved from disaster

ty tugs, when the mooring system broke up. Ref. 24.

+a

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The Seni-sutmersible plant has west of the structure wet? belon the mater Hine,

tnd @ rather saat] ares at the sea air tetortace, The warm water screen surrounding

the plant at the water Tine scts as e wave domer to reduce the force of the wave

ifDeCL On the marm and cold mater wells. which sass thru the air sea interface.

The exper?ence in the off driltING incustrys and cetiled studies, fet. 12,

have shown that» Sesion for ocean

~suonmrs bles are generaily the ?ost stabi

platforms.

table below. Conparative data

Plant perfomance date is presented in

4s also presented for our original proposed desion, Ref. 23, and for # government

Sponsored study rade by Lockheec in 1978, Ref. 55. fata ts based on a 199 He plant,

sesign, with cata propor stoned for

altho the Lockneed study was besed on 160 She pla

00 twe output

Power Plart Performance Comparison

units SSP Lockheed ss?

1985, 1781881

re difference tc a7 22.2 a2

arn mater flow sec 582 400 ae

Herm water Aon/net hw Ag/iwh 21,826 15,076 9038

Gold water fom Pisec 23a

Cold water flon/net kan Kg/tmn 19,802 15,895

Heat Transfer rea/Net ka-Bo:ter row 7193.28 10s

Heat Trensfer Area/tet kw-Condenser ie 13283 1.16

Overall heat transfer coefficient-Beller ? Ecu/ne ft? °F 220 22309

Overall heat transfer cocfficient-Condenser stu/nr ft? °F ? 200 23 vse

Gross Power oe 10.0 132.8 122.8

het Power ? 100.0 98.0 101.6

Ratio Gross/Net 11.36 1.208

Cold mater pipe dioneter Meters 8s

Plant weight including cold sater pipe Metric tons _ 75.400

Plant weight Metric tons 50280

Working fluid ee Propane moni Re?

---Page Break---

The 5

Ting reduction in plent weight chet con pow be achieved is the

result of sany cesign imprcvenents, the ?ajor one: ?ining inpraverents in heat transfer efficiency, reduction in mater flom, and ancreased turbine, generator, and pump efficiency. It shoule be noted thet each reduction in ecuipsent requirenent results in 9 reduction in s:ructural size end weight of the platform needed to support the equisnent, and in thrust ferces to keep it on station

The plant design presented above seus to setisty all the objectives outlined

tages which are ?ster nere

above, and hes rany adver

1. The Geep seri-sutrersibie design 4s weil known snd pro

te be highly
successful in surviving violent storms.

2. The smal? area

1 air sea interface with wave damping screens surrounding

the platform contritute: te good stability in storay conditions.

3. On

Soning is snorcugly proven to provide gout resistance to stores.

4. The seni-utrersible tyue plant cade of conventional steel, aluminum, and plastic 1s constructable at many shipyeards al! over the world, and the size fs siailar to sizes alrcady being buflt.

5S Heat exchangers, turbines, and purps are srall exough to be easily transportable

tH

they could be munufacturee at many faci?

6. The stociade pipe is corstructatle from the pletferm, ent does not need to be

constructed at @ specia) shore facility.

1. The plant is easily trarsportable to the site, tecause the ¢yoanic positioning

systen fs operable withcut the cold water cipe being attached.

8, Oynanie positioning is well proven in drill ric cperation, and completely

eliminates the need for costly deep water moring systens

9. Heat exchangers, being external, are easily accessible for cleaning or reptacenent

10. Pumps are conveniently placed so that they can be lifted tot

eck for repair.

V1, Turbogenerators are small, so that they can easily be handled for repair or replacenent.

---Page Break---

de

1B

1.

18

a.

22,

Intake screens are very accessible and ess) to clean and naintain.

Turbine driven punys are variable speed, ?aking st easy to agjust the design

to different opereting temperatures

The high efficiency ef neat excharaers cenirthutes greatly to reduction in

Fecuces area

plant size and cost, und to reduce! woter Mon require:

atso contributes to loner friction end suratmy losses.

Multistage neat erchengers increase tne emomt of heat usable from each

Ai lograr of water one recuces the plent aster ?Tow rate

Efticfent ing power, and permits

ign of the mater fae aysten reduces put

<Ahich on ture peraite the use of &

higher velcities in che cate weter

sealer, lighter, anc chearer pize

Wigh efficioncies of ?urtees, sensrutors, anc sunps azsrecvaply incresse

plant effistency and net cutput for 2 9

Elininotion of the ned for botier feed prys increases efficiency end reduces paintenence requirenonts

R22 working Muid hav many advantages. it 1s non Flenrable, non toxte, and

practicelly non corrosive. It ts also easily separable froo water, requiring

as that required for enenia, tt is

o> conplex mater removal syster, such

. ocean, It 4s also

Suswler than watery so thet Tost Tquid wilt sink dn th

congatible with copper alloys, rabing it possisle to use hermetic generators.

and copper alleys for heat erchangers,

Generators, pumps, and heat exchsrsers are al} in multiple, so that repaies

and maintenance can be done white plant is in operation. This insures a high

plant availability fertor

Low mater intake velocities cause nininut disturbance to marine 1ife.

Multiple discharge Jets fron condensers above the boflers insure mixing, 50

that the cold water will remain in the upper photic layers, and susply food

for fish production

---Page Break---

23. Cold water pipe design is Light weiont, strorg, and easily

structed from

the Moating platform, It car alsy Se designed te mininize effects of vortex shedding forces producr by underwater currents

24, External courting af hat exchangers. vapor piping, end turvcsenerators con-

tribute tvoyarcy and help to reduce size and weagnt of the plant

25. Onysen revoval from warer reduces nossability Fer corrosion and eacrofoul ing

26. Flexitte dive support system recutes interconmetion forces, end peraits cone

struction of the pipe ?rom tne platform

27, vera} srall size red. ces cast, and greatly a

ices thrust forces required

for station beeping

Economics is the ult

te factor tnat forces @ decision as to wiether ocean

thermal power is oractical 1s a large sceie source of yower. It cust be competitive

with

er availaple sources of poner

A pretty cenerelly accepted fornula for comer costs is that used in Ref. 9.

im 6 ery» (com)

FCR is fixed charge re

MiNTS per kon

where:

in annual percent

of capital investrant. This shoule

Gmclude jong tern costs of debt, insurance. tones, ete, During the 1870's, 16.

and 17 have Heen conmon values for the

C/Md $5 capital investrant in dollars per vesawett. This includes direct

costs and Financing charges dur

15 the time required to design and butte

the plant

Fh is capacity factor

st hours actually produced per

year to the total which a plant overated at constant full rated poner

could produce in the year.

5760 = nours per year

(CF) is the cost of fuel in aills per bilonatt ?our produced

(COM) is the cost of rainterance in mills per tah

-ae

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Capecity factors for oc in thera? plant:

8 expected to be auite high,

particularly for the type plat nere chucussed. The plant need practic

Shutdown, because 211 elenen's of the lent excent the cold water pipe are tn eultiaL cr replacesent work can te carried on

ple units, so that any maintenance,

while the plant is in nearly full pone tion. The plant produces saximum power

the fuel cost 4s

in the Tate sumer, when ele: tric poner cevand {5 greatest. Sine

Pero the plants would be overstes thru Ton cevand nignt time periods, when fuel using plents would preferably De srutéown, for these reasons 9 capacity factor of 90)

could be expected for ocean :nermal plents of thie vesion

Nuclear plants have a t:2oretical ava?l

lity factor of atov 682, necause they

?must be shutdonn for a pertor of stx weets

ly te change fuel rods. Thay also

are suaject te constete rian: shutdonrs for rary reesons. sinrly teceuse of the

Gangers of radioactivity. Wostoricaily the cazacity factor for nuclear plants has

averaged around §5:. This does not Incluae such cisasters es Three Mile Island plants,

which now nave a zero capacity factor. It Js generelly desiratle to run nuclear planté

as base Toad plents, because the fuei costs ere lower than ccal or of cests

Goal plants currently are expected to neve an evailad

ity factor of about 56

according to Ret. 36. The availability factor 1s the ratio of power that ceuté

be produced per year if the plant generated all the power it was cezable of proeucing.

to the total poner it could tneoreticelly procuce if operated at full rated power

Voor of the time. Capacity factor will Generally be less than availability factor,

particularly for plants shich use expensive fuel.

O11 Tires plants would normally heve an availability factor higher than that for

coal plants, because the fuel handling and waste handling are much Tess complex.

However the capacity factor 1s usually fairly low because fuel costs are very highy

?ang it 13 therefore inperstive to shutdown these plants whenever systen Toads are

oan.

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Hydrcetectric plants usually have + ratner low avaiiabitity factor, simply

because water flow varies gr atly throwsteut the year, While availability factors

very greatly with individual plonts, an caurall averse value is probably about 50%.

Capacity factors should be e.nost the sore as availability factors, because the fuel

4s free. It should be noted thet hydrorletric tidal power plants have a theoretical

availability factor of only ?st

a

of the chars

0 nuclear, fossil fuel, and nydrostectric

ter stics come:

plants 15 that a1] have lowe.t ceneresing capacity in the sumer, when system power

esands ere usually the nighest, In contrast to t's ocean themal plants can pro=

Gace their highest power outtut in the wurer, wher comer cenand 16 highest,

Recent capital costs for nuclear plarts vary from $1551 per ta., estinated

or Electric 1

by the Eee tisute (Ref 27) t0 $3037 ba ite an S3878/hw. (Bef 39

A large part of the capital costs involves the Financing cherges, because construction

tines are now azproxirately 1

years

Coat fired plants are recently estinated to cost abcut $2209 per kw (Ref. £0)

Nore conprehensive cost estimates have recently deer rade for EPRI (Ref. 41)

Since large oil fired plants are not generatly being butlt today, it is éiffi-

Cult to odtein recent cost estinetes, The cost recent cost estinate 1s er official

estirate for 2320 Mwe capacity, made by Fhiladelphia Electric Company for the Public

Service Commission of Pennsylvania in 1875. The estimated capital cost was $564.00

Per kw. Based on inflation of 10Z annually, the 1981 cost should be $1100 per ker

The estirated heat rate was £900 Btu/bwh, or .263 tueene) efficiency.

Hycroelectric plants vary widely in cost. Recent costs have necessarily

increased nore rapidly than the inflation rate, becuse most favorable sites have

generally been built, and the new plants are forced to use nore rerote, and more

costly sites. A recent estirated cost for the world's largest hydro project tn

Gueree (Ref. 42) 15 $1600 per kw. for 10,43 Ye, anc has an expected capacity factor of

-788. Based on 102 yearly inflation the 1921 equivatent cost should be $2340 per kw.

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Stes con be rade tooay for ocean thermal pi

Ne accurate e: ts, Probably

the best estirate can be sade cy using t°@ sacs cost por ton of weight thet ts used

vee se

for somi-subrersiole off eritting rigs. Se sutmersiple ery}? ig fs

considerably core complex tan an ocean therral power plant. At 53005 per neteiec

ton and a weisht of 250 ton: per kw from Title T the cost wovid be $1090 per kilowatt.

Other cost estinetes such a: Ref. 7.9, enc 3S estimate costs ranging fror £99 to

35 estimates 2 vient of 2159 tor

52700 per kw. Since per bw and 2 raxinun

cost of 3702/2150+81720 ver ton it appears reasonable to think that $1990 per ton

Thermal efficiencies Lecome important for plants which nust purchase fuel.

This would include of1, coal, an nuciear plants. The current price of of? fs

azproxinately $28.09 per dare, At £90) Stu/euh the fuel cost would de $5.67 per

Billion Btu oF $i iis per ean, AL 9899 Btusswn for a coal plant and $38.00 per

ton for coal tie fuel cost sould be enpreaimstely $157 per milion Bty or 12.3 niTTs

er kwh. At 10,290 Btu/twn for a nuclear plant anc $42 per pound for urenium fuel,

the fuel cost would be azoreairately $1.19 per millon Btu or 11.4 FATS per kwh.

Tne foltowing table shows expected power coats for the various power sources

1d etove, calcuieted ay the formula fron Ret. 9

Teste 2 Foner Cost

O11 Coa) hydro. tuetear SSP

Capita Costs W900 2200 238028801000

Fixed charge rate ee) 20

Capacity factor 1% 58S 3880

Cot of eaintenancesmil}s/bw a4 3 ? ?

Cost of fuel-ni Ns /tah 8.123 one °

Fower cos t-ril1s/kwh 65 1076 2 ae

Fron the above table it is quite epparent tnat ocean thems? poner plants

could cost as much as $5000 per ky and stil? te covvetitive with other sources of

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Power. It should be point d cut thet im rary tslany communities power presently

costs 15 cents or nore per tet.

Another may to evaluate power sources i: to compare ther on tne besis of

total enersy required to b.i1d the p! This ig done in Ref. 8, and serewnat

Gifferently in Ref. 43 and 44. In each case ceean thermal power shows @ sore

favorable enersy balance than any other for of power

When we consiger the additional produ

of food, fresh water, fuel, and

other chemicals, fram ocean thermal poner, fr esditian to the Tow power generation

cost, it is clear that eceom shernal power rust indeed be the world's best bargain

in energy.

9. Hilbert Anserson

President

Sea Sotar Power, Inc

2422 South Queen St.

York, Pa. 17802

Decenter 8, 1987

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UPADI 82

Sen Juan, Puerto Rico

?August 1-7, 1982

First Pan American Congress on Energy and

Second National Conference on Renewable Energy Technologies

WAVE ENERGY UTILIZATION IN WESTERN AUSTRALIA

By

?Authur Harry Nash

Western Australian Institute of Technology

USA

San Juan, Puerto Rico

August 1982

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WAVE ENERGY UTILISATION IN WESTERN AUSTRALIA,

ABSTRACT Western Australia 16 a large State occupying the vestern third of the Australian continent which approxiaates the area of the Usa,

?The State's population {s only 8% of Australia's with 70% Living near the gaptzal city, Perth. However, there are scattered towns, rainy along the coast, and in the renote North-West large iron ore developaent projects eve spavning new towns sone 1500 kas froz Perth, the aajor pover generating centre. The supply of economical electrical energy to ther pores proviens.

OF recent years ol has provided ast electrical pover but with escalating Prices of this taported consodity a conversion toa nearly 100 percent coal system has occurred. Wailer the renote east coast of australia fe well endoved vith coal supplies, Vestern Australia's are finite vith present Feserves lasting t111 about the end of the century. ?This, and the face that Western Australia's electrical energy {s relatively expensive, pores probiess ?and the State has shown sone interest in developing renevable sources,

Western Australia?s coastline extends for some 7000 kns 0 avatlability to wave energy 18 good.

The author is interested in the possibility of harnessing wave energy and is im contact with leading UK vave energy workers. Preliaiaary iavestiga tone Andicate that the Western Australian wave energy density available fe sech that a considerable portion of the State's energy requiresent could be provided by vave energy at economically viable prices, in the relatively near futures

The author has been com

energy utilisation in Wee!

oned to prepare a scenario for possible vave

rm Auetrald,

1 urmopucrion

The forces ansoctated with waves, albett thetr destructive rather than useful

ature, have been known to man since he first ventured forth on the senses

Suffice to state that these ancients and their aodern successors acknovlesged

(end often suffered from) the vast forces associated with the cease,

There are saall scale devices, such as puaps for eaptying water from anchored

pi which are activated by wave aotion. However, the general

fapression ie that interest in harnessing vave energy to supply large

apounts of electrical pover is very recent steming from the world energy

crisis, (Indeed to a large sector of the technical and nontechnical petite,

ave pover as a harnessable energy source ie still an unknown quantity), te

te somewhat surprising then to find that Stahl (Ref. 46) presented a guper on

the topic to the Anerican Society of Mechanical Engineere in 1892. He

There vas Little followup C111 the a1d 1960's vhen Masuda's self povered Maht-buoy, discussed by McCornick (Ref. 29) was developed comsercially. But de vas Left to Salter in the UK to kindle, at least anongst # lisited group of fechnical people, a real interest in the use of vave pover for large scalepover generation. To 1974 he described the {eitial work undertaken by him at the Untvernity of Edtuburgh's Departaent of Mechanical Enatneceiog (Raf. 42)

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To those interested in larnessing wave energy, Stephen Salter's ?nodding duck? is nov vell known. Bat apart from the developsent of the device {raelf, the frat large scale attempt to bring the vision of harnessing the vase energy of the ocean to reality, this vas the cacalyst that vas to generate wide-spread action, Satler's report, vhich cofne:ded vith the dramatic OPEC generated price spiral for of2, {s accepted as veing largely responsible for the UK Government rapid growth of interest. The Energy Techaology Division of the UK Departaent of Energy commissioned the National Engineering Laboratory to undertake a study of the economic and technical feasibility of large scale generation of electricity in the Uk by ocean waves. Concurrently with this study, vaich took cognisance of UK work and also that in the USA, Europe and Japan, Salter received a grant from the Departaent of Industry, later taken lover by the Departsent of Energy, to further Ms work (Ref- 25, pp+10-11)

?The NEL Report (Ref. 25) concerned itself with the need for wave power, data on vave energy available in both the [X and vorldvide, possible effects on the environnent, devices currently being studied, the eost prosising devices and entinates of the cost of vave-povered electricity. A point of particular Interest to Auatralians was the information that vave energy levels of Australia vould probably be aiatlar to those on aost of the Uk coast, particularly che southcoast, though energy levels in the Atlantic approaches fo the British Isles tended to be higher than elsvhere. The report, (Ref-25, +8) noting that the highest wave energy occurs ia the North Atlantic, goes oa fo say: ?This, hovever, does not imply that vave pover generation could not

be econonically viable elacvhere. Countries «with little indfgenous

source of energy, and shipbuilding and marine engineering capability anda

Level of vave energy roughly the same a that around much of the UK coast have

considerable incentives to step up thelr effort on wave power generation =. +

Jarch than had been

Other points noted: There vas more waverpower

delleved, cost estinates for wave-pover generation vere not unduly high, the

developing trend to offshore activities and associated technologies vould help

im cost reductions, and wave power appeared the most attractive alternative to

suclear pover.

?The report further noted that a substantial part of the UK energy needs could bbe met by vave energy. Specifically, by making certain assumptions, it was deduced that half the 197% energy needs could be supplied by between 600 and 1600 alles of wave harnessing devices. However, because of the relative shortness of the coastline, At 1s noted that these equipnents sight cause ateficulties with fishing operations ae they would occupy a coasideratle part of the Atlantic coastline.

The final recomendations vere for the UX Governnent to maintain an interest in the field, that Edinburgh and complenentary research prograne should be

adequately that design and developaent studies should run parallel to research prograas, and that environmental etudies should be sponsored.

?The Third Report from the UK Select Comittee on Science and Technology was also concerned with development of alternative enemy sources (Ref su). It Aneluded vave power in its cons (Refs Gb, pp xxiiinxi, LiLt-11¥)

This report to the House of Comons left no doubt that wave power offered a considerable potent ial for large-scale electricity generation if the technical development could proceed to econoatcaly viable generation. In noting that this source of alternate energy matches availability closely vith deeand, the Kecomendation was made that a developaent program be sounted such that ave power could contribute « significant component of the electricity supply by 1990. ?The governnent's reply (Ref. 10) accepted the recommendations and

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advised that its significant increase in fund ng indicated the high priority Ie accorded this work,

Im 1978 the Secretary of Stace for Energy presented an Energy Policy to Parliament (Ref. 43). This stressed that vave pover offered greater potential than any other alternate energy source for UK pover generation with good chances of success. The investaents in the research progran were also Justified as insurance againet shortage of otver conventional fuels even 4f whe cost of this electrical energy resained higher than for cther sourcese

Thus, from the early work of Ssiter s raptd expansion of the UX progran occurred to the point where that coustry 1s undoubtedly a world leader in the field. Sualler prograns are conducted in Japin, Scandinavia and the USA,

Meanwhile a Lintted susber of Western Australian workers becase Interested ta the possibilities of harnessing vave energy. The possibility of devices. deing developed to econorically harness wave energy was Seen agelast a special dackground in Western Australta. Escalating cost of imported ofl has forced a conversion of matnly of] fired generating stations to cos! fired units.
However, WA coal reserves are limited. ?There vas very strong opposition to @ Fecent governsent proposal to establish a nuclear pover statione, Western

Australia is a large, sparcely populated state with sizeable communities and industries in taolaced areas vell renoved from coal fired stattons. They have to use espensive diesel povered electricity. The State has a very long coastline vith seen!agly considerable potential for wave energy uses The State is developing cechnologies in connection with offshore activities and marice affairs.

It was against the general background stated immediately above and the broader coments fron the NEL, that the prelizinary study discussed in some detail hereafter, vas tnitiated with a view to influencing local authorities, Fegarding the possibilities of harnessing vave energy in Western Australas

2 WESTERN AUSTRALIA AND I7S POKER PostTION

2s Western Australia

Area-vise Western Australla {8 a Large State of 2.5 million square ktlonetres, 4@ third of the area of Australia, vith distances of 2500 Kilometres goreh to south and 1600 kilonetres east to west. However, it has a relatively sual

2 million population, approxtaately 6% of the total for Australia, Some 70 percent Live vithin 30'niles of the capital city of Perth but there are several country tons, nainly near the coast, with significant populatios

The coast stretches 7000 kilosetres. This offers considerable potential for waterbased activities. One fe the developaent of off-shore gas fields. The North Rankin field (Ref. 47) has estinated reserve of 265 bilion cubs Retres. A two platform unit to produce 40 million cubie metres of gas @ day is being inscalled. This field, situated about 130 kilometres off coast frow Dampier (1500 kilonetres from Perth), 4s in up to 130 aetres of waters

In addition to these developments the State already has very heavy adéitional

capital and engineering comattmente in the Northwest vith the iron ore

developeents in the Pilbara. These are all sajor engineering operations

requiring sizeable electric power

Experience in the development and construction of off-shore rige also exis

For exanple, the Ocean Endeavour, an off-shore rig involving $22 stilton #

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Cockburn Sound, ind

+ Woodane Polat west Perth Jo the sheicered

ing that the area is sare for this type of project.

Pigore 1 shows sone of tie above features and s140 gives @ relevant size fraze

im relation to the US\ § Uk. The relotive sizes and lengths of coastline of the UK and Western Avstrsiia have stcn-{icance. These points are discussed tn Section 6 as are the unduly scattered remote m/ning tewe.

2.2 THE POWER POSITION

?The State Energy Comission of Western Australia is charged with detereining the best vay fuel, energy and power car be used for the benevit of ehe people of Western Australia; vith ixplesencing fuel, «nergy and pover policies of the Government; vith prosoting and co-ordinating the developsent ant use of fuel, energy and power in Western Australis and with detersining the future denands for fuel and power in the State. It is also required to investigate whether the State can meet this denand and to assess the mpact of any fuel and pover shortage on developnents and to ensure that supplies of suitable fuel and pouer are availeble to the public (Ref. 68).

About 98E of the State's population Is serviced with Conmtssion electricity

Peak electrical denand recently exceeded 1,000 megawatts and it 1s est inated

that by the year 2000 up to 3,200 megawatts of additional generating

facililties nay be needed. The escalating of! cost has led to conversion to

fan alnost exclusively coal fired generating systen which worsens the position

Regarding linited coal supplies. The maximum extractable are only expected to

Provide a futher 1,400 megavatts. Plane already exist to install 400

egavatts of this Capacity.

Western Australia high electricty costs could be to the State

At considers introducing wave energy systense

advantage if

Western Australia's renote northern iron ore areas are dependent entirely on

expensive diesel electricity plants. Feaeibility studies to deteraine tf

these supplies can be nade cost effective are proceeding. Installed capacities at these centres ranges fron If through 4 and 10 eo 70MM

Western Australia {s also short of fresh water 0 that any excess clectrical generating capacity fron vaves in heavy veather conditions could be considered for desalinating water vhich can be stored against denand.

Extra sites for pover stations are betng investigated and 4 current political Assue revolves around statenents of the then Preaier that the State would have to look to uranium as a pover source in the near future. Indications vere that a nuclear pover station could be operating before che turn of the century Af none other energy source 1s not available. There is and vill continue to be considerable debate on this topic.

The State Energy Comission aod Solar Energy Research Institute of Western

Australia co-operate in developing and appratsing the possibilities of

alternate ? Tange from vind turbines, through solar cell

arrays back 8, and hybtd unite Linking a

100 KW solar tracking collection ayates with an exieting diesel unite The

Solar Energy Research Institute 18 Interested in futher encouraging research

?and has expressed {nterest in wave energy developuents

Thus, because of the high cost of fuel off and the fact that Western Austrlia

does not have significant indigenous of] sources the State has moved to firing,

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existing pover stations ith coals Future exp nsions in this éirection are

Limtted because of the limited knovn reserves. f coal ence, al

of energy generation vil? be required in the tures These

of renevable energy or riclear energy 2° 8 co=*t

these possibilities sre slready under investip tic

consideration ts wave ercrgs.

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y take the form

on of bot?, and sone of

3 COASTAL HOSPITALITY AND SHOFE FACILITIES

Before vave energy can be harnessed it is desirable that an adquare

hospitality? regarding facilities shuld exist, what of the KA coastline in this respect?

3.1 Weather Condition

?Though <t will be suggested that vave energy ?2 adequate, the area around Frenantle is generally aarked by the absence of violent storss, ihilet one oF two cyclones have been experienced over the past 80 years thelr effect has been small in the Perch area. The vorst the area normally encounters is depressions vith steady rains and gone winds.

The

the area is generally benign and well suited to experinental work.

3.2 The Harbours

The initial Fresantle harbour was the result of vork of the prominent engineer CY O'Connor who took the mouth of 2 relatively shallow river and converted it Anto a safe modern harbour to handle passengers and all types of cargo. The

land backed port has a sintous depth of 11 setres. Ie handles both container and other cargo. The 80 hectare harbour is safe for ships all the year

Found. Adjacent to it 1s a lerge odern fishing fleet harbour and another for prestige pleasure craft.

Because of WA's remoteness and the need to maintain existing vessels and build others for the fishing and allied industries, docking facilities are avatlable where engine overhauls and hull repairs can be pezformed.

?The area around Fremantle has developed as a light and heavy industrial areas One reason for this is the fact that the coastline {s sheltered, yet provides ready access to deep water.

Brief mention should be made of the general marine surrounds of Frenantle.

Off Prenantie's coast are long reefs which fora strings of protective islands, the major tvo being Rottnest and Garden Islands. Rottnest is some 19 KAlonetres off-shore and Garden Island ranges from about 8 kilonetres off to a causeway link vith the mainland, these tslands providing a protection for the

Of particular interest {s the 182 square kilonetre outer harbour or Cockburn Sound, between Garden Island and the mainland. This sheltered area has attracted industries, many requiring sea access to the coast. The AP Refinery couplex hae ite ove complex ?The RIP steel vorks operate two separate Jettion capable of handling both ateel products and raw materials

The Alcoa Jetty te used for loading bulk alusina, Two bulk unloaders fora ?another complex for handling bulk cargoes, These are used by the fertiliver works and others, The large Kwinana bulk wheat storage unit ales has ite couplex of four loaders. The Garden Taland Navy Depot vith {te 13.7 netre arbour, residential factlities, workshops and atores 1 also in the area:

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?Area access to 70,00 teane class shirs is via dredged channelsy

Other large industries in the area using gener. 1 harbour factlittes include

the State Electricity Co-atsston power station the alckel refinery,

Comonvealth Industrial cases, CS, Auctralis: Shipping Industry and food

processors.

3.3 Allied Tadustries ant works

?The UA econony was largely agriculture based priar te Horld var II. Since

then agricultural proninence has been maintained put vast strides have seen

made in {industrial development and the State his also become a major producer

of minerals including gold, caal, irox ore, Davnite, sickel, mineral sandes

Batural gas, Urantun and now diamonds. Minera? roedrces ave widely

Aistributed throughout the State with sineral sande, coal and baucive 200 kas

to the south of Perth, goid and nickel 40 kilometres to the east and naturel
gas, iron ore and diatonds 1,500 - 2,300 kLloneeres to the northe

?The nev developments in the arid apersely settied north have flowed fro governnent and private Industry. They are supported by an efficient system of ground (road trains), air, and spectaltsed sea transport. The four aajor {roa fore groups have multi-million dollar holdings. ?ew off-shore gas ventures see the expenditure of apptoxinately four thousand million dollars in the next four years or go. Viner aining groups are also making their coneribut fons

?These groups have sponsored che grovth of Large engineering and allied service in and around Perth so that there 1s anple sanufacturing and servicing capacity.

Mention should also be sade of other north west endeavours in the State. More than half of Australia's rainfall reaches the aea through the area. One river, the Ord, has been damed to form the large Lake Argyle used to irrigate the OFd River agriculture project where tropical ant sub-tropical crops are being grovn. Possibly sugar grown as an enerey crop eay be very significant. The hydrovelectric possibilities of Lake Argyle are also a political consideration.

?The north of Mestera Australia has been likened co an avakening giant. Including the possibilities of harvesting tidal pover the state 1s developing rapidly = "A State of Excitenent? ~ with a rapidly groving appetite for

electrical pover.

?To any group fnvolved in major engineering operations there aust be comfort in knowing adjacent unite have interests 1o common and Itke needs for servicing facilities. Major units fitting toto this category are located in the Perth-Prenantle and immediate hinterland ares include several shi pbul diag organisations and ship slipping facilities, © large f{shing industry, a large coal fired power atation, a nickel refinery, an oll refinery, a steel eaelter, 8 alusina sining aod refining, a large harbour coupler, # naval base and shore repair facilities, machinery manufacturing fndustries, ual! anvfacturing {ndustries , small specialise electronic industries, butlding Andustries and road and rail transport industries.

Several heavy wetal industries aod aupport groups experienced in fabricating Large setal structures, particularly thowe associated vith the rather Anhospitable ocean environment are also in the a

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4% THE MAVE ENERGY ENV:RO;ENT OFF ThE VESTER AUSTRALIAN Coast

Wave energy measurenent off the coast of Weste?n Australia are fairly Matted both in duration and in the geographical spres.. However, sone observations have been nade off Prenuntie, the port for the Capital Perth, which 1s 19kx from it. More recently a considerable azount of work has been undertaken by consultants for Woodside Petroleum Development Pty Ltd in thelt developsent of the North West North Rankin offshore sas field.

As the area of mediate interest is that

this paper are restricted accordingiys

Wf Perth the observations tn

Two sources of data on KA wave energy are:

Hunan observations of wind driven waves and swells from ships in the offshore area bounded by 30 degrees south, 34 degrees south and 112 degrees east for 1950 to 1957 a2 in Figure 2 (Refs 5)+

AL, ?Waverider? Bouy neasurenents at chose Figure 2 locations taken during the period 1970 to 1975 (Ref. 26, p.9)+

4.1 Energy Densities Determined froe Ship Observations

?The fifteen hundred and five observations of vind waves were separated into two categories. Those of vave heights greater chan 1.5 setres were tabulated but those less than 1.5 oetres vere not specifically Listed. Rather they vere Just specified as being less than 1.5 metres (Ref. 3, pel0).

The 641 observations for the bigger waves are ae in Pigure 3. The power per etre of wave front 1¢ calculated from

P= ce?mi,? vatts per netre of wavefront,

a

where 5 tw the density of sea water taken as 1025 kg/s

& {6 the acceleration due to gravity

T ts the sero crossing periods

Hy ts the significant vave height.

The pover for each tabulated value of Hy and T vas multiplted by the nusber of observations of vaves of that particular height and the total sumed to give 10,864 kw per aetre.

For snaller waves it 1s possible to ignore the energy contribution entirely oF

june that these waves were of average height «75 metre vith period tending to the order of 7 seconds. Using the latter assumption gives an extra vind component of 1927 kw hours per metre and total wind wave pover of 13067 ky per etre for 1505 waves studied. Hence:

average wave power density = 13067 = 8.68 kw per aetre

505

?The 950 avell observations sintlarly treated yield # pover density of 21250 kw per metre for larger waves, and with assuaptions as above, a possible 272 kw

Per metre for sualler vaves. This total density spread over 950

2 prom Salter (Ref 42, pp.720-1).

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observations gave an average power density of 22.65 kv per aetre, Data for

Jonger vaves fa tn Figure t+

The combined value for vind and svel! i 31.3) kv per setres

?These energy density fisures are obviously subject to sone concern

regarding accuracy. The effect of the assumptions regarding vaves of

hhefght less than 1.5 petres can be readily assessed. For example 1f the

Femaining 864 vind waves heights vere vero rather than the assumed «75 etre the total power from 1505 waves would have been 20,864 kw per metre for an average of 7-2 kw per metre rather than 8:32 Kx per getter Likewise the swell figure would Se 22.36 rather than 22.65 kw per etre. But there are other points of concern. The Bureau of Meterology notes (Ref. 5 ppe

1-2): "The data used vas restricted to the extent thst ships tend to bait reports of sea waves and svell vhen these phenoaena are regarded as in Significant?. And again, {n relation to avell vaves, "the percentage

Frequency of vaves of 1.5 metres oF greater does not present an accurate picture decause of the oaission of insignificant values of svell from the Synoptic ship reports. whecher thee osissions tend to bias the percentage frequency to higher values as might be assued, could only be established {f reports frou a stationary reporting vessel vere available?.

Again tt 4s of concern that the number of vind vave observations is not the sae ax for swell waves. It has been presuned in calculations that the

for the two sets of information vore reported simultaneously, If this 10 the number of observations should have been the same. There are tuo possibilities. The suell waves have been reported over a shorter

for the absence on an observation could ean there was no

observable swell. In this latter case there could de five hundred and fifty-five occasions when the svell height would have been zero and that would reduce the avell wave conponent fron 22.6 to 14.3 kw per setter

?Te inplicattons to be dravn are that further wave data and clarifications of those currently avatlable required, and the best estinate of wave eneray density off the Western Australian coast near Perth Se 31 kw per metre but under the vorst conditions of data interpretation this could be reduced to 21.5 kv per metre. Hovever, it ight be noted that Hull (Ref. 51, p.59), in estinating several average vave densities through the world identified a figure of 30 kw per metre off the South West WA Coast. Whilst expressing sone concern regarding accuracy of the above figures it 4s noted that the only data inttfally avatiable to Salter, were from similar husan sight observations albett from fixed location veather ships in the Atlantic.

2t {8 noted chat the most 1ikely Western Australian value of 31 kw per setre conpares with the maximus UK North Atlantic density of 77 kw per etre and the nore typical coastal UK value of 25 kw per metre. Even the Jovest expected figure for Western Australia 1s only slightly below thiss Thus vhilst accepting the Western Australian figures nay be subject to some error, they indicate energy densities of the sane order as those off most of the UK coast so that the possibilities of harnessing Western Australian wave energy should be pursued further.

The distribution of energy as a function of vave period, having significance in design vork, 1s plotted 4p Figure'5 using the Australian Bureau of Meteorology data (Ref.5). The corresponding data for Station Indta tn che Norch Atlentic te also plotted. It ss noted that WA peak energy ts available from shorter period vaves than ts the case for Station India. This may have @ bearing on the design of the WA wave energy extraction devices. (See Section 6).

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The direction of waves an also have cesign s::nlf ice. These are given in figures 6 to 9, with éf-ections reporred at I/> Intervals. 4 weve reported as 180° would Se moving fron south t north It vill be noted there 1s 3 slight tendency for waves to predoviste in thie direction in the October to March period with a predozinant spectrum fron 170° to 230°,

For the renaindar of the year vave ¢irections are sore varivsle for a Biniwal spectrum of 200 to 280°, The variability in wave direction may have design and device locstion significance.

4.2 Energy Densities from vaverider Souy Date

This data uas collected betueen 1970-1976, The off-shore Iocation of greatest Interest was about 10 kilonetres frou the coast in water 36.5 netres deep. Various malfunctions meant that cal punck, paper tape records were only availabie from August 1970 to August 1972 and Decenter 1973 to January 1975 with analogue chart inforaation fron May 1971 to July 1973 and November 1973 to Avgust 1975, The data is archived end ts avatlable for further data analysis. Unfortunately analysis to date 4d fot yield information in the form enabling the available power co be

readily determined. Processing of this data 1s now proceeding.

The Waverider Bouy gives useful design 1aforsation regarding the height of 10 year and 100 year waves as in Figure 10. Thus the probability of the staniftcant vave height exceeding £4 metres is one day in 100 years and that for a height exceeding 6.5 netres, 12 one day in 10 Years. Put another vay, 1f design {s based on the probability of a hundred year wave occuring in'the life of the device, it aust be capable of safely withstanding the forces assoctated with an 8-4 etre wave.

5. THE UNITED KINGDOM CURRENT POSITION

yrait, nor vould {t be appropriate in this paper, to the United Kingdom projects in detail. Te must suffice to wention sone in brief, particularly those which nay have relevance ta the Western Aurtralian scone.

Sel Saleer's Duck

In tts early stages the device was to consist of a series of ?ducks? fon a rigid floating horizontal shaft or spine anchored so the bly faced oncoming vaves as shown diagranatically for an early model in Figure 11 (Ref. 29, p.8). As the vave approaches, each ?duck? reacts individually raising (rotating) and thus absorbing wave energy. As the vave passes, they drop dovn again. Typically this oscillating action £6 converted to a uni-directional action of fluid to drive a turbine alternator. The schese, tested in all waves, was found to be very efficient in extracting energy for a reasonably vide spectrun of wave periods.

Salter envisaged that there would be twenty to thirty such ducks, having an inside dlaneter of about ten setres. Recause of the Tandon nature of wave fronts inpinging on individual ?ducks? the whole system was expected to float horizontally approxiaately parallel co the wave front with individual ducks oscillating upvarde and dovnvarde. Such proved to be the cage with both small scale and one tenth scale testing. Hovever, the latter posed problems. One design problem of euch aystens in the inhospitable Atlantic is that it has to be designed to withstand severe wave conditions. The

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Figure &.

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|

Figure 7. April ~ Septenber

fouanboas

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PERCENT PROBABILITY OF EXCEEDENCE

have Exceetance Plot - offshore WA.

Figure 10.

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tenth scale Loch Ness costing inéicetes ?t wour | be difficult to mcke

4 syster engineeringly strong and at the nase t se economically viables

Thus Salter changed his approach soneviat using a sophisticated

sleroprocessor controtlec ved tha: it is rigid up to cert

wave heights but collapses £9 a series of non~r gid spines, one per dvch, vith larger vaves. In acdition to spite sodifi ations the ener

conversion systens 15 be: Sertoux <oneide:

to using pairs of gyroscopes eounted {1 the ?duch's deal?

generation (Refs. 38, pp.337=2, 39, pp.105-6, 60, pedi le

Delieves che current develonsents will overcose problems.

?The developaent has received #812,000 governzent funding since 1974 wt contractors Joha Laing, and Cunsuttasts, Scottish Offshire Partnership

(Sc0PA) Joining the tedw for exten 11 scale design stuciee froe

1978-80 (Ref. Ty 9635) ally a configuration of twenty > thirty

ducks would Totate oa a concrete spine. Each duck would Se spproximacely

26 netres wide vith a total length in excess of 520 metres The team

currently estimates that a 2 Mute will generate power at a cost of 4.5

to 5.8 pence per Ki.

The ?duck's? develonent is descrined in Refs. 35 to 42.

5.2 The clea

Coventry Poletechnique's, Dr Bellazy headed the group Financed to conduct tenth scale tests on the ?duck? referred to above. ile sav the inherently weak circular spine as a factor contributing to high construction costs and Teasoned that a stronger nore economical spine could be obtained by using a rectangular section. But this seant that rotating ?ducks? were out.

Thus the ?duck? vas replaced by a flapping plate hinged at the base of the spine. About the sane tine Wells developed a turbine with blade configuration such that the direction of rotation was the sane frrespective of the direction of air flow. Bags fastened behind Bellany's flaps sesied to the open front of the spise so that an oncosing wave caused a flap to compress the air tn the bag behind tt and thus drive that alr through @ Wells turbine into a recovery manifold. On the passing of the vave the flap drops, thus opening the bag and the air passes through the turbine in the reverse direction keeping 1t rotating. There were about twenty flaps with one turbine and generator per flap. The ssine again effectively patallels the oncoming weve.

Studies relating to flaps shoved they constituted major cost couponent, would present considerable servicing difficulties ane wuld provide a tos than ideal interface with the trreguiar oncasing veves Thus the process of evolution let to the elizination of the hinged plates and their rentacesent by rubber bags - facing the sea - in the spines

?Though sone doubts have been rafsed regarding turbine efftetency and stability the group believes these ate not of great inport aa! at nest

Tecent contact, vork vas progressing vell, with detailed testing of pover take off units and bags proceeding with a'vieu to possitie early porsibie

prototype testing.

?The unte was evolved in 1979 following tenth scale testing on the "duck". Governaent funds have only aaounted to #187,009. SEA? Lanchester have worked vith Bellany's teas in funding the develoonent

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The device would be as aple concrete structure, have few aoving parts, with a closed cycle and hence a relatively corrosion {ree air traneiscion systea. Ten clams on a three hundres setre spine, 15 actrea dees, would jenerate an average output of Wi at ar est inated cost af ep per RM, Figure 12 shows dlagranie(c representations af the unit Sefure the deletion

The device is discussed in sone detai! by Bellany (Ref. 2), Sovtrill (Ref. 7), Wurdle (Ref. 23) and Raghunathan vt al (Refs Bae

5.3 The Lancaster Flexibie Bag

Work on this device vas initiated by Professor J Frenct at the University of Lancaster in 1977, The device has severai variations. Typtesiiy, te consists of a spine which can either float ar Se mounted on che sea ped in @ direction perpendicular to the vavefront. Along each side of the seine are a series of flexible bags in contact vith the sea on one side and communicating Via non-return valves to two longtitudinal aft ducts in the beam. As a vave crest passes dovn the device air is squeezed aut of the bags into the high pressure duct. As the trough of the wave approaches the bag expands draving air via valves from the low pressure tesurn dvct. Individual bags ork with different phases relative to each other bee into the common ducts which are joined through conventional single stage ait turbines. A diagranatic configuration Ss shown in Figure 1 (Refs 31, 289).

Bag design in full scale units 1s a critical feature. On the one hand it is clatued they contribute co the low cost, but on the ocher they sure aot aaly be mechanically strong - typically they would be ?a reinforced rubber Gtaphrags of corded construction, about the weight and strength of coated fabrics used in the big tyres of earth moving equipeent? (Refs 32, ged) e but must be able to collapse smoothly without Sucking onto 1ee backing Support on pressure from the vaver

Wave pover limited which vas infeially eatablished to develop the now defunct Cockerell raft vave harnessing device, joined the project in 1979 to concentrate on engineering design problens. Government funding hae asounted to 175,000 The device 1s relatively cheap and Tusse! end te

less stresses associated with it. Because of its realtive simplicity it te seen as also having auch potential in developing countries (Ref. 32;/pe3). The devices vhich are planned for sass production, would typseally be 200 metres Jong, about 10 metres deep and 4 metres wide with an average eurput of 2MW. Cost estimations vary around 3.5 to 4.7 pence per Kills the developuent of the device 1s detailed by Cottrill (Ref. 7), tvans (Refas 16 and 17), French (Refs. 19 and 20) and Platts (Refs. 31 and?32)<

5st The National Engineering Laboratory Osc{llating Water Coluan

?The UK Department of Industry's National Engineering Laboratory has nearly 4 thousand staff and is the largest UK estabiishaent concerned wich mechanical engineering research and developaent. Interests inclede flow of fluids, turbines, energy, flutd power, structures and off-shore expertioe. Folloving the wave-power feasability study undertaken by the Labeceey (Raf, 25), NEL decided that becouse of ts interests and enpertion fe should develope the oscillating water column principal then under consideration in Japan

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Figure 15.

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?The rise and fall of vaves {9 an inverted box, forces air back and forth through an orifice in {ts top. This alr flow ts rectified and the resulting unidirect?ona) flow ¢ used to drive an alr turbine.

Inteial work by Meir (Ref. 42) gave Low capture effictences. Tt was realised that a device, whether flosting or orton mousted needed to have land appropriate shape £0 absorb and not transmit wave ?Thue one aspect of the work wae Jo refining a structure which Could de wanufacture? of concrete oF steel, and sect these requirements. Running parallel with this was the cefinescnt of @ Francis turbine to match the characterfeties of the driving air stream ~ high Velocicy and low fnertia. Assoctated with the development of this robust turbine went the rectifying device convert ing rectpracating co unidirectiona? air flow.

Figure 1d shows a diagranatic version of the device (Ref. 12, pp.18 and 20).

The system has a sinple pover take off, can lead itself to floating or botton mount ing when st could double ai 4 break water thus effecting farther economies, and can be built using existing technologies.

Typically a concrete structure, aounted parallel to the wavefront, would be 35 netres wide, 33 setres deep and 121 metres long with six water coluans each vith its ovn turbine and generators to supply about aw (Ref 13, pi2l2). Costs are given in the range S15 pence per FW (Ref. 7, p37)

NEL {8 vorking 4n conjunction with Roxborgh and Partners who are the fengiocering design consultants. Detailr of the developaent are given by Elliot & Roxborgh (Refs. 12 and 13) and Meir (Ref. 30).

5.5 The Bristol Oset Mating Cylinder

Dr Evana of the University of Bristol, noted che theory that @ suberged cylinder vhich was soved to orbit its axis of syaetry in a liquid generated Waves aoving avay from the cylinder in one direction only. There vas no Bisturbance in the other direction. Evans reasoned that the opposite would flee be true. Waver incident on submerged cylinder vould cause At to Totate vith co disturbance of the water on the remote side of the

cylinder. That is all the wave energy would be absorbed by the cylinder. Evans and Shaw began experigental work in 1978 to prove Evans? theory and ?athenatical reasoning to be correct (Ref. 8). Sir Robert McAlpine and Sone Ltd, Hunphreys and Glasgow Led, Merz and McLellan and Hydraulic Analysis Ltd, Joined vith the University of Bristol teas to handle the ?engineering design concepts.

In the device being developed the floating submerged cylinder {s flexibly restrained by moorings vhich thus extend and contract as the cylinder Fotates as in Figure 15 (Ref. 45, p.267).

Te ds anticipated that each 12 metre cylinder will be 50 metres long tn at Least 35 metres of vater vith its top subverged about 7 metres below the sarface of atillvater for optinum operations: Tea axis ill be parallel to the wavefront. Mooring will be approxteately thirty five aetres from the cylinder to the anchoring pile cap. The rotating gotion of the cylinder thue translates to an almost Mnear reciprocating action in the mooring.

Mooring requirenents are severe aa they mist act ae a spring resonant aysten vith the cylinder, aust convert the reciprocating motion nto ont Coaventent for power take off, and gust withstand a buoyancy thrust Cotluated at eight hundred tonnes per mooring (Ref. 45, ap-262-3)-

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Shaw et #1 (Refs 45, pp-

346) considered voas

ty posible methods of

generating electricity fron the rec/sricatiae notion and discusses the

Various pros and cons. it Ls concluied thet ¢ btu aeting rock procating

Seavater punpe {9 the soortngs, ?sec ns seit water to shore based water

turbine generator sors, current?) appes? nie ?rst preposition, As the cost

per KW of hydro-turiine units reduces consieco'ly with increasing capacity

nts] about $0 MW units are ensnunterut, thts ?5 tho recommended sfze of leech shore untt to Se fed fy one hanced pues (sreaumabty four per cylinder).

Each cycLinder wil! generate about 2 Mii ot © cost eetinated at 5 to 10 pence per Kit. Though s late an¢ rather soshssticated starter, the device hhas received £109,009 goveramest funding use ?+ consigered favourably. AB St ts completely tubnerged tf is cine | si.! mare easily survive storms.

(Bet, 7), Davis et cet (Rete 45).

Details of the development are

(Ref. 8), Evans et at (kee 2

5.6 Other Devices

as they are all well

cers in the Uk fields

The preceeding five devices have been consic

advanced tovarde prototype testing end ave is ougse

There are other workers in the fletd

though the contributions from then are vs;

does not peraft discussion of these

available from several authors (Refs. 1,3,4,:1

in the? Roropes Japan and the USA

2 smaller seaie. Space

soe information is

427,28,33 and 49-51).

5:7 The Future for the UK Mave Progra

The UK program ts not of Long standing but there have been considerable developaents. The initial ist of thirty four cevices reduced to a few serious contenders, Soge of these such vcckorelive raft and the Bydravlte Research Stations rectifier :e1. by the wayside when Le vas Fealleed they could not become econct Sables A cecent funding decision sav government éirect suppor: far only three devices, the Lancaster lag, Bristol Cylinéer and che Osc! ?ating Wave colunn of NEL. Tt fe understood that funds vere iso ava?loble to the Vickers subserged version of the vater column. In addition, private funding and funds for generic studies such as for spines, and moorings have sustained the ?duck? and ?clan? vorkers. Thus there are six cos/ces stall in the field. Late 1981 visite vith oost ceans Indicates 2 genere! avareness that 1982 would be the year of decision. Most were puttiny !aishinz touches to their presentations which would be used ny the cnergs Techno?agy Support Unit to Present ite case to the Departnent of Energy regarding the deeirabllity oF Othervise of going to full-scale testing. ?here vas general confidence {a ?nose camps that one, at least, of the devices would be scheduled for a prototype testing prograa beginning vrurn 79A2. There were those who Considered that other projects covic go 29 prototype testing with or Without government funding. Some suggestions were that the initial operating unit vould be about three-cuarver scale, @ point of sone significance for esters Austrai?a as vi.l be seen laters

Recent private correspondence with C. crove-Paleer, Programe Manager, Wave

Energy Of the Energy Technology Svppart ait reflects the aost recent

position (Ref. 21) Unit analya!s for che cifferent devices indteates the

Cost of energy from a 2000 MY une (a com a 3f a number of individual

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units) would be in the region 5-10 pence per Sift but that further

Fefinesents as Large scale vork procveds should bring thie dow to as low

3-4 pence per Kitt. He notes that ehese costs are based on North

Atlantic wave conditions (high energ levels ~ hgh destructive forces),

sea bed conditions (rock bottons giving relatively high enchorage costs)

?and the spread of capital plant cost over # large station ~ effectively

?mass production of units. He believes there is a strong need for further

experiments in wide vave tanks and for cross fertilisation of the

innovative {deas vhich have arisen from the various teams. One of the

problens he sees is the need to assiilate the vast agount of new knovledge

that has been obtained. hen thie # done (and he does not give a tive

scale) ?we should be able to prepare a functional specification for a

Genonstration nodule of about 2-H capacity to de bullt at or near full

size". So it seems fairly cersain that one unit will be sponsored

least. But will work begin $0 19827

In the aeantine, others are interested in pushing ahead either in the UK or eleevhere. Thus tvo groups have prepared prospectuses detailing their systene and pointing out how they can be used in other parts of the world

id the advantages of so doing. They are actively soliciting interested countries to become associated with prototype developnent. ?They typically note that they are seeking funds to pursue this work in association with Interested countries because much engineering work related to specific Local conditions needs to be done before final costs can de established.

However, cost figures in the range 3-5 pence per KWH are anticipated (Refs. 12 and 32).

6 THE POSSIBILITIES 18 WESTERN AUSTRALIA

6.1 Western Australia and the UK Systens

?This however, does aot faply that wave power generation could not be econoatcatly viable elsewhere. Countries « - «with little indigenous source of energy, and shipbullding and aarine engineering capabiltities fand a level of vave energy roughly the same a2 afound much of the UK coast, have considerable incentive to step up their efforts {n wave power generation» = 7?

The WA wave energy ts probably adequate, the State certainly has Lintted long tern sources of indigenous fuel, and has required industrial and marine capabilities. Thus {n terns of the NEL criteria it should be consider becouing involved in a program relating to electricity from waves.

Sone further points are relevant. A continuing string of units occupying 129KM of WA's coastline (perhaps 200KM alloving for access between devices) vould generate average pover equal to WA's current load. However, the vave devices would not stand alone for obvious re Thus a much saaller percentage of WA's T000KH coastline is required than would be the UK cases

?The most recently available cost of generating power into the UA grid, ts from about 3.7 pence per KW which 1s somewhat higher than the UK base figure from about 3 pence per WMI. Thus econoate viability vill be eater co achieve in Western Auatralta,

of exchange, 1 cent Australian = 0.6286 pence

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Place notes that vaves te the Trade Wind Zones are much more constetent thus giving higher duty cycles and possibly sore energy than the higher denoity fore daaaging waver around the UK (e!. 32, p.32)+ He also notes the significance of length of vaves as thc efze of the device fe ?tuned? to the predominant vave length which 1s proportional to period. From Figure ? aost Frenantle energy 4s assoclated with 5.5 second vaves whilst in the North

Atlantic, the corresponding fsgure is about 11 seconds. Thus the linear Ginenetons of a UA device vould be half that for the Uk device. Platt goo! fon to note that ?The Servctural cart which ie more than half ehe systen cont, ts thus reduced by a factor of between 3 and 4. A pover rating needed tn the turbine generator and electrical transaisston aysten is also halved + + + Overall, the advantages again weigh heavily in favour of viability for the HA unit.

Agatn te aust be noted that the procotype unit to be bullt in the UK may not de too far renoved in size than the crtisus size for WA.

Other UK workers, noting that the seabed of WA is sandy, thus facilitating mooring, coment that this agsin could reduce the unit costs considerably tn Couparison with UK models as vould the fact that WA devices would not have to be built to withstand the fierce North Atlantic conditions.

In renote ports of Western Australia where power loads are relatively small but production costs are high, two to three wave energy devices could

Currently produce energy at very attractive prices. The units say be even

ore attractive if they con be incorporated as breakwaters.

6.2 Soae possible action in Western Australfe

Fairly apparent actions desirable for Western Australia include the following:

4 Clarify the position re wave data currently available to renove

aubiguities If possible.

tte Process further vave data currently avatlable.

A4f. Decide what supplenentary vave information 1s required and from

where, and taking {mediate steps to obtain this inforaation using

vaverider buoys. This will not only {nvolve testing in appropriate

geographical locations for heights and directions but also at

Selected distances offshore to assess the effects of distance from

the shore. Cognisance should also be given to the need for

{Information relation to device duty eye!

fv. Locate suttable device sites. This would take {nto account such

factors as reef locations, water depths, fishing grounds, and

navigation requireneats,

? Identifying cost factors for current generating costs in renote towns

to assist in vaverenergy viability exercises.

Locate possible sites for unite (e.g. setropstitay and country areas)

and assess Like:y future elecertetty loads.

vit. Lhatee closely with UK workers ao ?hat HA ts fully informed regardiag,

current and nea! future developaens +

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vitt. Create @ nucleus of a skitle: vorkfore for wave energy work in Whe

Tats could be done by such devices as granting scholarships to

encourage post-graduate stude its to Join Uk research teensy sending

Australian engineers to work in the Ch programs and by sponsoring

visite by eapineers and othe> -poropriate personne! to Uk projects

Ax, Inittate discussion mediately with «

possibly the Energy Technolo; © Support Unit) to ascersain what

further {nforsation is neede: if Joint wave energy harnessing

prograas are to be mounted

sropriate Ux seams (and

x Set up machinery to gather the inforaation identified tm ix and to

et up Joint operat tons euturily advantageous which could ove

Western Australia tovards ?uroessing wave energy at an econosic levels xi, Establish ap overall long te for harnessing WA wave enerey

should preliminary investigation prove it a viable source:

7. suMMARY

Im the paper, the wave energy clinate in Western Australia has been assessed

to the Itnit?of Anformation available. The partteular conditions fa HA, as

would suggest that vave energy could Se economically viable, have Seen

considered and found to suggest that further detailed investigations are

Justified.

A necessarily brief description of ost major CK vave projects has Seen given

land the current position regarding prototype testing, derailed.

It has been concluded chat there is sufficient evidence co suggest that the study should be furthered vith soae vigour {n Kestern Auseralia and. som appropriate proposals have been detal leds

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UPADI 82

San Juan, Puerto Rico

?Agosto 1-7, 1982

11 Congreso Nacional de Alternativas Renovables de Energia

ENERGIA DEL OCEANO

Por

Juan A. Bonnet, Jr.

Centro para Estudios Energéticos y Ambientales

Universidad de Puerto Rico

San Juan, Puerto Rico

August 1982

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ENERGIA DEL OceANO

Presentada por

Dr. Juan A. Bonnet,

Centro para Estudios Enery

Penencia nacional de Puerto Rico

ante el

Segundo Congreso Panamericano de Ingenieria Ocednica

Celebrado como parte de la

XVI Gonvenciéa de ls Unién Panemovicena

de Arociaciones de Ingenieria

del 2 al 7 de agosto de 1982

San Juan, Puerto Rico

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PRINCIPIOS EU SDAMERTALES

En el sistema solar a que pertenece ei a Terra, el sol es ia fuente de energia principal. En nuestra bioesfera no estamos aprovechando a cabalidad Is energia que nos prove la radiacién que nos llega del sol. La naturaleza aprovecha esta energia por medio de ls fotosintesis, proceso que sirve para energizar la accién vital y liberar el oxigeno necesafio para su subsistencia. Ademés, la energia del sol se almacena en el planeta en dife- rentes sities incluyendo los océanos. ?También la energia del ol ocasiona las corrientes tanto de agua como de aire, dando lugar a los movimientos de los océanos (Figura 1) "y los vientos que mantienen niveles de temperaturas adecuadas para sostener el ciclo de vida, Pero hasta ahora ha sido bien dificil a los seres humanos desarrollar téenieas para concentrar los rayos solares que Megan tan difusos a la superficie de la Tierra y aprovecharlos efectivamente como una fuente de energis-

En la Gltima década, debido 2 los aumentos tan altos en el precio del petréleo, el combustible principal para producir energiz, se ha comenzado a Fealizar ?es{uerzos significativos para utilizar los rayos solares como fuente de energia, Estos intentos incluyen entre otros, la utlilzacién de los vientos © energia eélica, de las olas del mar, de los cambios en ?as mareas o nivel del mar, de la concentracién de los tayos solares para calentar agua u otros Uquides y producir agua caliente o vapor, la utilizacién de ls biomasa vegetacién como una fuente de energia y muchos otros. Sntre estas postbili-dades también se ha considerado la utilizacién de la dizerencia en temperatura entre la superficie y las profundidades del mar, sta alternative la sugirié y ia probé por vez primera el francés George Claude en las costas de Cuba en el atic 1929. Operando con una diferencia en temperatura de tan alo 14°C el coctor Claude, miembro de la Academia ce Clencia de Francia, Negé a producir 22 kilovatios ce energia con su motor de prueba, La natu: Faleza, sin embargo, se encargé de vencerlo y un huracén rompié la tuberia que traia si agua fris. Desde entonces no ge consicerd este alternativa serlamente y se descontinué su desarrollo hasta la paraca década. El doctor Claude uthiz6 el ciclo directo de Rankine en sus exserimentos.

Blsicuneates ls iden de cimo extreer eata enersia se explica por ol principio te Carnot que rige el funcicnanionte fo" "Se) cinseotored ase Ufereacta de cemporature piece: aprovecharee ?pare oovesce emeeee meat nies os seyou solaves al penetar ioe primerot etsce ae ia Topo ah bar tranedieran cu energia al mar. "Bbto causa gus? etre Hodis de Giprtconto yc Todpico de Concerta tewporatora ce superticle Bel met feu dat ordn ?de 202 25° grades? Colao "Entes rapes, Set eabirgs. Tan Seorbidos en lor prineros ?eros ce ln cuperice se! seneties eta Tee Profuncicades del har,? tor io tants, segs se ve Scoiuscande ont mee Ei temperctura eg mda, baje. "Entre los 700s 900" ancien 86 profundlane Pesanoe por un ieee llameda termoclin, donde ?a tensors Bol marke Feduce?a una mayor razon que tn cusiouer? stra wep.Gs. "Cuonse gems

Spronínadanente.# los 1009 mettor de profundidnd, ?x temperasary eet oat

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utilizar la energia térmica contenida en un cuerpo es necesario moverla a un cuerpo de temperatura mis baja. Sélo asi, parte de la energla térmica trasladada podria convertirse en energia iitil, mecinica, eléctriea, etc. La ley fija una eficiencia mixima que vs proporcional a la diferencia en temperatura entre los dos cuerpos,

En el concepto de CETO se utiliza el diferencial de temperatura entre el agua del fondo y la superficie del mar. Fundamentalmente, ?se hace pasar el agus caliente de la superficie por los tubos de un intercambiador de calor Por cuyo exterior fluye un lquido de bajo punto de ebullicién lamado el liquide operacional. £] amoniaco es un buen ejemplo, El agua caliente evapora al liquido operacional, digamos amoniaco, el cual al expandirse mueve tun turbogenerador eléctrico. Et vapor del amonfaco, una ver expandido,

pasa por un condensador que usa el agua fria del fondo del mar como refrige-
Fante. Aqui el vapor del amonfaco se condensa a la forma Mquida y ee completa el ciclo para un funcionamiento continuo. De esta manera, la maqui

na CETO puede recobrar grandes cantidades de cnergia térmica y convertirla fen energia Gtil. Ver la Figura Nimero 2.

De lo que hemos dicho es evidente que la eficiencia termodinémica de la maquina CETO es bien baja, debido a Ia estrecha diferencia entre las tempera~ turas del fondo y la superficie del mar. Sin embargo, el "combustible® es casi ilimitado y gratis, de modo que si se construyen miquinas que puedan Procesar grandes cantidades de agua de mar, se podrin generar grandes cantidades de electricidad. En la Tabla 1 podemos apreciar algunos ?estima= dos al aflo 2000. ?La eficiencia teérica del proceso flucta entre un 7 y un @ por clento. En la prictica esta quedara entre un 4 y un 5 por ciento, La eficiencia del proceso CETO es muy baja si se compara con la eficiencia de centrales de carbén, petréleo y nuclear en Ia cual la eficiencia es de aproxi~ médamente 338 en las dos primeras y de aproximidamente 408 en la dltima.

Bl concepto descrito arriba es conocido como el ciclo cerrado de CETO, pero también hay un concepto que se denomina ciclo ablerto de CETO. En este concepto lo que se utiliza es el agua de Ia superficie del mar a una temperatura sproximada de 27°C. Esta ee lleva a unos envases donde la Presién atmosférica se reduce, lo que hace posible crear vapor. directamente de esta agua para mover la turbina, El vapor de agua expandido se conden= fa con el agua fria del fondo y se devuelve otra ver al mar-

De la figura nimero 3, proceso de ciclo ablerto de energia océanc- térmica, podemos darnos cuenta que es necessrio conseguir vacios del orden de 1/2 ?pet 0 1/30 atmbefera para ?conseguir que el ag

en vapor. En otras aplicacions clos para conseguir ?qui convierta ?en vapor ae le afiaden juimicos como detergente reducen la temperatura de ebullicién, Esto se conoce como el proceso de ln aspuma de energia oceano-térmica, La figura numero 4 nos demuestra. el cielo de dete, El Centro para Estudios ?inergéticos y Ambientales de la Universidad de Puerto Rico en cooperacién con Carnegie Mellon Univeraity he sido plonero en estudios relacionados con el concepto de espuma de CETO, En al proceso ?de ciclo ablerto de rocio 0 duchs (list) de tnergia oveano thrmica? se willie ?una calda de agua de mar a presiones reducidas, pire Mover una turbina-generador para producir. la electrieidad. Al exer vaporing ol agua de mar y ast so vuelve a oubir y retornar al mare

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PORCLENTO DE LA PROYECCION DE NECESIDAD \ ?LECTRICIDAD

PARA et. ARO 2000

GOLFO DE MESICO Y PUERTO RICO

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Figura 3 Diagrama Esquematicn

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iagrama Exquemdtico de un Sisters de Energie

CETO de Espuma

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FS OCEANO-TER"Y

ESTADO ACTUAL DEL.

E] Presidente de log Estados | sides aprobs \jarante «) 1979 dos tev relacionadas con el desarrollo def eneryla cease *érmiea. Estar leyes se Maman, La Ley de Investigacion, w=sarrello y Nenvstraciin de Energia del Océano. Es necesario senalar que «n ingiés el cencepto de energia ocesno~ térmica se conoce come "Ocean Thermal Energy Conversion" y se identitica en muchos documentos con las sigias de "OTEC?. Aqui hemos usac tas siglas CETO corresponcientes al espanol "Conversion de la Energis Térmic Ga Oceano?. ?Esta'eo Ie Ley Pobica, Nim, 96-310. del I7 de Julho. de 1930.

La segunda ley se conoce como E: Arta de Energia Oceano-Térmica cel 1980 y 5 la Ley Pabliea Nim. 96-320 del 3 de agosto de 1780.

La primera de estas leyes schala que se acclere el desarrollo teenolégico de CETO, de tal manera que se purdan consequir los siguientes objetivos de produecién energétiea:

1, Demostrar para el 1986 por lo menos 100,000 kilovatios eléctricos de produccién eléetriea por medio de CETO. Fsto equivaldria a) 0.098 Ge la demands de energia de los Estados Unidos ce América.

2, Demostrar para el 1989 por lo menos 500,000 kilovatios eléctricos de capacidad Ge energia oceano-térmica equivalente aproximidamente 4 0.28 de la demanda de energia en los Estados Unidos de América.

3. Alcanzar para mediados de la década del 1990 costos _promedio de producción de electricidad 0 productos equivalentes energéticos por medio de energia CETO que sean competitives comercialmente en. las regiones de la Costa del Golfo, isias y territories de los Estados Unidos de América.

Establecer como una meta nacional una capacidad de producción de 10 mil millones de kilovatios de energia eléctrica o en productos, equivalentes por medio de CETO para el afio 1999. Esto equivaldria a1'38 de la cemanda proyectada de energia pera los Estados Unidos de América, La figura niimero 5 resume estas proyecciones en forma > grifiea.

La segunda Ley de Energia Oceano-Térmica ordena:

(2) Al administrador de la Administracién Necional de Occanografia Atmosférice (NOAA) establecer un régimen estable legal para desarrollar comercialmente la CETO. Para Mevar a cabo esta encomienda ordena (a) implantar un programa para adquirir Hcencias de operacién; (b) preparar un. documento de impacto ambiental que cubra cada solicitud de licencia, (ec) establecer un programa de rastreo © monitoria en cada programa aprobado y (@) llevar a cabo todas las investigaciones ambientales necesarias con relaci6n a los aspectos de la energia ocesno-térmica.

(2) 5) Secretario de NOAA debe entre otras const: (a) cuidar de la seguridad de la vida y la propiedad en el mar por medio de iluminacion y otros métodos con relacién a las operaciones de futuras plantas de energla oceano-térmies, (b) evitar la contaminacién del medio ambiente marino, (c) limpiar cuaiquier contaminacién que pueda ocurrir cedido a la operacién de centrales de CETO, (?) prevenir o minimizar todes les impactos adversos que

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puedin ocurrir debide. a la construccién . uperación de centraies de mergia

Dceano-térmica, (>) asegurarae yur las Coscarg.» termales de Tas centrales

de CETO no alecten le vide mariiia ui los recursos de estas.

3) El Administrador de NOAA debe compsrtir responsabilidades para

hacer cumplir las reglas bajo esta Ley con e) Secretario del Departamento de

la Guardia Costaneray

4) El Secretario de Estado en cooperacién con el Administrador de NOAA

y el Secretario del Departamento de la Guardia Costanera debe llevar a cabo

egociaciones internacionales seg sea necesario para mantener Ja seguridad

de la navegacién y resolver cualquier otra cuestién relacionada cone) esta~

Dlecimiento de centrales de energia oceano-térmica.

5) El Secretario de Energia debe establecer y hacer cumplir las regla-

mentaciones y estndares que exijan la construccion y operacién segura de

cables submarinos para la transmisién eléctrica y cvalquier otro equipo que

?esté asociado con las? centrales de energia oceano-térmica.

DESCRIPCION DE ALGUNOS CONCEPTOS DE CENTRALES OCEANO-TERMICAS

DECICLO CERRADO

Las centrales de energia oceano?térmica de ciclo cerrado pueden consis~

tir de (aj una plataforma flotante en la superficie del mar agarrada por

cables; ?(b) ?torres descansando sobre el iecho del mary (ec) centrales

ubicadas en tierra firme o (d) barcos. Discutiremoe brevemente algunos de

?estos conceptos.

formas flotan'

Las plataformas ?lotantes agarradas por cables ee el concepto que

tis publicidad? ee le ha dado, Companias talee coms in Lockheed, TRI, Sea

Solar Power, han Gesarrollado Gescripciones artisicar de? sus concepts los

Susles. podemoe apreciar en las figures. 0", ?Blsiceneste vonsisten? de? una

Plataforma tocaandn em ur sitio donde ln profunciced Gel ?war ee, de mis

de 1,000 metros do donde cuelga una ?uberis para exivaer el agua Ge mar

fia, "n esta, plataforma, se resoge el agua caliente col mar cerea de la

superficie ¥ tambien queda insialado cl equips necesarie. vara producir le

Gecricidads ?La plataforma se wantiene Sja.en su ?ocslinacion por medio e

tin cable anclado (Anchorer cable), en el lecho del mar. fs posible producir

tlectricidad ?s otros. productos industraies cuya procuccién. Coneuma ?grandes

Cantidades de onergia tales como amoniaco, nidrbgene © ferizant

(>) Plataformas localizadas en la superficie

Segin se construyen plataformas para extraer petréleo en el mar es posible utilizar esta tecnologia para establecer plata?ormas a profundidades de 300 2 490 metros para instalar centrales oceano-térmicas, Se instala una tuberfa que baja de ?la plataforma hasta el fondo de! mar y de ahi sigue recostada al lecho del mar hasta legar a los 1,000 metros de profundidac. Véase figura Nimero 7.

---Page Break---

Modulos Energdticos Desmontables

Plotatorma

Tuberia de

?Agua Fria

Trapecio

Tirante Simple

de Ancicje

Ancie

Fég. 6 Planta CETO Anckada.

Sustens. (156. Siig}

Propuesta por Lockheed Ocean

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ENTRADA DE

Drcua-reuraon

DEscanca

ENTRADA be

OUR FRR

Figura DISEMO TIPICO DE TORRE D= DESCANSO EN

LECHO SUBMARINO.

FUENTE: SULLIVAN ef al., 1980

---Page Break---

tales ubicadas en tierra

En este easu la central

extiende uns tuberfa hasta conse:

metros de profundidad para obtener

llustrado en [a figura ndmero 3,

(e)

blece en Ia costa y de ésta se

aguas calientes y otra hasta 1,000

© aguas frias. Este arregio aparece

La central esté construida en un barco. Este sistema permite

Rover Ja central para obtener el gradiente de temperatura, éptino ?en ie

Gomento dado o ir de un sitio a otro. Su uso se adapta veniajonamente en la

Produccién de productos cuya preparacién requiere grandes contiandes Go

fRetaia como el hidrégeno o el nitrogeno. El barco erviris pers aiverenee

la produceién para embarque posterior « tierra,

En la Zabla Némero 2 se hace una comparacién de los diferentes quidos

gBeracionales que se podrian utilizar en estas centrales occano-tersicese

BaeEuOs Yer que se ha experimentado con amoniaco, {reén, cloruro de wetio,

SiGvide de mitrégeno, y otros. La tabla resume las caracteriaticas peinee:

pales de estos liquides.

metales de posible

fanio, el aluminio

POTENCIAL TERMICO

En la banda de latitud entre los 10°N y 10°S hay 80 millones de kiléme-

Gee, Gtgdrados de,mar que rggiben més de 215 vatioe por metre casdeeen al

dia para un total de 1.7x 10° megavation,

sa NETCE Tespalda Jo que sefalamos en la introduccién, esto es, que cenaigstas Gel Caribe ofrecen un gran potencial para la produccién oe ches Sceanertérmica. En adicién, encontramos numerosos sitios capecifices canes nee a Puerto Rico, Cuba, Jamaica, Islas Virgenes, y Florida aonde existe ca SocpeAte,Potencal para establecer centrales oceano-térmicas- ?Las figures 3 dad de 1 sao See, 40,18 distancia que media entre ln costa y ia phofand dad de 1,000 metros 0 mas.

Los iitimos informes en las noticias, principalmente en la revista Ocean Energy. son en el sentido de que se ha? removal un aren ieee nose aslones ?Industsialsadas? y" Sivec? acamovedo, oh, gra por la energie gcfanortérmica, | En Francia, ?India, ?Taiwin, Costa de Moon ls snares tution y evaluaciones de localidades pars ?centrales de CETO.? Senet? sn fi Caribe, Ueva muy adelantada su, considersclin tor ene 4emaae energia, Segin nuestra informacion, sil el gobierne de a Li nace uun consorcio con firmas suecas y ?noruegas eee aie

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Agua Templede (1Em.)

Descarga de Agua Templage (100m) Descerae oe Aave Fria (ino)

[Entrada de Ague Frie(1,000m.)

Figure. Dlseio Tipico de Base en Tierra

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Aparte de Hawaii, los Estados Unidos tienen sitios apropiados para 1a instalacién ce plantas de CETO. La Tabla 4 ofrece un posible escenario para fl establecimmiento de centrales océano-térmicas para el afio 2000 en dreas y territorios de los Estados Unidos. De llevarse ésto a cabo para esa fecha se podria aleanzar a nivel mundial un nivel substancial de produccién de energia Por medio de las centrales océano-térmicas.

ASPECTOS TECNICOS DEL DESARROLLO DE CENTRALES PARA CETO

Las dificultades que aparecen en el desarrollo del concepto de las centrales oceano-térmicas no requieren nuevos descubrimientos clentificos. Bisicamente gon los problemas de ingenieria que se encuentran al pasar de tuna escala mis pequefa a una escala mis grande o comercial unos conceptos ya probados técnicamente en experimentos llevados a cabo en las islas de Hawaii y Puerto Rico. En la isla de Hawaii se instalé una demostracién que ?se conoce como "Mini-OTEC" © "Mini CETO*. El 'Minl-OTEC' fue sefalado por la Sociedad Nacional de Ingenieros Profesionales entre los diez mis importantes proyectos base de la ingenierla en el 1979. Este proyecto fue finanelado por un consorcio de industrias privadas y el estado de Hawaii.

Se demostré con Mini-OTEC que es viable técnicamente producir energia, utilizando la diferencia de temperatura del mar. Se encontré que a esta ?escala de produceién la degradacién de los coeficientes de transferencias de calor debido a la utilizacién de agua de mar de las profundidades y al cre- elmiento de vida marina en los tubos de los intercambladores de calor es bien Pequefia, Se produjeron 10 kilovatios hora de electricidad.

Otro proyecto de importancia es el de OTEC-1 0 CETO-1 que se de yrolla también en la lala de Hawaii. En Gate ee prueban diferentes tipos d intereambiadores de calor como son los tipos convencionsles de tubo y Tshell y de placa verticales. También ve han probado diferentes tipos de materia- lea, Las fotogratiae némero 1 y 2 muestran estos laboratorios.

En Puerto Rico, al Centro para Estudios Energtticos y Ambientales de la Universidad de Puerto Rico poses un inboratoris otante? (ver in foto Nec 2) al cual esruvo anclado en'el sureate ce Puerto Rico « ails y media de la conta (Wer figure ?Nim. 12), En. Sete ae levé 2 cabo lon experinenton, de

Bis largo taupe de duracién decleados 1 prober diferentes eateries y el Greciniento de vida arina en su ruperticien También se entudie ie eficacie a erantas' std per ?liplar lov ateralat de ioe intereanbladores de caer. Be separa poder nutaar une fobs Ge agun fra durante 082 Para proceder con experinentoe alndlares an ests faberia, pero. Gatos titinoe Sefuerros ?han sido frustades. por falta de fondos. ?Hasta ahora, ha side Postble deterninar? las caracteriticas del crecimiento de vida murine y? les Eiferenter maneree de Unpiariae periedicanente:

INCERTIDUMBRES:

De lo apuntado anteriormente, podemos apreciar que las incertidumbres gon relacién a culles son los materiales mis apropiados y cull es al efecto dal crecimiento de vide marina es motivo de estudio en diferentes sition, Reclentemente a finales de 1960, al Departamento de Energia de los Ketados Unides de América solicits propuestas para la construccién de las primeras

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EXPERIMENTAL

TUBE MODULES

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A

50 KW GENERATORS

DATA ACQUISITION

~ LEAD WEIGHT

A

INLET AND EXHAUST HOSES

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délar (E.U-) por kilovatio hora, io que representa menos de una cuarta

Parte de lo que se proyecta costaria producir energia electrica tiene

Petréleo, | Los costos de instalacién de una central de energia oceano-térmce

Ge 250 megavatios en el afio 1990 se estiman en aproximadmente $71) mallee

CONCLUSION

Los paises de este hemisferlo deben unir esfuerzos en el desarrollo de

las ?centrales de energia oceano-térmica ya que éstas ofrecen una de Ine

Relores alternativa de romper Ia dependencia chergética ce los palses etree

leros que tanto dafio hace a la economia de esta regions

RECONOCIMIENTO

El autor desea expresarle las mas sinceras gracias al Dr. Manuel Garcia Morin y al Dr. Donald Sasscer por ayudar en la preparacién y edicion de gate trabajo yal Ing. Pedro Sarkis por claborar las grafices y tabieg inelufdas en este articuio.

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UPADI 82

San Juan, Puerto Rico

August 1-7, 1982

Second National Conference on Renewable Energy Technologies

ESTUDIO DE LAS CARGAS TERMICAS DEL HABITAT

EN UN CLIMA TROPICAL HUMEDO.

By

M. Dupont

Laboratoire sur TEnergie Solaire

CUAG (Antillas Francesas)

N. Molle

Ecole Centrale de Paris - CNRS GR 14 ~ Fran

San Juan, Puerto Rico

August 1982

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las construcciones actuales en 128 Antitias Francesas esta why a menudo mal adaptidas a 1as condiciones clinatoldgicus lovales, Lo que Conlleva un consumo energético importante para la climatisacién, Le meta de nuestro estudio es 1a de conocer 12 iaportancia relativa de los diferentes pardnecros del balance térmico de un local,

Goncrecanente, conparanos dos soluciones arquitecturaies clduicas en Guadalupe : EL habitat tradicional de madera cou un techo de zine, y el habitat woderno, de concreto, con el wedio de dos mbdelos aaventei-gos peritiendo caicular al paso de tienpo de la hora:

x14 carga térmica debida a 1a insolacién cuando la tenperatura inte~

rior se mantiene constante gracias a un sistema de climatisacign,

7,34 Kemperature interior alcanzada en el loca! en ausencia de. acondi~

cionaniento de aire.

2 ~ caractertsticas del clina

EL clina en Guadalupe se caracteriza por una fuerte hunedad rela

tiva : 80,6 Z y una teaperatura acbiente promedia de 25,5°C. Las varl

ciones ditirnas y mensusies son debiles, cono se mucstre eu la tiguea ty

La insolacién es alta (2800 horas/ano). EL promedio anual de la aevadiee

eign solar global en un plano horizontal es de 5,0 Kuh/a? «dia. Este

itradiacién comporta en valor pronedio un 40. de ircadiacién difues,

En Sptimas condiciones devinsolacisn (fraccién diarla superior & igual

20.9), esta taza baja al 202.

Para no depender, en los mbdelos, de los datos reales, utilizanos, para

las condiciones de buen tienpo, iat siguientes formlas simplificadees

z Ieradiacién global: G= 1100 (sinh) 12> w/e?

7 leradiacién ditusa : D170 (sin h) 7 wf

siendo hy la alture del sol encima del plano horizontal. La concordan~

cia con ios datos experinentales es satisfactoria, aunque se note usa Bran dispercién de los datos medidos de irradiacién difusa, debida « gue el cielo nunca es perfectanente despegado en Cuadelupe, Ver en 1a Figura 2,

Este estudio de as condiciones climatoldgicas confirma 1a inportancia de las cargas debides & Ia insolacién (directa y difusa) en un clina tropical himedo, y justifica el interds de un estudie cepecificanente térmico del habitat,

3 det

on ee edenico

fe suele considerar vm local como delinitado por un nore de pare-

dex incerfoten 0 exterioren se tal manera aoe ae"poeda solic atte

silage eranacerensin de eater steals de"eareer stant

Linarisando las ecaciones, y coniderando el protlens sosod nent font

ar

Bw

Siendo T 1a teaperstura al at

ice x de 1g pared, ¢ el tieapo y "a" La

difusividad térmica del mater:

Mas Ay ver en ta figura 3.

Can Ay zs

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Prosedios senguaies de Is toaperatira del aire en %

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T: Promedios aensuales 5 = valor tedrico con cielo despenado

Fig |: Datos climatoldgicos. Estacibn meteorologica del Raizet

(Goadalupe) Fuente : Servicio Nacional de 1a Meteorologta

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Sendicidn at Rinive cater ior +

iva do ingolacion, igvat a 1a com

che conto el flujo conductive

cuents los intercanbios por con®

wvelad celeste

peratira Tp alelfetda por 1a

se ansla (I) che = 22.1 t/a?

veecion con el aie aubiente y por radiacica con Ia

Te es 1a tonperatura exterior

DG es ol flujor solar inciden:

sconce 1a superficie considerata

1d ee Ta absortividad ev la supersi ie

Condicion st Limite interior

ger 8 Sl whe te oe HE OD

donde hej = Factor do conveccion cos ef aire interior # Le temperatura

t

| = flujo inteccanbiade por radiacton entre 1a pared considerade

y ef resto del recinto,

Para la resolucion de (1), (2) 5 (3), conviene diferenciar dos casos +

?a) Local _acondicionade : Se conace Tj a cada instante. Se puede

resolver la evacvacion del calor en cada pared y calcular el flujo

(@ ?carga termica") entrando en el local

95 = Rega) k= TH)

donde Aj © superficte do 1a? pare?

La carga total es 1a sunatoria de les Qj

») Local no acondicionade : T; es 1a incognita del problena. Se

tiene vina ecuacion suplenentaria os

Ehey (i, - 1) + O.3W (Ty Ty) = cS (4

La sunatoria de Los flujos convectivos (intercanbio con 1a5 paredes,

yirenovgcide de site) datine ta tenperaters del sire

Wen m/hora es el caudal de vent! lacién

MC es un termino que da cuenta de 1a eapacidad téraica del aire y/o de las aasas intornas suebles, pisos...)

Los flujos de calor debidox a ventanas y apertura: se coutabitizan en los intercanbios radiativos entre las paredes del recinto. Pueden ser importantes en el caso de un vidrio no protegide, pero se pueden reducir gracias a proteceiones. Segun (2), el factor solar de una ventana, Fazon entre el flujo entrando a dentro det local ye! flujo solar incidente, puede tomar los valores indieados en 1a Figura 4

Tomando en cuenta pata abservaciSn, y en un deseo de sisplitícactéa, fos Linttaaoe agaf? al estodie' de Tocaies opacen'a le taditeion solar.

4) Resolucion siaplificada

Utilizanos el método prictico de chlevlo de las cargas de clinetizacién (3) elaborado a partir de los trabajos de MACKEY y WRIGHT (4). Supone el regimen periddico establecido y La "anperatura interior

El flujo de calor a craves data pared ops'a je express +

5 = GS (Tony TH Ct OD

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[Contraventana vertical

3

Htoldo de telg opaca 1 12

IPersiana wetatica n "

lToldo veniciano 5 2

lproteccion interior

fTolde ventetane 3 oF 7

|coreina opaca 34 45 37

|cortina de transparencia 6 a 39

r= loz

[Sta proveccion - ~

dels blanco - 5 ? 1

WVideio atérmico verde 49

Fig 4: Factor solar de algunas protecciones (2)

A= superficie ,

K = coeficiente global de perdidas térmicas

Ty = tenpgratura impuesta a dentro del local

1 feet

Ton = 7g {Ey Tsi,promedio diario de 1a tenperatura fictive de inso-

lacion de 1a pared.

TE = tenperatura fictiva calculada horas mas temprano

= defasaje de 1a pared

= coeficiente de anortizacion de 1a pared

Los valores de m y @ se pueden calcular analticanente-Son dados por (3)

para materiales corrientes, Ver en la figura 5

mi 1.00.6 0.3

TS2530 4030 cm in

Fig 5 + Defasaje y anortizacion de algunos materiales (3)

---Page Break---

Nosotros anplianos este metodo para obtener una expresion de La tempe-

ratura interior, aleanzada en el oval ea -useneia de acondicionamien~

to.

La evacvacion (4) puede escribirs:

we fh + (ays + oan) 1, = 5 KACToR + w(ts ~ Tom))5 + 0.3 HY Te

donde el secundo mienbro es una funcion del tiempo, ,conocida al paso de

tienpo de 1a hora, gracias a lor datos de irradiacién, Linearisando esta funcién entre los dos Gitinos pasos de tieopo, © in~

tegrando la ecuacion diterencial, se abtiene =

Me 2°. ea) h -

Po ora [yPacranvaceF tem oct)

sosmn] ©

1 hora, paso de tieapo del calcuio

tenperitura interior al paso anterior

temperaturas fictivas caleuladas al paso anterior

Aparece una constante de tiexpo del local, que tona en cuenta La easa

tersica interna :

Oy

Cuando t es pequeno frente a At (local vacio), 1a expresion de Ty se

vuelve :

> oe om tm (TE - Ten}j +

wee mathe fies of tals male

4@ insolacion Ts; i

cuando + es grande frente a At (local inerte) se introduce una queva

ponteracién

Bets (Sg AE MAse + alts = ten); + 0.3 WY

5 - Analisis nodal

Esta descripcich det habitat, derivada de un wStele con diferen-

cias finitany he sido elaborada en'el laborarorio scfentftico de 10s,

Mesos).

Bi sistena ffsico y su wedio anbionte estan representados por una red

de W audos, cada coal representanto una regicn del espacio de tenpe

fura uniforne, Cale nado pele tener una capacidad térmica My y ser el

Sitio de una fyente de calor $. Foté ligedo a los demas nudos por una

Sonductancia téraica Ey de tal modo querel balance térmico en cada mum do ae escribe

N

a Sg:

Eki (i - Tp) +m; esi

jot

Disponenos asf de un sistema de N ecuaciones que ce pueden discretisar

---Page Break---

en et tieupo, y resolvenns luego i sfstena lineal, cbtenicndo Las tem-

peraturas en? cada tudo, en funcién vel teapo

Gono ejenplo, se ha representado en La figura 6 la red utiLizada en

uestro aételo para un local de georctria miy sencilla, donde se he diseretisado cada pared en'3 naiss s

??tenperatura de superficie externa

= enperatura en el edie de 1s pared

= tenperatura de superficie interna

Siendo ax et paso de espacio (aqui ax = donde ten el espapor de Ia pared), las conductancian a dentro dotla pared vaten Ech y Las capacidades M = pcA Ax. Una capacidad edia ¥ ha sido dada?a las fachadas externa? e interna,

Entre las superficies externas (respe, interna) y el afteexterior (ce Be. interior), se define 1a conductancia he h (cepts hid). tas com, Succancia supienenteria 0,3 AV entre Hi y Te teaiuce et ftje cowsee= tivo debido a la weatitacion

Las fachadas externas reciben 1a radiacion solar, y pues Saga.

8! representa el flujo radiativo intercambiado entre 1a pared conside rada y el resto del recinto,

6 = Reguleases

Couparanos entre si varias soluciones arquitecturales corrientes

en Guadalupe. E1 local considerado ez un cubo de 10x 10 de base, y de

?altura 3 metros.

pared

Norte

paced S pared ?sur

Fig 6 ~ Red utilizada en el analisis nodal.

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EL techo puede ser ho-izontal, Mevar dos 0 cuatro vertientes. Los

materiales utilizados son Ia mader, e! zin- o el concreto. Rstudiom

mos 1a influencia de un aislamiento del techo 0 de las parades con

?Sem de lana de vidrio, Enfin, varinnos arbitzarisncnte ta incecia

Interna del local atribuyends wna capacidad cérmica fictiva al aire

del local, o bien sea al piso.

Como se ensea en la Figura 7, 1a concordancia entre los dos médelos es my satisfactoria en el cazo de construcciones livianas . tas di~ ferencias observadas en construceiones pesaias se explican por la di~ ficultad de touar en cuenta las micas internas.

Estanos Llevando a cabo una experimentacidn sobre un local existante pata averiguar la precision de los cesultados. A priori, el gnalisis Rodal ge acerca afc a 1a realidad ffsica, mientras que ?el método sin- Plificado permite aprehender factisente cualquier tipo de geonetria.

Los médelos han permitido despejar los parfuetros importantes del ba~ lance térmico del habitat en un clima tropical himedo. En particular, conviene diferenciar loz locales acondicionados de los que no lo som, En el primer caso, las cargas son ptoporcionales al coeficiente glo~ ide perdidas témicas, a las superficies, y a las tenperaturas fic~ tivas de insolacién (cf ecuacion (5). El Ginico parémetro importance en el secundo caso es 1a temperature fictiva de insolacidn (cf ecuacion

(6))» lacual es mas elevada en el techo que en las paredes verticales.

Dadas estas observaciones, ae deducen las siguientes conclusiones

a) Proteceisn inva:

Es suy importante evitar Ia absorpcidn de la irradiacion solar

por las paredes, Las cargas a Tj ~ cate, y el recalentaniento (Ti-Te)

Soa proporcionaies a a. Ver en 1a figura 8.

Pues, pinturas reflectivas son preferibles-

En ei caso de los muros, se pueden utilizar parasoles borizontales

protegiondo de 1a irradiacion directa, y cuya eficiencia en del orden

de 60 8 80 Z, Esta es 1a solucion utilizada en el habitat tradicional

de Guadelupe con las verandas.

») Aistamtem

EI aislaniento es eficiente solamente en locales acondicionados, pues reduce las cargas. En el caso de un local no acondicionado, el Bislamiento del techo permite dissinuir en la expresién de T; 1a in portancia relativa de 1a cenperatura fictiva de insolacidn del techo. in enbargo se destruye esteefecto al querer aislar de la misma man ra todas las fachadas.

Estas conclusiones estan dibujadas en 1a figura 9, donde comparancs las tenperaturas aleanzadas adentro de on local de madera, con techo de tine de cuatro vertientes.

©) Inerei

En el caso de locales acondicionados, y en regimen periddico es~

tablecide, 1a inercia aparece en la anortizacion y ef defajage (@, #)

ocasionados en 1a tranamision det flujo a traver de las paredes exte-

Flores. En regimen transitorio (puesta en marcha del sisteaa de

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climatizdci6a), y en el caso de locales no acondicionados, 1a constan~

te de tiempo definida en (7) juegs ua papel tanbicn,

Si el efecto de 1a inercia gs bencficioss en locales acondicionados de

a permanente (dininiciga de 1a anplitud de las cargas), se obscr=

va un recalentamiento inconfortable en la tarde y 1a noche, en les

econstrucciones pesadss (de concreto). Ver en Ia Figura

En conclusién, construcciones ocupadas en el dia, tal com Las offci-
ynas pueden tener una cierta inercia, mientras que las casas deben ab-
solutanente estar lo menos interte posible.

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Refere

() Je pREVeUS
"Le confort dans ths!
Eyrollex 1940
(2) 3.0, BOREL,
?ta protection des ba
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en poy trop

(3) AIvE:

"Guide de chawffage, ventilation ot sondittonnonent dain?

Bd Seitic Paris (1955)

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Mean, Arguitectine ond &

Ed. Applied Science Publishers LID (1976)

)- MeFARLAND

?A general simulation program for passive eolan energy"

LA 7633 BS Informal Report (1978)

(5) Re

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Fig 9. Eficiencia coaparada de algunas protecciones

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UPADI 82

San Juan, Puerto Rico

?August 1-7, 1982

First Pan American Congress on Energy and

Second National Conference on Renewable Energy Technologies

WORK FROM STEAM EXPANDED TO LOW QUALITY LEVELS

By

ALE. Molini

Department of Chemical Engineering, Inc.

University of Puerto Rico

San Juan, Puerto Rico

August 1982

---Page Break---

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QUALITY LEVELS

ALB. Molint, Ph.D. 17

Professor of Chemical Engineering

Mayaguez Campus, UPR

assmeact

To improve the efficiency of steam turbines, engineers and Gesigners regorted to larger temperature differences between the beat source and the heat sink.

The efficiency of the expansion cycle in the usual, typical botler-stean-turbine installations 18 limited by the steam temperature which is itself limited by the temperature that the steam piping 18 allowed to withstand in the boiler. Since the first phase transition temperature of carbon stee} occurs at 4333°P, for corrosion and structural reasons, the temperature of the? surface of the steam pipes in the bosiers and super heaters is restricted to app. 1100°P which limits the maximum steam temperature to app. 900°?, allowing for 200°F temperature difference for heat transfer purposes-

?The heat sink 1s limited by the temperature of the environment. It 1s also limited tw a large extent by mechanical limitations when using modern turbines, for example, the mofsture level to which the steam is expanded. Because of the close dimensional tolerances together with the inability to simultaneously renove (separate) the condensate, modern steam turbines are restricted fo expansion cycles from Super-heat to steam qualities of app. 95% (5% moisture). Very large losses of efficiency and catastro-phic results are experienced when expanding to lower steam qualities in modern steam turbines. These limitations and improved efficiency of the expansion cycles, led to the develop~ ment of modern reheat cycles which use multiple super-neating steps with turbines after each one. These high pressure cycles yield efficiencies approaching 395 vs. cycle efficiencies ranging up to app. 33% previously. Of course, re-heat cycles are more gkpensive and require # higher investment than sinple super heat cycles.

?This paper presents the potential of extending the expansion of superheated steam beyond the saturated vapor iine down to steam qualities of approximately 70%, ?The concept ts especially applicable when using cellulosic fuels because ef the lower super-heats achievable. The need of reciprocating stean engines

As strongly indicated.

1/ Present address:Department of Chemical Engineering, Mayaguez Campus, UPR, Mayaguez, Puerto Rico, 00708

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WORK FROM STEAM EXPANDED TO
EW QUALITY LEVELS

INTRODUCTION

To improve the efficiency of steam engines (turbines), engineers and designers resorted to larger temperature differen ces between the heat source and the heat sink.

The efficiency of the expansion cycle in the usual, typical boiler-steam-turbine installations ts limited by the steam temperature which 1s itself linited by the temperature that

the steam piping 1s allowed to withstand in the boiler. Since

the first phase transition temperature of carbon steel occurs

at 1333°F, for corrosion and structural reasons,the temperature

of the surface of the steam pipes in the boilers and super heaters

4s restricted to app. 1100°? which linits the maximus steam temperature to app. 900°F, allowing for 200°F temperature difference between the pipes and the steam for heat transfer purposes.

?The heat sink 1s limited by the temperature of the environment. It is also limited to a large extent by mechanical limitations when using modern turbines, for example, the moisture level to which the steam 1s expanded. Because of the close dimensional tolerances together with the inability to simultaneously remove (separate) the condensate, modern steam turbines are restricted to expansion cycles from Super-heat to steam qualities of app. 95% (5% moisture). Very large losses of efficiency and catas~ trophic results are experienced when expanding to lower steam qualities in modern steam turbines. These limitations and improved efficiency of the expansion cycles, Jed to the develop menv of modern reheat cycles which use multiple super-heating steps with turbines after each one. These high pressure cycles yield efficiencies approaching 39% vs. cycle efficiencies ranging up to app. 33% previously. Of course, re-heat cycles are much Bore expensive and require a higher investaent than simple super heat cycles, Reciprocating steam engines overcome the above limitations.

?They do not require to re-heat the steam after it 1s expanded to

95% quality and can continue the expansion to much lower steam

quality levels.

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PREVIOUS WORK AnD JUSTIRICATI

?OTHE CONCEPT ?

Expansion cycles starting froz relatively low degrees of

super-heats will be valuable for the developing countries (tro-

pical) where the climate 1s amiable for the production of celia

Josie fuels at high productivities per acre. The nigh moisture content of these fuels, ranging from 15% wat. for air-dried woody matter to 525 wat. for "as-is" sugar cane bagasse will have a large effect in depressing their temperatures (1), (2) of com bustion to levels lower than 300°? (Figure 1) vs. combustion temperatures higher than 3500°F for the fossil fuels. The lower temperature of combustion of the cellujoste fuels wii) result an Super-neated steax tenperatures lower than approximately 650°F ya. superheated steam tenperatures approxinarely higher? then 308° for fossi2 fuels. (5).

Woody matter dried to 15% wet. moisture burns at a flame tem: perature of approximately 2900°F (1) with 20% excess air, while bituminous coal burns at temperatures higher than 3200°R. The case of bagasse ts notorious. Sugar cane 1s crushed to moisture jevels of approximately 50%. The fiber burns at flane temperatures of approximately 2U00°F (1) under adiabatic conditions. No wonder bagasse boilers are erratic in maintaining a flame! Soilers that burn bagasse should consist of two chambers, one to conduct the combustion in a strictly adiabatic fashion from witen the hot gases would then pass into a second chamber containing the water. pipes for the steam. Undried bagasse yield steam temperatures of approximately 525°? (7) The use of fuels as bagasse require steam expansion processes into the low quality levels to achieve desirable work recovertes as electricity.

Figure 4 shows what can be considered a modern typical expah- sion cycle with one re-heat step. Super-heated steam at 900°? and 100 psia, easily achievable with fossil fuels, 15 expanded in an impulse turbine to approximately 5% moisture and 90 psia, At 1s then conducted through appropiate piping from the turbine through a second super-heater in which it is Te-heated to approx- imately 600°F at 75 psta and expanded again in a second turbine to approximately 100°F and 1.0 psia, condensed and returned to the boiler. The cycle yields an efficiency of approximately 38%. The moisture condensed (formed) when expanding from 1-2 8 Gisengaged from the steam and renoved from the systen before re heating from 2-3. The super-heat levels of this cycle are easily achieved with fossil fuels.

Pigure 4 also shows cycle 1-2-5 which can be accomplished as follows. Super-heated steam at 900°P and 1400 psia is expanded in an impulse turbine to approximately 5% moisture and 90 psia (or preferably to the saturation line only) and tnen expanded

further in a steam engine to approximately 100°? at 1 pai

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(23% wotsture) condensed and returned to the voller. This cycle also yields efficiencies as high us the previ sus one. ?This eyele is similar to the presently calied ?co-geners:ton cyele" (3) but We want to use it to generate evectricity froa point 1 to point 5.

Figure 5 showa what could be considered an expansion cycle with two re-heat steps. The initial steam tenserature of 700°R

at 1500 psia approaches the highest levels acatevavie with "woody" cellulosic fuels (15$moisture). The diagram shows tne conditions Necessary to perform the expansion in a uodern impulse turbine, cycle 1-2-3. 6. The figure also shows cycle 1-2-7 whieh widl need a steam engine to expand the steam to 100°? at 1 psia (28%

moisture.) The efficienctes of both cycles are comsarabie, but cycle 1-2-3~----6 seems wore expensive since it requires two re-heat steps.

Figure 6 shows still another manner of performing the expansion from 70°F at 1500 psia to 100°F at 1 psia with nolsture removal without re-heating. Cyele 1-2-3-4 yields efficiencies equivalent to the cycles on Figure 5 with the aaded advantage of lower moisture levels which might help the operation of the steam engine.

Figure 7 attempts to present the case when using celluloste fuels yielding steam temperatures of 600°? at 1250 psia. The Gtagram corrotorates the desirability to perform the expansion down to lower steam qualities (32% moisture), The efficiencies of the three expansion routes are essentially the same, but the efficiency of Cycle 1-2-3------8, the re-neat cycle, could be

Significantly lower because of the motsture renoval before each

resheat step.

® could be alternatives to the

The processess shown on Figur

of two percentage points in

ones shown on Figure 7 but at 2 1

the efficiencies.

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SUMMARY AND CONCLUS £08

?The use of 1igno~cellulosic fuels to generate steam for the production of electricity appear to be a sound route for developing countries lacking fossil fuel resources. Eecause of the relatively high moisture content of the ligno-cellulosic fuels the steam temperatures will be restricted to approximately 700°P at 1500 psia and wi11 require steam expaneion processes down into gveaa quality levels of 70% as indicated in the Moliier diagram, Modern turbines do not appear to be econonically sulted forese panding the steam. The expansion processens make strong pointe for the use of reciprocating steam engines because of their ability to handle the hign moisture levels of the steam during the expansion steps.

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FIGUES 3

RADIANT SECTICY #2

Flue gas tedperature over

bridge wall - OF

Sources Kern, Donald Q.,"Process Heat Transfer" , McGraw-Hill

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UPADI 82

San Juan, Puerto Rico

?Agosto 1-7, 1987

1 Congreso Panamericano de Energia y

1 Congreso Nacional de Aiternativas Renovables de Energia

EL VEHICULO ELECTRICO EN LA REPUBLICA DOMINICANA

by

José A. Vanderhorst

Corporacién Dominicana de Electricidad

Republica Dominicana

San Juan, Puerto Rico

August 1982

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INTRODUCTION.

La potencial sscasez de combust:bles ifquides refinados
nos obliga a buscar sotuciones a los problemas de transporte para
extender el perfodo ¢2 transici¢n hacie el desarrollo de nuevas
fuentes de energia, in esta reuni6n, sobre lo ingenferfa como
Piedra angular ene] desarrollc de los pueblos, vamos @ tocar la
alternative de usar la energfa eléctrica como medio de propulsion
al transporte en la Repédlica Dowinicana. Cabe recordar la alta
interdepencencia que existe entre el transporte, 12 industrial iza~
ci6n y el desarrollo

Desde los albores de la energfa eléctrica se ha estudiado el uso de vehfculos eléctricos como medio de transporte terrestre, siendo el oran problema el rendimiento de las baterias (1). Grandes cantidades de recursos se dedican hoy dfa a la investigacién y desarrollo de mejores baterfas (2,2). Sebenos estar al tanto de ese progres. En aplicaciones de baja velocidad o de gran nimero de paradas por distancia recorrida, como los servicios de distribu ci6n de leche y correo, se ha puesto en evidencia la ventaja del vehfculo eléctrico sobre el de conbustién interna (3).

El propésito de este trabajo es el de exeminar el impacto del vehfculo eléctrico en la RepGblica Dominicana poniendo especial interés en aprovechar esa coyuntura para mejorar las condicio nes de operacién del sistema eléctrico nacional. No es el objeti vo de este trabajo entrar en discusiones estériles sobre compara~ ciones de largo plazo con los motores de combustién interna, puds es conocido que hoy estos Gltimos son, en la gran mayoria de los ?asos, mas econ6micos y nos hace falta una bola de cristal para ex trapoiar hacia el futuro. Es mis, los eléctricos de hoy tienen 1 mitaciones que dificultan el viaje de cmergencia e imposibilitan los viajes largos (5). Lo ditimo es cierto por falta de la in= fraestructura apropiada como veremos mas adelante.

Las econontas de alimentar vehfculos con propulsién eléc~

trica ests fundamentada en 1a posible capacidad ociosa que poseen Jos sistemas eléctricos en determinadas horas de cada dia. Este

capacidad puede posponer inversiones en refinerfas e infraestruc- tura de transporte de combustibles. Para poder palpar en su jus- ta magnitud, 1a realidad de esa capacidad sobrante, es necesario

incursionar?en la operacién de un sistema eléctricd como el de.la RepGblica Dominicana. Por esta raz6n henos incluide en un anexo

bien resumido, informacién sobre 1a operacién de sistemas eléctris £08 de potencia como un intento de seflaler que Tas reservas de 9@- neracién

1) deben siempre estar presente,

2) no se pueden determinar a priori, 0 lo que es lo mismo, tanto faltan como sobran en términos horarios dificul~ tando 1a operacién segura y econdmica.

3) Pudieran ser mejor controladas con la introduccién de

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un element» amortiguedor coms una varga interrumpible.

Le vecomendars al lector ver e: fnex» i si no posee Ta vi

vencia necesaria pars aceptar Ics sefialanientos anteriores. Por 9.
tro lado, el desarrollo de este trabajo ha incluido la siguiente Secuencie: antecedentos sobre vhiculos eléctricos, descripcién simple de un carro elSetrico, e! suministro eléctrico, las bate~ thas, le adwinistracién de cargc, Iuege una propuesta 'y las con~ clusiones..

EL VENTCULO ELEC

El vehSculo cléctrico ha sido encontrado econdmico en aplt caciones que requieren parades regulares y distencias cortas (1,3, 4). R principio: del siglo la tercere parte de todos los carros y camfones en los Estados Unidos eran propulseéos por baterias de plo no-dcido (6). No cave duda que el vehiculo eléctrico es una alter nativa inportante 21 problems del transporte. Por lo tanto, hay & Ventos que pueden cambier el penorama y dar paso al uso de vehfcu- Jos eléctricos en 1a RepGblica Dominicana. £s0s eventos son, si se demuestra que contaminan menos, si no hay suficiente suninistro de gasoline y si el carro se vuelve mas barato (7). Esa entrada debe Ser estudiada y conpareda con las otras alternativas disponibles e fneluirle en Yos esconarios de planificacién econdmica.

Para ubicarnos, veamos primere el tena de? vehSculo perso~ nal en 1a RepGblica Dominicana. Hay excesos ea la cantidad relati, va de carros. Pasar por alto ia posibilidad de renovar con vehicu los eléctricos parte de esa flote serfa una omisién peligrosa. La flota de carros ests estimada en 90,000 unidedes. Suponiendo que el vehiculo promedio recorra 16,000 'kms. anuales, y consuma 12 xilH diarios (8), seria necesario disponer dé una central de 50 NW en forma exclusiva para satisfacer esa demanda. Esto equivale al 17% de la energia total y al 11% de la denanda maxima experimentada en 1961 por le Corporacién Dominicana de Electricicad.

UN CARRO ELECTRICO.

Una idea simple de un carro eléctrico y su uso es la si- guiente: el vehfculo es similar al de combustiGn interna, En vez de un tanque de gaso!ina tiene un conjunto de baterfas. En ver de un motor de combustion interna tiene un notor cléctrico. E) wehicu Vo tiene también un sistema cargador que acepta clectricidad alter nay la convierte 2 1a electricidad directa necesaria para cargar las baterias, Para cargar las bater?as, e! usuario se conecta en 1g madrugada por un nimero definido de horas, pagando a la companfa eléctrica tarifas reducidas. En el dia también puede hacer uso, pero debe pagar una tarifa prohibitiva. Para manejarlo se conecta el motor de la baterfa "y a correr se ha dicho?. A continuacion discutirenos los problemas técnicos intrinsecos 2 une aplicecién en la RepGblica Dominicana.

SUMINISTRO_ELECTRICO.

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Estd fmplicita, de le descrapefon anterior, 1a posibilidad de aprovechar exceso: de capacivad del sistem: eléctrico y en espe cial de las horas de {a nadrecacs. Sin entarvo, en Ya realidad co mmo puede verse en el Anexo I, la ¢eoaci lad di.ponsble y cn ser- Victo ociosa, solo puede determiaarse cx el micnte preciso en que se-usa la energfa eléctrica.

Esta capacided eciose ev 12 diferencis entre Tas reservas reales y las reserva pragro:cu>. La operacién de resta puede Ser negative, en cuyo caso se deber desconectar usuarios o bajar

Ja confiabilidad det suninistro. isto pucde presentar inconvenien tes al usuario, 0 a ta compaita elictrica. Si se deja conectar eT carro a cualquier hora, peor adn, ?1 suministro de energia a pre- Gios prohibitivos genera 1a necosicad de anpliacién de capacidad de generacién en el sistema cléctrico, fn consecuencia, el usua- rio puede ser limitado, en el nimero de horas de carga, para sus necesidades de transporte solo sor problema de coordinacion en el horario, creando un desprecio por el servicio.

BATERIAS.

Es bien conocido que 1a baterfa es e} cucllo de botella del vehiculo eléctrico. £n realidad, <u potencia y energfa por unidad de peso, su costo y vida Gtil son los problemas. La variable mas susceptible de control local es la Gltina. En términos generates Va vida de una baterfa cs funcién de su iseno. Para un diseno dete! minado 1a varfable clave es su operacién y mantenimiento. Baterfas en manos de expertos puede durar dos 0 tres veces mas que con un usuario conGn. Lo anterfor no incluye tos peliaros de explosicnes asociados con descuidos al sobrecargar bater?as de plono-scide 9 a derrames de gcido sulfurico, pero incluye los dafios a baterfas aso- ciadas a sobrecargas, descargas excesivas, tratamiento de celdas de fectuosas a tiempo, inactividad y exceso de temperatura (9).

ADMINISTR:

f

ARG

La adninistraci6n de Te carga ha sido definida por un Grupo de Trabajo (10) del TECE que se Gedica'a este tema como: ?Es el control o influencia deliterada de 1a carca de? consumidor para trasladar el tienpo y 1a conti¢ad usada de potencia y energta elée-trica. Los principales objetivos do to adninistracién de earga son reducir el costo de 12 encrgia eléctrica, meseror en general el fac tor de carga, reducir 1a necesided de generociiny trastadando consu

mo pico sfuera del pico y mejorar 1a eficiencia del sistem? redu=

ciendo 12 parte proporcional de energia eléctrica que sumi ?stran

Tas unidades menos eficientes".

El aporte central del uso del vehfculo eléctrico debe estar

de acuerdo con tres de estos objet vos. En el mismo documento ante

rior (10) se definen tres clases de administracién de cargo. Solo

dos: control directo y control voluntario de carga nos aplicany el

tercero: uso de almacenamiento térnico, no corresponde a nuestras

condiciones climéticas.

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En la deseripcsén del carro eléc-rico hicimos mencién in-

directa del control voluntaria de carga cuando hicimos referencia!

a tarifas de uso en el tiempo de dia. 2s adelante harcmos men-

cién de control direct».

jo (10) Jos inpactos de la ad-

ministracién de carga no se entiences tan Siew cone las carecterss

ticas y costos. En realidad, ef corécte> aleztorio mismo de Tas

cargas produce efectos mas o menos pronunciados ¢2 Tos cuales no

puede depender mucho un operador ex casos de energencia.

De acuerde al 3rupo ov Tra!

La aplicabiticad det autemévil eléctrico en los EUA ha s1~

do reconocida en un reparte voluuinoso (8). El reporte indica que

Tos consunidores resicenciales, residentos en viviendas unifamilia-

res, serén tos que mas pronto wserén esta facilided. El usuario co rre'con muy poces gastos para rover recarger las baterfas del vehteu

jo de su propiedad. Se supone entonces que al carcar las baterfas

de un vehiculo en jas horas de madrugada, se aprovecha la capacidad

Gisponible por el usuario, Sin cmbargo, 1a correlecién que existe

entre un individuo capaz de poseer un vehfculo eléctrico y aire acon

dicionado en la RepGblica Dominicana debe ser alta. En conclusion,

es probable que el usuario tenge que incurrir en costos adicfonales.

wu

PUESTA

La administracién de carga, para usuarios dispersos (en sus hogares), no es la sotuciGn al problema total, ya que quedan otros problemas pendientes de solucién con relacién'a las baterfas. La eficiencia de un sistema eléctrico es suceptible dc ser mejorada me diante el control dirccto de cargas un poco mas grande y mejor defi nidas. Haciendo referencia de nuevo al Anexo 1, las reservas pro: gramadas en 1a operacion de un sistema eléctrico sin interconexio-Res importantes, distan por lo regular bastante de las reservas rea Tes y es aqui donde juegan un pape) importante estas cargas de blo que. Kuestra propuesta va dirigida a la concepcién de cargas como esas a través de lo que denominanos una Operadora de Baterias.

Una Operadora de Baterfas, entre otras cosas, podrfa ser un lugar dedicado a la recarga de baterfa. Esta idea es complenenta~ da con lo que expresanos anteriormente de dar cl manejo de las ba terfas a expertos. £1 reporte anterior comenta sobre provisiones

para recergar baterfas: ?una posibilidad final serva intercanbiar Yas baterias en una estacién de servicio. Con un diseho apropiado una baterfa de propulsién puede ser reenplazada en dos o tres minu

tos. El efecto es como Ienar cl tangue de un vehiculo convencio-
nal. Si las estaciones de intercambio fucran tan comunes como les
estaciones de gasolina, 1a limitacion de alcance del vehiculo eléc
trico fuera inconsecuente? (8). Estas estaciones de servicios po:
drian ser las Operadoras de Baterfas.

En relacién a esta idea, en Inglaterra se examinaron los

costos correspondientes al establecimiento de estaciones de inter-
cambio de baterias y se encontré que los costos duplican los de un
servicio similar de estaciones de gasolina (8). Este costo adicio

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mal de servicio al ciiente es sos aue e.rmine4 con los ahorros
que se obtienen con 1a extensié> cn la vida de Tas baterfas.

La diferencis fundamen

re una sotuctin competitiva,

un miso servicio com el mish

ae vide, do un venteulo de

combustion interna y un vahiculs « catrico radice entre el costo

inicial (mayor para ¢] cigeweiev) y el 2 opcracién (mayor para el

de combustiiin interno}, Uno pevti e fore de resolver este dilema

es separar el usuarsy Je? custo S5 que este alquile

dicho servicio de 12 Apcrece

teria servirfa de introestruc

los eléctricos.

ja Overadora de Ba-

ode 10s vehicu

Pare que un negocio do

cesario normalizar los baterfas. ?ve ext

dar lugar a consideraciones ce

panorama, un monopolio

pueda subsistir es ng

fe Ja idea podrta

condo 20n mas el

er de baterfas debe

Vamos a revisor impticac

un vehiculo con celdes intercard

tema de servicio mencionado arri

tes de 1a adopeién de

establecimiento del sis

SEGURIDAD,

ABASTECIE

S{ bien es cierto que los sistemas eldctricos pasan por Epa

cas dificiles de abastecimiento, no es monos cierto que disponer de

un transporte eficaz en esos momen:os es contradictorio, pugs e!

trabajo se ve impedido por la fait de Enc

denis, es estratégico disponer de vehfculos elsciricos por la rela-

tiva Independencia de} combustible liquida,

GONSIDERACIONES LEGALES

Dado que en nuestro pais na se han establecido todavfa nin
guna clase importante de vehiculos eléctricos es de suponer que no
hay intereses creados. £n consecuancia 1a legisTacién sobre 12 ma=
teria puede proceder de acuordo a los nejores intereses del pais.
De esa forna la Operadora puede se~ un negacio regulado.

asPectos

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&

La etape sociel que vive nivstro pats dentro de un mundo

tan cambiante nos hace suponer que do existir vohtcules que se car~

guen en las residencias, estos sevian fuente de fraudes en los ser-

Vicfos. La situacidn de hoy nos indica ta necesidad de entrenar

Personal que pueda mantener y repa-ar las d2zeras de los veniculos.

El aumento del transporte covect'v> na vanigo resotviends parte de

Ja necesidad y mas adelante verenes 1a posibi!2ad de sustitueldn

parcial de transporte colectivo. or otro taéo, la tarifa de ser-

Vicio residencial eléctrico en ia 2opab!ica Dominicana ha sido di-

Sefada para promover poco uso de erercfa elfetrica por usuario. ES

decir, subsidiando 2 los consumidores do escesos recursos y penali-

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zando con una tarife exponencia! 2 Tos Jends, y por To tanto, e1 dso de energfa para cergar boter fas seria prohibitive o creaffan problemas sociates. £1 control directe que puede ejercer Ta con~ panfa eléctrica sobre le Opersdora de fsterfes, hacen de esta energia mas barata que se pucds vender n un sistema eléctrico co- noel de la Repablic: Dominicana, inpriviénde'e facilidad al trans porte terrestre, a le ver ques crear enpleos.

IMPLICACTO!

Aparte de los conentarfos en e? punto anterior, sobre la vida de Tes baterfas y cl uso do tarifes mas desas, el?desarrollo de Operadoras de Saterfes puede resutter econérico para que el con Sumidor de vehfeulos no tengs que pagar por tes baterfas. La eco= Romfa puede hasta eprovechar e? reciclaje de ciertos componentes de las baterfas.. Esto sin embargo, cren una situacién financiera

diffeit para la Opercdora de Seterias, ya que inicielmente e1 nine

to de baterias es por lo menos el doble del neccsario. La solu-

cién es que se den facilidades especiales a 1a inversién. Unaspo-

Sibilidad ya ha sido mencionada y es lz creacién de un monopolio.

IMPLICACTONE:

TECNOLOGTCAS.

Luce atractivo salir al frente @ formar parte de un desa-

rrotto tecnoldgico completo, pero les inversions en Ifneas de pro

duccién y la capacidad tecnal6gica estén fuere ce nuestro alcance.

No hay dudas de que cxisten aplicaciones rentat?es de vehfculos e-

Véctricos. Estas aplicaciones se deben fomentar en pequefia escala

para ir entendiendo 1a tecnologfa que ests d?szonible y de acuerdo

Bun plan que persiga mejorar nuestra capacida? de compras de in-

Versione: modestas a otras, cada vez mas cuantfosas.

CONTANINACION AMBIENTAL.

El uso de centrates hidrocléctricas para elimentar 1a red eléctrica que suministra potencia a las Operadoras es Ta mejor op-ci6n. Sin embargo, 1a opcidn ejecutable puede sor a base de cen~ tralés caldeades a carbon. £n este caso estarfamos transfiriendo un problena de contavinaciOn distribuida a uno de contaminacién concentrada.

PLAN pILorO.

£1 Gobterno Dominicano ha tonedo series medidas para Vimi~ tar 1a importacién de vehiculos y asf enfrenter Tos problemas de balanzas de pagos. Si la recesién que se vive hoy continga a este mismo ritmo, 1a posidilidad de poser vehfcu?as privados se iré Vi mitando y sera necesario disponer de mesor trinsito colectivo. ET transporte terrestre es vital para el vesarroito de la industria.
Aesos efectos se constituyd 12 Oficin: Wactova! de Transporte Te-rrestre (ONATRATE).

Dicha oficins brinda us servicio con una flota de autobuses

---Page Break---

de 26 pasajeros y no cubre 1a dimarda todavia. La velocidad pro-
medio por rutas incleyendo toda- 1:3 peradas es ce 18 ku/hr, 10
que nos hace suponer 1a existen ia de enna> o rutas factibles eco
Romicamente para transito de vehicula: vléctricas. Por ejemplo,
Ya'zona colonial de Santo Uowin'o es bien conoetda por lo gran
densidad de trénsito en horas comerciales, En este caso sui gene=
Ties posible que se protenda mJorar las conviciones del ambiente
y asi conjugar dos problemas. tc se puede loorar cerrando al
tréfico normal ciertes calles coms ?a 62 £1 Conde (calle central
de la Zona Colonial).

Seodn comenta Schwartz de i NASA sobre el consorcto GES alendn *Elfos creen que el transvorle urdano (vehScules de reparto J autobuses) es el primer rol Tiyica yore esos venfeutos" (3). A manera de ejemplo, el servicio postal de Tos Estados Unidos ha obtenido costos promedios anuates de operacion en sus vehicules de Teparto de correspondencia de §1369 para Jos eléctricos y $1,528 ara los convencioneies (3). Eston getos nos Mevan © expreser una generalizecién.

* gadas ciertas condiciones slo tréfico (oue puedan ser satis, fechas por tos eléctricos dle hoy),

© dado un costo inicial de un vebfcuto,

© dado un costo de operacién y mantenimicnto,

© entonces debe existir un espacio recorrido anual para el

cual los costos de un vehicula convencional y un eléctr
co se igualen.

En vista de que el costo inicial de un vehfculo eléctrico es mayor, solo es necesario tener un coste de operacién y manteni~ miento menor. Teoricamente este problema es lz interseccisn de dos rectas, sin embargo, es necesanin comprobar 1a posibilidad de recorrer fisicamente tas distancias que resuTten de la solucion ma temitica.

A esos efectos podemos citar @ Hamilton (8) "Para et vehiculo eléctrico de corto alcanc: (100 kms.) con baterfas plono- &cido y el vehiculo eléctrico avanzado, ©? precio actual de 1a ga- solina hace que el subdcompecto consencionat sea mas caro". La com paracién de vehfculos de cuatro pasajeros es calculada on base a un costo de 4¢/KuH y 50.7¢/aal6n do casotins, $i suponcmos los costos de energia eléctrica (10¢/Kult) y gasotina ($2.80/gal6n) vi- gente en 1a RepGblica Dominicana, 2} panorama se hace nas favora~ Ble al eléctrico. En este momento no cebenas desarnos llevar por el resultado anterior porque podrfamos ?legar a conclusiones fal- sas. Primero el precio de la gasolina en ?a Repéb1ica Dominicana es posidlemente mas elevado de lo qe reatnonte debe ser, segundo el precio de la energie eléctrice suede ser renor a su ver y ter=

cero hay que tener en cuenta las limitaciones aceptadas al vehicu

Yo eléctrico. Sin embargo, 12 gencralizacidn hecha mas arriba cs

valida,

---Page Break---

Si concentremos ahora nuestra stencién en vehicules de

transporte colective y recordams que '} Ifmite de velocidad v

gente en zonas resivenciales ec de 35 Kn/hr, si tomamos en cuenta

To'angosto de esas vias y ef estado de los pavinentos, podemos

Tlegar a 1a conclusién de que existen condiciones que se ajustan

a las limitaciones ce los vehiculos eléctricos. Por lo tanto, de

be existir une distencia recorrida para la cual se consiga el pun

to de equilibria eccaémico, Esa distancia a su vez depende de las

necesidades de transporte, de Tas dimensiones y capacidad de los

Vehfculos. Un anatisis de esos detalles tan importantes para la factibiliged de un proyceto de transporte colectivo puede ser ob- Jeto de otro trabajo.

Con el propésito de ir adquiriendo tecnologia y experien= cia administrative en estos monesteres recomendanos la creacién de un plan piloto de transito terrestre, a base de una Operadora de Baterias, cuyas inversiones sean por si rentables. Ese plan puede ser establecido en las zonas mas densas del transporte de Ya ciudad capital. £1 plan piloto se puede crear con una flota reducida de vehiculos. El disefo de los vehfculos no debe presen tar mayores inconvenientes, pucs el diseflo aerodinamico realmente no cuenta mucho pare velocidades bajas. Se debe investigar 1a po- sibilidad de acuerdo con fabricantes de baterfes de propulsicén, Regociando acuerdos de licencias para fabricacién controlada.

Hay que reconocer que la Gnica forma de disminuir 1a canti dad de vehiculos privados es haciendo inversiones cuantiosas en eT transporte colectivo. En ese sentido se debe brindar un servicio en que 1a seguridad, e1 estatus social y la conodidad del vehiculo personal no sean degradadas 2 un Vfmite, que junto 2 la pérdida de privacidad inherentc al transporte colective, bloqueen la transfe- Fencia del uso de vehiculos privados al transporte colective. En consecuencia vemos importante penetrar mas a las zones residencia- Tes, esto es acercarse mas al cliente. Una combinacién de vehicu- Tos'eléctricos que sirvan en una ruta local y vehiculos convencio~ nales con paradas mas distantes (hoy tienen 250 m. entre parades) es un compromiso que se debe fornalizar como una etapa posterior al plan piloto. Aqui los resultados del plan piloto sirven para encontrar los parametros principales del diseno.

Un dato que puede surtir efecto es el siguiente; ONATRATE usa sus vehfeulos de 6000 2 11000 km. al mes. Si suponemos una ve Jocidad promedio de servicio para los vehiculos eléctricos igual ala mitad, adn asf obtendrfamos un uso anual de 36,000 Kms. Esta combinacién de baja velocidad de servicio y una considerable dis~ tancia recorriga nos hace concluir con una alta probabilidad de rentabilided al transporte terrestre eléctrice.

GONCLUSTONES.

En vista de que el sistema de potencia de Ta Repiblica Domi nicana no posee suficiente interconexiones es deseable fomentar 1a Feguiacién del servicio a vehiculos eléctricos. Esta regulacion persigue que las cargas eléctricas provenientes de recargar bote~

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wfas sean fSciles de controlar. Para e:lo es necesario prohibir ?el uso personal de le energfa evGctrica para cargar batertas de propulsién vehicular. 1 uso de To ene:gia eléctrica para el fin anterior deberd ser ranejado por estaciones de servicio, denomina das Operadoras de Baterias, cuyes funciones fundamentales son po seer, mantener, recaryar, alguilar e instalar dichas baterfas en todos los vehfeulos con autorizocién pare transitar a base de pro- pulsign eléctrica.

Se recomiends a su vez poner en vigencia un plan piloto con caracterfsticas econdmicas rentebles para generar una vivencia administrative, un quehacer cieut{fico y un ?couohacer® (know-how) tecnolégico particuler en nucstro pats que disminuya Tas erogacio- nes que por este concepto se haan en el futuro.

TRICOS

LA DEMANDA.

La demanda total de un sistena eléctrico es la resultante de Jas demandas particulares en la red. or el caracter aleatorio de las demandas particulares hora a hora, dia e dfa estas siguen patrones a base de ciclos diarios, semandles y anuates. Por lo anterior, y despreciando por el momento cl crecimiento néto de 1a demanda total, podemos considerarla como un proceso aleatorio. Con esta simplificacién podemos representar una curva tipica diaria como se muestra en la Fig. 1 (una funcidn continua del tiempo) y del mismo modo la demands a una hora particular a través del tiempo como se muestra en la Fig. 2 (una variable aleatoria).

LA GENERACION.

Todos sistema eléctrico esté compuesto, ademis de la red y sus demandas, por una serie de genoradores. Satisfacer 1a demande significa: 1) producir le energta en jos generadores de forna que se cubran las pérdidas en la red en adicién a las demandas particulares; 2) gue la divisién de la carga entre los generadores

sea 1a mas econdmica y en cantidades tales como sea requerida en

forma continua y 3) con una calidad tal que cada usuario no tenga

impedimento en usarla (11).

Los generadores particulares tienen una disponibilidad de

servicio cercana al 902 y es imposible dar un scrvicio contfnuo sin

disponer de reservas suficientes.

ROGRAMACION Y DESPACHO ECONOMICO.

Los diferentes tipos de generacién son generalnente adqui-

ridos en los sistemas eléctricos en vista de 1a cambiante naturale

za diaria, semanal y anual de 1a demanda.

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au

svuoH

unio 6 ot os oe 6 2 he 8

Te TTT 30 sa

SYSOH Uod HALEIS TE0 CYHAVH EvOUVD

GVOIONLOTT3 20 VRVOININOG NO!VUOduOD

Fig. 1

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tore?

SoLLvAvoaH

Fig. 2

---Page Break---

E} problema general de yrogramacidn y despacho puede ser

sub-dividido en tres sub-problenas (12)

1) programacién anual con aplicacién senanal

2) progranacién semana? con aplicacién horariay

3) progranaci6én horaria con uso momenténeo.

El primero es tfpico de 1a programacién del mantenimiento,

e} segundo es el conproniso de unidades y el tercero el despacho

económico de carga.

Cinco reglas que representan el comproniso de unidades fue

ron usadas en un reporte de la General Electric (13) estas son:

1) estar en servicio todo e1 tiempo excepto cuando esté en

tantenimiento,

2) Si se debe usar en hora pico debe ser usada por toda una

semana.,

3) si se debe usar en 1a hora pico, debe ser usada todos

los dias laborables,

4) si se necesita para la hora pico debe usarse todo et

diay

5) solo usarse por el ticmpo necesario.

Como regla general, el Grden indicado corresponde a las u-

nidades con un costo inicial mas alto y costos de produccion mas

bajos para el 6rden inverso.

RESERVAS £ INTERCONEXI

Por 1a naturaleza aleatoria de 1a demands, e1 compromiso

de unidades puede llevar a usar estimaciones conservadoras de la generacién. Por la naturaleza especial de la Repdblice Dominicana Vas interconexiones con otros sistemas eléctricos han sido muy re~ ducidas. Las reservas por lo tanto, constituyen un gran problema técnico-econ6mico. Las reservas definen la confiabilidad del ser- victo.

Esto mos ha Mevado a considerar técnicas de administra~

ci6n de corga con el objeto de mejorer ta operacién del sistema. En Vista de que tanto la demands como la generacién son afectadas por condiciones externas, es de esperarse que las reservas programadas disten de las reservas reales a cada momento del suministro. Los efectos positivos y negativos en las reservas pueden ser aprovecha~ dos si existen cargas interrumpibles a discrecién del operador en sistemas que no disponen de suficiente interconexiones, De esta forma la operacién de despacho se aliviarte enormenente.

La experiencia en programar intercambios es una practica

muy bien conocida en empresas cléctricas de sistemas interconecta~ dos. Para una carga interrumpible hay que hacer compronisos de una sola direccién y su programacion por lo tante es factible.

---Page Break---

En consecuencia, Tas fluctueciones de Tas reservas se po-

drSn controlar mejor on la mediéy que aunenten las cargas interrum pibles. fn el caso cupecial de transicidn, cuando entran o salen de servicio las unidides gencrodores compronctidas, es importante tener cargas de ese tipo pare o; Limizar Ia operacion.

Gracias a 1a Corporaciér Dominicana ée Electrici¢ad por permitir el uso de recursos a mi disponibilided en la elaboracién de este trabajo, a los Ing. fi. Pérez Polanco y Lic. MN. Encarnacion ge la Oficina Nacional del Transporte Terrestre, a mis conpaneros de trabajo Ingenieros E. Gonzilcz, J. Bonilia y'F. Maldonado por la revisién y comentario ai borrador y finalnonte a mi familia a quie- nes reduje la atencidn para cunplir con esta enconienda del Colegio de Ingenieros, Arquitecturas y Agrimensores.

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UPADI 82

San Juan, Puerto Rico

?Agosto 1-7, 1982

First Pan American Congress on Energy

RE-ASSESSMENT OF TRANSMISSION PRACTICES IN BELIZE

By

Robert J. Hatch

Burns & Roe, inc.

Sergio Brull

Belize Electricity Board

San Juan, Puerto Rico

?Agosto 1982

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(PRODUCTION

?The growth patterns of Belize have resulted 1

the

formation of several isolated population centers, surrounded

by rural areas of very tow population densicy. Due to the

relatively slight electrical demand for

vidual popu

sion centers, and the sometimes substantial distances becween

centers, each population center developed as an independent

Generation and distribution district. Distribution from
each district generally extended only several miles from the
Population center and, therefore, served only those rural

ion centers.

areas on the immediate fringe of the popula!

As development continued, and population centers expanded, distribution was also extended. In the case of Belize City and Ladyville, this expansion resulted in the interconnection of two population centers via distribution Lines, Although the benefits of linking isolated generation

districts is obvious from a x

Liability, expansion and
operating cost point of view, utilization of distribution cixcuits, in this case 22 kv for interconnection has serious

impact on the fucure capability of the combined districts.

---Page Break---

Assuming that the 22 kv circuits were initially constructed with sufficient capacity to handle expected line flows within the limits of acceptable losses and voltage regulation, load growth in either district. withour the

prscussrox

cost Basis

Dhis paper presents an evaluation of several trans-

mission line voltages and structure configurations.

Eatimated transmission Line co:

aze based on local

supply of treated wood or reinforced concrete poles for line

structures and importing tvansmission 1

sulacors,

hardware, conductors and other fabricated ma!

for the construction of the lines is considered to be Belizian labor. However, when unit labor cost factors and productivity are considered, local labor costs are equivalent

to these of the United States.

Substation estimated costs are based on local supply of masonry for equipment foundations and of treated wood or reinforced concrete poles for dead end structures. Esti mated costs for transformers, oil cizcuit breakers, buswork and other fabricated equipment are based on inporting these

items.

Al? eouioment and material costs are based on delivery

---Page Break---

Egy costs for evalui

based on a 42 fuel o: of $928 per bi

sel with enezsy

cal dieset

content of 6x19° ary per barrel. With a ty

engine generator efficiency 2¢ 29%, fuel costs vere cal-

culated to be $0.182 per kWh. Tt was es!

mated that this

cost would escalate at a rate of 10% annually

Economic factors utilized for cost evaluations in this

paper are 108 annual inflation and 128 annual vo!

capital. Insurance and maintenance costs vere assessed to

be 28 and S¥ per year respectively.

Since right-of-way for all lines

Presently owned by

e utility, no right-of-way costs are included.

Preliminary Design Facto!

The preliminary Line designs presented are based on evaluation of several structure configurations and their relative cost impact on the overall budget. various trans~ mission voltages were also evaluated for maximum power flow, voltage regulation and power loss considerations in order

that an accurate comparison could be nade.

---Page Break---

Preliminary evalua

ns 2f required

cture embedment

depth were made based on typical soil conditions for Belize.

?This assumption has a relatively elight impact on overall

budget estimates since poorer

conditions than the

typical would require only a moderate increase in pole

length. It is assuned that line erection will be perforned

ducing the dry season in aress which may preclude the use of ase!

nd pole setting equipment during the rainy season

where annual line Losses in kWh are presented in che

paper th

Je values are deri

from an assumed daily load

profile of @ hours of peak load operation and 16 hours of

308 of peak load operation. This profile results in a loss

ctor (ratio of average to peak losses) of S08.

the extreme wind condition used for mechanical design

was 150 mph, as winds of this velocity have occurred in

Belize under hurricane conditions.

Load growth

cima:

by the Selize Electricity Board

considered 108 annual growth in demand and consumption.

In this evaluation, consideration of higher voltages

for Belize focused primarity on the 34.5 kV and 69 kv levels.

---Page Break---

138 kV was not coneidered in éepth, due to

Line lengths, low power transfer requiremens:

1 cost increases for Tine construction and

equipmen:

For example,

nsforme: unit costs in:

ease by acproximately 248 when the high voltage winding is

jased from

24.5 RY to 69 KV. A subsequent unit cost increase of 878 is

Jd when increasing the high voltage winding from 69 kv

to 138 kV. The relative price increases for o

circuit

breakers (OCB) at 34.5,, 69 and 138 kV are even more extrene

with the coat of a 69 kV OCB being 278 higher

in that of a

34.5 KV OCB; and a 138 KY OCB approximately 2008 higher than that of a 69 kV OCB. Reduction in conductor size would not be sufficient to offset the above higher costs. Due to increased conductor clearances, taller structure heights and increased insulator costs, 138 kV Line construction would,

in fact, be substantially higher.

in order to evaluate various transmission voltages, preliminary conductor selections and span calculations were

performed for several voltage leve

and line flows. For

example

234.5 kV line carrying 10 MVA for 12 miles would require 2 266.8 kemil, ACSR, code work "Waxwing" conductor

based on sun without wind. Minimum vertical clearance above roads, streets or other areas traversed by vehicles is 22

---Page Break---

feat for open supply conduct. + s2¢ allowance,

conductor min: above

grade.

For equivatent transfer

environmental conditions, a 9 kV transmission Line would

require only a #2 ANG, ACSR conductor, code word "Sparrow".

However, preliminary estimates of radio noise generated by

1 #2 ANG conductors indicated low signal

the relatively smi

to noise ratio ranges during wet weather which would result

in radio reception near the line being just understandable

in the city and unintelligible in rural areas based on conventional rural and city signal strengths. Estimated

radio noise performance of a 3/0 ACSR conductor indicats somewhat higher wet weather signal to noise ratios providing satisfactory reception with some background noise near the Line within the city with reception renaining unintelligible within several hundred feet of the line in rural areas. However, rural reception in dry weather would be under~ Standable at distances 100 feet or more from the line. The 3/0, ACSR conductor also offers additional advancages due to

its lower losses, higher capacity and greater mechanical

proper: rence and

4. In order to minimize radio inte:

improve mechanical strength, a minimum conductor size of

---Page Break---

3/0, ACSR, code work ?Pigeon? was recone:

Feo ky

3 conductor size +

shad the additional benefit

of accommodating fusure leas growth co 29 MYA.

A subsequent increase in conducter size was not recom-

mended to further mii ural radio inte!

ze ference due to

the increased line costs resulting from

10s generazed by

hurricane winds against che larcer conductors.

Minimum vertical clearance above streets, roads or

jer areas traversed by vehicles is 24 fee:

the 69 kv

line. Using similar a sag allowance (2'0"), minimum con-

ductor attachnent point for 69 kV would be 26 feet above

grade.

Since the maximum allowable span for all line con-

figurations would be based on pole ground line moments due

to 160 mph hurricane winds on th

overhead conductors and

ground wire, the governing criteria for span was conductor

height and exposed conductor surface to the wind. Based on

preliminary evaluation, assuming similar configurations, the

34.5 KV circuit, with its larger exposed conductor area, had a maximum allowable span of only 86% of that of the 69 kV

line with "Pigeon" conductor when strung on gimilar strength

poles. However, due to probable differences in 4.5 kV and

---Page Break---

69 kY configurations and the slightly 24 pol

ight

required for 69 xv, struceurs costs ver mile were arproxi-

36.5 RY, "Waxwing"

mately

equivalent. condueto:

were approximately 258 hight

han those for 59 kV ?Pigeon?

resulting in a cost increase of approximately 33,1008 per

nereased.

mile. Conductor st:

nging costs were also

Substations, as mentioned

by transmission vol!

age. For 69 kV primary voltage, sub-

station transformer and oil circuit breaker coste

typical substation was approximately 264 higher than that of

equivalent 34.5 kv equipment (an approximate buds

pact

of $110,000B per substation). However, a substanti:

difference existed in the voltage regulation performance of the 34.5 and 69 kV lines. The 34.5 line, with "Waxwing" conductor, delivering 16 MVA at 0.80 power factor had a voltage regulation of approximately 14% for a 12 mile circuit. This value would require the use of automatic voltage regulators or load tap changers at the receiving end of the line, The 69 kV line with "Pigeon" conductors would have a voltage regulation better than 84 while delivering 19 NVA at 0.80 power factor over a 12 mile line. In light of its better performance, neither voltage regulators nor load tap changing will be required for the 69 kV alternative,

---Page Break---

resulting in a substa: 2 savings of approximate!

$76,0008 per substation.

increased insulator costs for 69 kV were offset by

increased striz:

ing costs for 34.5 kV (both items were a

relatively small portion of project cost), the cost increase

for a 12 mile, 69 kV installation over chat of a 34.5 kV

installation was approxinately $31,000B. This figure is

more than offset

yn tha increased line losses of 34.5 kV

vs 69 KV and the additional maintenance and repair costs of

automatic voltage regulators or load tap changers are

considered. Evaluation of losses for the 34.5 kV and 69 kv

ines indicates chat at 10 NVA line losses on the 34.5 KV

circuit will be approximately 114 vs 34 for the 69 kV Line.

Relative kh losses per year are 5,000,000 kwh vs 1,500,000

kwh for the 24.5 and 69 kV circuits respectively. Present

value of these losses would be 5630,0008 per year. Therefore,

for the 12 mile, 10 MVA case, 69 kV would be the preferred

transmission voltage.

Similar evaluations were performed for other line flows

and distances. These analyses revealed the following:

© 34.8 kV crossarm structures with conductors 1/0 and smaller are desirable in shor: interconnections

a

---Page Break---

relatively Licht

1 flows not anticizaced to exceed

40 wa. aur:

their service life

© Conductors Larger

yan 1/0 on 34.5 KY cir:

es a

competitive on a performance or cost basis wi

69 kv

wot:

With selection of 69 KY for bulk transmission, an

anatysis of various structures was nade.

Single Pole with Wood Davit Arms

Initial evaluation of structure types focused on single pole construction with fabricated, bolt-on, wood, davit arms

sion insulators.

and clevis or bal! and socket type susp
This structure offered the advantage chat the 69 kV circuit could be strung on one side of the pole with a second

circuit installed on the opposite side at sone future date.

Due to the requirement that cl

rance between phase con~

ductors be obtained vertically for this configuration, pole

length was required to be $5 feet, including the enbedded

section.

12

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Analysis of the 55 foor pole ground line moments

indicated that the maxinum coan of a davit arm, Class Hl

structure, with the installed, woull

be only 197

fet. This rather short spsn is due to the substan!

ground line moment generates by 160 mph hurricane winds

against the 3/0, ACSR phase conductors and the overhead

Ground wire. Additional factors limiting this span were

moments generated by extreme winds against the pole struc~

ture and the moment due to locating the conductors several

feet outboard of the centerline of the 5

scture (spacing

necessary to prot

fe for insulator swing and for clearance

between first and future circuits).

The moment due to conductor offset ¢ pole

centerline would be eliminated upon installation of a

second, identical circuit. However, this component of the

total pole ground line moment is relatively smali in com

Parison to the moment generated by extreme winds on overhead

conductors. For installation of a second 3/0, ACSR circuit

on the same structure, maximum span would be limited to only

112 feet using Class HI poles.

When considering the extremely short span dictated by double circuit construction, and the higher capacity avail-

able from the 3/0 conductor which was selected for mechanicat

b

---Page Break---

and radio int sors, it was recommended the

69 kV line be of single circuit design. when dictated by

future load requirements, adé2) 59 Y Line could be

constructed along 2 separate right-o

-way offering increased

reliability due to physical separation of

With the selection of single circuit for 69 KV con

onfigurations vere evaluated

struction severa? additional

determine maximum spans under extrene

8 conditions and

relative cost.

Single Pole with Double Crossarns

?The single pole with crossarms was selected for evalua~ tion due to its ability to provide horizontal phase con- ductor clearances thereby reducing structure groundline moments by reducing conductor heights. due to the relatively

large clearances required for 69 kV construction, only evo

conductors can be supported by @ single crossarm. A second

cro:

7m located above the lower arm is required for support

of the third phase conductor. All conductors are supported

by ball and socket or clevis type suspé

ion insulators

youred to the crossarms. Bracing is required for

---Page Break---

The double crossarn coz

line moments due to conductor offset

locating conductors on both sides

Moments of two of the phase conducters cancel and only the

upper phase generates a ground!

1 moment due to its weight.

Groundline moment due to extreme wind pressure on conductors is also reduced due to the decreased conductor heights above the ground. Sased on these abeve moment reductions, naximun

span for a Class Hi pole was approximately 220 feet.

Single Poles with Lin

Post Insulators

Although the single pole with line post insulators results in a slightly higher conductor profile than does the double crossarm construction, it was selected for evaluation due to its simplicity of construction and typically lower installation cost. This conatruction replaces davit arms and crossams with rigid, post type insulators secured di-

rectly to the pole structure.

The Line post structure configuration also results in smaller conductor offset moments due to locating conductors on either side of the pole. the resultant offset moment ts less than that of the crossarm structure since conductors may be located close to the pole centerline as insulator

swing is not a concern.

1s

---Page Break---

ce clearance between conductors is o} hos

zontally as well as vertically with line posts, conductor

heights are reduced over that of 4a

= arm conser

jetion, but

are slightly higher than that of crossarm construction. In

actuality, pole heights for line post construction are no

larger than those for crossarm construction, with the one

foot additional height above ground supplied by allowable

Gigterent embednent depths.

Although the higher profile of the line post structure

results in a wind moment approximately 58 greater than chat

of the crossarn structure, the lower moment due to smaller

conductor offet and the slightly larger ground line radius

due to shallower embednent, more than cancels this effect.

Maximum span for line post structures with 3/0 ACSR, Pigeon

phase conductors and 3/8 inch strength steel, overhead

ground wire was 226 feet.

Due to its slightly longer maximum span, simplified

construction procedures and nore aesthetic appearance, Line

post structures were recommended for the 69 kV line.

Figure No. 1 is an elevation of the selected Line post,

tangent structure using Class Hl wood soles. Figure No. 2

is an elevation of the single Class Hi pole structure

reconmended for light angle structures.

---Page Break---

Maximum Span Calculation

A computer analysis was zerformed in orée:

the maximum span under 160 mph extreme wind

nditions for

each structure configuration discussed. fach analysis was

performed for various pole classes ranging Class Hl to class 3.

The results of the maximum span analysis are included

as Table Nos. 1, 2, 3 and 4.

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Bt

34.5 kV circuits c

le

when compared wits a 69 XY circuit of equi?

ent, or siightly

greater 2apa

ghely higher substation costs for

69

uits may be offset by the elimination of voltage

regulating transformers or automatic load tap changing

equipment. Comparison of differential line losses and sheiz

associated cost results in 69 KV transmission being pregerzed

where line capacity is anticipated to exceed 40 MVA - miles.

Future expansion in Belize, which may exceed 250 HVA -

5 should include a detailed evaluation of voltages

greater tha 69 kV.

Preferred structure type for §9 kV transmission

single pole with horizontal line post insulators. In addi

tion to low installed cost, this structure offers a clean,

aesthetic appearance. Structures will be treated wood or

einforced concrete. Selection of pole material will be determined based on economic and technical evaluation o!

competitive bid

2%

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vulture

United Staces Department of Agri

Rural Elecsrification Adminis

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UPADI 82

San, Juan, Puerto Rico

?Agosto? 1-7, 1982

| Congreso Panamericano de Energia

IMPLANTACAO DE PEQUERAS CENTRAIS HIDRELETRICAS.

EN PAISES EM DESENVOLVIMENTO

By

Zuley de Souze

DE ITAJUBA - MINAS GERAIS - BRASIL

San Juan, Puerto Rico

August 1982

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RESUMO DO CURRICULUM VITAE

Engenheiro Civil - Universidade Federal do Para

nd - 1957, Mestre em Cigncias em Engenharia Mecinica - Escola

Federal de Engenhar!a de ItajubA(EFEI) - 1972. Livre Docente -

FFEI - 1973. Cursos de Especializacio: Ensaios de Motores. Die

sel de grande poténcia, Céleulo de VibragBes de Motores a Pis

to, Célcule de Projeto de Instalagdes de Potducia con Turbinas

gas em circuito aberto - SULZER FRERES S/A - WINTHERTUR, Suis

58 - 1963. Custo sobre turbinas a vapor e 2 gis, ITA - 1972 e

1975, Professor Titular da FFET, Faculdade de Engenharia Civil

de Itajuba ¢ Faculdade de Engenharia de Guaratingveta. Possui

diversos livros © trabathos publicados. Subéclegade de Associa

Sio Brasileira de Normas Técnicas (ABNT) para Itajubd desde 1966.

Presidente da Comissio de Térbinas Hidrdulicas da ABNT desde

1967, Ex-diretor da EFEI. Pesquisador na @rea de Méquinas de

Fluxo Frias ¢ Quentes, Centrais de Pequena Poténcia e Geragio

de Energia con Centrais de Baixa Queda. Participou de virios En

contros, Senindrios, SinpSsios © Congressos. Atualnente 6 0 Pre

sidente da Comisso de Pesquisa da EFEI.

ENDERECO

Praga Adolfo Olinto, 11 ~ Apt? 1101 - centro

Caixa Postal 198 - Telefone (035) 622.1004

CEP 37.500 ~ ITAJUEK ~ MG ~ pRasri,

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RESUMO

© Trabalho se propSe a descrever as vantagens

sociais, econémicas, ecolégicas e de seguranga das PCI! em pat

ses do ITI Mundo,

Apresenta,em seguida,una classificagio das

PCH um prograna de implantacio destas centrais de modo que

possa haver un resultado técnico, econémico e social, benefi

ciando a inddstria do pais, mclhorando as condigdes de vida

principalnente do pessoal do campo, sem que haja _necessidade

de contribuigdo externa de qualquer natureza.

Finaliza com apresentagio de tipos _ compactos

de PCH fabricadas om varios pafses do mundo.

---Page Break---

empreiteiras con equipamento pesado de porte, para que no Fi
que o pais na dependéncia estrangeira, o quc ird fatalnente o
Rerar sua balanga de pagamento com reflexos internos insuporta
veis.

Por outro lado, a maicria dos pafses das Anéri
cas centraiiza sua econdmia na agricultura, a qual é desenvol
vida em propriedades quase sempre distante dos grandes centros
© agrupadas em pequenos niicleos populacionais, os quais neces
sitam de pequenas nassas: energéticas. Tais massas para seren re
tiradas de un grande sistema implica em fatores tecnolégicos
econdnicos no disponfveis ou que ndo conpeten com aqueles ne

ces:

?ios @ geragio local. Também, deve ser levado em conta

que a chamada eletrificacao rural através de linhas de trans missGo, além de ter que ser subsidiada e estar ligada a tari

fas, traz consigo problemas a conercializagio dos produtos a

gricolas devido a nfo estabilidade do insumo de energia. Este

insuno cresce de importancia a proporgio que a agricultura se

desenvolve e o padrao sécio-econdmico do agricultor cresce.

De um modo geral as PCH apresentam vantagens

sob os quatro aspéctos basicos considerados na sequénci:

ECOLOGICO: ~

?As PCH permitem 0 aproveitamento do rios em cascata

con reservatérios de pequena area. Como tais centrais,preferen

cialmente, deve estar préximas aos centros urbanos © rurais ,

as perdas de terreno de alto valor imobilirio e fértil, so

---Page Break---

IMPLANTAGAO DE PEQUENAS CENTAATS HENEELTERICAS

EM PATSES FM DESENOLVIMEWTO

Uma PCH nio & ta miniatura de um GCH

1 - INTRODUGEO

De un modo geral, todos os pafses desenvolvidos

© en vias de desenvolvimento, em escala de pro

duso de energia hidrelétrica, partiram senpre dos grandes apro

veitamentos hidrdulicos para os pequenos.

Uma excegdo neste panorama foi dada pela China

que estruturou sua produgdo energética a partir de pequenos aproveitamentos hidrdulicos, associsdo?a un amplo

programa de energia de biomassa.

Nas Anéricas, prddigas em energia hidriulica ,

tanto seus pases desenvolvidos como os en de
senvolvinento ¢ mesmo 0s subdesenvelvides ten dado preferéncia,
inicialmente, aos grandes aproveitanentos tendo por base os fate
res de menor custo da energia gerada por unidade de poténcia e
2 obtengio concentrada de grande massa energética. Pérem, consi
derando que 0 estudo ¢ 0 projeto, bem cono a fabricagdo do equi
Pamento, construsio e operagio de uma central hidrelétrica de
grande poténcia exige nio s5 a existéncia no pafs de grandes em
presas de consultoria ¢ projeto, cono também, indistrias de ¢

quipamentos hidronecinicos © elétricos de grande porte, ¢ ainda

---Page Break---

Pequenas, Um aproveitamento do rio en casca?a regulariza a va

2Bo © estabiliza o lengdl fred

?o recuzinds substancialmente

4 erosio laminar que em muitos pafses alcanca milhares de tone

ladas anuais consumindo terreno altamente fértil. A estabiliz,

slo do lensol fredtico aumenta a drea fértil em torno da cen

tral methorando as condigées ecoldgicas da fauna e flora.

ECONOMICO:

© menor investimento inicial para construcio das PCH

poderd permitir a utilizagdo de recursos locais com geréncia

municipal ou por cooperatives. Um tal sistena altamente indi

cado na maioria dos paises das Anéricas que lutan con proble

mas de inflagio ¢ de balanca de paganentos.

© dominio pelo pais de todo processo de geragio e uti

lizagao da energia gerada pelas PCH @ possfvel com um mfnimo

de fatores econdnicos © tecnolégicos, quase sempre dispont

veis. Os fatores tecnoldgicos com 0 tempo perniten nio sé a fa bricagdo em série das PCH cono também contribuen para o apro

Veitanento de poténciais maiores sen o disvirtuamento da nacio

nalidade industrial. Por outro lado, as PCH apresentan um cus

to operacional menor © para muitos locais é 0 sistena de forne

cimento de energia a menor custo em relacio ao obtido através

de sistemas ?interligados.

SOCTAL:~

A eriagio de cooperativas no nunicfpio ou @ administra

---Page Break---

so municipal traz consigo una utilizayao mais racional dos re

cursos humanos normalnente existentes, além do criar una boa

expectativa para a juventude o que. contribuira para reduzir a

caminhada deste pessoal para os grandes centros, fato muito co

mum em todos os pafses da Anérica.

No ambito nacional, a ampliacfo da indistria eletro-me

canica aumentard substancialmente 0 niinero de empregos em to

dos os niveis. Estes fatores fatalmente melhorarfo a distribui

Gio de renda tio desigual na msioria dos pafses da Anérica.

SEGURANG)

Evidentemente, centrais menores em maior niinero,com me

nores Linhas de transmissio so muito menos vulncriveis que as

grandes centrais en menor niinero con grandes linhas de trans

missio. Sob este aspécto a China continental com mais de 70000

instalagées hidrelétricas de pequeno porte ? muito menos vulng

ravel que un pafs cono 0s Estados Unidos com 915 instalacdes

hidroelétricas de grande porte.

Enfatizanos que un programa nacional de Pcl sonente

tem sentido seo mesmo & planejado e executado com recursos in

teiranente gerados no pais.

2 - CLASSIFICAGKO DAS PCH

Nio existe um consengo mundial sobre o que se

entende por PCH, porém a OLADE ~ Organizagio Latino Americana

---Page Break---

de Energia, entidade criada e yatrocin ca por quase todos os

?paises Latino-Americanos, adotcu 2 classificugio apresentada

Pelo engenheiro Enrique Indicaches Reiz de Socomurcio, a qual

se baseia nas poténcias instaladas e nas quedas de projeto con

forme QUADRO 1.

QUADRO 1 - CLASSTFICACKO DA OLADE PARA AS PCH

QuEDAs of en03ec0tn)

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A BLETROSRAS, centrais E1étricas Brasiteivas

S/A, no Manual de PCH, propoe

Qquapro 2.

classificagio

contida no

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QUADRO 2 - CLASSIFICACAO DA_ELETROBRAS PARA_AS PCH

QUEDA Df PROJETO(m)

CLASSIFICACAD PoT.InsTALaciathw] sarKa [meora | ALTA

MICRO CENTRATS IneNos oe| Mars DE

HIORELETRICAS ATE 100 as as aso] 50

MINT CENTRATS NOS OE nars oe

HIORELETRICAS 100 A 1000 20 20 100] 100

PEQUENAS CENTRATS Irenos oe! InAIS 0?

HIORELETRICAS 1000 4 19000 25__ | 25 2 130 | 130

Neste mesmo Manual a FLETROBRAS observa:

" Assim as Micro Centrais Hidrelétricas pode

ro ser consideradas de até 100 kif, poténcia que se pode consi derar como limite superior para centrais hidrelétricas no meio

tural brasileiro, pelo menos no momento.

Ja as Pequenas Centrais Hidrelétricas, propria

mente ditas, terdo seu limite superior de 10.000 ki, igual ao

limite inferior adotado no trabalho bisico de definigao do po

tencial hidrelétrico brasileiro, ou seja, © inventério clabors

do pela CANAMBRA na década de 60. Como para una usina dese

porte ? conveniente prever-se unidades de no maximo 5.000 kW

ndo apenas uma de 10.000 kW, ficar-se- tanbén dentro do 1imi

te superior de capacidade de fabricagio dos pequenos fabrican

tes nacionais de turbinas e geradores.

---Page Break---

E muito importente cheaar a ateng3o para o fa

to de que os pardmetros QUEDA DE PROJETO © DESCARGA DE PROSE

TO, apesar de juntos definires a POTENCIA INSTALADA, necessi -

tam ser sempre, analisados também separadanente, porque cada

ua deles, por si sé, pode cond izir a obras civis e a equipanen

tos de porte nfo condizente con 0 custo da PCH, 0 que a pode

ria tornar economicamente desaconsethivel.

En outras palavras: uma central hidreiétrica

pode ser classificada como PEQUENA(pequena potncia instalada)

sem que isso implique a que ela soja de PEQUENO PORTE(quanto @

obras civis © equipamentos) ou de PEQUENO CUSTO."

3 ~ IMPLANTAGRO DE PROGRAMA DE PCH

Conforme afirmamos, una PCH no @ uma niniatu

ra de uma CGH, isto porque nao sé os parmetros que a definen

como também outros ligados estudos, projeto, obras ¢ oper:

slo muito se afastan daqueles relativos as GCH.

Assim, um programa de PCH deve ser iniciado
com una definigdo bastante clara de todos os elementos qué.
irdo caracterizar a PCI, partindo de fluxogramas de atividedes
Para os estudos © projetos, passando por metocologias © rotei
ros de c&lculo, financianento, para terninar na legislagio. Pa
Falelamente a esta definigio devon ser tonadas providéncias 1i
gadas @ mercado, familia-padrio, preparo de pessoal, desenvol

vimento de produto, normalizacio © controle de qualidade.

---Page Break---

Para caracteri ago dvs PCH deven ser convoca

Li

dos as entidades do pats liga? s a0 setor de cnergia hidi

ca que atuam nas varias area, sejan governamentais ou particula 's, de consultoria, estudos, projetos, fabricag3o, fesquisa, legislasio, financianento ¢ outros.

Através de representantes e sob uma coordena so geral deve ser elaborado un documento que caracterize as PCH.

No Brasil, sob a coordenagio da ELETROBRAS

foi elaborado o Manual de PCH ~ Inventario-Estudos-Projetos, 0

qual esti sendo tonado cono marco inicial para que © programa

equacionado e implantado. Esta implantagdo, provavelmen- te, sera iniciada no meio rural brasileiro.

Relativamente o mercado & fundamental em levan tanentos do potencial hidrico do pats para PCH, das necessida des de consuno rural ¢ urbana, dos fabricantes nativos de equi panentos hidromecinicos © eldtricos. Destes levantamentos 0 mais importante na fase inicial 0 relative a potencialidade dos fabricantes nativos.

0 estabelecimento das famf1ias-padréo impor

tante para que seja a fabricacdo nativa garantida e protegida

sob todos os aspéctos.

Para uso do documento que caracteriza as PCH ,

@ para que o programa possa chegar com sucesso aos iisurios &

indispensivel 0 preparo de pessoal en todos os niveis, ben co

Ro docunentagio complenentar ge entendinento a nivel do usu

---Page Break---

rio.

° Este preparo d:ve ser regional utilizando em

Principio, a rede de ensino suverior © técnico cxistente no

pais.

Un dos grandes problemas industriais em pafses

subsdesenvolvidos e em desenvolvimento das Américas, ? a limi

tacdo tecnolégica de suas industrias devido ao elevado custo da engenharia de produto, que exige equipes de alto nivel e 1,

boratérios de pesquisa e de honologacio. No caso das PCH este
Problema pode ser resolvido utilizando a potencialidade normal
mente existente nas instituigdes de ensino e pesquisa do gover
no. Neste caso @ possfvel, sob a responsabilidade governamen
tal para uso pelo fabricante nativo a prego de custo, 3 consti!

tuigdo de equipe de engenharia de produto, laboratério de pes

quisa e laboratério de homologacio. A esta triade caberia dar

a cobertura tecnolgica aos fabricantes natives, melhorando os
seus produtos, desenvolvendo pacotes de PCH para fabricago em
série e também fornecendo certificados de garantia.

Evidentemente, noraas e controle de qualidade
para PCH deven diferir bastante das relativas is GCH, princi
palmente partindo-se da hipétese que o programa deve ser imple

mentado dentro dos recursos existentes no pats.

Estas linhas gerais de implantagio de un pro

grama de PCH, deven sofrer adaptacdes dentro das condigées ?8

cio-econémicas ,técnicas ? politicas de cada pats.

---Page Break---

4 ~ CARACTERISTICAS DE PCH

Nas figuras 1,2,3,4.© 5, apresentamos caracte

risticas de PCH fabricadas em série em pafses diferentes.

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FRANCIS FABRICADA PELA

DREES - ALEMANHA

FIGURA 3 - MICROCENTRAL

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FIGURA 4 - MINT GRUPO TURBINA FRANGIS-GERADOR FABRICANO

PELA SORUMSAND VERKSTED A/S - NORUEGA

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VsSIns ~ aNuaonT - sNazUx

VW/S NOLLIMYISNOD AG SUBITALY THUG Vdd VOVOTWaVA WVINENL HOd - § VuNOTE

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UPADI 62

San Juan, Puerto Rico

?Agosto 1-7, 1982

| Congreso Panamericano de Energia

CENTRALES HIDROELECTRICAS: ALTERNATIVA ENERGETICA

PRIORITARIA PARA LATINOAMERICA

Por

Medardo Torres Ochoa

Sociedad de Ingenieros de! Ecuador

cuenca - Ecuador

San Juan, Puerto Rico

?August 1982

---Page Break---

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CURRICULUM VITAE DEL AUTOR .

Medardo Torret Ocho

Nacido en Cuenca ? Ecuador el 23 de abril de 1927

Titulos académicos: Universidad de Cuerica: Topégrafo en 1951. Ingeniero Civil en 1953.

jas comple

Ingenieria de

Costos, Anitisis Financiere, Administracion de Empresas, Esaluacion de Proyectos. Univer-

?dad de Gottingen y Escuela Superior de Trier ~ Alemania Federal: Obvervacion y familia

fizacion en los Gabinetes de Fisica y construcciones hidraiicas,

(Cargos desempetiados: Profesor Principal de Hidralica Aplicada, Administra

y Economia para Ingenieros en ta Universidad de Cuenca. Presidente

nieron y Arguitectos del Azuay?Ecusdor. Subdecano de la Facultad de Inger

del Departamento de Fisica, Director del Departamento de Investigaciones Téet

rector de la Universidad de Cuenca. Viceprevidente de la Comisién de Planeamiento en ta

Union de Universidades Latinoamericanas en México. Presidente de la Sociedad Nacional de

Ingenieros del Ecuador.

Amplio ejercicio proferional en ase-oramiento, ficalizacion, direccion y consteucción de obeas

de infeaestractura y desarrollo,

Delezado principal, ponente y conferencista en vatios congresos y semiinatios nacionales ¢ in.

y de docencia universitaria.

temnacionales de Ingen

Distinciones: Premio Gil Ramirez Divalos de Ia 1. Municipalidad de Cuenea. Nombramicnto

de Vicerrector Honorario de ta Universidad de Cuenca. Acuerdos deta I, Muniipalidad de Loja

ydela ipalidad de Azogues ~ Ecuador.

« veetiin Matemiticas, Condeeors

a de Ingeniero del Fevador.

pubticadass ?Peesupnestos de Olas Civles", ?Avaliia 5 Catastro

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?CENTRALES HIDROELECTRICAS: ALTERNATIVA ENERGETICA PRIORITARIA

PARA LATINOAMERICA?

Medardo Torres Ochoa

Sociedad de Ingenieros del Ecuador

?Cuenca ~ Ecuador

La Organizacion Latinoamericana de Energia (OLADE), fundada el 2 de noviembre con sede en Quito ? Ecuador, xe ha constituido en el instrumento piiblico regional Lamado 4 coordina las actividades encrgéticas de los 25 patses miembros y desarrollar programas de accién a corto, mediano y largo plazo,

Et autor de esta ponencia, recoge los trabajos de esta organizacin y los hace trascen- Sentales en oincidencia con ss propiae inquietudes y experiencias. Deateo de ellos, dee tos relacionados con las posibilidades hidroeléetsicas y que las erce prioritarias. Esto, en aten- cidn al hecho de estar subutilizadas por eontribuir tan s6lo en un 15 por eiento al consumo energético no obstante representar mis de un 70 por ciento de los eeursun eomencionales de- laregion.

Las queneas geogrifieas en Latinoamérica, con recursos hidricos de variads magnite zando a los mis ingentes del mundo, efrecen una gama de explotacion y consigviente con ihaciin 2 a solucién del problema, Fllo demands desde luego de lox conocimientos apiea én de todas las rainas de i

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CENTEALES HIDROELECTRICAS. ALTERNATIVA ENERGETICA PRIORITARIA

PARA LATINOAMERICA

Es evidente Ia crisis eneapética que se hace presente en el Mundo. Ella esti definida por dos sspectos contradictorios y muy distanciados .ene si. Por un lado las naciones desarrolladas {que se desenruclven en un contexto de deroche enéigético con voras agotamiento de recursos primordialmente hidrocarburiferos con la secuela de ?contaminacién ambiental en el agoa, Sierra y aire, Una succion desenfrenads de los recurnon de paises subdesarrolados » quienes xe Jes impone los bajos precios de compra y 2 quienes 1c les impone los altos precios de venea de los articulos industralizados, le mayor parte de los cules no les hace falta para su bienestar sino mis bien para la savsfaccibn de un deformado starus de superacin en base a alienances mbtodos propagandisticos que abientan al consumism. La disciplina del derroche infamante

para la humanidad es la una cara de la medals cuya cara opuesta es la disiplina de la aster
dad eraducida en intemperie y hambre.

La tenica que disenemos para el bienestar de la humanidad no debe ser fria y egoista
?que slo pueda medirse en cuantificacién econdmica independiente del bencficio soci
que puede generar, Ella debe ayudar a reesablecer el equilibriojusto-en los recursos naturales,
en su explotacion, consumo, y distribucién, Sélo as, Ia Ingenier?s podré ser verdadero y no
falvo apome i bicnestar humano, Podri ayudar a reestablecer la armonia ambiental de este
planeta resperando su ecologfa. Podri hacer un habitat racional para el hombre sin encadenaslo
?2 una prsion de asfixiante marcia,

Si la distribuciom de recursos, es rorslmente injusta comparanda los pafses dessrrellados
con fos subdesarrollados o mis comedidamente llamados en vias de desarrollo, mis grave aGm
+ fronteras adentro de extos propios paises llamados también del ercer mundo. El "per edpi-
1a de suyo bajo es un simple cocficiente que no trasluce el promedio realizado entce las rentas
de oputencia con las rentas de miseria. El drama encuentra su expresion en el éxodo rural
ads ver creciente, hacia las ciudades. El abandono del campo dejindo indefensa la tierra a la

crosibn desputs de haber sido desprovista de su equilibrié ecologic

sp a

El hacinamiento en tas ciudades wansformadas de la noche a la mahana en macrourbes

acordanadas de miseria, promiscuidad y desespwracin, Son esta, includibles consideraciunes

socioeconbmicas como premisa a Ios soluciones tenica cientificas y entre ellas La racionsfiea

cidn, dversificacion y distribucién energ

Latinoamérica, ha tomado conciencia de ésto y ha dado origem a Ia formacion de la ?Orga

sinaci6n Latinoaiericana de Energta? OLADE.

Fue ereada el 2 de novismbre de 1973, en el comenio de Lima y que wna ser apredda

?enurd en vigor desde ol 18 de dicicmbre de. 1974

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es miembros de la OLADE son 25, 2 saber: Barbados, Bolivia, Brasil, Colom-

bia, Costa Rica, Cubs, Chile, Ecuador, El Salvador, Grenada, Guatemale, Guyana, Haitt, Hon duras Jaimaica, México, Nicaragua, Panamé, Paraguay, Peri, Repliblica Dominicana, Suriman, ?Trinidad y Tobago, Uruguay y Venezuela

La Sede se encuentra en la ciudad de Quito, Repiblica del Ecuador. Los principales idiomas oficiales son: Castellano, Inglés, Portugués y Francés.

La OLADE es una encidad piiblica internacional de cooperacion, coordinacion y aseso- ria que tiene como propésito fundamental la integracién, proteccin, conservaciSn, aprove-. chamiento rcional, comercializacin y defensa de los recursos energéticos de la region.

Los principales objerivos y funciones son:

L.= Promover la solidaridad de acciones entre lor Paises Miembros para aprovechar y defender bos recursos naturales de sus tespectivos patses y de la region en su conjunto, ut indolos en la forma en que cada uno lo estime mis apropiado a sus inteeses nacionales

2 Propiciar wn desarrollo independiente de los recursos y capacidades energéticos de los paises miembros.

3. Promover una politica efectva y racional para la exploracién, explotacin, wane:

formacion y comercalizacion de ls recursos energéticos

4.? Preservar los recursos energéticor de la Region, mediante su racional utilizaciém.

5 Propiciar la adecvada preservacion de los recursos energéticos de la region median-
te racional uulzacion.

6.? Promover Ia creacin de un organismo financiero para la realizacién de proyectos cencigiticosy proyectos relacionados con Ia encrgia de la Region.

7.~ Estimular la ejccucién de proyectos encrgéticos de interés comin,

8 Propognar la industrishizacion de recursos encrgcticos y expansion de industrias {que pilin bs produccisn de ener

~ tmpulsar ef desarrollo de pulíticas eneegéticas coma factor de integeacin regional,

10.- Prommerlacreacidnds un mereade litisoumecricano de encreta fomentade p politca de precios que permitan una jess putiapacign de todos hn Pais Mobos,

M1.= Condinse negacinciones duectas entre fox Paises Mics vs, para auegurar ef semi

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mmistro esable y suficiente de la energia neccsare pars mi desarrollo y difusion de teenclogias, en las actividades relacionadas con Ia enesgia

14. Propiciar las formas que permisan asopucar y faciliar a lor paises mediterrineos del rea, en situaciones no reguladas por tratzdot y convenios, e! libre trinsico y uso de Tos diferentes medios de wansporte de recursos exergéticos asi como de las facilidades conexas, a través de los terrtorios de los Paises Miembros

15.?Impulsar ls adopcibn de medidas para impedir la coutaminacion ambiental

FUENTES DE ENERGIA,

BIOMASA,

Aprovecha del sembrado y cultivo de vannedades de rapido crecimiento para uso como combustible. i bien. no requiere dificil tcenologia, no obstante es de esperarse una optimiza ion de su desarrollo, La biomasa, producto de éulcivo o de gencracién expontinea, ha venido siendo vtilizada desde que el hombre descubrid e! fvege. Es una alter

vale bs pena admitir que la biomasa de generacion espontinea, ha venido reduciéadose en for.

ima alarmante con una grave alteracion ecoligica coma iesultado. La'biomasa producto de eul-

tivo, trae el inconvenience de Ia imitaci

?as agrondmicas, podrian no silo evitar,sinu a ia vee que aprovechar la biomasa para genera

avira impercedera, Pero

4c Las reas con destina alimentario, aunque. ten

ion de energia, urilizazla también, con sentida renovable, como un apoyo en eusinto formen,

cortinas de proteccidn al viento, cordones de incitacidn pluvial. eegulacibn hidrotopogrifica

¥ cots de terrazas antierosivas. Los digestores de materia orginiea, incluide exceementos, capaces de generar gas metano de conversicn en diferente tipo de energia: elécti

térmica, ete. viene resultando una interesante alcrnativa, en limitadas eirecunstancias, En este tipo, entrarian también cl alcohol resultante de ls destilacin de fermentos liquides entre low ue se destacan la cana de azGcar. Viene resultando sino un sustitute, en cambio un elemento, de apoyo para combustibles petroliferos. Brasil que ha debido dient evantiosas divas por 1a imponacién de petréleo, al no ser autosuficicise 48 produccion, da un buen ejemplo de ello al haber producido su gssolina exiles eon un aliotro mayor al 10 ofo en la guatina pura, No obstamte esto representa grandes ineomvenkntes: jor un lado, esti voleads a ahmencar los motores de explosion de los vehicules, y bicw sbsios que el pargue astonotor particular,

nde, congestimando y contaminando las utbes, can ua

no colectivo, esta sobre dimensio

negativo saldo de resultados socioeconinicus, Por otra Indo, el caltivo de ta eaha de arcar,

1 ?9 un gran factor pata solucinnar los requcrinicnten alimentos del hombre y bos aninaa,

Fes, por el anticar y ta melara que protuce, tine shea ums nus dessiacin que 8 ahide all

de! atchoholisme, cual es fa de imversiin em transpuiree a grave que lla se haga a

expen de cas de eukive afimentatio,Justanite, fin Brvail eed canta un ejempoe de

?ate geliru a poner en esidencia ba redueeion de hin pron ects A cultinee de preductes a

ticwns, para dedicarlos aly eaia de aviicar. La int:sacin de paraslin de catthooy dv

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Para auroconsumo, para decidarlos al monocultivo de cata, ha producido ya, especialmente

enel nacute brasileno, escenas de angustia y miseria.

SOLAR

El sol, generando desde hace millones de aos, ingentes cantidades de eneria hacia la

Tierra, podemos decir, x el oxigen Je codas ls otras fuentes de energia.

1a energia solar esti sendo captada con éxito para su wansformacion en energfa me:

dante celéas fotocavinicas, de manera especial para alimentar delicados instrumenton de c-

cuitosintegrados Ahi estin su aplicacion acasoinsustinuible en los aparatos de sondeo espacial ~

Accualmente se aplica incluso en aparatos de edleulo que van desde los simples domesccon de

botillo hast computadoras. Los hornos solares son ya un sistema difundido para la ealefac

«ibn, Como aplicaciones tenemos la desalinizacion del agua con sus miltiples benefiios de

carkcter doméstico, agricola industrial a generacineléctriea, ete.

EOLICA

El viento es para muchos casos, una alternativa econdmic

bombeo y desplazamiento de Iiquidos, sla genera

ciones historicas, encuentran en el viento que hinchaba las elas de los navios, su factcr deter.

GEOTERMAL

Telia, es quiad ep

grotcrmales para captarlas y mover turbinas gencradoras de clecricidad. El hecho de scr um

ais voleinco le da esa oportunidad como una pequets compensacion alos desastres afsmicor,

?Anséatriea, que tiene en sus entrafas gran parte del eirulo o anilo de fuego, podria utilizar ests

cnergia, Las tdenicas de extraccion no han aleanzado aim el desarrollo que puede experate.

(que mis adelantado esti en el aprovechamiento de las fuentes

MAREMOTRIZ,

Las grandes masas de agua en su oleaje de vaivén pueden yenetar fuerza mows tradu

cible en cleetricidad. Francia es quird el pa

una Facnte hidrocdiica,

{que mejor ha aprovechado de ésto. Viene a ser

ATOMICA

Los grndes adclantos cientificos en easi todos los érdencs fucron incomtivados por ef

econ hu

Hes

vdewo Movado a fa prictics, de des

mediante ly verra, Este exe orien de las

Cemtriles simicas 0 Resctores much

una gran eoperanva de salaciim a Ia erie

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cenergética aunque ahora, ciene y com rarén muchos detractores que ven en ella un peligro

?ecoldgico y una amenaza de la mis peligrosa cov tsmninacion ambiental. Los basureros atomi-

08, son al momento, el gran problema de los d:shechos. Como quiera que sea, hoy enisten grandes cencrales generadoras de electricidad. L energia axSmica, propulsa transportes navie-

ros con efectividad espectacular, tal el caso de Ios submarizos aémicos. Hay que admit que

1a espectacularidad es canto mis grande, cuanto que estamos en los albores de su aplicacion.

HIDROCARBURIFERA

Tiene su expresion en el earbin, petzéleo y gas.

El earbén hizo la prosperidad y detecmind ls hegemonia de grandes paises como Ale.

Francia, EE. UU. Su importancia, fue de:plazads con rmicho, con el surgimiento del

pewéleo, A su gran poder energético habria que atadir su facil manejo y eransporte, la enoeme

mn. en resumen su utiizacién con el més dptimo rendi

fama de sus derivados, su comercial.

?miento, Pero ésto justamente, determind la embriaguer de pctréleo asumida por los paises

industrializados y su consiguiente derroche encrgstico, cuya posesin, los transform en amos

el mundo, El surgimiento de las transnacionales que se erigicvon en entes mis podetoses que

las naciones dominantes y dominadas a x3) punto que ss gobiernos resultaron inermes asus de-
signios, fue el comienzo del drama cuyo epitozo esa fragiidad econdmica de un poder eimen-
tado en el abuso. Es facil comprobar este aserzo cuando sc piensa que por el bartil de pettdleo
8 1970, se pagaba § 2,00 (USA) para egar en 1930 hasta $ 40.00, y estar en esta fecha, 1982
8 $ 52.00. Pero dentro de ene juego de eiffas, hay que reparar, gue hace decenas de aos. el

bani en ef mejor de los casos para los paises subsiesarrolladas, ecaba a centavos de dolar, no
siendo taro, hace 50 aftos que paises como Ecuador y Peri, vicsen desaparecer el petroleo de
que
de evantifcirseles ahora, slo legatian = poco: diss de producein rentable. Dato interesante,
cs saber que las omas fuentes de enctgia, se pondiian en términos de competencia economies
con el petréleo sélo si éstesubiria de $60.00 el burl. Estamos hablondo en 194
tuna de las corrientes de la OPEP (Organicacion de Paises export idoves de petrSleo), es no subir
el precio del barril, pese al agotamicnto de las rescrsasy aleastigo por inlacion, para no incen-
tivar la bisqueda de otras fuentes de en:
leros. especialmente de aquellos que coms Aribis Saudia,
ments en el petrSleo, May critcrios disimiles solve «! prondstico de esta fusnte de energia, pero
el mis gencraliado es el que admite ef ripide comma de Ios revervas, a tal punto que pated
to ticipo, 20 eios, pasatian a nporrader

sas costas del Pacifico, sin haborse entcrado de su magnizud y apenas recibiendo regal

?gue debitvarian ta economia de los paises petro-

exportadores como Ecuador ¥ aun Vencssi

res Va sucedid con Colombia, Datos estos inicresintes para fa eis que teala cate eae

?que hemos comenzada a dersostearls

HI gas, antes subsstioude y aun desperdiidy con ef proceimiente de gums este

Prafucto primario en Ia exivaceiin det pottsteny by thine stat snp ntancia, Baste deste de bes sgasoductos en proceso, ene les que desta

UU. de Boivin a Argentine Cuambsos goso tucson my soa por they eficantes pose el

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transporte y consumo, se procede a su embotellamiento,

IDRAULICA

La generacion de energis hidratlica se base en dos factores de wabajo: fuerea por di

tancia. Si este wajo lo referimos 2 la unidad de siempo, tenemos el concepto de potencia ex-

Presable en HP o en KW si se traduce a energia eléccrica. La masa liquids con x4 peso, consti

tye el factor fuerza: mientras que el desmivel 0 caida constiruye el factor distancia En Lat.

roaméries, tenemos la mis generasa provision en el mundo de estos dos Factores. sso eldte.

ita hidrogrifico del Amazonas constiruye el 25 o/o de los recursos hidrailicos ain no contami:

?nadeos del mando, Los Andes, sblo son superados por los Himalayas en altura De la gran eade

ra andins, nacen y discurren los ros hacia las diversas cuencas de toda magnicud. Estos gene-

ros0s recutios,estin subutiizados aportando como mivimo un 15 of del consumo energérico no obstante representar mis de un 70 olo de los recursos convencionales dela regi, Estat

«ifeas, son deducidas de los informes de OLADE, como resultado de los balances energéricot

romovides en los diverss paises. No obstante, extamos lejos de tener un verdadero inventario.

de reunion

Es priovtaria esta alrernativa energética por muchas razones

L.= Porla abundancia de estos recursos.

2. Por la clasicidad de su utilizacion variando la magnitud de los factores segin laubia

ibn de las Cenrales,

J. Por su condicibn de tenovable y no contaminante

4? por les beneficios colserales de ricgo, uso deméstico, regulacion sanitara y transporte

anavegable

Por el estimulo a la conservacion e increment de la masa vegetal que opera como es-

Ponja reguladors de las entregas hideaclicas« a cuenca dando eomo resultado de balan

ce, a defensa ecologies. Decimos ?de balance?, porque estamos comacicntes de que la

presencia de las Centrales pueden y de hecho lo tienen un impacto ecologice negativo, que desde luego no silo se compensa sino que se mninimiza por la otra consideracion.

Por ta gama de magnitudes de las centrales a obtener segin disporibilidad de recursos

y demands, .

Por eclatvamente facil transmisibn y aplicactin de la eneegia obtenida,

Por et ahorro de divisas al sustituir alos recursos energéticus importados,

Por el exmspo repr

tos institutos wenico educacionutes, eomstituyendo un prictice Ldharatoria de capaci

ntativos de insets

9 y mcjora de comocimientas provenicntes de

ibm 3 tod nivel

10.~Porla mano de obca y materiales nactamsles demsndados para su conseruceion eon su

efecto ecunimico multiplicadur y su spurts al slvie aungoe patel ec ladesccopue

Eve recurso energie

op

sim scseweomitica de be Rey

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En América Latina, actulmente hay la tendenca sin excepcion de paises, a formar sgandes concentraciones urbanas con abandono del eampo carente de los mis elementales servicios de energia y santarios. Aun as, ls poblaciin ae encuenera hoy dia disper y loca. lads en pequefos nicleos runes que en té:mino medio significan el 50 oo del total con tuna tendencia disminuir ripidamence por as anotadss cccunstancias Es tan cieno so, cuanto que el crecimiento de la poblacion rural, a nivel de region, oxcla alrededor del 1e/e, La diferencia de porcentajes encuentra su gxplicaciSn en que el uno es mayor s expen del oro, Para Ia policca energética que nos proponcinos suger, es tambien valioso el dato de ?qe, el gato de dispersion de la poblacin rural es el del 75 of, lo col hace eiffel ls in, corporacién de todos los pequenos sectores rules, a los sistemas de clectificacion nacio. rales.

Estos pequefios sectores rurales, viven en general del ausoconsumo con un miaimo acceso al drculante monetatio, en base 2 la arresania, Desde luego que ésto, contrariamente 1 lo sostenido por algunos tebricos parciales de la Economfa, es una circunstancia mis acep- table que eransformarlos en un simple mercado de consumo 0 en mano de obra de falsas in- duseriag, .

ESTADISTICAS ENERGETICAS EN LATINOAMERICA

Si nos referimes a los estudios hechos por Ia Fundacidn Bariloche. Rep. Argentina. on

Enero de 1979, tenemos:

Las reservas encrgéticas cotales de Améries Latina conssiruyen el 6 ofo de la mundial, y 54 contomo representa el 4,5 ofo.

En relacién oon el comercio internacional de energia, América Latina participa en el 1155 ofo de las exportaciones y en el 8,8 ofo de las importacioncs. El pequeho porcentae del 2.7 ofe a favor de las exportaciones se explics por los pafses con encedtentes de petrdleo para Ia exportacion y que a la fecha son: Venezuela, Ecuador, Trinidad y Tobago y Pert.

Los niveles de consumo de encrefa primaris de drigen comercial por habitante, rpre-sentan un 22 ofo de los valores medios europcos. Este indieador esti deformade negutivamen. te, sies que considcramos que el rea tural participa de él en forms muy disminutda,

Para América Latina, los hidevcurburs aportan en niimeios redondos el 80 fe de ta produceiin de energia y el 65 oo del cunsurin senda que sus tesetuas on esta facets som adhe del 20 oo

Los recursos hidroclictricus estin sb vsivados eo Me con el 13 ofa

del consumo encegttice y cl 10 ofe de la pass" evi tee de as que rezeesomtat

1170 ofe de los recurs enengiticus de Issn sgn Li aprec.seuanea se OPADE on bcs

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?una metodologia para la elaboracién de balances energéticos acogida y realizada por los paises

miembros.

Enos datos exadisticos, desde luego, no pedemos tomazlos como cifras exacta ina-

rmorible, sea por la cambiance realidad, sa por la fora como han sido realizadas implicando

desviaciones dificiles de deseartrlas; pero, no podemos subestimarlas en cvanto nos dan una

ia panorimica de lo que ext acontecicado en nuestra reign en el orden energético,

POLITICA DE IMPLEMENTACION HIDROELECTRICA

+ Bs indudable que el montaje de las grandes centrale hidroeléevias, tienen la capacidad

de modifica el panorama energético de los paises Iatinoamericanos, multiglcando su potencial

?en forma espectacular. La prucba mis concundente de lo aseverado es el caso del Paraguay, que

dde poncedor de una incipiense energia adquirida en buena parte en base a imporaciones de

peurleo con gran sacrificio de su economia, pasard 2 ser el mis rico en términos ?per efpita??

al compartir con el Brasil la represaItaipG, Ia mis grande del mundo, que generaré 1.600.000

KW. Esto, sin contar con los nuevos y grandiosos proyectos como los de Yacyreté y Corpus

4 compartir con Argentina, Ecuador, pais petrolero, miembro de la OPEP que en 20 afiox vers agotadas sus reservas petroliferas de no descubrirse nuevas fuentes, tiene una politica de compensacién de este recurso perceible y de ampliacion de su base energética, mediante el montaje de centrales hidrocléctricas. La Represa Daniel Palacios, en el Paute, rio eiburario de] Amazonas con nacimicnto en los Andes, generars en su primera etapa 1.000.000 KW y-mis que duplicaré la incipienre actual poteacia enorgética del pats

a de les patses Latinos.

smericamos, cual es el de la captacién y uriizsciin de sus cuantiosos cecursos hidrices, Pero planccamos una pregunta: los pequefios poblados rursles tendzin ficil acceso al producto de las grandes centrales hidrocléctricas? La tespucsta es simplemente no, Todos estos pequehos y dispersos poblados, muchos de ellos carccen del mis clemental camino eaitozable. Llevar tuna Hines de derivacién desde ls grandes ccntrsles es problemitico; peor pensar en wn sistema, interconcetado. Los grandes conglomersdae uibanos con sus exigencias industrials y domésti-

it. El servicia 2 los pequetios y dispersos poblados

tno es solucion econdmica drenando a lis granccs centrales, Entonces eabe pensat en taimplex imentacion de pequeiias centrales hidrockictricss que, si bien no mereeerian la ateneion estatal en su manejo administratvo, si podrian sex estsnuladas por este y liberadys a la admin?stracin

Asi podriamos dar cjemplos det aciervo en politica energé

28 absorverian todo y alin acusarian di

CONCLUSIONES

rn sorma inteyral, dese los pequctios recursos hi

rrdiusos como Tor de YFAUPU y los

ome Tos de 19

mayors que és, come los de | secticate annardnies,

a epuesto, débese aproved

aces de gencrar dasde Tos 50 KW he sa lus g

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OLADE, ha propuetto y creemos acertado, una politica de reducidas centrales hidroelécticas

para exe tipo de servicios, clasificindolas segin potencias ysalios de esta manera:

?TIPOS DECENTRALES ?POTENCIA SALTO ETM,

HIDROELECTRICAS EN KW BAJO MEDIO. ?-ELEVADO

MICRO Hasta 50 Menos 15-50 Mis

ée15 de 50

MINI 50-500 Menos 20-100 Mis

de 20 de 100

PEQUENAS 500-5.000 Menos 25-130 Mis

de25, de 130

Exto seria un gran solucin para estos pequesos y abandonados poblados que verian en

?este recurso el apoyo para su permanencia en su suelo accediendo asi a la comodidad domés-

tea, al apoyo a la agroinduseria y refuerzo a la atesania.

Con este sistema, el horizonte encrsético en Latinoimerica se ampliaria mucho mis alls

de Ios prevsto en estadis

mente el problema socivecondmico que la af

?contribuyendo si no a solucionar, por lo menos a atenuar grande

Esto, de ninguna maners constituye un pronuncismicnto para que no sigan desarrollindo-

se, las Centrales hidrocléctricas de mayor magnitud, sino mis bicn en apoye a elss para que

sus recursos sean mejor racionalisados,

CCreemos asi, haber demoscrado que 2 Latinoamérica le conviene priositariamente apro-

vechar sis recursos hidrotopogrificos para generar electricdad, mediante el montaje de een.

trales que abarquen desde 50 KW hasta las mis grandes del mundo,

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FEASIBILITY ANALYSIS OF A DISTILLATION COLUMN

COLUMN WITH VAPOR RECOMPRESSION

By

Edgar Hernéndez

1 Engineering Department

University of Puerto Rico

San Juan, Puerto Rico

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neSTRACT

The conventional distitiation system owes its existence to its simplici=

Ly; lox investaenty and inexpensive eneroy.? Inexpencive energy is semeching that belongs to the past, Therefore, vagor reconpress ion has indecd becmae more attractive despite the more complex flow arrangements

In this research, a steady state mocel was developed to study the effect of different variables on the feasibility of heat pump installations. Ae ox pected, the heat punp system favored the close boiling mixture against the wide boiting mixture. A relationship between the savings and the themody~ amie availability of the mixture was devised. The savings mere also found to be very sensitive to the relative cost of steam and electricity. ?A pose fible way of predicting the pressure effect on the hest pusp fessvbility based on the Antoine equation for the vepor pressure of the key conponests was also devised.

Vapor recompression is a feasible way of economizing energy on a disti- lotion unit. ?The cutleok for the use of the heat pur concept has now induced process engineers to consider its applications.

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INTRODICTION

Most of the interest and attention in recent studies is being devoted to energy conservation. During the past decade the price of ofl has increased considerably. Two reasons for the shara increase in the price of oll were: the Arab enbargo in 1973, and the Iran crisis in 1979, which made the U.S. to Took for alternate sources of encray and for energy conservation. Consequent= ly, distillation became a focal point of many studies because:

1, Distillation is the most widely used unit operation for separating

components in a mixture.

2, Distillation is a heavy consumer of energy.

To have an. idea of how much eneray is consuned in a distiMation processy in 1076 the U.S. distillation eneray consuaption was. estinated to be nearly: 3b Of the entire national energy consutstion, ?It 10s of the energy used? in dys Ullation ts soved, ?energy consinpt ie NOUId be reduced by nesrty, 100,000 B51/day of oil uhich represents about O75: of the entire nationat production (tix, Bwecky and Weinberg, 1978). This is one of She reasanse grstiTletion has been e subject of continuows research, Figure I shows # typical Sistitlation coluen,

The purpose of this work was to investigate the feasibility, dynanies, and control of @ distillation colunn «hen it is integrated for energy conser- vation with special interest on heat punp installations.

Basically, energy integration is divided in two major categories: mul= tiple effect systems and vapor reconpression, Figure 2 shows an example of a multiple effect system applied to a distillation colum. the multiple ef= fect distillation is analogous to the multiple effect evaporation. The eultiple effect system presented in Figure 2 \s called the single source, single load system (Buckley, 1978), The source colusn $2 the one that sup- plies the energy to the systen, The load colum 1s tie one that removes the heat from the system. In this schene the bottom strc im of the source column is the feed stream to the load colunn. The top strest of the source colum serves to drive the reboiler of the load coluin, Theve are a wide variety of multiple effect arrangetents besides the one describes shove.

Figure 3 shows an example of a vspor recompression systen also applied to a distillation column, The system is comanly refered to as 3 heat punp sys~ tem. This is the most simple Feat pusp arrangement, It uses an external refrigerant for heating and cooling, The colunn condenser is cooled with eva porating refrigerant at relatively low pressure and the colurn reboiler is heated with condensing refrigerent at relatively high pressure, This system is highly recommended when the coluin fluid is highly corrosive and it can not be used asa working fluid, :

Another type of heat pump syster is shown in Figure 4. This is a heat.

pump system with reboiler liquid flaviing, In this «ysten, the reboiler is

eliminated by flashing the rebovter I guid accross an expansion valve, This

arrangenent eliminates the use of 21 boiler.

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Figure 5 shows another example of a heat pump system, This is a heat

Pump system with compression of overhead vapor. This scheme is appropriate

when the colunn fluid is itself fairly good refrigerant and it is not

highly corrosive. This particular schene eliminates the use of the overhead

condenser. The vapor from the top of the column is conpressed in order to

drive the reboiler of the sane colunn, A trim cooler is normally used to

remove the excess energy developed in? the system, This heat punp arrangement

is the one being studied throughout this research,

?The heat punp principle involves the use of a conpressor to recycle the

latent heat in the vapor from the top of the tower at conditions suitable

enough to drive the reboiler at the bottom of the tower. Some of the key

variebles in analyzing a heat punp installation on a distillation column ine

Clude the pressure difference between the top and the botton of the tower, the absolute pressure level of the tower, which affects both the relative volatility and the cospression ratio, the temperature difference in the re- boiler vs the horse power to provide'it, and the size of the duty involved,

There are several factors that must be considered regardless of the schene under study. These are:

1, Reserve capacities which may be required

Extra heating capacity

Extra cooling capacity

Extra process equipment capacity

Interact ions~-elaborated heat recovery schemes are often highly interactive.

Qveral? material belance--How to maintain it?

Overall heat balance--How to maintain it?

Economics--Is it feasible?

One of the most relevant work done in this area, is the work done by Quagri (1981). He wrote two papers dealing with process design and process optimization of a heat punp installation with particular reference to Propylene-propene splitters. In part 1 he discussed alternative process Schenes and a computer oriented calculation method for the design optimiza tion of heat punp splitters. The computer calculation method was siso general enough to be applicable to rectification cases other than propylene-propane.

The design optimization was perforned case by case. In part 2, the results of the optimization obtained by applying the calculation method to an industrial Propylene-propane splitter were ?Tlustrated and the instrunent control systems. were discussed based on data and experience from the design and early opera tion of @ similar unit by the author, Finally, the economics of the heat pump rectification was compared against aitornative systems.

The work done by Null (1976) included the study of sone of the variables that affect the heat pusp installations of distillation coluans. In his work he studied different overhead condensz: ion temperatures, different rebofler temperatures, the tempereture driving force for heat transfer and different cooling media, His work involved an economic evaluation by conparing the available capital resulting from utility savings with that required to in= Stall 9 heat pump system. The definit.on of avatteble capital depends on the type of installation, and on the utili:tes capital allocation policy of the company. According to Hull, in a new installation, wiere neither @ heat, pump

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?nor a conventional design has been previously selected, the available capital is to be applied to the difference between the cost of the heat exchangers for

?the heat punp system plus the conpressor and the heat exchangers for the conventional column. In a replacement situation, the conventional colunn has already been built, Therefore, the aveilable capital is applied toward the total cost of the exchangers and the compressor for the heat punp system, He described the methods used and the results obtained in a study conducted to develop guidel ines to conditions under which heat punp systems might be economical substitute for conventional distillation processes, He concluded that heat punps have extensive applicability to distillation specially in rew process design. The range of applications is diminished in replacement situations.

Additional work was done by Danziger (1979). His work dealt primarily with vapor recompression as applied to @ pilot piant distillation column. He performed an energy and economic analysis for both the conventional and the heat integrated column as applied to pilot plants, He was able to.cone up with savings of over 80: for a system of cis/trans decelin,

This research program which was initiated by this work was not an exhaustive study on heat punp installations. The ultinate goal of this research progran is the completion of a definitive study on heat integration systems for energy conservation, in order to evaluate its feasibility, operation and control problems. This?study was considered the first step ina complete research program on heat integration on cistillation columns, laying the groundwork for future studies.

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EFFECT OF COLUMN VARIABLES ON HEAT

PUMP INSTALLATIONS

As mentioned before anong the most important variables that affect the heat punp installations are:

1. Pressure drop across the colunn

2) Absolute pressure of the tower

3: Approach tenperature in the reboiler/condenser

The purpose in this part is to develop the necessary tools needed to per-form the above mentioned Studies. Anong the tool's needed are:

1. A design program to estimate number of trays, reflux ratio and feed tray location of a distillation colunn fora given separation based fon shortcut calculation methods. A mechenical design of the column with the heat pup system is also needed.

2. A steady state distillation routine to perform distillation calculations.

3. A steady state routine for the heat punp system.

The purpose of the desion progran is to come up with a reasonable design of a distillation coluan basec on shorteut methods

The steady state routine for the distillation colunn is based on the well known Thiele-Seddes method. This method is chosen because its simplicity allowing more conputer time for the heat punp system, and. because our prine interest is to evaluate the heat punp installation and not to perform rigorous studies on distillation which are well known,

The steady state routine for the heat pump system models the compression of the vapor at the top of the colunn which? 1s used to drive the reboiler of the coluan, In this process 2 considerable avount of energy in the rebofler ccan be saved, but 2 more expensive el-ctrical eneray is used in the conpres-sor. Only economics dictates its fea: ibility. The economics of heat pump installations are discussed later on.

The location of the tri condenser was decided based on economic conside-rations. Preliminary economic calculations said that it is more economical to have the trim condenser before the co pressor rather than having it after the compressor (See Figure 6). The reason for this is that at higher pressure, for the same heat load, the tenperature driving force is larger compared with that at lower pressure, This means tat if the overall heat transfer coeffi cient does not change significantly tie high pressure system requires a smaller heat exchenger than at a Tower pressure, Vonever, the capital savings obtained in the trim condenser by locating it after the compressor does not compensate for the extra energy consuption of having 4 higher flow. thedugh the corpressor. For this reason, in this particular arrangenent, it is more economical to have the trim condenser before the compressor rather than after the conpressor. The trim condenser condensates part of the top vapor in order to close the overall energy balance.

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In order to make comparison studies, the product conditions of the col- lunn with heat pump should be the same as? the product conditions of the conventional column. To accomplish this, the reflux rate was modified in Such @ way to keep colunn products the same as the bese case colunn products, The base case conditions are shown in Tables 1 and 2. All conparisons are fade based on these colunn conditions as reference points.

In this part of the research, two binary systems were tested: Benzene- Toluene and Methano!-Ethanol. These two binary mixtures were chosen because they behave fairly ideal and?also because one mixture is 3 close boiling mix- ture while the other is a relatively wide boiling mixture. The boiling range for the Methanol~Etheno) mixture is about 14 K while for the Senzene-Toluene system, the boiling range is about 30 K. Scientists have claimed that heat pup installations are more suitable for close boiling mixtures than far wide boiling mixtures. Therefore it is expected to save more energy with the Methanol-Ethanol mixture than with the Benzene-Toluene mixture, It was mentioned before that the electric cost is more expensive than the steam (689.5 KPA) cost per unit energy basis. In order to account for this fact, a cost factor wes developed based on the cost of electricity and steam, This factor is the ratio betwen the electric cost and the steam Gost.? According to the literature (Peters and Tinmerheus, 1980), it was found that this ratio varies from 3.52 to 5,34 for self cenerated clectric= ity and from 5.86 to 10.42 for purchesed electricity. Only self generated electricity was considered in this research. The same approsch followed

for the self generated electricity alternative can be used when the purchased electricity alternative 1s consicered,

Savings were estimated in the following fashion:

4% Savings = (1 ~ (¥./0,)*(Factor})*100 a)

where:

Ke = compressor work

Q > Reboiler load .

Factor * cost ratio of eleciricity to stcan

Hf this factor is greater than O./¥,, then the heat pup system is not

economically feasible under the state! conditions. & cost factor greater than one means that the electrical en rgy costs more than steam energy. Therefore, reducing the enount of savings. The higher this factor is the Hore infeasible becones the hest punp installation. This study did not cone sider any capital cost needed to ipl ment the heat putp installation. The study considering capital cost associ ted with the implenentation of the heat pump system is discussed Tater on,

Loluan Press

The column pressure effect on th. energy savings, column differential tempersture between the top and the b tow of the colin, renoiler load and

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TABLE 1

BENZENE-TOLUENE COLUMN SPECIFICATIONS

FOR THE STEADY STATE MODEL

Nunber of Stages

Feed Tray Location

Feed Rate

Feed Rate Conposi tion

Quality of Feed

Distillate Rate

Distillate Composition

Quality of Distitlate

5

9

1000 g-moles/min.

50% Benzene, 50% Toluene

Saturated liquid

500 g-moles/nin,

94.2% Benzene, 5,8% Toluene

Saturated liquid

Bottors rate == $00 g-moles/min,

Bot tons Conpos ition <2 5.82 Benzene, 94.2% Toluene

External Reflux Ratio = 12

Top Pressure == 101.3 KPA (1 atm)

Pressure Drop per Tray a)

Steam Pressure => 689.5 KPA (100 psig)

Cooling Water Inlet

Temperature ~~ 299.8 K (80 F)

Cooling Kater Temperature

Rise n+ 22.2 K (40 F)

Polytropic Efficiency oD 78s

Approach Tenperature on

Rebotier/Condenser -- 5.0K (9 F)

TABLE 2

NETHANOL-ETHANOL COLUMN SPECIFICATIONS

FOR THE STEADY STATE MODEL

Number of Stages 15

Feed Tray Location 9

Feed Rate = 1000 g-notes/min,

Feed Rate Conposition =

Quelity of Feed -

Distillate Rate == £00 g-moles/nin.

Distillate Composition == 98,72 Methanol, 5.

Quality of Distillate 2 Saiurates Tiquid

Bottons Rate 22 500. g-noles/nin,

= 5.38 Methanol, 94.2% Ethanol

= 4.5

102.3 KPA (1 atm)

Bot toms Conposi tion

External Reflux Ratio

Top Pressure

Pressure Drop per Tray

Steam Pressure

Cooling Hater Inlet

0

689.5 KPA (100 psig)

Temperature --299,8 K (80 F)

Cooling Water Temperature

Rise + 22,0 K (40 F)

Polytropte Efficiency aera

Approach Teaperature on

Rebotler/Condenser -- 5.00 (98)

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the compressor work were studied for both mixtures. In order to keep product specifications the same as the base case, the reflux rate was adjusted as the colunn pressure was increased,

Figure 7a shows the effect in the energy savings when the column pressure was increased from 101.3 KPA (1 atm) to 506.5 KPA (5 atn) for the system Benzene-Toluene. Curve No. I represents the savings when a factor of 1 1s used. Curve No. 2 represents the savings when the lower limit cost factor of 3.92 was applied. Curve No. 3 represents the savings when the upper limit cost factor of 5.34 was applied.

As noticed, savings of over 80% can be achieved by implementing a heat pump system. Once the cost factor is applied, the savings drop drastically but they are stil] in the feasible region. Cooling water savings were con~ sidered negligible compared to the savings in steam,? In the case where a resrigerant 15 used as a cooling media, the savings? in cooling can Becone significant.

The Benzene-Toluene system appears to favor a lower operating pressure 25 shown on Figure 7a. On the other hand, Methanol-Ethanol system appears,

to favor a higher operating pressure as shown on Figure 7b. This is caused by the effect of the pressure on the saturation temperature of the components involved. For the Benzene-Toluene system, the saturation tenperature of Benzene and Toluene tends to get further apart as the pressure of the system is increased. On the other hand, for Methanol-Ethanol systen, the saturation temperature of Methanol and Ethanol tends to get closer as the pressure of the system is increased. This effect can also be noticed on Figure 7c where the coluan differential ?temperature between the top and bottom of the colunn for the Benzene-Toluene system increases as the colunn pressure is increased, Figure 74 shows the opposite behavior for the Methanol-Ethanol systen as the column pressure is increased. A theoretical explanation was derived to explain this behavior.

If the Antoine equation is re-arranged to solve for the saturation tenpe-

ature, the following expression is obtained:

Te = Bs (A-tn Ps) -C @

where:

Ay B, C = Antoine Equation Constants

saturation Pressure (rm hg)

T* = Saturation Temperature (K)

Taking the difference between the saturation tenperature of the two key

components yields: :

aT = Bef (Ay - tn PA) ~ By / (Ay = Ln PA) = at ()

where:

aT* = Saturation temperature difference between the heavy conponent

(2) and the Tight component (1) (Tp = T*))

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AC = Difference between the C constants (Cp = Cy)

Differentiate equation 3 with respect to pressure and rearrange,

P (d at*/0P) = 8) (Ay ~ tn Pr)? - 8 / (A, - Lm pa)? (a)

Therefore, substituting the Antoine constants in equation 4 gives you the slope of the Curve of saturation temperature difference vs pressure asa fune~ tion of pressure. By using the above equations, it might be possible to predict beforehand the pressure effect on the heat pump feasibility for @ particular binary system,

Tray pressure drop

The tray pressure drop effect on the energy savings were studied for both systems. Figure 8a shows the effect in the energy savings when the trey pressure drop is increased from 0 to 1.333 KPA (0,013 atm) for the Benzene-Toluene system, ?It shows that the energy savings decreases somewhat linearly when the tray pressure drop is increased. The sane happens for the Methanol -tthanol systen as shown on Figure 8b, This mesns that heat pump systens are favored by low pressure drop trays. ?The reboiler Toad and the compressor work behaved the sate way as in the column pressure studies.

Approach Temperature in Rebotler/Conde

Figure 9a and 9b show the effect of the reboiler/condenser approach temperature to the Benzene-Toluene system and for the Hetnancl-Ethanol. system respectively. This variable appears to be the one that hes the largest effect ?on the energy savings than the one pres fously studied, In this study, the approach temperature of the reboiler/ccndenser was increased fron § K'to 50 K.

The figures show that the energy sevines erosped drastically as the approach

temperature is increased. This ie « risult af having to increase the work in

the coupressor for the same redviler liad. A large teijerature approach will

Fequired a small heat transfer arca, bit a large conpressor capacity. Since

the approach temperature is the variab?e having the largest effect on the heat,

pump economics, @ complete economic an: lysis including capital investment 1s,

Performed in the next part to find out the return on capital investnent.

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ECONOMIC EVALUATION OF A DISTILLATION COLUMN

WITH A HEAT PUMP INSTALLATION

No project is complete unless some kind of economic evaluation is made.

It was found in the previous chapter that of the variables studied the one

having the largest effect on the heat pump systen being studied was the ap-

proach temperature of the reboiler/condenser. Therefore, the purpose in

this chapter is to come up with a more detaiied econonic evaluation of the hheat punp system when the approach tenperature of the reboiler/condenser is increased,

To compare the cost of a column with a heat pump system against a con ventional colunn, the anount of new capital needed to inplenent the heat Punp systen needs to be determined and compared against the savings in util ity costs. The ?extra capital needed to implenent the heat purp system 1s determined by the difference between the capital investaent. in a distilla-tion column with heat punp and that in a conventional column, The net Fesult 1s the capital needed to be invested in compression and heat transfer equipment for the heat punp instellation, It was essured that other design, changes are negligible compared to the one previousiy mentioned,

A zero allocation credit in utilities capital was considered. This means that although credit for utilities not use¢ can be claimed, the fact is that. the utilities capital has already been spent and the heat punp installation will not reduce it. However, if this release of capacity in steam and cooling water is needed elsewhere in'the plant, its allocation should be properly, Credited to the heat pump syster,

Energy tax credit was not considered in this research, because of the dif-ferent variations in which this credit is applied, However, if a project is feasible without the tax credit being considered, then it may becone more fea-sible once the tax credit is applied. On the other hand, if a project is not feasible considering @ zero tax credit, it may becone fezsible once the tax credit is applied.

According to Pavone and Patrick (198i) in order to qualify for the energy tax credit, capital projects mist meet the criteria written into the Taw. Eligible investments are limited to:

1. Alternative energy property, solar or wind energy

2. Specially defined energy property

3. Recycling equipnent

42 Shale-oil producing equipnent

The alternative eneray property includes conbustion equipment plus the auxiliary pollution contro? hardware necessary for firing fuels other than ?oil and gas or their derivatives. Facilities for procucing geothermal energy, and certain hyéroelectric generating equiphent. .

Specially defined eneray property refers to equipment used for increasing the energy efficiency of an existing facility such es waste heat boiler, econ omizers as well as heat pump systers, otc

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Recycling equipment is limited to facilities for sorting, preparing and recycling solid waste for conversion into energy.

Shale-o1 producing equipment is defined to include production and extraction equipment but exclude equipnent for downstream processing such as refining,

Most chemi =2l-process industries investments are entitled to a standard 10% tax credit. Facilites satitying the Energy Tax Act and Windfall Profit, Tax Act definitions (except for public utilities facilities) are entitled to an additional 10: credit or a total of 20%.

?The economic evaluation was performed by doing a rate of return analysis. Kurt's (1980) cost estimation and economic evaluation prograns were used for this study. The compressor costs were obtained from Peters and Tinmerhaus (1980). The feasibility was determined by the alternative having the largest rate of return, This analysis differs slightly from Null's (1976) analysis where the rate of return was already fixed and the availability of capital twas determined based on that,

In this evaluation, the steam and cooling water savings were considered our main products, with? the power spent in the compressor as fixed operating costs. The difference in capitel investment between the column with heat pup and the conventional column is the capital investment needed to imple-tment the heat punp installation. Table 3 Shows @ summary of the economic factors assumed.

Table 4 shows 2 sunmary of the heat transfer and compression requirements for the conventional colunn systen. The cost of the colunn itself 1s not in= cluded in the economic evaluation because it 1s assumed to be the sane for both the conventional case and the heat pump case. The reboiler is assumed to be a partial thermosyphon reboiler using steam of 689.5 KPA (100 psig). The condenser is assumed to be a total condenser using coaling water at 299.8 K {80 F) with a temperature rise of 22.2 k (40 F).

Tables 59 and Table 5b show @ suimary of the conpression and heat transfer requirenents for the heat punp installation under study for both bi-nary systems, The heat transfer requirenents for the reboi ler/condenser decreases while the heat transfer requirenents for the trim cooler. increases as the reboiler/condenser approsch tarperature is increased for the Benzene-Toluene mixture. For the Methanol-Ethunol mixture, the heat transfer requirenents in the reboiler/condenser ducreases, then after 15 K the reboiler/ condenser heat transfer requirements is constant. On the other hand the com= pression requirenents increases with the reboiler/condenser approach temperature for both mixture,

Table 62 and Gb show the saving: and costs incurred by implementing ?the heat punp installation for both systems. The total exchanger cost de- creases and compressor cost increases when the approach tenperature is, increased, The net savings in steam and cooling water decreases as approech teaperature is increased, Electric co:t increases with approsch temperature.

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TABLE 3

ECONOMIC FACTORS ASSUMED

Cost Reference vate + January 1981

Cost of 689.5 KPA Steam

(100 psig steam)

Cost of Power

Cost of Cooling Water

Running Hours per Year

Depreciation Factor

(Straight Tine),

Salvage Value

$0.007 J kw-hr

$0,034 / kwehe

$0,032 / metric ton

8000

10% of differential

capital investnent

10E of differential

capital investment.

50r

10%

Income Tax Rate

Inflation Rate

TABLE 4

CONVENTIONAL COLUMN HEAT TRANSFER REQUIREMENTS.

Reboiler Condenser Water | Steam

Area Area Required {Required

2

Ko/ne Ko/he

Methanol

Ethanol

n

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TABLE 5a

HEAT PUMP SYSTEM HEAT TRANSFER AREA ANO COMPRESSION

REQUIREMENTS FOR BENZENE-TOLUENE SYSTEM

Reb/Cond,

?Area

Trim Cooter

?Area

2

Compressor

Power

we

wi watts

TABLE 5b

HEAT PUMP SYSTEM HEAT TRANSFER AREA AND COMPRESSION

REQUIREMENTS FOR METHANOL-ETHANOL SYSTEM

Reb. /Cond., Red/Cond. {| Trim Cooler { Compressor } Cooling

Appr. Temp. Area area} Power water

wi

2

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TABLE 6

HEAT PUMP SYSTEM SAVINGS ANO_cOSTS

FOR BENZENE-TOLUENE SYSTEM

i ttectric | Compressor

i for. finch | cost | Costs Exchangers

{Temp Sten : Cost

i wet se Eg

1 $48,930 $17,890 $186,230 $81,030

f 2 f §35;s10 518,560 $188,730 $66,220,

f 3 f $361880 $19,230 sistj3s0 fg

$4 f S36te60 $19,910 gissjzca tg

5 f $36,830 | $20,590, $196,500} $45/630,

30} $36,710 ©} seafoso?F $209}600 «= | $23,420

1S $36,890 | $27,520 f Sazztaza =} $8230

2 ft $36,460 § $hisis0} $236,760 =} 5281370

TABLE 6

HEAT PUMP SYSTEM SAVINGS AND COSTS

FOR HETHANOL-ETHANOL SYSTEM:

Savings Electric | Compressor Heat pump.

in ch Cost £ ?costs Exchansers.

Steam : Cost

K sive sive i s $

1 $115,210, $25,970} $216,550 0

i 2 $115,240 $27,850 f §2241070 $58,950

3 $115,060 S2sieso?} S231;640 io |

ia $14,960 | gaijeto | §239/220

ios s1910 | 240 $246,820 :

1 10 $114,550 1030 $285,530 $39,240.

15 $113,170 §se,2z0 $324,240 $38,610

2 $113,790 | Seevai0 $362,950 $40,160

3

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Table 7 shows the heat pump economic evaluation sumary for both binary systems. The internal rate of return is tabulated against the reboiler/ Condenser approach tenperature. The optimum region was found to Tie at

lower reboiler/condenser approach tenperatures for both mixtures. For the Methanol-Ethano] system a 13.9% rate of return is obtained for an approach temperature of 1K. The rate of return decreases as the approach temperature is increased in both systems. This is because the increase in compressor costs are more significant than the decrease in heat transfer costs, Also the electric costs increases more than the savings in steam and cooling water,

In sumary, the heat punp feasibility strongly depends on the thermo- dynamic availability of the mixture and on the relative cost between steem and electricity. The overall tenperature driving force that the compressor has to overcome is a conbination of the saturation tenperature difference between the key components, the tenperature difference cause by the pressure Grop on the trays and the approach temperature on the reboiler/condenser. AS expected, the heat punp installation favored the closed boiling mixture against the wide boiling mixture.

TABLE 7

HEAT PUMP ECONOMIC EVALUATION

Benzene-Tolvene Methanol -Fthano}

i -Reb/cond =} Internat Reb/cons | Internal

{Approach | Rate of Approach | Rate of

Temp. =} Return Temp. = | Return

x i + K i Fi

13.95

1 i

2 f a3!a1 i

3 £12160 :

4 f illee i

5 £ 10:99 i

10 i 6.70

15 i 2126

135

u?

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SUMMARY

The primary purpose of this research was to investigate the feasibility, dynamics and control of distillation columns with heat pump installations, A steady state model of a distillation coluan with 2 heat pump was developed to Study the econonic feasibility of heat pumps in distillation columns, This model was used to study the effect of different variables to the heat pump feasibility. The effect of colusn pressure, tray pressure drop, and reboiler/ Condenser approach tenperature to heat punp? installations was investigated, It was found that the heat punp feasibility strongly depends on the thermo dynamic availability of the mixture end on the relative cost between steam and electricity. The overall temperature driving force that the compressor has to overcome was found to be @ combination of the saturation tenperature difference between the key components, the tenperature difference caused by the pressure drop on the trays and the approach tenperature on the. reboiler/ condenser.

A possible way of predicting the pressure effect on the heat punp feasibility was also devised based on the Antoine equation for vapor pressure. Therefore, the pressure effect on heat punp installations can be predicted beforehand by using the Antoine constants without having to Jo rigorous

calculations.

It was found that of the variables studied, the reboiler/condenser approach temperature was the one that hove the largest effect on heat punp installations feasibility. This is because the increase in compressor cost are more signifi-cant than the decrease in the heat transfer requirenents. Also, electric costs increases more than the savings in steam ard cooling water, As expected, the heat pump installations favored the closed boiling mixture against the wide boiling mixture. Therefore, for very difficult separations where a considerable amount of energy is used in'the reboiler, the heat pump concept might be @ feasible way of reducing the energy consumption considerably.

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San Juan, Puerto Rico

?August 1-7, 1982)

?Second National Conference on Renewable Energy Technologies

HYDRO AND GEOTHERMAL ELECTRICITY AS AN ALTERNATIVE FOR INDUSTRIAL PETROLEUM CONSUMPTION IN COSTA RICA

by

Wayne R. Park - Matthew S. Mendis

?The MITRE Corporation

McLean, Virginia ~ USA.

Leonardo da Silva

The Inter American Development Bank

Washington, D.C.

?San Juan, Puerto Rico

August 1982

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ABSTRACT

Tais paper reports the results of an assessoent of the

potential for substitution of electricity for petroleum in

the industrial/agro-inductrial sector of Conta Rica

After a preliminary estinate of the industrial process

energy needs and a survey of the principal petroleus con=

the paper assessen the

electrical technologies appropriate for substitution and

their economic competitiveness against petroleun fired

The electric technologies include industrial

slectric boilers, hot vater generators, electric heaters,

electric heat pucps, and aicrovave eysteas.

?The report chovs that fifty two percent of the current

and projected industrial petecleus consumption in Coste

Rica can be replaced vith electric energy

hydro and geotheraal resources available within the country.

fed on current consusption patterns, this substitution

Would result in a 14 percent reduction in petroleum ieports to Costa Rica. The additional electric energy required can be obtained by an acceleration of the current hydro elec= tric expansion program.

The Key to the success of @ Coste Rican progran for substitution of electricity for petroleum in industry rests in energy pricing policy. The report shows that if Coste Rica Bunker C prices ere increased to conpare equitably with caribbean Bunker C prices, and increase at 3 percent per annum relative tos special industrial electricity rate Beructure, the entire substitution program, including both industrial and national electric investment, vould be cost Pffective. The definition of thece pricing structures and their potential impacts need to be assessed in depth:

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BAckcRoUD

?As vith all of the countries of Central smerica, Costa Rica suffers from the serious economic penalties resulting fron energy dependence on high priced imported petroleum. The approximately 200 million dollar petroleum taport bili for Costa Rica in 1979 Fepreseats 13 percent of the value of inports and 16 percent of the value of exports in that year (IDB, 1981). Clearly, = cost~ effective technique to reduce Costa Rica's dependence on foreign ofl would significantly taprove this serious financial drain te the Costa Rican econoay.

Adthough Costa Rica has no known petroleum resources, the gountry {s endoved vith numerous indigenous energy resources:

hydro, geothermal, biomass, vind and other solar resources, as vell 48 potential resources of nevly discovered coal Reduction of for eign ofl ioports requires that these indigenous energy resources be Antroduced as substitutes for current uses of petroleum.

Hydro potential stands forenost in Costa Rica's energy resources. More than 8500 Mi of hydroelectric poteatial yielding pearly 37,000 Gi electric energy have been identified {2 the coun- try Glepublica de Costa Rica, 1981). Only 445 MW of this potential capacity are currently developed providing about 98 percent of the 1843 Gih of electricity denand for the country in 1980 (BID, 1960)+

On a much sualler scale, geothermal energy for electric genera~ tton 8 also a promising indigenous energy resource for Costa Rica A total of 80 Mi of installed geothermal generation capactty ts scheduled for completion in 1986 at the Miravalles site in sorth:

west Costa Rica. Although the total national geotheraal potential

tg not known, a preliminary estimate has been placed at 720 ¥i

(btois, 1973).

The question immediately evident is how the large hydro potea~

tal might be used effectively to substitute for the many eneFEy

end-use needs in Costa Rica now being satisfied by pecroleun.

Table 1 below describes direct petroleun consumption by sector

Sm Costa Rica in 1979:

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TABLE 1

SECTORAL PETROLEUM CONSUMPTION IN COSTA RICA (1979)

Percent of Percent of

National Sectoral

Petroleus Energy

Sector Eoergy (TI) Gonsuaption Consunption

Restdential/Comercial a3 ? 7

?Transportation 9310 66 100

Industrial and Agro~Industrial 7109, 24 4

other 1088 4 34

370 0

ref: (Reptilia de Costa Rica, 1980)

Although the transportation sector {s the largest consumer of petroleun the technology for substitution of electricity for petro~ Yeon in other than rail and urban transit eystens is not yet adequate.

The second highest petroleum consuaing sector, the industrial and agro-industrial cector, and the target of this paper, does pre- sent opportunities for substitution of electricity for petroleum. In 1979, electricity accounted for 16 percent while petroleua accounted for 44 percent of the energy consunption in this sector. Electric, Povered industrial technologtes are available on the maicet today and dn many cases can be substituted directly for oil or diesel fired Gndustrial heating systens. This paper investigates to vhat extent these industrial techoologies can be applied in a cost-effective way in Costa Rica.

INDUSTRIAL/AGRO-INDUSTRIAL STRUCTURE AND ENERGY USE

?The food products industry dominates the industrial sector

of Costa Rica. This sector consisting primarily of coffee, meat, dairy, grain, and sugar production, accounted for over 50 percent of the gross value of industrial production in 1977. The contribution of the remaining sectors is vell distributed with no single sector exceeding five percent of the gross valve of industrial production Beading this list are textiles and clothing, followed by chenicals, vod products, and petroleun refining

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?The agro-industrial sector 1s also aa taportant sector of the

Costa Rican econony accounting for 18 percent of GDP. The major agromindustries are: coffee beneficiation, banana aad fresh fruit crop irrigation and packing, sugar processing, rice and grain willing, cattle and related activities, fishing and crop epraying-

To identify primary opportunities for substitution of elec tricity for petroleua use in Costa Rica's industrial sector it was Recessary to make an {nittal assesment of the magnitude and purpose (Le, process energy need) of petroleum use in each of these indus trial sectors of costa Rica.

Energy Use in the Industrial Sector

Table 2 presents the 1980 industrial petroleun consuaption for Costa Rica- In 1980, as in the past, the sajor petroleum product

4m the industsial sector was Bunker C. Bunker C consumption Feached 740.8 x 10° BBL tn 1980, equivalent to 68 percent of the total fndustrial petroleua consuaption. Diesel consuaption was the ext highest at 266.8 x 10) BBL. Only 9 percent of industrial Petroleum consumption vas made up by gasoline, kerosene, Jet fuel and asphales.

The other non-netalic atneral products sector 1s the Largest Pefroleum consuning industrial sub-sector accounting for 348-6 x 2109 BBL or equivalently 32 percent of the 1980 industrial petroleum consumption. This sub-sector is dominated by two ceneat tudustries which account for 96 percent of the total consuaption. As seen, this sector is by far the largest consuser of Bunker Ce

sector is the second largest petroleus

consuming sub-sector accounting for 186-4 x 10° BEL or 17 percent of 1980 induserial consumption. The dairy products industry ts the Jargest energy consuser within this sub-sector accounting for 42 Percent of the petroleum consumption. The meat products, grain mill products and fishery products industries are also major energy con Suners- Like the non-metali{c mineral products industry, a few large consumers dominate the food products industry. The five largest

Petroleum consuners account for 65 percent of the sub-sector con suaption. The remaining petroleum 1s consuned by approximately

45 smaller industrie

The next three Jargest petroleus consuatng sectors are con: struction and mining, other cheatcals, doainated,by the fertilizer Andustry, and glass products. Of the 169.5 x 10? BBL of petroleus used 1n construction and stning, 50 x 10 BBL of this consuaption ?are asphaits with no practical energy value. In addition, diese!

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TABLE 2

1980 INDUSTRIAL SECTOR PETROLEUM CONSUMPTION

(IN BBL)

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Eepresents 64 percent of its total petrolous consusption, much of

which ts used to operate heavy transport, construction and nining

eguipaent. Both the fertilizer and glass products industries are

?ajor consusers of Bunker C.

Ene

sro~Indust

tae Sector

Table 3 presents the 1980 petroleus consueption data for the ajor sub-sector {ndustries in the agro-industrial sector. Eight gubvsector industries are identified. The largest petroleum consum~ ing sub-sector in the agro~industrial sector 1s the banana and fres fruit prodycers. Total consumption {a this sub-sector accounted for 137.8 x 10° BBL or 54 percent of che total sector consumption. The majority of petroleum consused vas diesel used for powering electric generators. Many of the banaca and fresh fruit producers are located 4m renote areas of the country aot presently serviced by the elec= tricity grid. They require electricity for irrigation, vashing and packing operations and for employee residential consumption:

Coffee benefictators and sugar producers each consused ap-

Proximately 42 x 10° BBL of petroleum. Again, the majority of

this consyapeion was for diesel fuel. A significant portion

(4.5 x 107 BBL) of aviation fuel was also consused in 1980 fn

the agrowindustrial sector for crop spraying activities. Grain

milling, cattle raising, fishing agd other agro-industrial related

ictivities accounted for 27.1 x 109 BBL or approxinately 11 per~

cent of the agro-industrial sector consunption in 1980.

Industrial/Agro~Industrial Fuel Use by Process Need

Table 4 provides 9 breakdown of the energy requirenents of the

Andustrial/agro~industrial sector in Costa Rica by energy process

requirenent

The conversion to high temperature process heat represents she largest consumption of petroleum fuels accounting for 36303 x 10 BBL or 42 percent of the energy value of the petroleus fucle con- suned in the sector. Approxivately 90 percent of the petroleum sed to generate this high temperature process heat 1s Bunker C, the majority of which {s used by the cenent industry in Costa Rica.

Steam ratsing for industrial processes represents the second Largest consumption of petroleus in the industrial and agro= Andustrial sector (23 percent of the total). Again, Bunker C accounts for the eajority (approxieately 80 percent) of the total energy value of petroleun used to generate steam

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Approxtaately 11 percent of the petroleus purchased {9 used

for transportation purposes. This included 26 percent of the total

diesel purchases in the sector and all of ite gasoline and jet fuel

Purchases. Over 9 percent of the sector's petroleun consumption 1 used to generate electricity alnost exclusively by the use of éie~

sel. Of the remaining petroleum consumption 1a industry, 5 percent

ts used for low teaperature process heat, another 5 percent for

Elonary mechanical energy, 2 perceat for generating hot water and

approxieately 4 percent for non-wnergy feed saterials such as a5~

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(CONVENTIONAL INDUSTRIAL /AGRO-INDUSTRIAL TECHNOLOGIES AND THETR ELEC

RICPWEEDSUSTINTES

The industrial petroleum based technologies most commonly

observed in Costa Rica, can be grouped as follows

© Bunker C and diesel oft-fired boflers for steam and hot

© Bunker C, diesel and kerosene oft-fired combustors for

lov and high teaperature process heat

© Diesel ofl-fired tnternal coubustion engines for on-site

mechanical pover and/or electricity

?The petroleum-based industrial energy technologies may be sub? stituted by several different electric technologics: The electric technologies may te classified ax direct substitutes (1.e-, provid- ing the sare energy product and requiring no change to ?heer 3¢ {ne Andi serial process or fritrect subecitutes (i.e. replacing both the energy product on sy:tem and the existing industriel proces:)+

?The dicect electric substitutes applicadie to industry in Costa Flee are:

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The indirect substitutes most applicable to industry in Costa Rica a3

© Electric senbrane separators

A conversion eatrix relating the potential technical substitution of the extsting pecroleua-based technologies with appropriate substitute electric technologies 1s shown ta Table 5.

?THE KEY INDUSTRIES AND ENERGY PROCESSES WITH POTENTIALLY CONVERTIBLE ?PETROLEOH CONSUMPTION

By matching the electric technologies available against the Andustrial/agro-industrial process energy needs by fuel type as Just shown in Table 4, it was determined that the maximum techatcally substitutable potential (i-e., not taking economics, institutional oF site specific factors into consideration) 1s about 52 perceat of the total 1980 industrial and agro-iadustrial petroleum consumption OF 14 percent of the total 1980 national petroleum consumption. ?This maxinun substitution potential is shown in Table 6 vhich subdivides each entry in Table 4 into a substitutible portion (under? Lined) and unsubstitutible portion. The technologies that represent this 52 percent conversion potential are steam and hot vater boflers, low and high tenperature process heaters and diesel electric gener ators. Steam and hot vater boilers account for the largest portion oF 47 percent of the total conversion potential of 693,400 BBL. Of the 693,400 BBL of petroleum, 424,300 BBL is Bunker C,'243,900 BBL. is diesel and 17,200 BBL is kerosene-

Table 7 Lists seven key industries vhich represent 65 percent (or 448,000 BBL) of the total convertible petroleum consuaptions Within these seven tndustries, 60 percent of the petroleum consuap? tion is used to geaerate steam or hot water, 23 percent to generate qlectricity and 17 percent to provide low of high Ceaperature. pro~

ECONOMIC POTENTIAL FOR ELECTRIC SUBSTITUTION

To determine the economic potential for converting industrial Petroleum consumption to electricity in Costa Rica, six generic case Studies vere defined which compare the econonics of existing petrolua based technologies against potential alternative electric tech

nologies. These case studies are:

© Petroleum versus high-voltage electrode 800 EP etean boilers.

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TABLE 5

TECHNOLOGY CONVERSION MATRIX

Direct Hsctrte Subecteuten ?_Jaddrece Hlacerte Substtivtee

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TABLE 7

KEY INDUSTRIES WITH POTENTIALLY CONVERTIBLE

PETROLEUM CONSIMPTION

Percent of .

Total Industrial

Convertible Convertible

Petroleum Petroleum

Industry Gonsumption Consuapt ion

© Food products? 1s 23

© Fresh frutt producera®* 108 as

fe Beverages 49 7 -

© Paper products a 6

© Textiles a ?

© Coffee benefictatore*** 3 5 -

© Rubber producta 19 3

us s

Fille Key energy consuming industries within the food products tn-
dustries are: dairy products; meat products; grain mill products
and coffee processing.

?**Dtesel for electricity generation 1s the prisary source of petro-
leun consuaption by fresh fruit producers.

?**Petroleun {9 presently used by coffee beneficiators primarily to
dry coffee beans and in sone cases generate electricity. With -
Fegard to érying coffee beans, electric resistance heaters are a
technical possibility.

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© Petroleua versus low-voltage resistance 250 UP steam boilers.

2-11 63 (2.0 toescu)/ur petroleus versus electric resistance

low teaperature process heaters.

© 2.11 63 (2.0 msBeu)/ir petroleim versus low-voltage

Fesistance and electric heat puape hot vater boilers.

© 2.11 G3 (2.0 méBtu)/hr petroleum versus electric aicrovave

food ovenmirter aysten-

¢ 1M petroteus electric generator versus purchased grid elec~

ertetty-

Buel Price:

?The economic conpetitiveness of petroleum vs- electric tech

nologies is heavily based on the relative prices of petroleum and

electric fuels. The fugl prices in Costa Rica as of May 1981 are

given below in Table 8.

TABLE 8

COSTA RICA MAY 1981 FUEL PRICES

TH electricity $.035/eim

T-10 electricity $-010/4imh (ttme-of-day price)

Bunker © $1132/11e0r

Diesel $1365 /1ie0r

Kerosene $2423/1se0r

of Electricity

Te current standard industrial 1-4 tariff for electricity ts dased om both a desand charge on the saximum peak power that the Andustry requires and a kWh charge for electricity. ?The T-4 cost fiven above {a based on the energy charge plus the denand charge averaged over the auaber of hours of electricity used tn a weuche Monthly electricity use 1s assuned to be 356 hr/ao. The T-10 tar Aff has just recently been instituted which provides {ndustries a significant savings in electricity charges for the onths May. through

January if they are willing to use electricity only during off-peak

?Wosts Ta this paper are given tn May 1961 dollars. Costa Rican

curreacy exchange is based on 18.9 colones to the U.S. dollar in

effect at that tine.

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hours (all hours except 10:00 to 12:30 and 16:30 to 20:00). During

the dey months of January through May the T-10 tariff reverts to the

6 tarttee

4s seen, the T-10 tariff represents about a 70 percent discount

to the standard T-4 industrial tariff for electricity. In this anal?

ysts, the T-10 tariff vas applied as a potential future electricity

price, not so much representing a tine-of-day price, but rather as

4 benchaark for a lover electricity price that would encourage tn-

dustrial conversion to electricity. The extent to which a TA10 type

price discount is financially feastble on a large scale is not eval~

vated and represents an teportant potential constraint to the tmple?

Bentatioa of an industrial electrification progran-

Goat of Bunker C

The present low price of Bunker C in Costa Rica ie a result of governaent aubsidtzation and recent curreacy devaluation: Ia May

ef 1981, bulk prices for Busker C in the Caribbean market were posted ?about 36 percent higher than the delivered price to industry in Costa Rca. ?Consistent with the low cost of Duaker Cin Costa Rica, how ever, 2 the excess supply of that fuel produced by the Costa? Ricaa RECOPE refinery. This excess supply 1s curreatly being re-exported to Caribbean aarkets. RECOPE ts now planning to upgrade the refloery fo produce less residuals.

Feononic Comparts

The Life cycle costs of obtaining the desired end-use process ?energy vere calculated and coupared for each of the six technology Pairs listed above. These coats vere based on the most recent veador capttal and operating and maintenance cost estinates and the fuel prices Just listed. In the case an electric option was less costly on @ Life cycle basis, thea the total petroleus product use im Costa Rica industry/agro-industry to which that technology applied was considered to be oubstitutable vith electricity. Total national potential vas estisated by repeating this calculation for each combination of petroleun products and end-use energy pairs as was done previously in Table 6

Table 9 susmartzes the analysts of the economic potenttal for substitution of electricity for petroleum in the industrial sector- For each of five cases of petroleum and electricity prices and price grovth rates, the table presente the industrial /agto-indvstrial Petroleun energy consumption that could be converted to electricity on 4 cost effective basis. Two substitution options are considered-

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In the first, only conversions from petroleum to electricity are cos

Pared. The Second option peraits, tn addition, conversion of diesel

and kerosene systens to Bunker Cif Bunker C12 acre econoaical than electrietey.

The results shown in the table ave sumarized below:

If present petroleus and electricity price relationships continue in the future, the economic poteatial for sub stitution fs estimated at hetveen 13 to 19 percent of industrial snd agro-tndustrial use. (Case 1)

© If present ?ndustrial electricity tariffs are discounted by about 70 percen: (as is representative of the restricte: THO tariff), then the economic potential for electricity substitutio: for petroleum ranges between 14 to 52 percent. This range ?5 depe dent on the annual real price increase Of petrolew produ:te relative to the discounted electricity pric

~ A constant price ratio between petroleum and elec~ tricity results ta a 14 to 19 percent substitution potential. (Case 2)

= Athree percent anmal increase tn petroleua prices reruite {n'a substitution goteatial in the range of

19'to 23 percoat (ease 35

4.20 percent annval tnerease {n petroleum prices or a rise in the dosestic petroleum prices to May 1981 Caribbean spot prices vith a three percent annual Petroleun price increase achieves the saxinun tech- Bical substitution potential of 52 percent. (Case & and 5)

Clearly, the tvo key factors that will tapact an fadustrial electricity substitution progran are future increases in petroleun Prices and the extent to which electricity price discounts can be extended to the industrial sector without undersdaing the finan= ctal viability of the electricity sector. The T-10 tariff which represents a 70 percent discount over gormal industrial electricity tariffs is presently avatlable ona Iinited tine-of day basis eed sentially represents excess pover during off-peak periods- The ent to which this or sintlar tariffs ate feasible within the Present and future financial structure of the Costa Rican electric~ Aty sector has not been addressed in this papers Ary coualtment to

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4 significant industrial electricity substitution program must first carefully evalute the financial viability of petroleua and electric~ Sty pricing structures relative to the health of both the nattonal petroleus and electricity coapanies as vell as to the Costa Rican Batioaal econoay-

ADUITIONAL ELECTRICITY REQUIRED FOR MAXIMUM SUBSTITUTION

Under the Case $ scenario, the maximum substitution of elec trtetty for 52 percent of the industrial/agro-industrial petroleum consumption could be obtained by 1987. Based on industrial grovth, of 9-1 percent per year, the 52 percent of the projected 2239 x 10? BBL of petroleum consumption acounts to 1164 x 10° BEL of petroleum savings in that year. Based o. relative efficiencies of petroleum and electricity use, the electric energy equivalent of this 18 1526 Gil. This additional electricity denand taplies a 314 ?W increase 1n national electric power requirements from 723 Mi to 1037'MW. By 1995, the requtreneat tncreases to 624 MW measured from the hase case of 1343 Mi co the case of maximus industrial electrification of 1967 Mi.

The additional electric capacity requirement to 1995 can be obtained by a one to three year acceleration of the hydroelectric Projects in the current hydroelectric expansion plans.

(GOST/BENEPIT ANALYSIS

For the purpose of an initial trial test of the poteatial econoaie viability of an industrial electrification prograa in Costa Rica, MIRE perforaed 4 national cost/benefit analysis for the Case 5 scenario presented in Table 9. Case 5 vas selecte?, not ae a nost Likely case, but rather asa test case to see if under the energy Prictag conditions which permit naxinua substitution, the entire 12~ Yestnent required, both for industrial conversions and for increased hydroelectric capacity would be cost effective. Assuming only the Primary benefite of saviags tn tsported petroleum, the internal rate of return for the total industrial and hydroelectric favestment was estinated to be approximately 13 percent. At thie rate of retura, for,the period 1963-1995, discounted benefits of petroleum eavicgs of $220 million watch the additional hydroelectric and industrial Aavestuent costs of $202 wi1lion and $18 million, respectively AB een, the industrial costs constitute oaly 8 percent of the total favestnent required

OF interest to note is that by extending the cost/benefit stream

from 1995 through 2015, the internal rate of return increases to ap~

Proxinately 20 percent:

uv

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Relative to the guidelines of a minisun of 12 percent rate of

retura for national developaent programs, an industrial electrifi~

cation program based on Case 5 conditions 1s cost effective. This

analysis leaves unsnevered whether a relative petroleum and elec~

tricity pricing structure equivalent to the Case 5 conditions is a

potential reality for Costa Rica.

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Tis paper has shown that it 1s techaically possible to substi~ tute approxinately 52 percent of the total industrial /agro-industrial petroleus consuaption in Costa Rica vith electricity that comes from hnydro and geothermal resources within the country. The hydro and geothermal resources are more than adequate and the electric tech~ nologies for industrial conversion are readily available. The key

fo the success and recomendability of a large scale electrification program in industry in Costa Rica Iles in energy pricing. If price Subsidies on Bunker C fuel can be eliminated and special industrial, electricity rate structures such as the T-10 tariff can be effec tively and videly tnplenented, then an electric substitution program could be effective. It is taportant to renenber the taplenentation of an accelerated hydro-geotheraal electric generation program will require significant anousts of capital. Finally, other non-petroleus alternatives such as industrial /agro-industrial use of biomass fuels im sone cases might be nore cost effective than electric substitu= tion. What {s needed at this point {s an assesanent of both national energy pricing alternatives in Costa Rica and an integrated evalua tion of all non-petroleua fuel substitutes for the Costa Rican indus trial sector-

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UPADI 82

San Juan, Puerto Rico

?August 1-7, 1982

First Pan American Congress on Energy

MATERIALS, ENERGY, AND THE
U.S. NATIONAL MATERIALS ADVISORY BOARD

By

Donald G. Groves

National Materials Advisory Board

Washington, D.C.

San Juan, Puerto Rico

?August 1982

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MATERIALS, ENERGY, AND THE

U.S. NATIONAL MATERIALS ADVISORY BOARD

Donald G. Groves

Staff Scientist

National Materials Advisory Board

Washington, D.C. 20418

U.S.AL

Abstract

Advances in technology are based upon corresponding advances in the ability to utilize the proper available materials and/or to evolve appro-Priate new ones for design applications. History is replete with examples that dramatically illustrate this point.

Today, many of the vii

gies for energy production and conservation are Raterials limited. Hence, "idealized" design concepts and accompanying prototypes for such technologies cannot be successfully translated to practice.

ly needed new technolo-

This paper outlines several aspects of materials science and engineering that pertain to this national interest problem. It also delineates the important role the National Materials advisory Board (of the National Academy of Sciences-National Research Council) plays in recommending viable solutions to the present materials-enegy-environment dilemma.

Tobe presented at the XVIT Convention of the Pan American Federation of Engineering Societies, San Juan, Puerto Rico, August 1-7, 1982, by Donald G. Groves, U.S. Delegate to the Convention.

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Introduction

A material can be definec as anything that is formed of matter and has substance. Therefore, there are a countless number of materials. However, iz has been estimated that some~ thing considerably less than 1¢,000 kinds of organic and inor= ganic engineecing materials exisc. These are the very ones Eton whith Ramang wits the application oe aeet attitudes, objectives, and technical abilities can use to turn into prod= ucts for their welfare,

If one examines the pattern of history through the course

there is no question that all advances in technology in determined by corresponding advances in our abilicy fo utilize effectively materials from this reservoir of 10,000. In a sense, this is not surprising since basically there a! but two predominant technological entities in this world of Qurs--Composition (or Materials) and Configuration (or Design). Thus, everything--machines, instruments, tools, etc. and even humans--depend on these two "C's."

A detailed recitation here of the many substantiating aspects of this long and fascinating history of the technology= materials relationship is, of course, beyond the scope of this Paper. However, briefly, such a history dates from che very. early advances based upon accidental discoveries oy craftsmen, who, for example, found that by impacting suitab! gether cleverly permitted the shaping of cutting arrowheads. Later, during the ?bronze age" and periods, achievenents were also gained by the exercise of empiricism or a trial-and-error methodology. In tne 17th century chemistry came into its cwn and many species of atons were discovered as were the laws under which they combined to form compounds. Several significant subsequent events, from those times to the present, fora the basis of our present-day work in the field of materials science and engineering.

Today, materials science and engineering can be thought Of as a coherent system of scientific and engineering discie Plines that combine. the search for expanded knowledge into materials with the resulting knowledge applied to society's

Reeds. Still, it is only within the past two or taree decades that the materials scientist farted to comprehensively delve into the nacure and capabilities of materials. This scientific progress has been aised very tangioiy by such present-day analytical tools as auger spectroscopy, scanning teansmission electron microscopy, computers, et al. plus the technigues available for optimizing their uses

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However, at the present time, there is a growing concern over wnat appears to be a deciine in ?tne emphasis on needed materials research, and especially in the innovative application Of the results of such reseacch. If an erosion of this effort is, indeed, taking place, and ftom all indications it probably is?due to various present-day economis factors and the general Public's lack of awareness and support of materials science and engineering, it is most unfoctunate. Tne field will be stymied in putting forth its full end potential capabilicy in meeting the many required materials needs of the present and future.

These needs are certainly matters of concern to the fation, Materials are basic to our lives and to our mode of living. Their supply is of critical impoctance as is the manner by which they can be most efficiently processed into useable forns for engineering hardware, Then, 200, there is the para mount question of how to best dispose of certain materials (e.g., radioactive wastes) and various materials of consi

tion when the hardware no longer interests us. Also, and pechaps in the long run one of the mo ortant considerations Of all, is the urgent need for a much netter scientific knowl- edge of how materials "hang together." sy this, I mean to say, a better in-deptn understanding of the atomistic character (composition, structure, and defects) of many engineering (especially polycrystalline) materials. Acmed with sucn infor- mation, the tasx then is to correlate these atomistic parameters to the properties and benavior that she materials exhibit in engineering usage. As snown in Figure 1, tne primary knowledge barrier is not within tae inner or outer world of materials o¢ the techniques usec for probing into these worlds. It lies between the two and separates them. This 1s unfortunate sin the character features of materials are oasic and form the real basis of how materials pecform. Admittedly, the removal of

this barrier represents a rough, touga problem. However, it is only by such a correlation of the property-character relationship that we can be predictive and mace materiais so that they, are reliable, uniform, anc reproducible. as yet, materials science has not reached this mature ccage of materials under~ standing and development.

Enecay and Materials

The life blood of industry--materials--interact dramatically with energy at virtually every point in what has been termed the materials cycle. Shown aere, in Figure 2, this physical concept, the materials cycle, is driven by societal emand and the life cycle in this analytical framework is closed. However, throughout there is a total systens technol-097 waich includes a number of interacting subsystems involving

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?THE IVWER AND OUTER SPACE WORLDS OF MATERIALS,

?THE OUTER WoRLD

ar, proparting of materials predominate «== THERE ARE AN INFINITE NUNERER OF MATERIALS

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Ehe total economics and with societal impact present at each step. The application and use portion can be called the Con-Sumers Circle since it is a subsvstem as indicated by the input arrows. The Producer Circle is another subsystem; for examples R&D done early in this cycle should tace into consideracion ene Gisposal and ceclamation part ci the Producers cycle. the Public sector circle orings into play the societal impact and Social forces that may impinge fxoa tine to time on the materi-als life cycle,

The cycle conceptually is independent of tne rates of Raterials flow but is intertwined with the Lines of supply and

Gemand. ?the flow of materials can be disturbed radically around the loop by unpredictable evants cutside of tne materials worlas However, steps can be taken within the cycle to prepare for Such contingencies (e.g., stockpiling, recycling, and the substitution of one material for anothec). Materials in the cycle flow through it in essentially five stages

© Extraction of raw materials: ores and minerals, rock, sand, timoer, crude rubber

© Processing of raw materials into bulk materials: metals, chemicals, cerent, lumber, fibers, pulp, rubber, electronic crystals

© Processing of bulk materials into engineering materials: alloys, ceramics and glass, dielectrics and Semiconductors, plastics and elastomers, concrete, building board, paper, composites

© Manufacture of engineering materials into structures, Machines, devices, and other products

© ? Recycling discarded products (materials) to the ays-
ten or disposing of then by ground burial:

Via Figure 2, some perspective of the materials, energy, and environment interaction can be obtained if we first scary with a natural resource sucn as, for example, bauxite asa Source of aluminum. This natural resource is processed to the elemental material, aluminum, and this processing cequires energy and most likely creates pollution. Nest, tne ?alaninum As Processed into a usable form such as an aluminum casting. Again enersy is required and again pollution may be involvw Finally, the material is converted to its engineering applica~ tion. Subsequently, it secves its purpose and then the disposal Peoblen is faced, with additional enessy required and possioiy Rote pollution. ?Disposal, depending upon tae material? can take the form of cecycling or sone ot! 2. reclamation

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process returning the material directly to the elemental state or useable form as a supplement to the natural resource. Dis. posal can also be more of a challenge just as it is in the case Sf radioactive wastes.

In this materials-energy lite cycle relationship, the, industrial sector of the U.S. curently accounts for about 37 percent of the nation's energy consumption and the industrial share is projected to increase to 50 percent by 1990. In size reduction operations of raw materials (@.9., ores and minerals, etc.) alone, U.S. industries use about 32 billion kwn of elec- trical enecgy per annum. This asount of energy is approximately 2 percent of our total electric power production nationally. More than half of the size-reduction energy is consumed in the crushing and grinding of minezals, one quarter in tne production of cement, one eighth in the preparation and utilization of coal, and'one eighth in the processing of agricultural products. However, current comminution tecanology is both energy-intensive and notoriously inefficient. Most of this blame can o@ ateri~ buted to improper selection of materials and poor design of equipment.

Thus, matecials are not only crucial in situations like this but they are of pivotal importance in making energy available in the fizst place, At present, it is fair to say that inadequacies in the performance of materials are tne principal constraint on the efficiency, reliability, cost-effectiveness, and even the actual realization of most of our advanced enersy-conversion technologies such as gas turbines, nuclear reactors, high energy density batteries, fel cells, magnetonydrodynamics, coal conversion, and solar-enorgy conversion.

?The National Materials Advisory 3oacd

upon many of the foregoing facts rests the case for the need of the National Materials advisory doard (NMAB)

This Board, a part of the National Academy of Sciences, the National Academy of Engineering, and the National Research Council, was established in January 1369 as successor to the

Materials Advisory Board, which was formed in 1954.

?The NMAB is uniquely involved in the world of materials.

It is concerned with the entire life cycle of materials, and it

Provides a national forum that focuses on a wide spectrum of

Scientific and technical problens. ?The modus operandi of the

NMAB is essentially the sane as -hat of lts predecessor, the

Materials Advisory Board. Sriefly, the objectives in the

national interest are to: provide advice and assistance to

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government, industry, and academe; bring attention to the

Materials aspects of national problems and opportunities and

Suggest possible solutions to the proslens; identify materials

Problems interacting with othec technologies and recommend

Solutions; cooperate appropriately in tne development of

advanced educational approaches; promote cooperation among

materials-ociented professional societies; maintain an aware

hess of trends and advances in materials science and engineec-
ing, call attention to opportunities, and promote applications
of advanced concepts.

In the execution of its various study projects, wiich ace
funded primarily oy U.S. Government agencies," Committees are
established. Members of the committees are chosen for thei
objectivity and expertise in their professional fields. These
Members serve without pay and are reimbursed only for their
travel and incidental expenses. At any one tine there are about
300 people serving on these committees that are engaged in aa
many as 30 different study areas. .

One such NKAB study, "Matecials Technology in the Near
?Term Energy Program,? which was carried out in 1974, was largely
responsible for the initiation of several subsequent NUAB mare-
Eialswenergy studies. efhis particular study of the near-term
enecgy program (1985) in the United States identified several
specific areas where materials technology plays an imporeane
role. In this regard the principal areas so identifica include
(a) pressure vessels in nuclear power plants, (s) oil shale,
(c) coal liguifaction, (d) fuel and materials recycling from

municipal and agricultural waste, (e) coal gasification, (f) high-temperature turbines, and (g) hot water geothecmal, Other areas, which were considered but judged to have less impact on the enecgy supply/demand balance in 1985 were: solar heating, extractive metallurgy processing, fuel cells, Uz3q separation, and batteries for energy storage.

Four of the most recently issued representative NMAS studies deal in depth with some of these above-mentioned aceag. Two Of these (Reports NNAB~375 and NNAS-344) treat with the materials needs for efficient utilization of geothermal enecgy in the U.S. Another, NNAB-364, addresses the energy consumpeicn problems in the comminution (crushing and grinding) of materials Such as minecal ores, cement, coal, etc. Algo, the study enci~

"The Academy of Science, incidentially, is a private organiza- tion established in 1863 with a Congressional mandate co advise the government on matters of science and tecnnology in the national interest.

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tled "Reliability of ceramics for Heat Engine Applications" (Report NMAB-357) outlined tne potential as well as tne problem areas for tne use of monolithic ceramics in heat engines. Such

Presents an attractive possibility for significant improvement in engine durability, efficiency, and multi-fuel capability.

In tne geothermal energy area it may be safely stated that the extraction and conversion of heat present in the earth's core to useful forms poses many problems of a technical and institutional nature. First, the use of geothermal fluids for electric power production and otner purposes causes aiffi- culties not normally encountered wnen fresh water is used for such purposes. Many of these tecnnical problems must be identified and some means developed to overcome them. Due largely to these factors and the lack of knowledge regarding the tech~ ical and economic feasinility of developing geothermal energy kesources, such resources have oeen underutilized.

In view of this background, the U.S. Department of Energy in 1978 requested that tne National Materials Advisory Board convene a study effort to detail the inportant physical and chemical properties waicn characterize geothermal brines (in Liguid-dominated fields) anc the instrumentation whicn can be used in situ to measure such properties. Geothecnal brines ace heavily loaded witn a variety of chemical species which can Precipitate out in the well causing fouling, decreased flow fates, gas formation, and otner undesizable effects. Hent

tne characterization of geothernal fluids in experimental of operating geothermal fieids, now and in the future, is of vital, importance to the development of this energy resource, Instru- ments are cequired in geothermal wells in order to perform this characterization and to monitor changes in the brine characteristics as a function of tine.

?The NMAB committee assigned to study this problem made several recommendations, which were persuasively argued and substantiated in their report. These included the development Of specific ion electrodes, CO, sensors, standard reference electrodes, cable protection, and electtical insulation materials, as well as other itens.

In 1980, the U.S. Department of Energy requested that the WMAB do an additional study specifically on the "Materials Needs for the Utilization of Geothermal Energy." In response to this request a committee was formed and in March 1981 their report (SMAB~375) was issued. In this report it was concluded tnat geothermal systems designed using existing materials are capabl

Of withstanding conditions in dey geothermal resources and in

wet geothermal resources with temperatures up to 2400C and

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ojected Geothermal Electrical Cenerating

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total dissolved solids (10s) less than 28,000 ppm. In moce Severe wet geothecmal resources, more expensive materials or More frequent replacement of less expensive, less duraple mate- tials is required. Major materials proolems that will limit design and operation of geothermal energy systems until the year 2000 were identifies and recomsendations for solutions to the problems are presented in tne report in detail. Table 1 is an adapted listing of problens associated witn drilling and completion while Table If presents similar data for operations related to production, utilization and relnjection.

The committee recommended that the feaeral government Support the development of the less hostile geothermal re- sources, as well as R&D on novel, resistant, strong materials that ace cost-effective for use in the harsher geothernal envi ronments. To that end, it was recommended that tne Department of Energy and national nonprofit laboratories, colleges and universities, drilling and completion contractors, equipment and service Suppliers, and geotnecnal energy system operators, Work in a coordinated? and cooperative effort to speed develop Ment of materials for geothermal energy utilization (see Figures 3 and 4).

In regard co the study on Comminution (sponsored by the U.S. Bureau of Mines, tne Department of Enecay, and the National, Science Foundation), several detailed reconmendationsdihe NYAS Committee on Comminution and Energy Consumption were evolvea in theic study of the problem. These cover more than 15 topical areas involved in the fundamental and practical aspects of com- Minution. Five specific areas (classification device design, comninution device design, control, grinding additives, and materials for liners and media were identified as areas to focus on to achieve large, short-term (less than five years) savings in energy. Further, it was estimated that the implementation of recommendations in only two of the areas, classification and automatic control, could result in savings of 6 billion kWh per yeac. Also, this committee reported tna: a decrease of only 10 Percent of the energy consumed in commination could save $160 Million annually. ?The implementation of recommendations in both tne short and long term requires the support of fundamental studies in a number of areas, including fragmentation science,

particle-fluia and pacticle-particle dynamics, particle charac-
terization, surface science, and materials science. tt is apparent that a high level of interdisciplinary effort is necessary to cary out the required fundamental work. Even with tne small amount of research being currently conaucted in tnis field, it is estimated that consiceraole duplication of research exists in the etforts of government and individual industrial companies. Sucn an observation fas triggered off sone current 1942 initial efforts directed to more cooperative

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TABLE I. Some Systems and Components in Geothermal Drilling

and Completion Whose Pertormance is Constrained oy Materials

Problens/Needs

System of Compan

Drill pipe and tool joints

Rock bits and drilling tool:

Seals for rock bits and

drilling tools

Elastomer seal for rotating

head

Lubricants for rock bits

and drilling tools

Downhole Motors

Cement

Insulation for logging tool:

High wear cates. New materials,
nazdfacing, or surface treatments
needed. Corrosion and corrosion
Eatigue, sulfide embrittlement

$ High wear cate of carbide insert
and hardfacing materials

Degradation of elastomers at
elevated temperatures. Need
high temperature (300%)
elastomer

High temperature elastomer
(200°C) needea

?Theemal and chemical deconpo-
sition of conventional lusricant
fluids/greases,

Seal and bearing life limits tine

between overhauls for turpodrills

Flow properties at elevated

temperatures (350°C). Setting

characteristics and strength

after prolonged exposure to

heating in production are

unsatisfactory

3 Degradation at elevated

temperatures (350°C)

-ne

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TABLE II. Some Materials Proplens/:

leeds in Geothermal Enersy

Production, Utilization, and Reinjection

?Systen_or Component "trodes or ea?

Downhole pump motor

and cable

Downhole pump hydraulic or

gas turbine impellers

Pump rotating shaft seals

Downhole Lineshaft pump

bearings

Hot brine (350°C) trans-

Port pump

Brine reinjection pump

Cements

Gas separator seal, bearing life, and insulation limit life of moter cable covering. Connection seals limit life of electric cable. Hign temperature elastomers needed for motor and cable insulation

Lowest cost of service material needed to prolong life of nigh speed rotating components

High temperature elastomers and corrosion resistant alloys needed

Exosion and corrosion resistant materials need to be determined for this type pump

Materials resistant to the

mechanics of cavitation required

when two-phase brine enters the

pump

Precipitation of solids

(carbonates and silicates)

requires materials resistant to

corrosive and erosive attack

Longer service Life during

production

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andustry-government organized research in comminution, thereby

Raking it more productive for tne future

On still another subject, a mention of the recent NMAB

study on Reliability of Ceramics for Heat Engine Applications

(Report NMAB~357) is merited. asically, this Department of

Defense-sponsored effort was initiated in view of the well-known

fact that significant improvements in efficiencies can be

obtained by operating heat engines at temperatures above those

that can be-attained with high-temperature metals and super-alloys. This fact combined witn the recent advances in the high-temperature capabilities of ceramics including their improved mechanical properties and resistance to chemical attack, make certain ceramic materials ateractive candidates

for heat-engine components. However, the structural use of these ceramics introduces problems arising fron lack of experience, which require resolution oy design tecnniques, materials, and methods of materials processing.

5 study, the principal gaps in knowledge

ailuce origins, nondestructive testing,

life prediction, and proof testing--were identified. Additionally, an outline as to how a moce rigorous understanding of

this class of materials can be used in the production of reliable component parts for heat-engine applications was evolved.

At present, we have several ongoing and just completed representative study efforts including those relating ro (a) the materials problems of aqueous and nonaqueous battery systems (to be used principally in electric venicles and electric utility load-levelling applications), (b) an assessment of the energy considerations that play 4 role in determining the nature of materials for the national stockpile (in this report, assessments of current energy costs versus those projected into the future, as well as current energy availability versus availability in time of a national emergency, will be made),

(c) a critical examination of the current materials technology being applied in the researcn and development of selected fuck cell propulsion systems and subsystems for vehicular transportation, and (d) an assessment of the Industrial Energy conservation? Program.

It is expected that the ceports on these subjects will provide valuaple road maps in the necessary matecials development for increased application of these energy systems.

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= About the Author -

staff scientist of the National Materials
Advisory Boaré of the U.S. National Academy of Sciences, has worked with sone 50 Acadewy committees on Materials Setence and Engineering convened in the national interest. Before Joining the staff of the Acadeay in January 1962, he served as a U.S. Naval officer (Reserva) on active duty during the Korean Coaflict. Subsequently, he was enployed in industry as an electrical design engineer, an engineer in advanced patertals engineering, and as a syscens specialist in Oceanography and Ocean Engineering.

A menber of several professional technical and scientific societies, Groves is a three-tine avardee of the Freedom Foundation Honor Medal, an honorary citizen of Key West and the Florida Keys, anda fellow of the Washington Acadeay of Sciences. He is the author of two books on Science and Technology, a contributor of chapters to Several others, and has published over 200 articles in various national and interaational journals and nagazines

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UPADI 82

Sen Juan, Puerto Rico

?August 1-7, 1962

First Pan American Congress on Energy

ENERGIA NUCLEAR. LA EXPERIENCIA ARGENTINA

Por

Mario Eduardo Bancora

Argentina

Sen Juan, Puerto Rico

August 1982

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ENERGIA WUCLEAR, LA EXPERIENCIA ARGENTINA, Ings Karl 5 8fncor

En Flsica el parSmetro Energfa se define como la capacidad de efectuar abajo. Es evidente que esta capacidad es absolutamente necesaria po

Fa que una Naci6o est en condictones de mejorar su futuro y consign ? evar el nivel de vida de sus habitantes.

Existe, en efecto Toa relacién directa entre el consuno de energta y el grado sarrolio econfnico y social, Esta es la raz6n por la cual el Indice de consumo per cfpite resulta uno de los nfs fehaclentes para me dir el nivel de progrese de un pats,

La crectente demands surge no solanente de lat V8sicas expectativas de los habitantes de ios pafses subdesarrol lados por mejorer sus condicto~ nes de vida, sino tanbifm por los efectos de la explosign denogrBflea que se nenlftesta o$s crfticamente en estas naciones y que va Increnen tendo ia poblacién del mundo 2 razin de un mill& y medic por senane,

El temp de cubrir adecuadanente 1a demenda de energta adqulere hoy ca Facterfsticas de ursencia pero ha sido una constante en toda la historte de la Human dad,

El hoabre, que us ortginalmente su propia mergta, comenz6 9 destacarse sobre los 'denfs cuando descubri6 1a enorme ventajs de exslotar 12 enere ofe ajens.

Progresaron aquflloz que pudieran é¥sponer de! mayor nfnero de animales Y¥ esclavos para efectuar las tareas dlarias y por consiguiente tuvieron 2 gu dlsposici&n mayor tiempo para pensar e Innovar. La Antigua Grecia,

sobresalié en su cultura, en artes y en clencias Impulsade por Atenas.

No es un hecho muy conocido que los? 20,000 patricios atenienses tenfan

® su disposictén casi 400,000 esclavos.

Desde el punto de vista eneroftico esta fuente es muy precaria, una po~ tencla supertor a 100 W no puede suministrarse muscularrente nis que, / Por cortos Intervalos. No es posible, por ejemplo, suninistrar por vfa individual la potencia etfctrica que necesita una'ana de casa pore plen

char la ropa. Si esto sefora es una habitante de los Estados Unidos, e=

tadfstlcanente tiene a su dispastein 10,000 W instalacos, y puede co

far con una enerafa superior a a ave podrfan proporcton

Esto Hustra ta situaci®a e privilegia de ese pots que con s6lo el 6%

de Te poblactén mundtal consume el 302 del total de To energfa produc!

da, En el otro extreno hay patses que apenas superan? tos 100 W tnstala

40s por habltantes. No es 18gico esperar que el consumo de los EEW dis

mminuya 0 que el consumo de les subdesarrol lados se nantensa en Yes nIve,

Tes paupErrinos actualesy

Es Indispensable recurrir a todas las fuentes disponibles para cubrir /

1a denonda, pero el desarrollarlas requiere grandes invers tones

Se crea asf una especte de cfrculo vicieso: Sin energta no es posible /

Progresar pero el costo de obtenerla requiere recursos que diffe! Imente

estEn disponibles en una comunidad empobrecida, Si no se ronpe este cfy

culo con nedidas enfrgicas y oportuna la humanidad se cncamtna hacts

Un preeipiclos

Indla ha dado un ejenplo desarrol lando con vigor un programa energfttco

que Incluye Te fuente nuclear, Su filosoffa de base ha sido sinteeizads

en ta stgulente frase por el?extInco Presidente de su ConisiGn Atémica

---Page Break---

Dr. Hommt Babha: "io hay enercfa nfs cars que no tener energfals

Stun pats pretende salir de su estado de subdesarrollo debe coro condi

?l8m necesaria tmpulsar la explotaci?n de todos sus recursos energeticdbs

En las ditimas dfcadas el petréleo ha sido e! recurso mis utilizado, pe

Fo el fenomenal increnento de sus precios de 10 ahos a esta parte (307

veces) he planteade problemas económicos que exigen buscar otras fuentes

pare suplmentar su uso,

SI bien 1a OPEB ha sido el Instronento gue he provocado esa multipl tea

elGn de prectos, el hecho era previsible a largo plazo, por a éisminu=

cl de las reservas y por el obvio increnento de lo demande, No son 8

tos sin enbargo los Cnlcos factores. Se ha estudlado la evoluctén ge 7 ,

los conbusttbies 9 través de lo historia Megindose a ta conelustn /

que Estos cunplen un clelo en las cifras de su consumo relative,que es

suceptIble de. ser expresado natenSt icanente,

Ast el conbustIble primitive que era la madera fue desplazado luego por

el carbGn mineral, que a su vez fue posteraado por el petrBleo, Este pre

sumtblenente alcanzar§ e! nfximo de su ciclo y ser8 gradualnente sust!?

tufdo por fuentes no convenclonales. Lo notable es que ninguna fuente ha

perdido Importancta por haber agotado sus reservas, sino ngs blen por hi

ber aparectdo otras fuentes cuyo empleo resuitaba m$s précticos Pore)

Plo, la menclonada madera, recurso renovable que hoy est8 casi descarte

do, podrfa -rectclando los bosques existentes- sustitufr 1a enerofa que

se'obttene quemando conbustibles f8sites (Potencial estimado 25 Tw-afo) «

Otro tanto ha sucedido cone} carbén que ha sido sustitufdo en gran par~
te por los conbustibles Ifqdidos y aseosos, a pesar de tener alin consi=
derables reservas.

Estos a su vez deben ser suplenentados Inevitablenente por otros nuevos

La Gintca fuente no convenctonal que est$ en condiciones de aportar ese /

suplenento, es Ia energta nuclear, que se encuentra en estos momentos, en

la parte cfeclente de su ciclo de utilizaci&n. fxisten en efecto al I

de Fnero de 1982 doscientos cincuenta y tres Reactores Ge Potencia enor

peraciBne

Se trata tanbifm de la fuente que nfs oposicifn ha provocado, al punto /?

que algunos pertidos polfticos incluyen en sus respectivas platafornas,

Je prohibict&n de su enpleo.

Es IBgico entonces, que los pafses en desarrollo que tienen tantos pro

blenss prinarios que resolver,se pregunten si tiene sentido enbarcarse,

fen un prograna de energfa aténica,

Como tantos otros interrogantes no existe une respuesta universal. Sta

eabargo con tal valléez puede aftrnerse, que ningtn pats puede peralele

se el Ignorar, ya sean 19s posibiticades © los Inconvenientes de este 7

Ello significa que cono programs mtnino deberfa pronoverse ta fornact&

de recursos humanos @ los efectos de mantener actual vada le Informactén

Y postbilitar que se tomen en el futuro las ceclsiones que sean necesar

Flas sin éepender enteranente det azesoreniento externos

Argentina dio efectlvanente tos prireros pasos en su programa de fnergfa

Nuclear fundado en la local ided de San Carlos de Bariloche un Centro ee

formacifn espectallzada, donde los profesores y alunnos en un rfginen de

tlempo completo conviven en un campus universitario cuyo acceso se lz0

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3.

facttble @ todos tos estudiantes del pats, mediante un sistena de beces,

Hoy da al denominado Instituto Balze'ro len honenale @ av pelece Bieese

tor) es un Centro de excelencia reconocldo 2 nivel Internactonaly

1a de su actividad, te sido por supuesto 1 Comi

AtBakca pero no existe Universidad Argentine 7

jorte de tos egresados del Inst itutor

La principal beneficia,

In Naclonal de Energ

?que no haya recIbhio el

Un programa de enersta at8nica, aunque sea mfnino, tiene como Importan=

te subproducto el de pronover ¢} acelents clentTtica y tfenico generale

Por tratarse de una tecnologta de punta, requiere el cesarrollo de to-

1s las dends.,

En Argentina 1a ConisiBn de Enerote Attica fue fundade en el afo 195)

¥ constituy6 e! priner Organisno no universitario de investigaci&n que

PrecedI8 en seis aos a! Consejo Nacional de Investigaciones y a lot Ins

Eltutos Nacionales de Tecnoloc¥s Incustriat y Aoropecuariag Real zB ast

tuna labor pionera en materia de trabajo cientffico por equipore

Un segundo paso en un programa de Suergta ACGnica, que conplenenta prfe

tleanente al prinero consiste en equiparve para trabelar con por, Aparte de traterse de une herrontenta valiosa de GlagnBst;

raputica, resulta diffeil encontrar alguna actividad vecnotég

el use de? radiotsBtopos no produzce resultades Gtivess

En Argentha se decidi® encarar su producci8&n local y pare elle se conen

28 con la Instalacitn de aceleracores de partfeulas en 1855 y se conse?

truyS el primer reactor experimentel en 1558,

Se construyeron adenSs, las facilidades necesaries para el fraccionanien,

to y coneretallzacién de radiois8topos.

Las aplicectones industriales se ampliaron con 1a instaleciGn de umptan

ta de trradtaci&n de alta intensidad mediante cobalto 60. La cantldad /~

e usuarlos de radiois6topos ha crecido en forma notable y hoy se brin con ellos un servicio de indudable inter: sociale

EL tercer paso, que es en realidad el primero en 1a direceia de un pro grana energBtico, consiste en realizar la exploraci&n uranfferas 1 cone cer los recursos ?no solanente en materia de rant, sino también de coon) bustitls f8slles es un requerimiento obvio para poder encarar los planes rnacionales ?de enerota. ?$

EI problena es que se trata de actividades que requieren Inversiones sig Bifteatives y cuyo Exito no est8 de manera alguna garantizado, Por ello Ro constituyen una proposiei®n faci! de sdoptar.

Extsten dos soluctones: a) el pats encers por su cuenta le prospecctén y fen ese caso tiene que formar y/o contrater personal idfnco y dedicat. ree cursos rentas generales para? inpulsar las tareas neceseriae que inclos yen la actividad privada & b) entrega a Empresas forfneas le explorseléa ® canblo de concesiones en caso de obtener Exitos Se trata de una dect= S1En polftica al ns alto nivel, dence Influyen una serie de factores./

no téenteos que conplican su adopcitn, Se debe sopesar 13 desventaja de

hipotecar el futuro a! compreneter reservar, con la necesidad de eaters

Binar la cifra de las misnas en un tienps razonebles

Lo que ctertanente no se deberfa hacer, es postergor la toma de decisior

nes por el compromiso que inporta una efiniciBns tn ef cose particuter

de un plan de energfa nuclear hace un mundo de diferencia e! tener 0 no

Ve rateria prina en el territorio nacional, sobre todo cuando se deba a

doptar una determinads Ifnea de reactores.

---Page Break---

Argentina se decidi6, desde los comienzos de su plan nucleo!

Mas opctones que le permi:ier-an aicanzar su avtosuficiencte

En.funcién dedlo se doté a te Conisitn de Energfa At6mica de los pre-

Supuestos necesarios para que realicars ia prospeceién urantfera del. te

Fritorio nacional, formora ios én con neceserios y consteuyera Inclus,

sive el Instrumental de prospec. Se promilg6 una ley que estimulaba

1a bOsqueda por prospectores privacis, brindSdoles privilegios en a ex

Plotactén de los eventualer yacimienrcs. ~

por aque-

Gono resultado se localizaron nuserosas manifestactones en distintos /

Puntos de! pats, se conen26 la explotaciin de aquelles mis promtsortas

Y 38 Instalaron?dos fibricas ce concentra:iGn y purificacién en las pro *

Vinelas de CSrdoba y Mendoza. <

$1 blen Ta exploract&s cubri6 una pequens parte det territorio con post

Bitidades uranfferas 10: resultados abtenidos permitieron determinar ee

?yas suficientes para alinentar unas seis Centreles Nucleoeléctricas>

fe 600 Mile dur? + Ello fue base suficiente para poder de

Fintr una Ifnea de reactores que provorctona-S las mayores garantfos 7 contra la dependencia exterior en maceria de suministre energétlea.

En efecto, tomada 1a decisién de usar la onerata de origén nuclear, ef

Pr6xino dilena consiste en ia adopeitn de ta 'Trea de resctoress Comm /

5 sabldo existen dos Mfneas bien prosacat para producie tal energte en

forma econfmicamente conpet!civa. Lo primera use e! uranio. de compostei&n

lsotéplea normal, es decir 'a wisra con que se lo encuentra en es mic

En este caso las condiciones ffsicas para que le reacci&n concatenada /

tenga lugar exigen lz presencia ce un moderacor de los cuales el més e-

fear ha probado ser el Exico de ?euterio (Agus pesada)s

La segunda Inea usa agus contin como noderador pero en tal caso 1a reac

Ein concatenada no procece a menos cue se altere la conposiclén tset

ples del uranlo aumentando le proporcié de Usaz en relecién al Uyyg

Em resumen Ta opcit es enriguecer ¢! combustible © enriquecer el mode~ +

Fador, alterando por redios ffsicoz la proporcién natural Ge sus, (s6to~

pos.

Las difteuitades técnicas y econfaicas para alterar 1a concentract&n to

tEplee del uranio de ninguna manera son equiparabies @ las de obtener eT,

agua pesada, Es bien conocica !s fe Jos esfuerzos y la Inver-/

s8n que debleron realizar tos fos durante 1a segunda guerra

Pundiel para Megara les alcas concentraciones Ce Use necesarias pare

Ta borbay ast cono del Secreto que save a tooo ef ofbfacieg: tees Bint

mo ha sido superado pero e! cestc de una plante de separacién por difu

s18n gaseosa, que es e! nfcodo usade por arhas potencias mucleares para

obtener el wanio enciquecido, cuets fuere-de tes pesibilicades econtal

cas de un pats en desarrollo.

onente accestsle, tanto /

En canblo una planta ce agus pesade

co. India lo ho denos-/

desde el punto de vista econtn

trado al poner en operaciSn = ss Adenfs debe tomarse en

consideracién el hecho que e! uren?o es un material de consumo y como /

tal debe ser renovado continvanente, como cua quier combustible? ?atene/

tras el agua pesada es un materia) Ge stock, cue ectua por presencla y

Fequiere solamente 1a reposicitn ce sur pérdicas. Con etlo el grado, de

Urgeneta en Ta provisién conita funé-nentalnente, Tocas estas considers

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clones son pertinentes cuando uno de los parSnetros fundanentales en la

elección de la Mnea de reactores, es la autosuficiencia energftica, Cuan

fo por razones tEcnicas coro no disponer de yacimientos 0 por razones / >

Polfeieas no sea posble obtener tal suficiencia las tazones expuestas /

Elenen relattva validez y en canbio cobran inportancia las consideracto

nes econfmicas. Um reactor ce uranic enriquecida tiene menor costo Int=,

clal que uno de uranic natural de igual potencia debido a! precio. del

ua pesada y al menor volunen de su nlicleo. Ofrece adenSs mayor flext-

DUNidad operative y estos factores justifican su mayor popularidad, En contrapostei&n el costo del ciclo de combustible es bastante menor / con uranto natural debido 2 que no se requiere el enriquecimiento y & que hay menor penal idad econfmica por no reprocesar los elenentos trra* dledos. Los reactores actuales utilizan apenss el 1% del porenctal ener Et Ico de su combustible, Ello se debe a lo acumulaciGn de los producsT tos resultantes de la fisifn del uranic que van disminuyendo la reacti- vidad y terminan por hacer imposible la prosecuci®n de le reacetEn con catenada, Cuando ello sucede hay que canbiar los elementos combust tbles En el caso de elenentos con uranio natural no hgy mayores problemas eco nfmicos en descartarlos. Cuando se trata cn cantio de uranio enriqueel> do su valor residual inpone la conveniencia de reprocesarlos para reco brar el uranio enriquecido y e! plutonic. Las dificultedes de trabajar con elenentos irradiados, con activicades de megacuries © Inclusive de transportarlos, hacen que el reprocesaniento see une ectivicad dificil

Y clertanente poco accesible oun para pafses avanzados que en general / Brefleren diferirla, La penatidad econémica en ue incurren por ello es Se] orden de diez mitiones de dSlares por afo pars un resctor de 1000 HW eléctricos, sin contar e} potencial energttico desperdiciacos

Como se wencionS, desde los conienzos de su programa nuclear, Argentina decidi6 que si bien no tener energfa es muy caro, el disponer de ella 7

$2 condiciones precarias representa un precio iniceptablenente alto. Y se la dispone s6l0 precarianente si la fuente de surinistre puede ser / interrunpida o retaceada a voluntad por una potencia extranjeras

?Ain sin mala volunted del proveedor de combustible enriqueciéo, 1 pro- Mferaci&n de reactores de esa Ifnea Ievar8 inevitebleneate a saturar as instalactones existentes y en tal caso habr§ que esperar turnos pa~ Fe aprovisionarse, con los problemas que es ficil inaginar.

La Moca de uranto notural ofrece un seguro contra tales eventual {dades. En priner lugar si se dispone de yacinientos y en segundo lugar. por e~ Xistir muchos proveedores posibles de uranio, En nuestro concept bien yale Ta pena pager la prina de ese seguro, que 1a postre no resultan tan onerosa por el menor costo de! combustible, por la menor éenanda 20 bre las instalaciones de procesamiento de! mineral y porque se puede J prescindir del reprecesamiento de loz elerentos irradiadoss

Es necesarta, sin enbargo, car pasos adicionales para que e) objetivo / de autosuficiencia energética sea efectivanente aiconzedo. Representan tuna cadena a cuya totalidad de eslabones es necesario forjar dentro del

pats, Debe dominarse asf ta tecnolocta de la fabricaci&n de los elenen-

tos contustibles, Esta abarca desde !a obtencién de concentrade® de. pus

Fera nuclear, 1a produce i8n de pastillas sinterizedes ee U0, haste To /

fabricaciBn de las vainas de Zircaloy, Se trate de una eleagiGn s base

de zircanfo cuye existencia ene) terfitorio nacional tarbifin fue feper,

tante verificar, La fSbrica de los clenentos combustibles se encuentra

ya en operaci6n,

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Le operactén local de esta fSbrica cs 1a mas imperative por el carSeter

Consumible de los elementos pero avenfs hay que tomar las previsiones ne.

Eesartas pare maxinizar el suminisero nacional y como mfnino pos ibi i

el "service! de los distintos sistenas de la Central sin tener que Fecu

Frir al exterior,

For supuesto es imposible fabricar todas las piezas y accesorios de la Planta en el pats, For consiguiente en e) contrato de provisién respec? tlvo deben Incluirse clSusulas que garanticen junto con ta formactén de Personal capaz de efectuar mantenimiento, y 1a adecuads transferencia de a tecnologta, 1a provisi8n de los repuestos mSs crfeleos. Es. fundenet Pronocionar 1a participeciGn creciente de 1s industria nactonal en lo pro, visiée de partes,

Como todo lo que represente una cortribuci&n a 1a Independencia, esto tie Be un costo, que resulta tanto nfs importante cuando mayor sea aquella /? participactéa.

Los proveedores forSneos pueden dar cr&ditos para adquirir os equipos de su fabricaci&n, pero salvo casos especiales no se puede esperar que estos crfditos cubran la provisién nacional. AdenSs esta Cltima, por ra~ zones de "derecho de piso! resulta necesariamente ms cara y menos, conf! ble en sus prineras versiones, que la inportacs, Las diferencias debe cut brirlas el pats, como parte de su prograns para autoabestecerse.

Para Inductr a la industria naciona! a equiparse es importante deftnir un

tipo de reactor y un mbdulo de potencia que se repita en el futuro. £1 /

Programa nuclear debe ser form:laco con vistas a ofrecer una amortizacién

razonable @ les faversiones que efectGer y es poco probable que ello se 7

ogre con solo un prototipe.

las mayores dificultades @ vencer no son, sin enbargo, de orlgen t&cnico

Inf econ6inico, Son de naturaleza golttica, La gesti&e de un pats en proce,

ra de su autosuficiencia ne puede realizarse sin afectar tos tntereses 7

de potenclales proveedores. Fs0s Intereses por supuesto no confessbles,

Fecurren a maniobras bajo otros rétulos que promueven simul tSneamente en

les frentes internos y externos. 7

Internanente tonan 1a forma de movinientos que colocen por sobre todo fac

tor tas consideraciones de carScter sconfnico ya veces ée cardcter ecofE

sico,

Externamente se levantan Tas 6.

cleares.

oderas de Ta no proliferactén de armas nu=

Las grandes potencias que son las responsables ¢e! desarrollo de agué)1as no hhan podide penerse de acuerdo en la {imitacién de sus arsenales. REpldas mente concordaron, en canbio, en limitar 2 cero el de las dens. En Jutlo de 1968 se firmS SimultSneanente en Vashington, Londres y Mosel el Tamas do Tratado de No froliferacién de Armas Nucleares (INP). Se establecen en £1 dos clases de Estados: los posedores de armas nucleares (Nuclear Weapon States) y los no poseedores. A estos Eltinos se les prohise no solamente fabricar 0 recibir armas, sino equipos, materiales © informactones que / puedan ser usados en Ia produccifn «te materia! fisfonable, si previanen= te no han acordedo un sistena de inspeccién Internacional que cubra todas las actividades qucleares. Este denoninads de "salva guardias" se extlende hasta el infinite en e! caso del combustible Irradiado. Los Est os Wo Hucleares no tienen siquiera ta garantfa, por parte de los Nuclea Fes, que este tlpo de armas no serfn usados en su contras

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En 1974, India, pats no flemonte de! tratado, denoste® que por sus pro~

plos medtos podfa fabricar un explosive nuclear.

Los Estados Nucleares, en lugar de incorporar India 2 su grupo demost

ron ta asinetrfa de trataniento aplicindole sanciones y reforzando para

los dens pases 21 sistens restrictive mediante lo que se conoce cone

NEI Club de Londres" cuyos miembros originales fueron las cuatro poten

clas nucleares ms Canadf, Alemania y Jap6n.

En teorfa, un pats dedicado excivsivanente a actividades pacfficas, no

deberfa tener problemas en un sistena de InspecciGn a las mismas. En 1a

prSctica las cosas suceden de otra manera sobre todo si uno de los fun-

Gamentos del prograna nuclear es alcanzar 1a independencia de les pre-/*

slones externas. Para lograrla existe el evidente requerimiento que to~

dos los eslatones de 1a cadena queden bajo contro! nacional, Ello enti

fen collsién con la teorfa de salvaguardias que sestiene que el Gnleo

proliferaci6n es evitar que existan Instal

clones denominadas "'sensitivas" bajo ese control (Plantas de enriquect=
iento, Plantas de reprocesamiento y an Plantas de Agua Pesada)..

Argentina acept6 la aplicaci&a de salvaguardias pare toda instalaci&n /

intstrada por otros pafses. Ha rehusado en cambio soneterse
las Vinftactones.disertiminatorias que establece el Tratado de No Pro~
Uferactén, Resulta diffetl explicar a la opinién pablica le aceptacién
de clfusulas que los patses que originaron el problene no estén dispues
tos a aplicarse a sf misnos.

Esta posicién le ha traféo y le continla trayendo dificultades en el de

sarrollo en su programa nuclear. Cono parte fundamental de un program

de esa naturaleza es necesario prepararse para afrontarlas.

En el caso argentino, se considera undnimemente que, en beneficio de las

futuras generactones, la Naci6n debe estar dispuesta a pagar el sobre

precio que esa preparactin representa,

1

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ouARDO

GURRICULUM DEL_INGENIERO KAR:

NCORA

* Ex Presidente del Conité de Centrales Nucleares en Argentina

a Comisién Nacional de Energia Aténica

* &x Asesor Client fico principal de 1a Comisién Preparatotie del Organis

?mo Internacional de Energia AtSmica (Nueva York).

4 Ex Director de Sumi

ofa Atéotea (Viens).

* Ex Director Nacional de Investigaciones y Laboratorios del Institute Ma

stros Técnicos del Organisno Internacional de En

cional de Tecnologia Industeial.

* Receptor del Prenio Internacional Haas de la Universidad de California.

Director de 1a Escuela de Fisica de 1a Facultad de Ciencias ? tngenie-

fa de 1a Universidad Nacional de Rosa

* Director del Centro de Investigaciin Tecnolégica de la Provincta de Sa

ta Fe.

Direccién Postal: Av. Pellegrini 56°- 2000 Rosario - Argentina

Teléfono: 82-3283

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First Pen American Congress on Energy

SOME VIEWS ON ECONOMICS OF POWER COGENERATION

by

Nath S. Parate

Department of Civil Engineering

Tennessee State University

Gajanan M. Sabnis

Department of Civil Engineering

Harvard University.

San Juan, Puerto Rico

?August 1982

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ANTRODUCTION.

The taportance of economical energy can hardly be over emphasized, vhen we are geared to high energy consunption. There vill be a continuing fa~ grease in the use of electricity in spite of various conservation sessures, environsental restrictions and alternative energy sources. The average cost of producing one kilovatt hour of electricity by nuclear or coal is relative= ly cheaper than ofl. Solar and other type alternate energy sources sre wore expensive at the present level of technology and econonically uafessibie at least for a feu years to cone. Approxinacely 39% of the U.S. electric power is preseatly generated by burning coal; 17-5t by burning ofl; 12 by sae, 11k by hydrofauclear, OX by pumped storage, 2.1% and geothereal 1edk. This

Paper (refer to Tables 1, 2, 3 and 4) reviews literature and discusses the anlayses of various studies and data. These analyaes indicated that nuclear Beneration has an econonic advantage over coal generation at the present tise and will continue to be so in the fuuvre. The past, present and fueure trends im the costs, prices, supply and relative economies are analysed and discuss. ed.

AXD_RESULTS_OF axazysrs

Nouber of parameters should be considered in such analysis to compare the costs of various sources. These include:

1, Capital and generation costs,

Duel supply and these costs,

Nuclear Regulatory Connission (WRC) Regulations.

Results of analyses perforned using these, are presented in the following sections.

Generation and Capital Costs

Data presented in Table 5 clearly indicates that it {s possible to Atoerthute generation costs for these plants according to regions. Nuclear costs are, however, cheaper than coal costs in pract cally ell cases. The Puclear generation? is economica? than fossil generat ion ae the present tine and it {s believed that this tread will continue up to the next few years,

The capital cost for coal generating plants in the North fast region as

snalyzed by various reports is relatively higher than that for other repions,

TMs secas to be a continuing (Table 1 and 2) trend and will sake 2 nove

fsftieult, as an economic choice, to replace the exist :ng operating nuclear aeration plant by new fossil/eoal generation plant, Secause of the sdvan=

0 a5 indicated in Tables 3 and 5 and Figures 1 and 2,

vel Supply and their Costs

There is an abundant supply of doch cosl and uranium according to various sources resulting im sufficient supply of readily available weaniaa for the

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existing and future pover generation plants. The cost of uraniua is at $40 per pound (1978) to fuel Light water reactors through thse century and perhaps ?up to $70 per pound well into the next century. (Fig. 3) Geological and ining activities for uranium are in general geared to the existing denand, supply and marketing conditions and econosics interests, ERDA has for this purpose initiated the National Uranium Resources Evaluation Program (NURE) to complete the comprehensive uranius resource estimates for the United States. This and the International Uranium Resource Evaluation program (IUREP) has concentrated on new types of deposits and low geade resources.

It is probable that aore uranium will be discovered in the years ahead which vould further extend the availability of uranium as fuel. owever, several factors will affect the actual uraniua denand dared on the overall denand for electricity, the nusber of nuclear plants to cone on line, the economies of other energy sources and 4 political, soéial, econosie and? environ seatal considerations.

The enrichoent process, which produces slightly enriched vraniua and leaves a strean of depleted vraniva known as "tails" can be adjusted to vary the amount of uranium feed required to produce a desired anount of nuclear fuel. Reduction in the tail assay at vhich the plant operates will result in a decrease in the anount of natural uranium required. Reprocessing of spent fuel to recover and recycle the unused uranium would also reduce new natural vraniun requireseats, Sinilarly, recycling of the plutosiun which is ereaced as the uranium {s consumed in the reactor, will further reduce natural uran= ium requirenent. Further to this, the liquid setal fast breeder reactors (1k) are now under developaent. Since a breeder reactor generates nore fissionable fuel than it consumes while converting vranius to plutoniua, the LIBR will be able to utilize the stockpile of uranium tails discussed earlier in the enrichnent proce:

The costs for fuels in different regions are different. Cost for coal fuel in North East region is relatively higher. In spite of recent higher prices, the uranium cost per million BIU renaias couparative to the coal cost The projected fuel conte over next two decades shown in Pigs fy clearly indi= cate this trend,

?The curve in Figure 1, shove how the price of U30g in 1986 will affect the total generation cost of a nuclear plant. The total cost of owning and operating a nuclear plant ts relatively insensitive to the cost of the Te source; a 50 percent Increase in the assuned cot of 030g increases the total generation cost by only 7 percent. Figure 1 shows the 1986 price of Uj0g Te- quired before the nuclear and coal alternatives have equal tote! generat ion costs. Tt means that the uranium price will have to be $162 per pound to

© the nuclesr/eoal choice equal. Clearly, the cost of U0 voulé have to scossly exceed the industry's expectations to-sbandon nuclear power as The

preferred method of generating electricity. In contrast to this, the total

Leneration cost of @ coal plant is very sensitive to the cost of the fuel sed. A 50 percent increase in tre price of the coal fora plant located in

t Increases the total busbar cost by over 20 percent !.e. approxizately

8 the inpact of a nuclear plant on the total power cost. (Table 3).

In a particular study the relative costs between the coal and nuclear

---Page Break---

generating plant during the period 1985-2025 have been examined, which indi cated that the nuclear fuel cost will be at approximately half the cost of coal even when baseline nuclear fuels are estinated at $75 and 2150 per pound For Us0y and SWU, respectively.

Nuclear Regulatory Commission Regulat for

?These regulations are designed to ensure safe operation and offer adequate Protection to the public and enviroasent. They are continuously modified based on the new experiences and probless and the environsental and safety Fequirenents. The cost incurred under thie item according to sone studies, for both fossil and nuclear plants, are significant ad of the same nagnitude. Te is understood and anticipated that there will be an increased cost to weet the new requirenents, including chose for retrofitting to satisfy the new Fegulations an@ requiresents, (Table 4) However, the {npact will not Jeapar- @ize seriously the econoaics of power generation, (See Fig. 4)

The operating License is iesued according to the period requested by the Ueslity with @ saximum of 40 years for coimereial nuclear pover plant unless the Cocnission estinates the useful life to be less. The license say be Fenewed according to 10CFR 50. 2asis of licensing is the design of these plants. This has been a najor issue in rate increase cases before the state Public ?Utility Coanissions in detersining the useful Life of power plants for depreciation and valuation costs.

AS EUAMPLE OF cosT_ courant

08 IN_ PENNSYLVANIA

4n econoic comparison of nuclear versus coal base load generation for the 1,000 ?a capacity has been ade using the available cost estimates. Oil~ fired hase capacity ts not considered an acceptable alternative in keeping up vith new national goal of no cil-fired base capacity by 1980. The results show that nuclear fe the proper econonie choice, based on 1978-79 costs.

A coaparison vas rade betveen @ nuclear unit and a sine-sonth coal uate for doser City 3 located in PA. The current construction budget cost for ?TMI 2 plus nuclear fuel initial investaont are considered in this analysis. The nuclear fuel cost ie taken ag $2.63/M4-HR (1978). The nuclear fixed and variable operation and =aintezonce (06%) costs reflect current experience in excelation at 8% per year.

?The coal unit investuent cost f the currently budgeted for the 650 M4 Homer City Unit. This cost includes sulfur dioxide scrubbing investaent. The fixed end variable 06M costs for the coal unit include estimates for opera Hing the scrubbing equipnent. The present (1978) delivered cost of cos) is about $25/ton approximately.

Results are shown in Fig. 5 in terms of the total yearly costs for nuclear v¢ coal units as a function of the number of hours of operation per year.

e@ on 7,000 hours/year load operation, the nuclear unit has an economic vantage Of $37.7 willion/year for a unit size of 850 Md, This ?isferential Is likely to increase in the future because muclear {uel is expected to. ine Tate at a sonevhat slower rate thin coal

---Page Break---

OTHER ENERGY RESOURCES

Other sources, such as Magnetohydrodynanics (MID), solar energy, fuel cells, wind power, tidal energy, ete., were considered but found £0 be inpract tical! These sources require additional research and development efforts for their practical implenentation and large commitments of land to achieve the Power production level of a comercial nuclear unit. However, brief discuss fon on some of these follows:

Practical conversion of solar energy is Limited to space applications or other unique applications based on the technology available today. Te fe estimated that nine square ailes of photocelle would be required co generate the sane pover as of a connercial nuclear unit. This power production level WAIL be realized. only four hours per day during sugny weather.

Practical applications utilizing geothermal energy are liaited to areas in the western United States where a large source of steam or hot water can be tapped by drilling up to 6,000 to 10,000 fect. It has been estimated that, the similar porential in the Eastern region will be tapped by Seilling up to Gepths of approxinately 25,000 feet and extracting heat by pusping water {res the surface through hot rocks at that depth to generate steam. Drilling up to 200,000 to 150,000 ft. through the carth's mantle may make St possible to utilize geothermal energy sources almost anyuhere on earth. However, a prace tical recovery of geothermal energy at prucent iz not a svitable alternative due to technical difficulties expected to be encountered during deep drilling greater than about 25000 ft.

?Thernonuclear fusion presente very attractive long-range possibilities for central station poser generation. Tusion fs attractive because ite feel supply {5 aloost unlinited compered with nuclear and foseil fuel processes. The fuel used i¢ Deuterius extracted from seawater. Fuel transportation would, therefore, not be a constraint in station siting. It has been estina~ ted that there £2 enough Devteriue in scauater to last ten billion years at the present rate of energy consumption. Fusion a not considered @ suitable energy source wince, one of the major probless is that of containing the re action, which takes? place at 500,000,000"F, An interesting possible out grou th of fusion technology, which at the present tine ts largely in the discuss ion stage, is the use of fusion energy to extract hydrogen fron water: Hyaror gen would be a clean fuel for may uses ae its only product of combustion ta ater vapors

1h. The muctear generation is economfeal at the present tine end vill renain so in the near future.

Tiere ds enough evidence to siiow that uranium supply vill be avattable and ?ALL stII! cont inue to romain as an economically competitive fwel sources

7. The test kind of gencrating statfons for the acar future wi2 be nuclear. Incressingly, auclear is an¢ will be the economte cholee as a practical solution to the energy problen.

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ACKNOWLEDGEMENT

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}0 all those vho were concerned and helped make this

publication possible.

The opinions expressed are the authars owns

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(Extensive references were used as source material for this paper. Because of

their nunber they vere not identified in the text.)

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Table 1 Break-up of Energy Generation (1970)

company

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Doke

?Alabaza Pover

Appalachian Power

Balttzore Gas and Electric

Clevetand Eleceric

Comcnvealth £dison

Consuners Pover

Detroit Edison

Florig: Power

Georgia Power

outf States

Tin ste Poser

Jersey Central

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---Page Break---

Table 2 Break-up of Energy Generation (1979)

Company,

vepeo

Carolina Power 6 Light Co.

Duke Power Company

?Alabama Pouer Company

Appalachian Power Co.

Baleinore Gas & Elec.

Cleveland Elecerse

Connonsealth Edison Co.

Consumers Power Co.

Detreit Edison Co

Florida Fower & Light co.

Georgia Power Company

Gulf States Urilities

T1Linoss Power Co.

Jersey Central Pover

Long Teland Light ing

Louisiana Power & Light

Nagra Nohavk Power Co.

on

Péison Company

Ose Poser Company

Pomaylvansa Power

Poitodelphie Electric

Public Service Electric

mated from informat fon

88.75

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15.10

ENERGY GENERATED BY FUEL TYPE (2)

979)

tuclear

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---Page Break---

Table 3 Various Plant Energy Product ion Expenses (Hills/kim)

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Sospany, ins 1973 ise

Virginie Electric & Power Co, 21.37 30.25 15.48 16.35 6.42 9.58

Carolina Fover & Light Co. ~ = 33.98 14.22 7.36 7.29

Duke Fover coapany > = 33.83 18,03 5.33 6.88

?Aabana Fover Company = = 16.5 16.11 6.28 18.40

Appalachian Power Coapany ee ee

Balttaore Gas & Electric co, 22.30 30.71 13.94 1315 6.38 8.33

Cleveland Electric Tuminating Co. = == 16.20 18.77 8.58 9.30

Commonwealth Edison Cospany BLAS 38,86 12.58 18.69 4.17 5,95

Consusers Pover Company 31.32 38.69 14,00 15,95 9.58 12.05

Detroit Edison Conpany 24,36 37.29 14.70 16.39 = =

Florida Power & Light Company 20.65 26.28 - = 5.38 5.89

Georgia Power Conpany > = aan 1359 6.23 9.69

Gulf states ULitities we =

TLinots Power Company 25.86 se nme

Jersey Central Pover & Light Co. 27.50 38.94 13.98 13.16 3.61 6.09

Yong Island Light ing Coxpany 19.43 2648 =

Yousstana Power 6 Light Conpasy 14,81 26,78 =

Nagra Nohavk Power Company 18.66 25.08

?Ohio Edison Company a

Chio Power Cospany = 12s ee

Pransylvania Power & Light Oo. 24.22 34.01 - -

chiladelphia Electric Company 23.25 29.35 6.22 6.26

Public Service Elec. 6 Gas Co. 35.45, 6.71) 6.89

---Page Break---

Table 4 Cost and Benefit Comparison Between

?@ Nuclear and a Coal-Fired Power Scation

Aspect Coal-Fired Plant Nuclear Plane

Gaseous Discharge

Liquid Discharge

Aesthetics and Land

cose (80% Capacity

Factor)

Use of Trretrievable

safery

S02 discharge - 172 tons/day

NO, discharge ~ 115 tons/day

Ash sluice water runoff from

coal storage and ach deposi

Larger land use and unplesant

Besthet ics of coal storage

and ash sluicing areas

876.700 Beye.

Use of coal - supply Limited

and needed in other industry

Ro inpact

Annual integrated popu-

Lation exposure ~ 9.95

man-ren ().0025% of

natural background)

Annval integrate? pop=

ulation exposure - 0.7

uan-ren (0-0002% of

natural background)

§72.90/ eye

Use of uraniuz ~ supply

Linited ~ breeder reac~

tor shovld improve sit?

uation

Insignificant ampact

---Page Break---

Table 5 Average Costs of Energy Product ion (1986) capicar

Region Goat Yuclear Coat Nuclear

Northeast 698.50 829.00 48.10 41.60

Southeast 369.00 m1.50 4.25 37.69

Fast Central 663.00 787.00 46.85 40.20

West Central 654.00 754.50 42.55 39.10

South Central 649.50 734.00 41.05 38.75

west 718.00 823.00 46.20 41.30

National 666.00 791.00 45.15 40.20

NOTE: Capital cost est inates vere developed for the Electric Power Research Institute by the Bochtel Pover Corporation for coal-fired generat ing plants and by United Engineers and Constructors for nuclear generat ing plant:

---Page Break---

COAL PLANT

MORTHEAST ©

---Page Break---

LEVELIZED PLANT GENERATION COST(MILLS KWH)

6

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S02 REMOVAL

EQUIPMENT

© 80 100. 180 200. 280. ~~-300

1986 CoaL Price (¢/mmsTu)

2 COAL PRICES AND BREAKEVEN ECONOMICS

is

---Page Break---

FIG.: 3

1.8. THE AVERAGE 1000 MW (1GW) NUCLEAR

POWER PLANT WILL CONSUME ABOUT

5000 TONS OF URANIUM THROUGHOUT

ITS LIFE TIME

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8 3.70

= SPECULATIVE RESOURCES

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5 Possis.e Resources

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2 NOTE: CASES A,9 AND C COVER PLANTS

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CAPITAL COST AND OPERATING COST- #//KW YR

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ANNUAL HOURS OF OPERATION

AVERAGE PENNSYLVANIA

FIG.5 COMPARATIVE ANNUAL COSTS OF

NUCLEAR VS. COAL BASE- LOAD GENERATION

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Second National Conference on Renewable Energy Technologies

THE GEOTHERMAL ENERGY POTENTIAL OF DOMINICA

?A CASE STUDY FOR DEVELOPING NATIONS-

By

William B. Taylor

4001 Belle Rive Terrace

Alexandria, Virginia ~ USA

San Juan, Puerto Rico

August 1982

---Page Break---

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?LNV1d LOd

MW & SLI WOUS ALIDIHLO313 JO F1VS 3HL AG SUVA E NI

OVE Civd 38 GINOD GNV NOITIIW Z's LNOGW LSOD GINOM

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ABSTRACT

?The Commonwealth of Dominica, in the Windward Islands of the Abbean, is of volcanic origin and is near a boundary of the arth's tectonic plate system. ?Therefore, geologically, Dominica should have a reasonable probability of owning a geothermal source gapable of producing cheap energy. Surface manifestations in the form of steam geysers and fumaroles in three areas of southern Dominica do, in fact, indicate the presence of geothermally heated water trapped at unknown depths below the surface.

c

This paper will analyze results from geotechnical surveys by

several independent geologists representing several nations who were invited by the Government of Dominica to conduct such surveys guring the period from 1969 through 1980. The paper will outline the exploratory effort necessary to measure and locate the geothermal source adequately to attract investors for the development of &@ geothermal power system on Dominica. Assuming that measurements confirm the 1965-80 experts? opinions, the paper will outline a Program of geothermal resource development for Dominica, The first Phase of the program, constructing and operating a smali power Plant, would meet the near term domestic power aeeds of Dominica and would provide engineering and cost data for the later develosment of the geothermal field's full potential on a schedule comparible with the ability of the Dominican economy to absorb it. The paper will examine options for developing the geothermal energy ana For marketing any energy which may be excess to Dominica's neede

The proposed program for Dominica will be used to define more Generalized guidelines which other developing nations can use in Planning the beneficial use of their natura! resources to mect their national needs. ?These guidelines will consider various combinations of international aid, investment and trade, phased over varying periods of time, as may be best suited to the individual nation's situation.

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Introduction

?The Commonwealth of Dominica, a newly independent nation in the Eastern Caribbean region, is struggling to achieve economic self-sufficiency. Faced with growing unemployment, a dwindling agricultural econony, and a balance of trade deficit which is growing each year, Dominica has one potentially valuable natural Fesource--geothermal energy--which may be the key to realizing her full potential as an emerging and productive member of the Carib- bean Basin group of nations. This paper will analyze the results of several reconnaissance surveys of Dominica's geothermal e! Fesource and outline a strategy for developing that resource at a pace consistent with the fragile national economy's ability to absorb industrial growth. From the predicted results of Domini- a's development, the paper will outline a set of principles which other developing nations can apply in their efforts to achieve their national goals.

From the viewpoint of a geologist, Dominica is a superb example of an elaborately dissected, composite, voleanic island, 1ocated on the margin of a pair of the earth's crustal tectonic plates (1).* As depicted on Slide 1, Dominica is 27 miles long, north and south, and 12 miles wide, with a land area of 290 square miles dominated by mountains rising from the sea to an altitude of 4,747 feet. An average annual rainfall of approximately 160 inchés fills high altitude lakes fecding nunerous streams and rivers. The soil, being of volcanic origin and with heavy erosion @ue to large rainfaii, is not particularly fertile. However, it supports luxuriant natural vegetation and such crope as bananas, coconuts, and limes. ?The population of Dominica is approximately 80,000, Of which about 16,000 live in the capital city, Roseau.

Because of its rugged, mountainous, defensible terrain, Dominica was a stronghold of the Carib Indians waich inhabited most of the Eastern Caribbean islands prior to their discovery by European explorers in the 15th century. The last Carib settlement in the Caribbean region survives today in the hills of Dominica, but the majority of the island's population are descendants of Europeans and Africans transplanted there over 300 years ago. Under French rule briefly during the 18th century, traces of a French patois still rezain in the Dominicans? speech. But the culture is essen~tially British colonial in form ané substance. After alrost two decades of semi-autonomous rule under British protection, Dominica was granted full independence in 1978.

The economy of Dominica is essential.

representing the predominant (7

s refer to sources Listed in the Bi

the text.

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small industries produce such products as coconut oil and soap for

Profitable export. The gross domestic product is about Usss0

million, or under $625 per capita. The British-style schoo! sys~

tem is compulsory for children between the ages of $ and 15,

sulting in a high (808) literacy rate. However, the 208 overall unemployment is unacceptably high, and it approaches 408 for young people. Agricultural productivity is declining, leading to ik Greased trade deficits resulting from the need to import food There is thus a strong motivation, reflected in the Government's national plan, to improve the infrastructure (roads, power, ports, gtc-) so as to attract foreign ?investment in industries to provide jobs and to stimulate agricultural revival. A 1979 project? for Rew bridges in Dominica (3) was deferred by the devastating Hurri- sane David, from which recovery was still not complete in mid-1982.

Dominica's Energy Resources

Energy, in the form of either electricity or process heat, is an essential element of the infrastructure which a developing nation needs to develop domestically and to attract internattons ally the industries which can provide jobs and revenues to stima- late economic self-sufficiency. Dominica's geographic and ge gig situation provides an energy potential in at least two forme, hydroelectric and geothermal, which can be developed to meet all the domestic needs for growth over the next two decades and can giso provide excess energy roughly twenty times the domestic needs for export in the form of manufactured products, or other forse of stored energy, to provide jobs and economic independence, Dominica's mountainous terrain and tropical rainfall combine te form a hydropower potential which is approxinately three tines the current electrical demand of the island's 80,000 people and small industrial base. Two small hydroelectric stations of Scot~ tish design presently provide approximately 2,500 kilowates of electric generating capacity, or roughly 40% of the island's total installed gencrating capacity of 6.600 kilowatta (4).~ How- gver, the hydroelectric stations provide over 908 of the island's 37 million kilowatt-hours per year, with the balance being pro- vided by diesel engine driven generators used to meet peak de- mands and to back up the hydro units when the river flow is low. Studies during the past decade of Dominica's hydro potential have goncluded that three principal rivers on the island could be hace nessed to provide as much as 17 megawatts of hydroelectric power to the island, which would allow reasonable domestic growth with some new, small industries during the next twenty years {§)." ho

Dominican government, with financial backing fron the Caribbean

Development Bank and the U.S. Agency for International bevelose

ment (AID) has begun a project to increase the existing hyercalec~

tric generating capacity by a factor of up to two, which

meet the projected growth in domestic energy demand thro

1980's. Referring again to Slide 1, this project is inten

realize the full hydroolectric potential of the Roseau Rives by

doubling the capacity of the Trafalgar gencrating station and by

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building a new station higher in the mountains at Titot. The feasibility of this addition has been studied by Scottish, French, and Canadian engineers in separate efforts during the past 10 years. The concept depends on increasing the hydraulic head of the upper Roseau River by raising the banks of Fresh Water Lake, high in the mountains, by approximately 20 feet.

Near the southern end of Dominica are three areas of steam geysers which indicate the possible presence of a significant geothermal resource. These three possible geothermal fields, known as Boiling Lake, Wotten Waven, and Soufriere, have been known for years, and some attempts have been made to use the sulphur depos ited by the steam eruptions for making matches. In the late 1960's the Government of Dominica requested the United Nations Development Programe to send a survey team to Dominica to evaluate Dominica's natural resources--particularly the geothermal resource.

Before examining the results of the UNDP and subsequent reconnaisance surveys of Dominica's geothermal potential, we should examine the basic principle of extracting useful energy from a geothermal resource. Slide 2 depicts in simplified form the type Of geothermal energy systen which appears to be possible in Domin~ fea. The volcanic nature of the island and its location near @ boundary of the earth's tectonic plates creates the likelihood that entrapped water, heated by the molten magna of the earth, could underlie relatively large areas in the southern portion of Dominica, where many steam geysers are evidence of potential energy below. If so, the hot water might be flashed to steam which could, in turn, drive steam turbines to generate electricity. The exhaust steam from the turbines could be re-injected into the ground te replenish the source.

?The geysers have been observed and measured by several inde pendent experts. In 1969, the UNDP sent a team including Dr. Janes MeNitt, @ geologist experienced in geothermal explcration, in re- sponse to Dominica's request (6). Or. MaNitt sampled the s

fron a few of the geysers and had then analyzed. As sunmar: Slide 3, Dr. McNitt concluded that the probabilities are high that hot, ary steam exists in a large, shallow heat source which might be tapped to provide power more cheaply than anywhere else in the Caribbean Region. In 1981, Dr. MeNitt re-confirme his tentative Conclusions but noted that?new techniques for sampling and analy- sis are now available which should be usad for a more modern and extensive survey than he conducted for the UNDP in 1969 (7).

In 1978, the United States Geological Survey responded to a

request from? the Government of Dominica by sending Mr. Janes E.

Case to conduct a month-long survey of the island's natural re"

sources (9). Caco identifies the existence of materials which

might fora the basis of industrial development, such as 1!

and clay for manufacturing coment, provided sufficient ensrzy

sourc:s were available. Case also noted the major hydro and quo-

thermal potential, and he reconmanted a comparative study be m2:

Of the costs of developing these two sources

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In early 1980, at the request of the newly independent govern-

Rent of Dominica, the French Government sent an experienced geolon

gist, M. Jacques Varet, to assess the Dominican gesthermal fields

(a). Varet's conclusions, summarized on Slide 5; were that the

Dominican fields are significantly stronger than? those being devel-
Qped by the French on the neighboring island of Guadeloupe (10).
Varet estimated that the three Dominican fields might have a poten-
tial of approximately 300 megawatts of electric power. He recon-
mended a thorough geotechnical measurement program, including ex
ploratory drillings, to obtain quantitative data on the prec:
jogation, depth, chemical composition, and energy content of the
fields at Boiling Lake, Wotten Waven, and Soufriere. If these
Reasurements confirm his and the previous estimates, Varet recom
mended development of a pilot plant to generate up to 5 MW of elec-
tricity, in order to provide hard engineering and cost data needed
to design and justify the investment for full scale plants which
could realize Dominica's full geothermal energy potential.

Required Exploration Program

Slide 6 summarizes the geothermal exploration program which
these international experts recommend be undertaken to provide the
hard data necessary to convince financiers that the Dominican power
Potential could yield an attractive return on their investments
A Measurement Phase of approximately one year's duration would in
elude in-depth geotechnical exploration to provide measured date
and laboratory analysis on the geology, the chemistry, and the phy=
sical characteristics of the three areas of geothermal surface mana
Afestations. Assuming the preliminary results are positive. the

Source. The estimated cost of the Measurement Phase is $660,000.

Assuming the measured results confirm the experts! prediction fhat dry steam of approximately 500°F is at depths of approximately 2,500 feet, ?the project should move into its Pilot Plant phase,

The objective here would be to drill at least one production well. at the best location determined by the Measurement Phase. Tt may Fequire drilling up to three wells to achieve one high production well, at which would be installed a well-head steam-turbine genera for unit. This type unit, factory-assembled ona skid which can be transported by truck oF helicopter to the wellhead, is manusac= tured connercially by several U.S. firms from essentiaily off-thes shelf components of the rusged types found in ship-board use, Such a welivhead generator unit can be purchased for a few hundred thous sand dollars with ratings up to 5 megawatts electrical power out= put. The Pilot Plant phase would continue with operation of the well-head unit for several years, to provide data applicable to the design, operation, and economics of full scale geothernal power

Plants in those fields at sone future date. The estimated cos

of the Pilot Plant phase, including one year's operation, is $4

million.

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?The current price of electricity in Dominica is more than 10 cents (U.S.) per kilowatt-hour. If the 5 MW output of the Pilot. Plant were connected into the local utility grid, it would provide for the entire growth in consumption of electrical energy projected during the 1980's. If this Pilot Plant's electricity were sold to Dominican customers at 6 cents per kilowatt-hour (that is, at 60% of the current price), and if the Pilot Plant operated on?a year-round average of 508 of its rated capacity, the revenues produced could pay off the entire cost of the Measurement and Pilot Plant Phases in approximately 3 years. The Caribbean Projects Develop-ment Facility of the World Bank's International Finance Corpora~tion (IFC) has advised that Dominica seek a grant for the Measure-ment Phase, since that phase will not produce revenues, per se, which could pay off a loan. If results are favorable, as assumed above, then IFC suggests that a Dominican company be formed to raise'up to 40% of the cost of the Pilot Plant phase through equity financing from local and foreign private investors. With this demonstration of comnitment by the private sector, IFC is confident. that the remaining 60% of the Pilot Plant phase cost could be obtained as loans on favorable terms from international financial sources.

As of this writing, the Government of Dominica has discussed, with representatives of France and the United States, the possibility of grants for the geothermal exploration effort, and they have accepted a French offer of 2 million francs to start the Mea surement Phase of the program.

Concept of a Dominican Geothermaliy-
foveted-tadusteial Comper

Slide 7 outlines a concept for the altinate development of the Dominican geothermal energy potential, assuming that the Pilot Plant has operated successfully long enough? for the Dominicans to develop confidence and competence in the system. If the ultimate capacity of the three fields does, in fact, total 300 Mi, the conservative concept shown here would include three separate electric power plants, each rated at 100 MW. It is possible that the three Dominican fields: Boiling Lake, Wotten Waven, and Soufriere--all represent surface manifestations of a single large steam source. Thus, the exploration program might indicate the attractiveness of a single, large plant of 300 Mi,? On the other hand, since the economies of scale for geo-therra) steam power plants level off at about 50 ?W electrical ca-pacity, it might be preferable to develop a larger nunber--perhas as mary as si each catering to a different market.

And, of course, if i proccsses heing catered for requite stean instead of or 1 the plants could be @esigned to provide a varicty of mixes of steam and electric power.

For simplicity and conserva!

three 100 ttf electric power

duction wells and 10 ro-injection

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well, on the average, would produce steam equivalent to 4 MW of electric output, which is 20¢ less than the lower end of the range estimated by the French survey in 1920 (12).

Of the energy-intensive industries listed as examples on Slide 7, the manufacture of ammonia by electrolysis of desalinated Seawater to obtain hydrogen and by extraction of nitrogen from air is particularly attractive, because of both the almost limitiess supply of essentially free raw materials and the ready market for ammonia for agricultural fertitizer and industrial chemicals in the Caribbean Region and the U.S. Another strong possibility is the reduction of Caribbean-produced alumina to aluminum for world markets.

Slide @ summarizes cost estimates for a 100 Mi electric power

plant constructed at one of the Dominican geothermal fielas, as~
guming the exploration phase finds 500°F dry ateam at depths of
1,500 feet. The capital cost of the steam collection and power
generating system is estimated at $900 per kilowatt, based on cur-
Fent experience with two 50 MW additions to the Geysers complex

in California, and it includes an amount to cover contingencies
which could arise from local conditions in Dominica. The estinate
of $1 million per production well represents 2 conservative extrap~
olation, inflated as necessary, from recent experience with geo-
thermal drilling in Central Anerica-

Qver an assumed 30-year plant life, it is estimated that 35
additional wells will be required to account for depletion of the
initial field. operation and maintenance of the plant is est:
Rated to cost $100,000 per year. With these budsetary cost esci-
mates, with provisions for inflation and debt service, and assun~
ing an average capacity factor of 70%, the cost of generating
energy with this plant is estimated at an average of 12-2 mills
Ber kilowat-hour, or less than one-eighth the current price of
electricity in Dominica. This cost is well below the competitive
price of electricity being paid by the large aluminum sanufactur~
ers at their 300-400 Mw smelters in the United States, where elec-
tricity prices in the range of 20 to 30 mills per kilowatt-hour
Prevail today.

Phased Development Program

Slide 9 outlines a six-phase program for full developnent of Dominica's geothermal resources (13). This proposal was made to the Prime Minister of Dominica in December of 1931, and the pro. gram got underway essentially as proposed here, in the Spring of 1982. Phases 1 and 2 could actually be carried out in paraliet, since neither requires the results from the other in oreer 0 by gin. Studies to accomplish the objectives of Dhase lare being conducted in the United States, and the Government of Dosinics has accepted an offer by the Fronch Government to begin the ox- ploration of the geotheral fields at Soufricre, Wotten fi

Boiling Lake, as noted above

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If the results of the exploration are positive, then the Pilot Plant phases 3 and 4 can be expected to produce revenues through the sale of electricity fed into the existing Dominican grid. As suggested by the World Bank's International Finance Corporation, discussions have begun on the possibility of equity and loan financing for the Pilot Plant phase, perhaps by reviving a Dominican corporation chartered in the mid-70's during a previous, unsuccessful attempt to initiate the development of Dominica's geothermal potential (14). I£ equity financing of approximately 408 of the estimated cost can be obtained from private investors, IEC is confident that the remaining 60% could be obtained fron international banking sources to carry out the Phases 3 and 4 indicated on this slide.

On this slide Phase 4, Operation of the Pilot Plant, is shown as continuing for four years: 1985 through 198@. This is probably the mininun amount of time required to prove out the resource for long-term operation of full scale plants and to permit Dominica

to become comfortable with operating and financing of a geothermal ower system on a private sector, free enterprise basis. Actually, Phase 4 can be somewhat open-ended and could continue indefinitely at the option of the Dominican owners. The assumed 5 Ma capacity of the Pilot Plant, added to the existing 6.6 MW combined hydro and diesel capacity, would be ample to meet expanding requirements of residential customers as well as those for new, small, agri-cultural based industries which Dominica's Industrial Development Corporation is actively attempting to attract to the island.

Again assuming favorable results from the exploration program, and using hard geotechnical and engineering data developed by oper ation of the Pilot Plant, the Phase 5 design of full scale geo-thermal power plants could begin as early as 1985. The choice of

plant capacities and location would be influenced by the results
from Phase 1, which should have identified several energy-intensive industries having requirements for electricity, process heat, oF @ combination of both which might be met by the predicted 300 Si equivalent electrical capacity from the three fields tapping the predicted source of 500°F dry steam. The choice shown here of three 300 MW electric power plants probably represents the most expensive option for converting Dominica's geothermal resource to useful energy. Such a complex could power an aluninum smelter capable of producing approximately 150,000 tons of aluminum per year from 300,000 tons of alumina, which could be shipped to Dosin-ica from ganaica, St. Croix, or Guyana. Other possible uses of the 300 MW potential could be tho production of approximately 300,000 metric tons of liguid ammonia per year hydrogen and Aitfogen extracted electrically and air, or 15 mil-
lion tons per year of cemont from 26 million tons of limestone, gypsun, an? clay plus 2 million tons (one ship per weck) ef ce imported to provide the 2,200°F hot gases for the rocating hil required in cement manufacture. Many of these industries woul)
ap power, if the logistic
jon of the island's in-
). As shown under Phase

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§; the owners of the Dominican geothermal power system could rea~

lize gross profits in excess of $10 million per year during the assumed thirty-year plant life, which would represent a 208 ine Grease over the current Gross Domestic Product. In addition. and Perhaps of even greater importance to Dominica, the power complex and its industrial customers would become major employers, with hundreds of jobs covering a wide range of skills which Dominica's Bppish schooled population could master with effective training

Summary of Current status

Slide 10 summarizes the findings presented in this pape!
As mentioned earlier, the Government of Dominica has places geothermal energy development high on its list of priorities and has accepted the French Government's offer to begin geotechnical exploration of the island's three geothermal fields. ?The Prine sin-Aster of Dominica told the 6th Annual Miami Conference of Caribbean and Central American nations last December to mark their calendars for 1983, as an important year in Dominica's development of geothermal energy. Tf her program goes as planned, she should by then have the results of the exploration program and be well into the planning of a Pilot Plant, to be developed by tne private sector.

Guidelines for other Developing Countries

This analysis of the deliberate, step-wise study, planning, and development of Dominica's geothermal resource provides a basis for the following guidelines which other developing nations can use to realize the full potential of their natural resources,

First: The Government should analyze the country's natural ources, based on local observations and history.

Second: The Government should request professional appraisals of its natural resources by appropriate international agencies, Such as the United Nations Development Programme, and such natéonal agencies as the United States Geological survey, the North of Scoe-jand Hydroelectric Board, and the French Bureau de Recherches Geo-logiques et Minieres.

Third: Results of the professional appraisals of the coun-try's natural resources should be analyzed sith a view to desining feasible and cost-effective options for the able devolopient of those resources and to developing a progren plan with national priorities for that developent.

Fourth: As soon as reliable technical data on the natural Fesources is available, the Government should encourage tho private etors at home and abroad to invest in a phased program to Gevelop.

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the nation's resources. If adequate technical data are not available, the Government should seek grants from developed nations to conduct the efforts necessary to obtain data adequate to support engineering and economic analyses capable of attracting international venture capital.

Fifth: Private investors and entrepreneurs in the nation should form a corporation and raise local and foreign private equity financing for the pilot phase of the ultimate development effort, whose objective should be (1) to denonstrate the technical and eco nomic feasibility of the ultimate development; (2) to generate §1 ficient revenue to pay off any loans and to pay dividends to the investors; and (3) to provide local experience and data adequate to support detailed engineering and economic financial plans for the full scale development.

Dominica is pioneering in this joint public-private sector concept for achieving the full potential benefite of a developing nation's natural resources, leading to ultimate economic indepen~ dence for a free society. Others can follow Dominica's example to their mutual benef:

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¥3MOd MW O01 33HHL TING GNY NOIS3IG-S

88586 YA/NOMTIW 918 SNVO1 440 AVd ONY UH My/#9 © O31WOG

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UPADI 82

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First Pan American Congress on Energy

RECOVERY OF ENGHALPY AS WORK FROM

?THERMAL EFFLUENTS

By

ALE. Molini

Department of Chemical Engineering

University of Puerto Rico

San Juan, Puerto Rico

August 1982

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RECOVERY OF ENTHALPY AS WORK FROM

HOT EFFLUENTS

ALE, Molint, Ph.D. 1/

Professor of Cherical Engineering

Mayaguez Campis, UPR

asstaact

It 1s commercially feastbe to recover enthalpy as work from hot industrial effluents by the controlled expansion of Liquids through convergent-divergent nozzles using 1igquid turtines. For hot liquid effluent: , the effluent itself serves as the working-fluid. For gaseous éffluents, a high boiling stable liquid is heated by direct contact with the gas in a scrubbing tower and then the liquid ts expanded as the working fluid. If the effluents contain andestrable levels of parti-culate pollutants, the hot liquid 1s cleaned before it ts expanded.

Lower quality fuels can be vcd when the process is coupled to fossil-electric power plants because the flue gases are discharged to the atmosphere cleaner and cooler than they would otherwise. Expansion cycle efficiencies ae high as

26% ere possible. Recoveries as high as 37 NW, valued at approximately $17 millions per year seem possible from the flue gases of a 500 MW, fosstl-eloctrie utility discharging flue gases at 500%,

Results predicted when using work-flutds as glycerol, tricresyl phosphate, by-phenyls and silicone ofls are presented.

V/ Present address: Department of Chemica) Engineering,

Mayaguez Campus, UPR, Wayaguoy, Puerto Rico, 90703.

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RECOVERY OF ENTHALPY AS WORK FROM

oS ROP ERFLUENTS?

INTRODUCTION

We do not have to go into the details of how much the increases in the prices of petroleun fuels are affecting our economy. It 1s sufficient to say thet the deficits are huge. In Puerto Rico, it runs at more than $2.5 billions every year. Comparing this deficit to our gross national product of approxinately $13 billions gives a clear picture of the econo mic squeeze that the aspirations of our people have suffered. Just imagine what we could do with this amount of money for the betterment of life if we could keep it in the island, plowing it back into our economy year after year! Unfortina~ tely we do not have such a source of energy and we must satisfy ourselves with improvements in the way we use or convert the fuels that we purchase.

?Those of us who at one time or another in our educational process dealt with the second law of thermodynamics remenber the typieal problem assigned to every student to calculate the fraction of liquid and the fraction of vapor resulting from fan isentropic expansion of a liquid. We learned how to solve the problem but somehow we missed sight of the fact that the - expansion of a liquid also provides 4 route to convert portion of the liquid enthalpy into mechanical energy like a Fotating shaft, which is by far the most useful form. If we extend the principle and perform it in a controlled fashion through c-d nozzles, the much increased kinetic energy of the expanded mixture can be used to drive liquid turbines coupled -

to electric generators. Commercial application of the principle requires the most effective fluids. The liquid must be thermally and chemically stable at the temperatures at which it will be in direct contact with the hot flue gases. Direct contact in a scrubbing tower will make the enthalpy transfer from the gases to the liquid most economical. Since the thermal : efficiency of the expansion step is dependent upon the tem= Perature difference between the initial and final temperatures of the expansion, the liquid must be stable at the highest possible tenperature. At present this is limited to about 550°F = 650°F. To close the work cycle it will be necessary to return the work fluid to the scrubbing tower thus the a flashed mixture needs to be condensed. The most effective and economical manner of doing it 1s in a direct contact spray barometric leg condenser. This requires that the work fluid also be insoluble in water. Tre spray water 1s cooled ina cooling tower. All the heat transfer steps are performed in the most effective manner,by direct contact -

?The process presents algo a nore environmentally attractive means of producing electricity.

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PREVIOUS WORK AND JUSTIPICATION

5S

Fossil-electric power plants are notorious for their

low efficiency in converting the thermal energy from the gombustion of fuels into electric power. (Exhibit =). They are also notorious as pollution sources, specially of the atmosphere which receives their conbustion gases. Bodies of water or the atmosphere receive the waste heat from the tur- bine condensers. The temperature of the flue gases and thelr enthalpy is related to the sulfur content of the fuel. The bigher sulfur fuels will require discharging the flue gases at higher temperatures to prevent the condensation of Sulfuric gn the netal surfaces of the flue gas handling system. Fallure to do so will have catastrophic effects.

The proposed process will reduce the pollution level of the combustion gases by scrubbing then wntie simultaneously Fecovering a large portion of their enthalpy. Serubeing of the gases with high boiling poins fluids give us the opportunity to clean the flue gases berore discharging then to the atmoss phere. The particulate pollutants will be washed from the gases. Removal of the sulfur compounds 1s poceibie by incorporating trapping agents in the scrubbing fluid to react with the suifur gompounds and remove then with the fluid to the bottom of the tower, where they will be removed fron the system,

?The scrubbing operation 1s well known in the chemteal Process industries. Sufficient expertence in the design and Qperation of scrubbing units has deen accumilated during he last few decades which factittate the application of the prin ciple. The gases will leave the tower at temperatures somewhat bigher than 160°F to make certain that all of the moisture originally present in the gases will leave the tower and not accumilate in tt. The vaporization of the high bolling Iiquid used in the scrubbing operation will be almost nil if'not aero.

The technology for the design of scrubbing or packed towers is readily available (9), There 1s 2 large selection of packings in terms of materials, efficiency and cost (esnioie V) We do not expect problens with? this step with reference to the scrubbing mechanism and the direct contact heat transfer mechs anism.The proposed enthalpy recovery system connere/aily feasible to recover stanificant anounts of thermal energy FoR

the flue gases ¢ fossil-electric power plants. For exasple,

approxinately 40WW, wlued at more than $17 million can be

Fecovered from the Gaseous effluents of a 500 Mii, fosetl-elec-

tric utility discharging flue gases at 50°F, (E8nibit IT)

Recovery of this energy throug the use of the \wual tubular

heat exchange equ?pnent would be prohibitive (Entel TV)?

The isentropic expansion of liquids is well known and

gxtensively used in the chemteal process industries: (Exninit VI)

The technology of flashing liquids as a route to separate low

Dotling compounds from mixtures is very common tn the petroe

leum industry. To control the expansioi we propose to Bo Te

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through convergent-divergent. nozzics. This is a well known Bechnology tao. We do not expece major ditficuities in tes application.

The controlled isentropic expansion of surface sea water is the basis ror the sroposa: cf Zener and Fetkoviteh(1) to recove= electric power from the thera? range of the ocean. Their FOAM OTEC concept takes advantage of the temperature difference existing between the surface waters and deep ocean waters. In their open cycle FOAM OTEC approach Zener ad Fetkoviteh (1) expand warn surface water at approximately T79F through a multiplicity of orifices to generate a well behaved uniform foam at approximately 50°F. As originally envisioned, their process 1s @ low power-density process. Their flashing rates amount to apzroxtmately 2 Ds. of water / sq.ft.-sec. Nolini and Zener (3) used the prinetpies for the design of iend based FOAN OTSC plants for bottoming eyeles. Our present approach envisions using tenperature differences as high as 50°F. when expanding wock-fluide from 60°F (Exnibit V11) to?a" condenser operating at 100°P. Under these conditions the flashing rates apsroach values of 275 1ba./eq ft.sec. The hot high temperature vicuid serves as the work= fluid to drive Liquid impulse turbines. (Sxnsbee XI)

SUMMARY AND CONCLUSIONS

Present day knowledge show that 1: 1s commercially feasible to embody a low cost process to recover enthalpy as work fron hot industrial effluents 2y the controlled expansion of liquids through c-d nozzles usin: Yiguid Impulse turbines. Direct contact iieat transfer between hot gases and high botling stable liquids followed by the isentropic expansion of the hot Liquid is the basis for a low cost process to recover enthalpy as work from hot gaseous effluents. The direct contact heat exchange 48 performed in an atmospheric pressure scrubbing tower. The cleaned gases leave the tower az approximately 160°F: For hot liquid effluents, the cffluent itself serves as the work-fluid. The hot vork?fluids are cleaned before the expansion step to remove undesirabic levels of particulate pollutants.

Lower quality (cost) fuels may be used when the process 4s coupled to a fossil-electric power plant because cooler and cleaner flue gases are dischargec to the atmosphere. The process 4s an environmentally attractive way of producing electricity.

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T. hobo, W. E.,Evans,

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Zener, "Foam OTEC syste

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02-8459, 4000, Augus

Molint, A.E., Zener, v

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Washington, 3. C., Jone

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OTEC Conrerence,

CER Resecreh Prop:

Design Project, INQ! 56%,

Chemical Engincertng, Nay

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Houston, Texas.

ocess Lesign for Chemteal

Von. 2, Gi

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BwIBIT OT

UTILIZATION OF FUEL BY Foss

POWER PLANTS

Electrichty sesssseserescees 500 Me,

Flue gases ...., + 250 My

Cooling water . = 930 My,

Hearing value of fuel used .. 1680 Nw,

+ Work-cycle efficiency ..

Botler efficiency ...

Flue gas temperature .

35%

seeees 500 OF

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paUIBIT IT

VALUE OF FLUE GAS ENTHALPY

Total flue gas enthalpy .

Enthalpy recoverable by scrubbing fluid .

Power recovered from work-fluid

Cost of fuel ot No. 6 ++ $30.00 / bor.

Fuel cost / KW

+ 90,0546 / Ki

Value of flue gas enthalpy .... $ 17-69 millions/ yr.

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TNO WOT WITTE

spti0s soe? a0y

Ln £009 =

zed PrOks 430%

f L \sasuepu0g

eno2

Butt009, 4

auyqana pynby7

enor payors

?T9001 pinbyt Suyaanaog

oot

sose pi9oe5

i trea

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20-

pousrr iv

COMPARATIVE COSTS OP HEAT TRANSFER SURFACES

Heat load « s+ 583.62 E6 BDUAIr .. 272 Mi,

Gas 7, = 50°F Work-fluid Ty, 100°F

Gas Toy? 160°F Work-fluid Tugs 480°?

out?

TUBULAR EAT EXCHANGER

Meat transfer coefficient = 10 BIU/ he-tt?-°P :

Area required = 1.6 £6 Pt.

=§ 12.00/tt? = $ 16 Mi21L0ne

PACKED TOWER - Direct contact host transfer

Meat transfer coefficient «7 BTU/ nr-tt2°F

wat mag r07/ 2) q

Packed volume = 198,250 £t?

Purchased cost of packing raterial = ¥ 7.00/ ft?

Purehs

= ¥ 7,00/tt? = § 164 Bitasons 7

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Petrochemteat walt fubtishing Co.

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au

TEVPERATURE = ENTROPY DIAGRAM

1100

x Echylene glycol

9 Gtycerot

| A Diethytene et: ot

1000 Vapor phase

900

,

Liguid phase

800

R

Liquid-Vapor

700

Temperature

600

> oo

a2 3 3 a

Beu/ Yor R

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Borert 1x

TEMPEPATURE = ENTROPY DIAG!

Tritolyi phosphace

1000

900

°R

800

700

Tesperature

500

Precopy BTU / ab, =

Source of vapor p:csaure datas Perry, John li,, * Chesteat

Engineers! Hand: 2%", McGraw-Hill Book Co. ied. Ee. 1950

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UPADI 82

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?Second National Conference on Renewable Energy Technologies

CLIMATISATION SOLAIRE PAR ADSORPTION SOLIDE

EN CLIMAT TROPICAL

By

P. Brandon

CETAIT ~ 69000 - Villeurbanne

B. Celestine - M. Dupont - J.B. Monier

CUAG = B.P. 592 ~ 97167

Pointe-a-Pitre Cedex - Antillas Francesas

?San Juan, Puerto Rico

August 1982

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ouverts par adsorption solide ont été plus particulid

renent analysés dans les conditions clinatiques des pays tropicaux,

Dans une prenire partie les caractériatiques des dessicants ne sont

pas pris en compte. On aontre 1a faisabilité de systémes & dessication

fen mettant Iaccent sur 1'influence des échangeure de chaleur et des

humidificateurs sur la performance, dans le cas da Lit adiabatique et

du Lit refroidi,

Dans une seconde partie on développe 1a wodélisation du comportesent de L'adsorbant avec un godble simplifi¢ basé sur 1'identification du Lit 3 un échangeur de masse. L'efficacité de l'éhangeur est Le rap port de 1s masse réelle d'eau cyclée et de la valeur maximin pour un fycle infiniment Long.

Plusieurs cycles sont analysés et comparés. Le modéle est calculé sur des mesures effectuées sur un bane d'essai perneteant pour un lit Fixe adiabatique et pour un lit refroidi de fixer les caractéristiques de Mair,

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I = Introduction

Plusieurs travaux ont montré que l'utilisation d'un cycle ouvert & adsorption solide pouvait tre une alternative intéressante pour le conditionnenent de Iair (5,7 hla certain noabre de produits actuelle fent connercialisés ont des capacités de sorption suffisantes dans des écarts de tenpératures de L'ordre de 50°C entre les phacs. "adsorp. tion et de désorption. Ces écarts sont accessibles avec 1a techaslogie des capteurs solaires plans

Nous développons dans ce travail une étude de systime de dessication A Lits fixes cyctés entre L'étape de séchage et 1a régénération. Cenk ralenent les capteurs solaires a air sont conseillés car ils évitent La mise en plan d'échangeur entre "sir et un fluide caloporteur.
Nous analyserons cependant un systése 2 eau en plagant l'échangeur dans le Lit dessicant ce qui permet alors successivencnt de le rechauf-fer au de le refroidir 3 volonté.

II ~ Description des systimes § air et A eau,

La figure 1 schénatise les différents composants des systénes étu-
igs, L'air du local est teaité a chaque cycle, Le lit fixe est forme
de deux conpartinents alternativenent en adsorption puis en desorption,
La figure Ia est relative au systiue adiabatique, 1a figure tb a ays
tase a eau avec Lit refroidi. Les cycles correspondants sont représen=
Cés sur le diagrame peychroaétrique (fig 2). L'air laissant le local
(1) est wélangé avec l'air extérieur. On appellera "a" le taux de re-
nouvellevent d'air. L'air pareiellenent renouvelé est desséché en tf:
versant le Lit (N)"(£ig.1)'. L'air sec et chaud est préslablenent ren
froidi & travers un échangeur de chaleur e)(P) avant d'ztre rehusidi~
£i? adisbatiquenent dans le laveur de clinitisation e,(5). Site lit
est refroidi par une circulation d'eay issue d'une toor de refroidis~
senent e,, en lininant partiellement La chaleur d'adsorption on est
conduit directement 2 un point proche de P (figlt). Entre § et T on
uodifie les caractéristiques de L'air 3 cause de leffet simltant
@'une charge calorifique dans le local sous forme sensible et latente.

La régénération du lit s'effectue avec l'ait extérieur E. Cet ait
est préalablenent refroidi par Evaporation dans un laveur e, de Cason
3 abaiscer 1a température d'entrée (G) dans 1'échangeur de thalear ey
indispensable au fonctionneaent de 1a machine. Un. second échangeur de
chaleur e, permet de récupérer des calories de l'air chau! a ia sore
He de la?régénération, avant d'entrer dans le captesr a air (D)-Enere
Le point F (sortie du Capreur) et le point ¢ s'etfectue le oéchege du
Hie, Le point # caractérise les conditions de sortie de 1'échangeut ep.

Sion effectue le chautfage du Lit 4 Laide d'un échangeur chaut te

par I'eau pouvant provenir de capteurs solaires, on passe direct erent

Ge D2G (ig 18)

TIT ~ Analyse thernodynanique

a) Coefficient de performance

La eapacité frigorifique de ces systines et le coefficient de

perforsance thermique COP est caleulé & l'aide du diagramme psychroné=

trique. Le COP se définit par

cor = SE = Sanaclts Sgr st i a

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?vee Qe = (hy ~ hg) o

e? =H, (hy = hy) ese 1 énergie calorifique utile provenant des cap-

eure & air.

Dans Te cas de aystdne & eau

Qs = 8, ty TD ?

) bilan dans Les diftérentes parties de 1a aachine

les equations de conservation de masse et d'énergie sont écrites

pour chaque partie du cycle.

1) Local

La composition de aire du local est modifiée entre § et Ta cause

de la présence d'une charge sensible

P= 8, c(t; - 7) ©

dune charge Tatente

Py yee ~

2) Renowvelleneat dair

RD) o

Sia est le taux de renouvellenent d'air le bilan de masse a 1a

sortie du local s*éerit

By = ake + Ce a) Rp a

De mine a partir dy bilan chaleur

Ty tet, + =) Te @)

que celles du local Dy et Pg. I en régulte qc plur un taut a conseant uous

3) Adsorrtion

Se mayne qi fu copliiares de dnaetonat ok dn Ves eet Ue 0

rab(BM = By) = Bao (y=)

~ pol 18 tit'retroidi 1a chatellr a'adsorption e'évacue dans 1'air

ee Lea

AL Gy ~ RY = He et + Ayo -7,) o>

Une équation suppléaentaire apparatt avec l'efficacité de 1"?chan-

geur placé 2 1'intérieur du lit défini en tenant compte seulement de

tenpératures de l'air et de l'eau.

hoy

et poet ao")

On a nécessairenent eg 1

om caractérise 1a source froide par une etficscité g = TEM cn")

4) Echangeurs de chateur

Pour e; on a deux équat ?ons, L'efficacité

---Page Break---

h- 4,

ix Tp

4 - fle G0

VRS

et La conservation de 1a chaleur sensible de Iair

Tyo Tp Te Ty any

avec ¢, <1 done T, > Tp et Ty > Ty

Pour e, L'efficacité et 1'équation de conservation s'écrivent

e) Hib aay

avec Ty 7% puis

Tp Te Toth «ay

done > Ty

Dans le cas du systine

les points 8D GH

5) Levene

eau on a deux Equations analogues entre

Pour écrire les équations du laveur on va adnettre que celui-ci

maintiont I'eas 3 Ia température humice T'' du point consiséré, Pout le

laveur de climatisation, on définit l'étficacité pars

BES ao

On admet ensuite que toute Ienthalpie de vaporisation est utilisé au

refroidisserent de ''air

te BS hy - my) = E coy ~ 7) «s)

our Le Laveur dans te circuit de régénsration

est

«ER a

ee By ty ~ BD = ELC GH ~ Ty) an

6) Désorption

Pendant 1a désorption on retrouve trois relations analogues a (9) pour le Le adiabatique et 3 (9") (10°) pour te systine teas

Pour Ie aystae 3 air 1'absorption de chaleur dans Le processus

endothermique de désorption gire le refroidissenent simltane du dessi-

cant et de Lair,

ag by Ry) = BC (pete) «as

Avec Le systéme A eau on 2 sinultantment échauffanent (relation 4) et

eésorption.

By Gy TY ~ A MR +8,ca-1y) ae

Comme en (10") on caractérise 1"échangour intégré ou Lit deasicant par

e,- Tee 19")

7 tp g

7) Rapport de mélange

Le passage de Lair dans les échangeurs de chatesr ne woditie pas

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Le rapport de mélange. On trouve

a aa

RR sage my (20)

By an

Dravtre gart, il faut que 1a nasse desu cyciée soit ta wine dane Tes

hance dadscrption ede desorption #

Roo Beh By en

Lrentesble de cas Gquations peroet de earcttriser Ty et By en chacon

des points de fonctionnement. En effet pour ie cycle adiabatique a air

on dbgonbre 18 inconsoes

Tey RS GS Te Ty Myi Tyfas Tyalys Toker TyoteeTye Tye Tp

et 15 equations © 2.18 ee 2)

Gn sat done snené pour résoudre te systiae 2 fixer trots perast

see, ret tense To umes Oe tgell 2a tuopbeamnen Sa omg netalton ty'at'la Conpératace minide 8 I'enliée do Teeel Md

Pour le systime a eau on 3 come inconnues suppléaentaires les tenpératures d'eau Ty, T2, Tj et Ty- Au total 16 équarions et 20 incon ues (les points C et'F alexiscent plus dans le cycle). Comme précé- dement on fixe Tp, T's et Ty et T les tengératures d'entrée dans Le Lit,d'eau froide et d'edu chiude respectivenent. On peut done résoudre Je bysténe d'équations Lingaires et mettre en évidence I?intluence des lénents de la machine : Laveurs, échangeurs de chaleur, renouv. air, IV ~ Résultats

Le couportemont des deux systimes 2 air et 3 eau sora décrit dans les conditions cliaatiques les plus chaudes possibles dans 1a région,

A savoir T, = 35°C Ry = 20 g/kg air sec. Le local sera mainten entre 15 = 22°C Ee t, = 30°C" pour une charge calorifique, sensible de Py=5, Sk et latente P, 70,5 kw. Le débic d'air &, = 2000 n/n ese compatible avec un volufe de locai d'habitation de f'ordre de 300m (6). La ten perature de régénération, sortie des capteurs & air Tp ou entyGe d'eau Chaude dans le Lit T est fixée A G0"C avec un dEbit d'eau t1y°2000 @3/h. On fixe gpaleaent Le dcbit d'eau froide ty = dy. Les chaleurs lateates de vaporisation et de sorption sont respedtivedent Ly = 2450 ki/kg et

L = 2600 ki/kg.

On mainticndra dans le local des rapports de mélange de L'air compris entre 10 et 15 g/ky air sec.

1) Laveur

Les caractéristiques du leveur de clinatisation e, permet de godi~ Hier le rapport entre les charges sensible et latent? du local sans changer le COP. Par contre lorsqu'on augnente la performance du laveur eq dv circuit de régénération on observe une réduction sensible de la masse d'eau 3 cycler (fig 3) et une légere augmentation du COP. Avec fe, of augmente Le rapport de mélange au début de la desorption (point Fu aystime a air ou D du systéne 4 eau). Si les capacites de sorption varient peu avec le rapport de mélange pour une mine tenpérature Te, it apparait que pour un fonctionnenent donné de 1a machine (débit d'air et

---Page Break---

a'eau, période du cycle, etc) I'anélioration de la performance de ce

laveur permet d'eavisager une diminution de 1a quantité d'eau a eye

cler et par voie de conséquence de 1a sasse d'adsorbant 3 utiliser,

2) Echangeurs de chaleur

La figure 4 met en évidence le cle important de 1"échangeur 6

dans le systéne 3 air : augnentation notable du COP et diminution de

Leau 2 cycler.

L'échangeur © permet dans les deux systénes d'anéliorer le COP

sans changer 1a masse d'eau i cycler (fig 5 et fig.6).

3) Renouvellenent d'air

Les figures 7 et 8 moatrent qu'il est préférable d'utiliser Le

Eaux de renouvellenent d'air le plus faible possible pour ne pas aug~

menter inconsidérément 1a quantité d'eau i cycler.

4) Source froide

La figure 9 traduit un résultat attendu. On 4 un meilleur refroi~

dissenent du lit dessicant lorsque 1a source froide est plus perfor=

ante. Le COP augmente avec e, et 1a quantité d'eau 3 cycler dimimie.

5) Echangeur de chaleur dans le dessicane.

jeu a un Ble capital dans Le fonctionnenent du systioe

a eau, La figure 10 aontre que la quantité d'eau 3 cycler dimisve tees

Fapidenent avec L'anélioration de la qualité de 1'échangeur e,

©) Conclusion

Ges résultats contrent 1a faisabilié du cycle ouvert a adsorption

solide dans un clinat trés chaud et trés huside, Le niveas de teapé-

Tature de régénération est accessible avec 1a technologie des capeeurs

plans. On obtient un coefficient de perfornance thermique de l'erdee

de 0,5 avec des valeurs des efficacités pour les Isveurs et Les écher

geurs de chaleur compatibles avec celles données par les fabricants.

On @ wis en évidence Itintéréc d'un systéae a eau A lit refroidl

en utilisant toutefois une expression sinplifice de l'efficacite de

Léchangeur intégré 3 l'adsorbant mettant en jeu des échanges de cha~

leur entre trois composants : eau-air-adsorbant. 11 sera done nicese

saire de wieux définir cot échangeur et d'introduire, ce sera 1*ebjet

de Le suite de ce travail, en plus de La chaleur de sorption des par

metres spécifiques du matériau dessicant.permettant de nieux derive

son coaportenent.

V-~ Approche munérique éu comportement du dessicant.

Deux approches sont proposes. Un modéle simple pernet d'obtenir des réponses infornatiques rapides pour faire une analyse prospective de divers produits et de divers agenconents des Echangeure et Laveurs. Une méthode plus exacte est Glaborée pour simler le comportement dee systimes en rGgine transitoire

a) Méthode simptifise

Le Lit adsorbant est le sidge é"échanges de masse et de chaleur. On admet par analozie avec 1'échangeur de chalevr que le Lit sdsorbant

---Page Break---

©

peut Bere caractérisé par une efficacité "échange de masse constante.

Celle-ci se définit conme le rapport de 1a masse réelle d'eau cyclée

sur la masse d'eau cyciée si les tenps de sorption étaient infiniment

Tongs, c'est-2-dire dans des conditions d'équilibre. Siw est La masse

sau dang Le deseicant par unité de masse de dessicant anhydre on &-

crit eee

: ey

hea ~ Yoeg

ee Uy sont Lea sence cordau on fin dladsorption ot de désorption

taapettveatnes Es Eade ndyy cepetatace 1Macae dtequiiinees algel ta

Eeponae de'Ivedsorbane?incervicat ay ravers de ses caracteciat iver

UTrequilforer Cen dernittes sont gentraleceat domes pat ler {abr

fanca'conme dea fonctions de Ivbimidite telavive de Lait, et de la

teepérature

oa or

0.20 ~s ~ ~ ~

DUNKLE 0.3 TT ? is

oe 0.35 6 a 7

xp 3 2

wemmation | gap} % 7

ox 7 x

te eof Tew % 7

crt 0.30 o 7 1 is

vO |-e 5 7 7

BES ep 0,8, 05 7 [_ a

Tables 1

Résultats conparatits de Tn wodélTsation du cycle avec une "efficacité "change de aasse? constant

Données. du calcul

Ty = 26°C et Ry = 1, 13, 15 g/kg

25 = 47 5 ey = 0,95 &) = ey = 0,85 aH 05 = 04?

Ty By conditton déentréd dand ie tie'a 1'adsorption,

cUaafeions extériewres : Ty = 30°C Rp = 22 g/ke.

On détermine done Nog et ye 4 partir de ces données et des conditions d'entrée dans le ?{7t'a I¥asorpcion et a 1a desorption. Lorsque est fixé 1a quantité d'eau eyclée réellenent est déverminge par 1a relation (23). Les catactéristiques de I'air resteat inconnues. Une méthode ginilaire 2 celle présentée précédement, c'est-s-dire la résolution d'un eystime é'équations Linésires permet de les calculer . La non

---Page Break---

Linéaricé associée aux courSes TTquilibre n'incervient que dans les coetficients de ces equations. saut pout te cycle de OUNe (35 leee leque) les valeurs 8 I'equitibre entrent dane te spotted evasion résoudces On optre alors par substisutions macessedeee fuege hy cenaee gence de te solution,

Le Eablens I donne quelques césultats comparatite de plusieurs cycles 2'sir pemertant de voit Sinflucnce des confieiont dieatete dans TELE (iy typ dU attorption sur Le 20" et Is geaeeiee ated eee!

On a FineUatenpérature de sortie du local a'T¢ = 265 et eonctaeee plusieurs pointe dans 1a sone de confor! (6) Eq = O,11 0018 a 815 e/g sir sec

b) Approche munérique en régine transitoire.

Pour ce faire on utilise 1a méthode des différences finies en consi- aérant un réseau de pas at, Ox pour le texps t et 1a position x dann le Lit. On traite alors tes quatre équations couplées qui gouvernent Le Somportenent du dessicant : I) transfert et 2) conservation de unsees 3) transfert et 4) conservation de chaleur. On utilise les coefficients de transfert proposés par WONGEN et MAXSHALL (4) entre les particules tun Lit coapacté et Laie.

On peut alors suivre en fonction du temps et de 1a profondeur du Lit Le comportement dynamique du Lit. Actuel lenent 1a mise au point du. pro grame s'effectue par comparaison avec les résultats de BULLOCK ot THREISELD (1) et avec LeB"lonnées d'une boucie expérimentale en cours dessai.

Dans le travail deux objectifs ont sté poursuivis..

Liétude de faisabilicé de systéme de climatisation par adsorption soli de a 6 dévelopaée dans Les conditions dw climats chavd et humide. En saintenant une contrainte sur les teapératures de réginération compat i~ ble avec les capteurs plans, On a ais en Evidence Itimpartance relative des couposants pour un cycle adiabatique a air et un cycle A eau, On contre gue l'élinination de La chaleur d?adsorption dininve considérablenent In masse d'eau A cycler done 1a masse d'adsorbant.

On a introduic ensuite les caractéristiques du produit dessicant dans 1a nodélisation du cycle d'abord par une néthode sinplifice en considé= Fant qu'une fraction seulonent de la variation de ta teneut en eau a Léquilibre ext cyclée. Une description plus Tine ext enmite Siasoeée

veilisant 1a méthode des ditférences finies. Elle permet d'envisager une Stude détaillée des caractéristiques des produits : grain de 1'adsorbant

Profondeur du Lit, perte de charges et des conditions de fouctionnement +

Conclusion

Nous avons montré dans ce travail que ies cycles ouverts & adsorp~
tion solide présentaient un intérde pour le coadirionnevent de Tate
ine dans des conditions climatiques difficites. Une tude de faisabili-~
{6 a &6 A'abord développée pour un systéne aliahatique 3 air et un syo~
tne A cau 3 1it refroidi. Cette étude a perais de wettre en évidence
dans les deux cas 'inportance relative des différents composante | &=
changeur de chaleur, laveur.

On cherche ensvite & introduire tes caractéristiques des dessicants
solides en proposant une méthode sinplifi¢e dans laquelle on consisere
iu'une fraction seulement de 1a difference We tencur eh eau 2 1"équil i=
bre est réetlenent cyclée, puis en développant une deacripeion, plac Eine
fen régine transitoire en utilisant la méthode des differences finies,

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Capacité calorifique de lair

Enthalpie de l'air hunide au point i

Notations

T= Température sche au point i

Rj = Rapport de mélange au point {

Thy» Température hunide au point i

mgs Debit d'air sec

ay = Debit d'eau froide

==

PL + Charge sensible du local

P] = Gharge latente du local

e; = Efficacité des échangeurs et laveurs

Lb = Chaleur Lacente de vaporisation de l'eau

Ls chaleur de sorption

Gy = Capacité calorifique de Leas

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|

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cor

0,52

0,48 0,49 0,50 0,51

0,47

0.0 0.2 O48 0.6 08 10

erricacite %

Pig 3 - Influence du laveur de régénération sur le

COP et 1a masse d'eau cyclée,

(098 aTe 81/8) aat919 av

---Page Break---

cor

Ot

$.

é co

Sos 3 OT 0.8

EFFICACITE e,

Fig 4 ~ Influence de 1"échangeur de chaleur e, sur

Ye CoP et 1a masse d'eau cyclée par 12

systiae a air,

34/8 aaTOKD ava

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0 (02 04 06 08 10

EFFICACITE e,

Pig 5 - Influence de 1"échangeur de chaleur

fe, sur le COP et 1a aasse d'eau cyclée

pour le aystime 3 ea

84/8 a31919 va

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cor

0.65

's

L

st

é 1 L L ~

° 76 Ba B

?TAK de RENOUVELLENENT 4*ATR a

Fig 7 ~ Influence du renowvellenent "air sur

Le COP et 1a masse d'eau cyclée dans le

systime a air

4/8 gxT19 ava

---Page Break---

cop

0,50

0,48

3 g

° 2

5

3

So 0.05 0,1 01502025

TAUK de RENOUVELLEMENT D'AIR a

Fig 8 - Influence du renouvellenent d'air sur le

CoP et 1a masse d'eau cyclée dans le

aystime 3 eau

---Page Break---

cor

0.36 0.38 0.4

0.34

05 0,6 0,7 08 0,9 10

EFPICACITE DE L'ECHANGEUR DE LA SOURCE FROIDE e.

Fig 9 - Influence de 1a source froide e. sur le

COP et 1a masse d'eau cyclée dais le

aystine 3 em

5

oF

84/8 ay1910 ava

---Page Break---

cor

0,55

0,50

0,45

84/2 agtDKo ava

0,40,

0435

30

so 0,2 0 06 oe 1,0

EPFICACITE DE L'ECHANGEUR DE CHALEUR DANS LE LIT

DESSICANT e,

fig 10 ~ Influence de 1'échangeur de chaleur ¢, permettant Le chauffage et le refroid?ssenent

Gu lie

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UPADI 82

Sen Juan, Puerto Rico

?August 1-7, 1982

First Pan American Congress on Energy

ENERGY STRATEGY FOR GUYANA

By

Melvyn Sankies

Faculty of Technology

University of Guyana

San Juan, Puerto Rico

?August 1982

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fursqeuerzoN

The present econoate crisis in Guyana {s due mainly to the high

Soe oF ott yr, the chlet source of energy. In 1971, Guyana inported (USS

$3 Millton dollars worth of of1, in 1977 (Us) §74 willion dollars and by

She end of 1961 imports had risen to approximately (US) $135 aillion,

Guyana has a land area of 216,000 ka?, with agriculture, mining

and manufacture together contributing approximately 50% of the gross dow

Bestic product. The three econonic sectors ulso account for 80 or the

fetal enersy consucption in Guyana. The economic activity of Guyana te

based on bauxite, sugar, rice and

to be a balance so us £0 waintain a steady ecological system, ?Gre use of

lopment must therefore sake into account the exvicenmeat

and consequences of the use of enersy.

Jie 4n Guyana have to spend more tine deciding how to allocate

Sur scarce resources for the development of energy Cechaologies and choos ing those that are cont cost-effective for the situation. Priorities wil have to be established so a9 to avoid a e-'s(nued foreign dependency situs Sion as exists with petroleum. Our ever il success will depend on checker Ye can find local solutions for pur proble.t. Sone intercating facts on the use of energy in the U.S.A." are a guide for Guyana to avoid sertein pitfalls.

"They have shown to procure a can of sweet corn, 270 calories value food in the USA on requires 2,150 calories. Only 200 out of this 2,790 = used in Browing corn, fertilizer, tractor use, ete, process~ ing and canning take 1,200, transportation taking another 700 calories, cooking and distribution mske wp the balance, A130, to obtain the sane 270 calories fron meat the production figure soars to over 21,000 galories. There is evident a similar vastage 10? the Sistribution of energy in various sectors of the U. economy. Transportation for instance, accounts for 20 ~ 25 percent of the tota! encegy consumption, which is 85% autonobile and oaly 14t freight. The Poor nations cannot afford this energy intensive vay of Life not only because it ig wasteful but because there are inherent constraints to it- Fer which Feason the rate of enerzy consuaption has got to Slow dowa and settle into a steady state,"

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tun oT = 956 OT eS = sOINOF oT Xx zI'9

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THE PRESENT ENERGY SITUATION

A preliminary Natucal Energy Assesoment of Guyana vas carried

out by CARICOM as a first step covards improving the energy situations

2

Table (1) ?shows energy consumption for 1979,

Expenditure on petroleus inports in 1979 was 23% of total saports

9f goods and services and 26% of total export earnings

The main energy sources and their uses are as follows:

(@) Hydropower used for generating electricity for

domestic Lighting, saumiiling and works at

?Tumatuaari, vhich'is approxinately 272 kn fron

Georgetown, The energy installed at Tumatusart

is 2 x 0.75 ew of which only 200 kw is used at

Present.

() Guyana Electricity Corporation which supplies

electricity to ost of the country.

Table (2) gives the installed capacity of the

Guyana Electricity Corporation.

Steam (Busker ¢) 36

Diesel 7

Gas Turbine (cetane 47) _20

3

(©) Gasolene and Dieseline are also used for transportation.

In fact transportation accounted for 20 percent of {vel

used in Gable (3), the country as a whole.

---Page Break---

FIG. 1

Map of Guyana showing

HYDROPOWER SITE

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secron

?Agriculture

Mining

Industry

Services

Transportation

Hlectricity

Residential

TABLE 3

SECTOR USE OF IMPORTED PETROLEUM FUELS (1979 BASE)

PERCENTAGE ryees

DEFINITION INCLUDES OF FUEL USD oF

Sugar, Rice, Fishing,

Forestry, Livestock,

other Agriculture 5 Diesel

wuxite, Gold, Diamond,

Quarrying, Other 45.

Sugar Milling, Rice

Milling, Manufacturing,

Food Processing, etc. 6 Bunker 'C" Diesel.

Governnent Services,

Comerce, Hotels,

Other services, 3 Diesel, Lee

Goods and Passenger Diesel, Casolene,

Transport (Land, water Kerosene, Aviation

and Air) and Communi- Fuel

cations 2

GEC, Cuyaine, Other

Generation of Electricity Bunker 'c* Diesel.

Households LPG, Kerosene

Other Local energy sources are:

@

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®

)

Bagasse - a by-product of the sugar industry used mainly

for generating electricity and steam. In fact the sugar

industry provides most of its on electricity by biomass

and soall anounts of diesel.

Wood-cooking and industrial heating.

Charcoal ~ cooking.

Rice Chaff - used in the rice industry for generating steam.

Coconut Shell ~ industrial heating.

There are slso small private wind pover units for pumping and

generation of electricity.

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@

@

ENERGY ALTERNATIVES

?The Guyana Government has been Looking at hydropower since the

early 60's. A survey was carried out by the UNDP of all poten

tial hydroneleceric sites which had a potential of over 6 mega-

watts. Recent studies of such sites as TIBOKU, UPPER MAZARUNT,

KAMARIA has shown that the UPPER MAZARINI as the most advantageous

?The estinated hydropower potential of Guyana 4s 2000 Mv.

Since 1976 the Governnent has been actively exploring the economic possibility of an hydropower plant on the upper Mazaruni,

Asa first stage, the total capacity of the plant was expected

to be 700 My to Cater for a proposed ~ Aluminum saelter of at

Least 152,400 per year capacity, Asontun Nitrate Fort iliser,

50,800 per year capacity.

?The possibility of obtaining the funds for the project has become

renote with the present world economic situation. Consideration

is therefore being given to smaller hydropower projects such ae

upgrading Tunatusari to installed capacity of 50 YW.

BionMase

Fover Alcohol vas first produced im Guyana in the 1920's but

Production ceased around 1932, In 1976 the Government of Guyana

?owned Guyana Liquor Corporation reviewed work sa corporation with

Brazil on the production of Ethyl alcohol for use as a fuel for

See. engines.

As late a5 1979, molasses was carning badly nested foreten

exchange; Table? 4 shows production over the past five years and

Table 5 shows molasses exports over the past five years. The general trend is decline in overseas purchases and decline ia foreign exchange earnings. Table 6 shows production of industrial aleohol.

TABLE 4

SUGAR PRODUCTION (LONG TONS)

SOURCE ~ GUYANA SUGAK CORPORATION 17D

Date	ESTIMA	soTvat
1977	ai2j1s3	21,527
1978	356,801	324,805
1979	329,884	298, 268
1920	214,637	269,634
er	310,000	300,790

---Page Break---

DESTINATION

U.S.A.

United Kingdom

Conada

Trinidad

Martinique

St. Vincent

St. tucta

aruba

Antigua

Puerto Rico

St. Maarten

Suriname

TOTAL. n345245,220__.12.372,640, 154

LONG TONS

(160)

7

4

1977

1978

1979

1980

1981

TABLE 5

MOLASSES EXPORTS

SOURCE ~ GUYANA LIQUOR CORPORATION

1977

1979 1980 2981

198,560 10,910,240 8,759,000 7,161,920 4,641,920

866,400 3,609,920 2,341,600 3,084,480 4,994,560

937,460 1,998,080 2,818,080 2,127,520 233,920

160,160 407,690 - 1,759,840

94,5600 = 7 - 7

84,800 - - - -

276,000 307,680 359,520 561,120 293,920

598,400 643,360 300,000 ? 446,880

- 316,800 352,960 164,260 443,520

- 913,440 = - -

- 465,400 = - -

98,852 122,329 93,911 75,495 80,091

TARE 6

PRODUCTION OF INDUSTRIAL ALCOHOL

SOURCE - CUYANA LIQUOR CORPORATION

MOLASSES LITRES OF ALCOHOL

fin tonnes)

43,674.54 432,313

89,610.60 354,858

46,435.72 292,917

66,611.53 412,923

54,445.63, 370,633

---Page Break---

At this stare with the sugar market being depressed for a nusber

of years due to the challenges of high fructose corn syrup and bect sugar, we have to consider alternative uses for our sugar factories.

It ts possible to produce per ton of sugar cane the folloving:

49.28 Litres of dehydrated alcohol

51.04 Litres of 967 alcohol.

Based on the assumption that 63,140,000 Litres of gasolene were used in 1979/80 and ascuming 30.5 toanes cane per acre, the projected area for the cultivation of cane sugar would be 48,000 acres inclusive of the 6,100 acres for yearly rehabitation. The estizated operat ional cost per tonne of cane is \$36.95 ~ 6544.20 and the operational costs per one gellon (4.54 Litres) of absolute alcohol is expecta to be \$3.30 to \$3.95, We therefore have carefully considered vhat are the economic trade-offs in sugar and molasses to be exported and percentage to be converted to Ethyl alcohol. A factory constructet to produce alcohol directly by fermenting cane Juice, will

produce surplus bagasse of approximately 100 kg of bagasse/ton of processed

For the excess bagasse to be produce from the projected 48,000 acres to be cultivated will result in 6.72 million kilowatts of electricity Power available to the national grid.

Ethanol should be considered in any energy plan that is conceived. Ethanol is used in tho production of solvents, cosmetics, printing inks and plastics. In mixtures of 15 - 202 with garolons, ethanol can be used in autoaobiie engines with essentially no carburetion nodif ications necessary.

An air-cooled atraight ethanol-fueled engine has been developed and is presently being tested as tho result of # cooperative research progra between Volkswagen do Brasil and Volkswagen Research in Germany.

oHARCOAL

Charcoal unt{l the late fifties was used primarily for cooking.

In 1965 product ion was 2,460t, by 1974 this had declined to 21it. The main reason for the decline was tho use of petroleum based products for cooking such as gas or kerosene and also electricity generatat by fossil fuels. Once again charcoal has become important for cooking because of increasing costs of LPG, kerosene and electricity.

---Page Break---

One important consideration as regards charcoal ts taproveaents

in design of the coal pot so that its efficiency could be improved. Another

gonsideration io the preservation of our forest resources. The use of forests

for the production of charcoal could soon have an effect on the ecasysten,

ros being denuded at a high rate. The coastland

Of Guyana ts abundant with rice waste, coconut husks, sone of the rav materials

tused to aake "green charcoal", About 60 million coconuts are produced yearly

Fe Fepresenting a total of 10,600t of shelts (based on an average fresh melgnt

of 180 ge per each shell). Te is estinated that carbonization of the 10,160t"

Shell would yield 20,320 of charcoal.

Nos: of the forests in Guyana are of the Tropical Rain Forest type.

These trees are mixed broad leaf tropical hard voode. The voods vary fa,

density from about 400 kg/a? (STMARUPA) to as high az about 1000 kg/a3 (WAMARA) .

Practically all the woods in Cuyana ean be used as fuel. Generally,

fuelwood can be derived from:

() Trees that are defected;

(48) Stems left over from Logging operations;

(441) Trees cut tn the process of clearing land for

agriculture;

(Gv) Sawai wastes.

In 1981, 0.155 ailtion = of wood vas estimated to have been produced

4m Guyana, Also? in 1981, 0.062 million a? of board was produced. Ihe weston

fron these sawmills are about 0.011 million m of wood.

Firewood is used mainly for cooking (households and bakeries), and

for generating steam at sone of the saumille®

AGRICULTURAL WASTES

Tm Goyana, there are sany sources of agricultural wastes for the

Production of fuel gas, anong these are the folleving:

(Rice stra

(43) Baga:

(it) Manure;

(iv) ater Hyacinth,

---Page Break---

~~

Jn 1980, OLADE, the Latin Anerican Energy Organization, set up an ore apgtated Pilce Project to help develop BIOGK® as an Alternative Baer.) Sourcet®). ?Guyana entered into agreesent with OLADE to construct nige (9) Biogas Pilot Plants, based on the CHINESE, GUATEMALAN and MEXICAN types of BIOGAS DIGESTORS. These are nov being assessed and evaluated so a8 to determine their feasibility in the Guyanese socfo-cultural environsest.

Work with water hyacinth is also belag pursued at the Univeraity of Guyana. A pilot plant has been built ang the data will be available in July when ?the second stage of the project 1s completed. It is estimated That the wood waste and coconut husks could provide-hest and electricity by co-generation or gasification for sawnilling operations and surroumding communities. Large scalo use of vood would require energy plastations and thus the development of new skills. ?There is no intention in this part of Ehe paper to present the case for ecological balance in developing any new energy mechanise. To quote fron Georgescu = Roegen"s

s+ History affords us anple proofs that the price mechanism cannot defend our ecological intereste. The savage deforestation which at one tine menaced all the woods in the vorld was the result of the fact that the prices were "right". And it was not brought to a halt by the price mechanien but only dy the introduction of some quantitative restric tive rules. It was precisely because the prices of coal and oil were right after World War I that the automobile intustry turned to producing mannoth gasolene guzzlers while coal technology lagged behind and poverty spread in Appaluchia.

ECONOMIC CONSTD ERATIONS

Guyana's present economic situation makes it difficult to predict what our energy needs would be in the next ten years or nore. What can be said is that the presoat energy supply is unreliable, cannot meet denands and so affects production. Tie lack of spare parts because of the foreIgn exchange problen, and the high price of oil aggravates the problem.

What then should be the enerzy strategy for Cuyana to provide

economic development? In developing any energy strategy we mist sake sure

that our energy environnent is not dependent on petroleus,

points out the myths surrounding energy alternatives.

Georgeseu-Roegen!

---Page Break---

-u-

s+ Yat happens today is chat the solar collectors,

2 are produced with the help of cone energy

other than solar radiation ~~ primarily, with

the energy of fossil fuels. Consequently. at

Present, all direct uses of solar radiation

Tepresents parasites of the fossil fuel

Eechaology. That $s not all. If y) denotes

the fossil fuel energy consuaed in? the

Production of Xj solar collectors, we are

confronted uith"ehree alternatives: ¥y,?Yyp

<0 = 0, or > 0. In view of the

Asmense propoganda for the solar heated hones, we must hope that X1 "Yj, <0 is not trues

But the case must Tnot!? rest here; dats must

decide vhich alternative is actually true.

Cuyana's development of any energy alternative must be the saving

Of foreign exchange. In the case of sugar it may be tore econseient fa

soyvert 8 few factories to produce ethanol as a nixture for use in automobiles

and produce enough molasses to meet the export market,

Kendall> has developed an energy strategy for Guyana based on its

Fragen econosic environment. He used the Linder criterion of efficiency for

EIEOEE substitution as neans of saving foreign exchange. Hie rankiag of

?energy alternatives is given in Table 6, TAME 6

RANKING OP ENERGY ALTERNATIVES

cost | Prorie- | wee tevet | oppor- | cope per | coat

per | ability | Foreign of | tunity | 10° pens | per

UE | index? | exchanges | tmp. | cost of | (1980) in | kan

Subs, Gsm 6§) | subs. | tp.? | Gs & rate | year

Subs. | of snfla~

tion.

mro | 2 1 3 2 1 a 2

?wooo 2 2 1 1 2 2 1

Avcouo, | 3 3 2 a fa 3 3

---Page Break---

- ae

?The strategy proposed by Kendall involves -

- Hiydropover as a replacenent for all fossil fuel based

electricity;

? Charcoal as an export commodity and not as an import

substitute;

w= Restructuring of the transport sector to utilise alcohol.

In the long term it is obvious that Guyana's main energy base

WLLL have to be hydropower to promote economic development with Bionass

playing a subsidiary role. The majority of the population live in the

rural and hinterland areas and they will have to mike use of biomass as

their wain energy source. With our present social ant econoaic probleas

wwe have to be careful how scarce resources are allocated for the development of energy technologies. We choose those that are most cost effective

for thetr situation. Our priorities have to be clearly defined,

LONG-RANGE. ENERGY PLANNING

Jo arrive at any Long-term energy plan for Guyana the following

action fe necessary:

Analysis of the energy situation, to a great extent

this bas started,

w= Analysis of future trends in the energy supply.

== Selection of the method of investigation,

Preparing an energy model to handle the problea.

= Working the alternative long-tera energy paths,

condition, consequences ete.

?= Bvaluation of strategies and conclusions.

A systenatic methodology ie needed for deaand supply situation and

optimization of the investments being planned for the energy sectora would be

determined fron inforsation provided by the planning comission. Information

Provided wuld include production targets in physical unite in various sectors

of the economy

A wacro-energy model would have to include energy denand forecasting

models, energy supply sector models. The macro-cnergy should have as ite main

objectives, genoration of economic scenarios and oveio-econonte forec

tthe next tuenty (20) years.

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-be

ECONOMIC MODULE FOR THE GUYANESE ECONOMY

POONOWIC MODULE FOR THE GUYANESE ECONOMY

denand

oeray demaal forecasting | ?Er"., | Energy surly sector

module fora. | module

pee Jee

1, tndustriat Baerey Hlectricity production &

jv Tedustrial Boersy |

2. Resident int poe trangntssion model Hydropover

3+ Transport deaand soe | <Btises | yo. cowerciat roneuante

t = Sources, wood Charcoal

?4. Agricultural demand ona

vegetable and aniaal vastes,

odet

Hogas, solar & vind.

| |

Energy Consusption Energy input in the Energy conversion process (Investment

needs)

ENVIROMENTAL MOOULE

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ue

concussto%

To make any energy plan successful and hence achieve development

we mist tap our hunan resources. We must develop researchers with a broad

Fange of skills who vill have a basic understanding of the problea. In

the final analysis we ask ourselves several questions.

= Does the energy technology satch the particular

eed? .

== Can the technology survive in the national

econoay or local economy on its ovn merits

without external support.

?The people mist have confidence in the potential of the new technologies. Support sust be given so that the technologies reach the

rural and hinterland areas.

?There is urgent need for the generation of new energy technologies

to improve the lives of the people in Guyana. To achieve this the politicians

WALL have to work closely with the Engineers and Scientists in the Guyanese

comunity.

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1 ven

2 ben

2 bb

2 bn

2 bor

1 bb

1 ben

1 metric

1 metric

1 metric

2 metric

1 metric

-15-

APPENDIX

(CONVERSION TABLE

PETROLEDM PRopUCTS

Reconstituted crude

we

Casolene/aviation gas

Kerosene/Jet fuel

Gas oi1/Dieset

Fuel

Leo.

ton

ton

ofl /Bunker C

= 192.5 bs of Lec

cont.

= 24.0 x 10? joutes

ccnanconn,

= 28.0 x 107 joutes

Woon

= 16.0 x 10° joules

BAGASSE

7 7.9 x 10 soutes

0.967

0.691

0.905

0.977

1.004

1.083

3.92

4.48

2.29

1.29

doe

doe

boe

boe

doe

doe.

doe

boo

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a

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countries

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October 1981.

?2000000000000

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UPADI 82

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First Pan American Congress on Energy

CALIDAD Y CONTAMINACION AMBIENTAL,

DE LOS SUELOS DE PUERTO RICO

Por

Juan A. Bonnet, padre

Centro para Estudios Energéticos y Ambientales

Universidad de Puerto Rico

San Juan, Puerto Rico

August 1982

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CCONTENIOO

CALIDAD Y CONTAMINACION AMBIENTAL DE LOS SUELOS DE PUERTO RICO*

Intercanbio de cationes de los suelos

PROCESOS DINAMICOS DEL SUELO RELACIONADOS CON

EL AMBIENTE

Reacciones biolégicas

Las tres siglas 800, 00, ToC

CONTAMINRCION DEL SUELO APLICADA A PUERTO RICO

La quena anual de le cana oe azacar

La erosién del suelo

Efectos de las sales, minerales y metales

de Tos suetos 10

Efecto ecologica y fsico u

Efecto de las construcciones 12

Desperdicios s6lidos 3

Plaguicidas persistentes y agentes

infecciosos de los suelos 16

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CALIDAD ¥ CONTAMINACION AMBLENTAL

DE LOS SUELOS DE PUERTO RICO

Por

Or. Quan A. Bonnet, padre*

EXTRACTO

El ambiente de tos suelos consiste de aire, agua, s6lidos minerales y orgEnicos y microorganismos. £1 oxigeno, el biéxido de carbono, el moviniento de las aguas, los particulados: arena, Timo, arcillas las reacciones bioquinicas de las bacterias, la acidez, 1a alcelinidad, y 1a erosién juegan un papel importante en el ambiente de Ta calidad de los suelos y en su sistema dinémico.

El impacto del honbre en el menejo deficiente del suelo y su so como cementerio de los desperdicios s6lidos téxicos de las industrias y poblacién y de aguas contaminadas contribuyen a su

contaminacién.

Los suelos de Puerto Rico se han clasificado ahora bajo un nuevo Sistema Taxondmico que facilita su mejor evaluacién y diat nostico de sus Timitaciones como sigue: Orden, Suborden, Gran Grupo, Subgrupo, Familia, Series, Las 163 Series de Suelos locali- 2adas en 311 mapas de suelos, escale 1:20,000 se evalcan ahora o bese de las cualificaciones y caracter'sticas de las cinco Catego- ras superiores y se reducen a nueve Ordenes: Alfisol, Entisol, Histosol, Inceptisol Mollisol, Oxisol, Spodosol, Ultisol, Vertisol. Es mis facil discutir este tens a base de 9 Ordenes en ver de 163 Series de Suelos.

*Profesor @ Investigador Enérito, Recinto Universitario de Mayaguez

Contribuctén del Centro para Estudios Energéticos y Anbientales de Ja Universidad de Puerto Rico,

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INTRODUCCION

El suelo es un sistema o recurso natural dindmico que con-
siste fisicamente de una mezcla porosa con un promedio mitad s61 ido y otra mitad en partes iguales de aire o atmbsfera y agua; la parte sblida consiste de un promedio de 45% de materia mineral y de St de materia orginica muerta y microorganismo vivos y activos: hongos, actinomicetos, bacteria, algas, protozoarios, lombrices y neni todos (Fig. 1).

EL AIRE DEL SUELO

E1 oxtgeno del aire del suelo es indispensable pare el proceso de respiracién de las raices de las plantas y los microor= ganismos. £1 oxYgeno se toma; una parte del aire y otra del que esté soluble en el agua. La mayorfa de las plantas requieren para su crecimiento normal une zona radical oxidante rica en oxigeno, no una zona reductora pobre o carente en oxigen.

La composicion del aire de los suelos porosos com los arenosos puede subir igual al de 1a atmbsfera; 20.97% de oxtgeno y 78.09% de nitrogeno; generalnente tiene 0.25% de bidxido de car- bono; ocho veces mayor que el de la atmisfera y concentraciones algo mis altas de metano y de sulfuro de hidrégeno producto de Ta escomposicion de la materia orginica por Tos microorganismos. £1

contenido de oxigeno baja considerablenente a 10%; a veces @ 2%; en

algunos suelos que tienen mala aeracién causada por un bloqueo de

Ja difust6n gaseosa producida por las Muvias. £1 contenido de

bibxido de carbono del aire del suelo puede subir de 1 a 5% en un

lima templado y haste 10% en el trépico en un suelo orgénico

durante e1 verano. £1 aire del suelo es mis rico en humedad que el

de la atndsfera; 12 hunedad disuelve pequenas cantidades de varios

gases. Los coloides del suelo retienen por absorcién en su super=

ficte cantidades de ciertos gases. La composicitn fisica del aire

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del suelo no es constante en su perfil o corte vertical; es afece

tada por el espacio poroso aprovechable, las reacciones bioquini-

cas, el intercambio gaseoso, 1as inundaciones y las fluctuactones

del nivel freatica. Podemos decir que hay una relacién inversa

entre los contenidos de oxtgeno y bi6xido de carbono en el aire del

?suelo; el oxigeno disminuye cuando aumenta e1 bidxido de carbono.

EL_AGUA DEL SUELO

El agua del suelo se divide fisicamente en cuatro grupos:

(1) Higroscépica -- Es e1 agua de la atnisfera absorbida por los

coloides del suelo; es retenida enérgicamente y no es

absorbida por las plantas porque no se mueve.

(2) Capitar No-absorbida -- Lena Tos espactos micro-porosos del

suelo; circula con dificultad en el suelo porque

también es reteniga enérgicamente y no es absorbide

por las plantas.

(3) Capiiar absorbida -- Es e1 agua retenida por el suelo en

tiempo de sequia por los poros de tamafio intermedi

del suelo; se mueve por difusi6n capital y es absor=

bida por las plantas.

(4) De gravedad -- Es e1 agua que Tena monenténeamente 10s poros

mms gruesos del suelo después de las Tluvias que es

removida por el drenaje.

EI drenaje 0 exceso de agua se renueva de dos manerass por:

(1) Desague -- Escurrimiento superficial.

(2) Percolactén -- Movimiento descendente que libera 1a huneded

---Page Break---

superflua_en la superficie del suelo y parte superior

del subsuelo,

La pereolactén produce normalnente pérdida de sales solubles

Por lixiviactén en los suelos que puede agotar ciertos nutrimentos.

Las pérdidas por desague incluyen no s6lo el agua y los nutrinentos

sino tanbién cantidades apreciables del suelo por erosién.

La solubilidad del oxtgeno y del bidxido de carbono en las

Soluctones del suelo se caracterizan por una concentracién mucho

mnis d8bi1 de oxigeno y una mis alta del bibxido de carbono que en

Ja atmésfera del suelo. La cantidad mixima de oxigeno en 1a

Soluctén del suelo es 6 milfmetros por Vitro a 20°C y mucho menos

fen aguas estancadas que no se renuevan y son ricas en materia

orginica reductore; a tenperaturas altas del trépico pueden redu-

cirse @ cero, Inversamente; las aguas frias ,renovables pobres en

materia orgénica pueden contener una cantidad de oxigeno soluble

mayor de 6 mililitros por litro,

LA CONSTITUCION MINERAL DE LOS SUELOS

La porcién mineral de los suelas es variable en dimension y composicién; consiste por su tamafio en una conbinacién de tres particulas: Grueses como 1a arena con didnetro de, .05 a 2.01 finas como el limo, de .002 2 .0Snm; y muy fina como Ta arcilla, menos de .002nm. Existen doce clases de textura en 10s suelos segin 1a proporci6n de arena, lino y arcitla.

METEORIZACION

Las particulas se producen por la descomposicién 0 meteor!-zactOn ayudada por 1a temperatura, 1a Tuvia, la nieve y el viento de as rocas tgneas con el granito, la diorita, el besalto, y 1a andesita; las rocas sedinentarias con 1a arenisca, 1a piedra

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caliza, la cuarzita, 1a pizarra, y el mirmol. Las partfculas se componen de minerates primarios y secundartos que contienen stli-cio, hierro y aluminio con o sin bases: calcio, magnesio, potasto, Sodio y otros minerales secundarios como le calcita, 1a dolomita, Sxido de hierro y de aluminio. La fracción fina de la arcilla se compone de minerales ?importantes com 1a Montnorillonita, Tas Micas, la Caolinita, y una Mezcla de minerales residuales, en proporciones variables que resultan de un proceso de meteorizacin mis 0 menos activo.

LA MATERIA ORGANICA DEL SUELO

La materia orginica del suelo se forma de los residuos que dejan las plantas, los animales, y Tos microorganisnos, a} morirse y desintegrarse. Tanto los tejidos de los vegetales como la de los ?animales estan constituidos por un 50%, en pronedio: de carbono, Que incluye el almidén, los azicares, 1a celulosa, 1a hemicelulosa, Te Neninas tos Sctdos organicos que contienen algo menos del 40%, ¥ as grasas y ceras con més del 60%. Los procesos quinicos com Son la reaccién del carbonato calizo con los Scidos de? suelo y 1a exudacién en el proceso de respiracién de las plantas y sus ratces contribuyen también a Ta liberacién del gas anhidrido carbénico, COp5 pero le cantidad es inferior a 12 que 14beran los organtsnos. del suelo al descomponer la materia orgénica fresca. £1 humus es Ja materia orginica descompuesta; més o menos estable, que le da el Suelo un color oscuro; @ veces, negro y un mayor potencial de fertilidad.

LOS COLOIDES DEL SUELO

Hay dos grandes tipos de colotdes en los suelos segin su

carga electri

(1) Coloides electropositivos o basoides -- Tienen carga positi-

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vas son los hidratos de hierro y aluminio 0 sesquidxi-

os conpuestos de bases d8biles; se dispersan en medio

Acido y floculan en medio alcal ino.

(2) Coloides electronegativos 0 acidoides -- Tienen carga nege~

?tives son los mis abundantes en los suelos; son Tas

arcillas mineralégicas, los geles minerales complejos

y los acidos himicos; tienen propiedades acidas débi-

Tess se dispersan en medio alcalino y se floculan en medio acido.

Algunos coloides del suelo son anfotéricos; cambian de signo un pH @ punto isoeléctrico determinado. Ejenplo; el mineral Caolinita en la fraccién arcilla cuando se electrolisa @ un pH 7.0 neutral, tiene carga negativa;s a pH 4.0, su punto isoeléctrico, canbia de signo y 2 menos de 4.0 es positive,

Intercanbio de Cationes de los Suelos

Los cationes electronegativos del suelo y el humus retienen alrededor de sus moléculas los fones de hidrégeno H+ y los catfones etélicos: Calcio Ca++, Magnesio Mg++, Potasio Kt, Sodio Nats y cantidades débiles de otros jones: Anonio NHgt, Manganeso Matt, Cobre Cut+, Zinc Zn++; y el Aluminio Alt++ que es abundante en Tos Suelos Acidos. Todos estos ones tienen e1 poder de intercanbios pueden participar en un proceso de intercanbio reversible con los jones positives que existen en 1a solucién del suelo existe un equilibrio entre los iones intercambiables retenidos por el com plejo absorbente y los jones en la solucién del suelo. £1 equili- brio no es estaticos es cinético.

PROCESOS DINAMICOS DEL SUELO RELA

VADOS CON SU AMBIENTE

Los procesos dindmicos de1 suelo relacionados con 12 calidad

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de su ambiente envuelven reacciones quinicas, fIsico-quimicas, y biolégicas. Las reacciones quimices son tres: (1) solucién de minerales y sales en e1 agua del suelo; (2) oxidacién o conbinacién del oxtgeno con otra sustancia en el suelo y (3) reduccién o emocién de oxigeno de una sustancia en el suelo. Las reacciones fisico-quimicas importantes son el Intercanbio de Cationes y la de os Coloides del suelo com se ha explicado.

Reacciones Biolégicas

Las reacciones bioldgicas en los suelos son producto de una combinación de enzimas y microorganismos del suelo que se clasifican en dos grupos: (1) Autétrofos, cono las algas y ciertas bactertas que producen su propio alimento igual que las plantas obteniendo Ta energia oxidando una sustancia espectfica y (2) Heterdtrofos, que no poseen la facultad de nutrirse a st mismo, Sino que toman sus nutrinentos y energia de los restduos orgénicos. Hay algunas bacterias que son facultativas autétrofas que pertenecen a anbos grupos.

Las bacterias autétrofas espectficas pertenecen a seis Grupos: nitrificantes, sulfoxidantes, ferroxidantes, hidrégenoxi~ dantes, metanoxidantes y manganesoxidantes. Las bacterias heterétrofas fijan el nitr6geno del aire y descomponen les protetnas y compuestos orginicos nitrogenados a1 grupo amino, Ny; al gas ?amonfaco, NH; por los procesos de aminizacién y amonificacién espectivanente. Desnitrificacién es el proceso por el cual ciertas bacterias especiticas reducen el nitrato, ?} nitrito, 0 el nitrégeno molecular que se pierde como gas K, en condiciones anae~ robias 0 sea, ausencia de oxgeno. De igual modo ciertas bacterias espectficas reducen los sulfatos, sulfuros y tfosulfatos al gas HS, sulfuro de hidrégeno.

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Las Tres Siglas B00, 00, ToC.

Estas tres siglas representan respectivanente tres palabras fen inglés: Biological Oxygen Demand, Dissolved Oxygen, Total Organic Carbon. Los procesos que degradan y convierten las sus- tancias solubles en Tas aguas polutas del suelo y en los desperdi- cos orgénicos lanzados como basura a los suelos son extrenadanente complicados. Tiene que haber suficiente uxigeno en el afre y la solucién del suelo para reaccionar quimicamente con el carbén total de los desperdicios orgénicos y completar la l1beracién del gas bi6xido de carbono, La zona radical aerobia de la atmbsfera del suelo se convierte @ una anaerobia debido a1 agotamiento del oxtgeno en su ambiente, produce asfixia y muerte de as plantas.

CONTAMINACION DEL SUELO APLICADA A PUERTO RICO

La contaminaciGn anbiental es algo muy antiguo que viene causando malos efectos a los suelos y Tas plantas desde hace millones de alos con més 0 menos intensidad. Muchas especies de plantas, animales, aves y peces han desaparecido o disminuido en omero por efectos ecolbgicos que han acelerado la erasién de extensas Greas terrestres. Los desperdicios s6lidos minerales y orgénicos lanzados por el hombre y ios animales, las industrias y construcciones han contribufdo @ 1a contaminacién de los suelos. Sales acunuladas por procesos naturales y polvo fino volados por los vientos en zonas desérticas han producido infertilidad en muchos suelos. La parte mineral del suelo es materia muerta; pero Ja orgénica incluye microorganisms que tienen vida. La reaccién de algunas plantas @ los efectos indeseables de Ta conteminacién ambiental es un buen indice que senala que el suelo puede haber Sido también afectado. Muches cosechas y variedades de plantas son daftadas cuando crecen en un suelo contaminaco, otras son afectadas 2 menos grado por ser més tolerantes a los e%ectos téxicos de Ta

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contaminacion. Cémo se contamina el aire del suelo, cuéndo el suelo est& conteminado y cuéndo actéa como descontaminante son topicos de interés,

La Quema Anal de la Paja de Cana de

En Puerto Rico se viene quemando parcialmente la paja resi-
ual antes de Ta cosecha de cana desde 1950 y en su totalidad en 1a
Gtima década. Una tonelada de caha produce aproximadamente un
Promedio de 25% de paje en cosechas normales. En la zafra del 1978
se molieron 2.84 millones de tons cortas de caha, se quend alrede-
dor de 710,000 tons de paja. En 10s anos anteriores la producetén
fue de 22 10 veces mayor. El aire se contamina anualmente en
Puerto Rico durante la zafra de azicar con enormes cantidades de
los gases biéxido de carbono, mondxido de carbono, dxidos de
nitrégeno y azufre que se Tiberan en la quema de los campos pre~
cosechados. Los procesos biolégicos del suelo que influyen en Tas
elaciones normales de carbono-nitrogeno y de nitrégeno-azufre son
afectados por 1a quena anual; el hums del suelo se destruye y se
reduce su fertilidad,

La Erosién de} Suelo

Los sedimentos que provienen principalnente de la erosién de
Tos campos cultivados, de Tas construcciones de caminos, carrete-
vas, urbanizaciones, derrumbes, etc, Ienan y obstruyen los lagos,
enbalses, rfos y canales, aumentan el costo de la purificacin de
Jas aguas para consumo, interfieren en los procesos manufactureros,

destruyen las cosechas en tiempo de inundaciones, reducen 1a vida de los peces, ensucian las playas y los balneartos y absorben fosforo, plaguicidas y agentes quimicos indeseables. La rapidez del movimiento de Tos sedinentos por erosién depende de 1a topo- grafia, el declive, 1a Mluvia, su intensidad y la velocidad del Flujo de Tas aguas. La cantidad de sedimentos Iiberados depende de

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la propiedad erosiva de las series de suelos en las cuencas hidro- gr8ficas. La erosién de los suelos se divide en dos tipos princi- pales: la erosién laminar que ocurre cuando se pierden Tas capes superficiales del suelo o subsuelo y 1a erosién por cércavas que ?ocurre cuando se forman zanjas profundas o barrancos.

£1 f6sforo tratdo por los sedimentos y los nitratos remanen- tes de los fertilizentes aadidos al suelo pare alinentar 1a cosecha contribuyen al mayor crecimiento de 1as algas, los jacintos ¥ otras plantas acuéticas y producen 1a eutroficacién o muerte de Jos Tages. 1 US Geological Survey? informs en novienbre de 1981 que con 1a excepcién de 1a Laguna Tortuguero y el Lago Guaja~

taca las estaciones monitoras establecidas en las corrientes Fluviales de Puerto Rico exceden 1a concentración máxine estable-ida de 0.01 niligramo por litro de fósforo total que evita Ta eutroficactén (Fig. Z).

Efectos de las Sales, Minerales y Metales de los Svelos

Las sales comunes, los ácidos, las sales de los metales pesados, los cianuros y el gas apestoso, sulfuro de hidrógeno, contaminen os suelos. Se originan de depósitos naturales, del drenaje de aguas acidas de las minas, de los procesos industriales, de las aguas negras y las aguas de riego. Tienen afecto dafino en Jas cosechas, pueden ser t6xicos a os humans, Tos animales y las aves, producen malos olores y sabores en las aguas y pueden corroer el equipo mecánico y las tuberias metálicas de agua y drenaje. La agricultura sobrevive en una zona rida bajo riego si se establece un belance favorable de las sales disueltas que entran y salen en el Grenaje.

Bonnet? explica en su Vibro: ?Edefclogte de tos suelos Selinos y sódicos", publicado en 1960, el efecto de las sates en

Jos suelos. Bonnet y Brenes? informaron en 1988 que en 1a zona

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Semidrida del Valle de Lajas al suroeste de Puerto Rico hay 8,835 acres de suelos contaminados con sales en el Distrito de Riego que cubre 19,769 acres. Esto se debid a sales del mar atrapadas en el subsuelo por efecto de cambios geol6gicos. . Bonnet y Roberts? informaron en e1 1967 que hay 5,756 acres contaminadas con sales en el area de suelos orgénicos en el Cano Tiburones en Arecibo, al norte de Puerto Rico. La contaminaciOn se debe a filtracién del agua del mar debido a 1a topografta baja y al manejo inadecuado de le hidrologia de Ta regién. Los metales pesados como el cobre, mercurio, cadmio y plono son noctvos a los seres humanos, las plantas y Tos peces pero no hay suficientes pruebas para sostener que contaminan los suelos.

Efecto Ecol6gico y Fisico

Estudios hechos por Bonnet y Roberts? en 1968 de las finces Propiedad de la Autoridad de Tierras de Puerto Rico en Rio Grande-Lotza, revelaron un canbio ecolégico de una serie de suelo a otra debido a contaminacién de1 agua del mar. Un area de 92 acres en Ta finca Blasina clasificada en 1a década del 1940 como e} tipo de suelo, Coloso franco-limo arcilloso, que era productive, cambié @ otro tipo improductivo clasificade como, Pihones franco-1imoso Contaminado con sales. £1 suelo, Coloso, estuvo sembrado con caha de azicar hasta 1952, protegide por un sistema continuo de bonbeo y un dique de arcilla pare evitar las filtraciones del agua de mar durante el alza de las mareas. La bonba dej6 de funcionar después de 1952. £1 canbio ecolégico ocurrié en un perfodo de 10 afos. Le vegetacién natural cembié 2 una tolerante a la sal y a unos Grboles de mangle. Una fotografia tonada en 1952 comparada con otra tomada en 1962 revela el canbio ecolagico.

El cambio ffsico se observd en un Srea del tipo de suelo, Coloso franco lino arctiloso, de dicha finca Blasina senbrada de

Pastos. Las huellas de Jas pesuias y e1 peso del ganado y 10

one

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compacto que estaba el suelo debido a su estado himedo excesive 10 hizo mis impermesble. £1 suelo sufrid una alteracién 0 contamina~ cin de su estructura normal superficial. La nivelacién, el arado y el uso de maquinaria pare roturar los suelos deben hacerse con cuidado para no afectar su estructura.

En los trépicos himedos el corte de los bosques para dedicar el area 2 cultivos de cosechas productivas produce cambios de textura y estructura en los suelos debido a1 impacto de Tas gotas de Muvia que huredecen e] suelo a1 cesar 1a estaciin seca.

Efecto de las Construcciones

Las estadtsticas sin publicar del Servicio de Conservacién de Suelos de los Estados Unidos en Puerto Rico revelan que entre 1958 y 1967 se dedicaron 17,698 acres de suelos a construcctoness un pronedio de 1770 por afc, Estimo que hasta 1961 la cifra debe haber subido sobre un minino de 42,478 acres. En cada acre se pueden establecer entre 6 y 9 edificios para residencias; cade una se Teva aproximadamente cinco yardas cibicas de hormigén que pesan 100 toneladas cortas. En las 42,478 acres se han depositado aproxinadamente de 25 2 38 millones de toneladas de hormigin. Estas construcciones yacen sobre muchas de las mejores tierras agricolas planas 0 con poco declives estén contaminadas irreversi-blemente con concrete como se puede apreciar en las Vanuras costeras e interfores. Este planificactén inadecuada ha afectado nuestra produccién agricola y producido canbios en la hidrolagia de Ta regién que han contribufdo a as inundactones de los sitios bajos en los perfodos intensivos de Muvias, Por consecuencta ha subido el nivel freatico 1o que ha afectado en muchos sitios 1a buena aeracion produciendo agotemiento de? oxfgeno en 1a zona radical, afectando la calidad de la cosecha y el rencimiento de aalicar de la cafa. La construccién de algunas partes clevadas de carreteras en Puerto Rico han cortado el crenaje natural de varies

le

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fincas productivas afectando su hidrologta y reductendo su potencial agrfcola y productivo.

Desperdictos sBlidos

En 1972 1a Junta de Calidad Anbiental infornd que se recogte lun promedio de 5.7 millones de libras de basura; un pronedio de dos Vbras por persona. En 1982 ef promedio se estima entre 4 y 5 Vibras por persona. En 1972 en 75 municipios se quemaba més de 60% de Ta basura en 65 vertederos abiertos, pequetos, que cubrian en su mayor parte 5 acres o menos; hay uno de 19 acres. £1 mayor} el de San Juan, cubria 163 acres. £1 canén de San Cristobal, un paisaje natural my atractivo, se usaba como vertedero de basura en los municipios de Aibonito, Barranquitas y Orocovis. Habla 18 verteeros @ To largo de los rios. Un censo real{zaco en 1969 denostré de 1,344 mint-basureros a to largo de las carreteras principales, fen solares yermos y otros sitios vulnerables al fuego; son focos de moscas y ratas que contribuyen a contaminar las aguas fluviales. La quema de estos desperdicios contamina el aire. £1 Departamento de Salud considera que estos vertederos abiertos son fuentes que contaminan 1a salud.

La dunta de Calidad Anbiental ha establecide un sistema de elleno senitario para 1a basura bien planificado enterrsndola en capas finas dentro de un hoyo; cada capa se afirma con méquina hasta llegar @ uno altura de diez pies; se cubre después con una capa de tierra firme también apisonade; 1a cape superficial se cubre con 2 0 3 pies de tierra bien apisonada. Un relleno sanita- rio hecho a 1a medida no tiene problemas de olores, moscas y rates. el nuevo relleno sanitario de San Juan comenzd en 1958; tos de Bayamin y Aguaditla en 1969, 10s de Caguas, Cidra y Cayey en 1970, En 1982 hay 50 vertederos establecidos en Puerto Rico; 36 adyacen- tes a las fuentes fluvieles de los 46 rios y 9 en Tes cuencas hidrogréficas (Fig. 3).

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E1 US Geological Survey® preparé en cooperacifn con La Junta de Calidad Anbiental de Puerto Rico y publicé en 1962 Tos resulta~ dos obtenidos en un estudio hecho en 1977 sobre los 50 vertederos sanitarios establecidos: se basa ene! efecto potencial sobre la degradacién de los recursos de agua. La Iuvia es abundante; ?excede 1,500mm por afio en 40 vertedetros. Se tomaron nuestras de aguas para andlisis quimico y fisico cerca de 26 vertederos loc: Tizados en Tos pueblos de Aguada, Aguas Buenas, Aibonito, Barran- quitas, Bayanén, Caguas, Ceiba, Fajardo, Guayama, Guaynabo, Gurabo, Humacao, Jayuya, Juncos, Maricao, Mayaguez, Naguabo, Naranjito, Grocovis, San Germin, San Lorenzo, San Sebastién, Sante Isabel, Utuado y Villalba. Las muestras de aguas se tomaron en la parte alta del rio con agua fresce y en la parte baja que recibié los lavados de los vertederos. Los pardmetros quimicos analizados que fueron significativos en 1a determinacién de la contaminacién de Jas aguas superficiales y los acuiferos son nueve: Bicarbonato, Calcio, Cloruro, Oxigeno Disuelto (00), Magnesio, pH, Potasio, Sodio y Sulfato. Los pardmetros fsicos determinados son tres: Temperatura, Conductancia Especifica y Descarga.

Veinte y cinco vertederos indican un potencial significative de filtracién contaminante y 21 son relativamente permeables. Los resultados indican que el pardmetro de Conductancia Espectfica es el mejor indicador de filtractén de sales solubles de los vertede- ros a las fuentes fluviales; mide le habilidad de Ta solucién en conducir una corriente eléctrica; su valor aumenta con el aumento de 1a concentracin de los fones en soluci6n y est& relacionado con

Va concentracién de 10s sélidos solubles. Las fuentes fluviales

frescas, no contaninadas en Puerto Rico, tienen un valor de Con-

ductancia Espectfica de 400 mitinhos por centinetro, Estes inves-

tigactones contindan @ largo plazo.

Los contaminantes lixiviados pueden incluir netales tOxicos,

fenoles, patdgenos, etc; pero estos andlisis son algo nas conpli-

a1

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cados y no deben incluirse en un programa rutinario de monitorta.

Estos andlisis y los records de descarga pueden hacerse cuando los

anlisis rutinarios indican las estaciones que pierden s6lidos

solubles por filtracton - lixiviaci6n.

En 1979 las petroquimicas © industrias Quinicas Aliadas y las

farmacelticas eran las més importantes en Puerto Rico. La mayorta

de estas industrias estén localizadas en las reas Manati-Sarcelo-

neta, Humacao-Yabucoa, y en 1a Costa Sur, Cada area est afectada

or sustanctas téxicas mayores que afectan la salud piblica y 1a

calidad del ambiente. La Junta de Calidad Anbiental de Puerto Rico

inform: ?En 1970 en el area de Guayanilla en la Costa Sur, el

Cloro liberado de un complejo quimico, 1a soda céustica, el glyco?

etileno y el cloruro de viny? causaron problemas de contaninacién, En 1973, en Bahta Sucia de Cabo Rojo, residuos de aceite derranados Por un barco petrolero destruy mucha de la flora y fauna de la Playa que causaron problenas y gastos serios de limpieze. En 1978-79, 1a Quebrada Corozo de Hunacao se contaminé con mercurio exudado por una industria quimica; se produjeron altos niveles de mercurto en sus aguas y murieron 20 vacas. fn Dorado, algunos empleados que trabajaban con hormones y pildoras para el control de Je natalidad fueron afectados por cambios en sus actividades sexvales. En Juncos, algunos enpleados se contaminaron con el mercurto perdido en la preperacién ge termémetros que al romperse se echaban en un basurero lavado pro las Muvias que contaminaron Vas aguas de una quebrade adyacente. En Bayanin y Baranquitas, 10 Fotura de una tuberfe que conducta gasolina la lanzé y contamind Jas corrientes de aguas adyacentes",

Los desperdicios industriales Viberados de los ingentos azucareros de Puerto Rico: Cachoza, producto de los filtros de Prensas Scidos y soda céustica usados para limpiar las incruste-Cfones de las tuberias de los tachos y evaporadores; las mieles y

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Jos guarapos fermentados han destruido gran parte de los mangles que han protegido las costas de la erosi6n marina y servido coro refugio de ostiones comestibles. Muchos Srboles de mangles han muerto por asfixia o falta de oxtgeno; esta especie igual que la planta de arroz tienen 1a propiedad especifica de que el oxtgeno atnosférico circula de las hojas por los tallos hacia las ratces y Proven oxfgeno para la respiracién del sistena radical que crece fen suelos enchunbados 0 en un ambientes anaerobio agotado de oxtgeno. La descomposicién de los desperdicios orgSnicos por los microorganismos anaerobios de los suelos se detiene porque Ta materia orgémica al desconponerse compite con las raices de estas plantas en el uso del oxtgeno disponible disuelte en las aguas del suelo y en el de su atmésfera, La Autoridad de Energia Eléctrica de Puerto Rico inform en 1972 que quedaban aproxinadamente 16,500 acres de mangles de as 65,000 que habian originalmente,

El Estado Libre Asociado de Puerto Rico a tenor con Ta Ley Federal Nim. 94-580(RCRA), segin enmendada y la Ley Nom. 9, Ley Politica Anbiental, segin ennendada, se propone actualizar el Plan Comprensivo para e? Maneso de los Desperdicios S6lidos aprobado en el ano 1973.

E1 plan estate! estard disenado para considerar todos los desperdicios no peligrosos y peligrosos que se generen en Puerto Rico y que presente efectos adversos potenciales @ la salud piblica y el ambiente; 1a planificacién seré a corto y largo plazo de conservacién y recuperacién de recursos.

Plaguicidas Persistentes y Agentes Infeccigsos de los Suelos

Los plaguicidas mis persistentes son los insecticides del tipo de hidrocarburos clorinados como el DOT, aldrin, dieldrin, hheptaclor, lindano, etc. Los insecticidas fosforgémicos com el malaciOn, paract6r, etc. y ios del tipo carbamato, se desconponen

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répidamente. La mayoria son descompuestos por los microorganismos del suelo; algunos son my persistentes. Los plaguicidas persisten mayor tiempo en los suelos que tienen un alto contenido de materia ?orgdnica que en los suelos minerales y arenosos. ?1 plaguicida es menos efectivo en un suelo orginico y "muck" con alrededor de 50% de materia orginica que en un suelo erenoso. Los factores que afectan Te acumulactén de los plaguicidas en los suelos son: el Plaguicida en sf, su concentracion y mBtodo de aplicacitns 1 tipo © serie de suelo, 1a humedad, 1a tenperatura, el cultivo, los microorganismos, e1 movimiento del aire y del viento y las cosechas ue cubren el suelo. Los residuos de 10s plaguicidas persistentes Permanecen muchos aftos en los suelos, contaminan los microorganis-

MOS» pasan a la cosecha y a le cadena de alimentos. Su larga Persistencia en los suelos es motive de preocupaciéns pues se acunulan en las lonbrices en concentraciones de una parte por MINI6n, en tos peces y en los tejidos grasosos de Tos animales y Jas personas.

Los plaguicidas son importantes para defender 1as cosechas de os ataques de insectos, de las enfermedades y de la conpetencia de Vas malas yerbas, No deben eliminarses pero su aplicacién debe controlarse pare evitar su concentracién en los alimentos que Producen las cosechas. Dubey informd que los fungicicas: maneb, Binab, y de cobre tribésico, aplicados a una cosecha de tonates sembrada en una finca de la Central Aguirre al sur de Puerto Rico en 1968, contamind al suelo. Una proxima cosecha de cana de azdcar Crecié con mucha dificultad, se marchits y aurio,

Los agentes infecciosos que habitan tos suelos: los virus, Vas bacterias y Tos honges, tienen su origen en las aguas negras, en Tas cosechas enfermas y en los desperdicios de aninales, mata eros y tenerias.

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EL SUELO COMO DESCONTAMINANTE

Weber? ha informado que Tos suelos bien drenados ofrecen condiciones favorables e los microorganismos si se mantienen himedos para que estos degraden biolégicamente de 280 2 336k9 de ?oxigeno por hectirea igual a 250-3001b por acre, durante e} tienpo ?que dura una cosecha. Un volumen pronedio de 473,0001bs de aguas negras; es decir 125,000 galones, 403 metros cibicos 0 0.8 de acre-pie, contienen 136.2kg 0 300 Mbras de oxigeno. Parisek y otros® informaron en 1967 que los excelentes estudtos realizados en Je Universidad de Pennsylvania denostraron que los afluentes de aguas negras contaminadas son beneficiosas cuando se usan para el vriego de cosechas en suelos bien érenaéos,

EL_NUEVO SURVEY DE SUELOS DE PUERTO RICO Y SU CLASIFICACION TAKO-NOMICA

Un Nuevo Survey de Tos Suelos de Puerto Rico se ha terminado. Se han clasificado 163 series de suelos distritufdas en 311 mapas escala 1:20,000. Los suelos se han reclasificado en seis catego fas taxondmicas: Orden, Suborden, Gran Grupo, Subgrupo, Familia y Series. La categorfa Superior: Orden, se divide en 9 grupos:

Alfisol, Entisol, Histoscl, Inceptisol, Mollisol, Oxisol, Spodosol , Ultisol y Vertisol. Las letras subrayadas identifican las Ordenes fen las tres categorfas inferiores, La nomenclatura usada para las Categortas y sus divistones taxonémicas se describen en mi trabajo: ?Evaluacién de 1a Nueva Clasificactén Taxondmica de los Suelos de Puerto Rico?, sonetida para publicacion al Colegio de Ciencias Agricolas Recinto Universitario de Mayaguez.

Las Series clasificadas en las Ordenes: Inceptisol y Ultisol con declives entre 20-60° son afectaces por Ja erosion. Les Series Clasificadas en los Subé-denes: Aqualfs, Aquents, Aquepts, Aquolls y Aquults tienen problenes ¢e dreneje cono lo indica el prefijoy

nie.

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Agu, que significe agua. Las Series clasificadas en los Gran Grupos: Calciaquolls y Calciustolls son excepcionalmente calcéreas; se reduce Ta absorcién del hierro por tas plantas que sufren y debilitan su crecimiento por el efecto de la clorosis por contami-naci6n del calcio.

Los 311 mapas de suetos publicados donde estén distribuidas Tas 163 Series de sueios clasificadas deben ser usados en un estudio planificado relacionado con la Calidad y Contaminactén ?Ambiental. Los mapas indican el declive y el estado de erosién de las Series. E1 Boletin 245 del Colegio de Ciencias Agricolas del Colegio Universitario, Recinto de Mayaguez, publicado en Junio de 1976, en inglés, por el Or. M.A. Lugo Lopez y Luis H. Riveram, bajo el titulo: "Taxonomic Classification of the Soils of Puerto Rico, 1975", debe de usarse para 18 conversién de las Series de Suelos en Yas Categorfas Taxondmicas Superiores: Familia, Subgrupo, Gran Grupo, Subarden, y Orden.

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| Congreso Panamericano de Energia

COMBUSTIBLES NUCLEARES Y DE CARBON

LA ALTERNATIVA A CORTO PLAZO PARA PUERTO RICO

Por

Modesto Iriarte

Centro para Estudios Energéticos y Ambientales

Universidad de Puerto Rico

?San Juan, Puerto Rico

?Agosto 1982

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COMBUSTIBLES MUCLEARES Y_DE CARBON

LA AUTERNATIVA A CORTO PLAZO PARA PUERTO RICO

By

Modesto Iriarte, Jr., Ph.D.

Centro Para Estudios tnergéticos y Ambientales

San Juan, PR.

TwrnoDuccrON

EL prograna federal para desarrollo de las fuentes alternas de energia tales

cono 1a energia solar, 1a energfa oceanotérmica, ae6lica y otras ha sido redueide

srandenente, £1 gobierno federal espera que 1a enpresa privada sea la responsable

por el des:

rollo de estas altemativas y ha reducido drésticanente los fondos fe-

derales pa

el desarrollo e investigacién de estas alternativas. No obstante, cree:

an si se hubiese continuado un programa vigoroso de investigacién y desa-

rrollo por el gobierno federal en el campo de 1as alternativas energéticas mencionadas,

fo serfa hasta de aquf al préxino siglo cuando podrfanos contar con una industria

privada altanente de:

rrollada y conpetitiva en el campo de las fuentes alternes de

energfa, An asf 1a magnitud con que las fuentes alternas de energie vendrfan a te

nar las ne

nidades de demands por energia en el caso especffico de Puerto Ricos

fa pequetia conparada con los requeriientos totales. Al presente Puerto Rico utiliza

anualsente sobre 60 millones de barriles de petrSleo para aus necesidades energéticas.

Si esta cantidad fuera producida por 1a energfs solar directa y presuniendo aproxima~

danente 5-1/2 kwhr/a? por fa de insolacién pronedio (valor tSpico para el sur de Puerto

Rico) y si presuninos una eficiencia de recolecci6a de 10% y un espacio de 3:1 para 1o-

calizacién de colectores solares (9 fts.? total por cada pie cuadrado efective de area

colectora) se requerirfan aprosinadanente 400,000 acres de terreno, Si esta enerefa

fuera a recolectarse por biomas

on una eficiencia de aproximadanente 3-42 10 cual es

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Fepresentativo del proceso de fotosfntesis el frea serfa 2-3 veces mayor. Toda plani-

ficaci6n de energética razonable para el uso de fuentes alternas de energia deberé

Limite

fignar quizas entre 10-15% a las fuentes alternas. Queda por lo tanto

1a problendtica de generar el grueso de nuestra energfa, 0 sea, entre el 85-90% del

total, Para subsistir a corto plazo el grueso de miestro consuno de petréleo solo

existen dos

Lternativas econdmicanente viables, a sal

1. carbéa

2. Energia Nuclear.

RECURSOS MUNDIALES DE CARBON ¥ URANIO

Las alternativas energéticas utilizando carbén o combustible U-238 representan

1 85z de los recursos de combustibles de! planeta para uso comercial innediato. La

figura 1 miestra una distribucién de los recursos y consumo relative a nivel mundial

de combustibles fésiles y mucleares (fusisn). La figura 2 nos muestra el cuadro de

los recursos energéticos mundiales incluyendo el uso de uranic 238 (reactor reproduc~

tivo) y energfa de fusiGn. La energfa solar representa una buena porcién de los re~

cursos disponibles, pero su uso a gran esca

como henos apuntado presenta dificulta-

des debido a su baja intensidad.

Para 1a substitucién innediata del petréleo que consuninos debenos pues erifocar

nuestros eafuerzos a la energfa nuclear y 1a energfa del carbén. Creenos que ninguna

de dos alternatives debe cerrarse.

EL estudio internacional Lanado "World Coal Study" MOCOL realizado con represen-

tantes de unas 17 naciones con un staff de 80 téenicos e ingenieros por un perfodo de

18 meses y publicado hace un afio incluye infornacién detallada de los recursos de

carbén en el mundo, pronSsticos de 1a denanda bajo varios escenarios de creciniento, aspectos anbientales @ interre

iciones de precio~demanda. Les figuras 1 y2 de

artfeulo armonitan con el estudio OC.

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INVERSION CAPITAL-UN_OBSTACULO

En el estudio titulado "Energy Analysis

snd Socioeconomic Considerations for

Puerto Rico? de mayo de 1980 del CEEA denostramos que ?1 costo de generaciGn de ener-

fa eléctrica en una central de carbén convencional resulta on costos de menos de 1a

itad que los de una central equivalente a base de petréleo o aceite combustible Bunker .

Iguaimente denostranos que los costos de yeneraciGn de una central nuclear resultaben

fen menos de 1a mitad de los costos de una central de carbén. La figura 3 nos ilustra

108 costos en milts/ewhr como funciGn del aio en que se conienza s operat 1a central.

Los costos son valores actualizados durante 1a vida de ta central.

Este andlisis fue realizado para centrales nuevas y afin es vélido.

Anbas alternativas, nuclear 6 carbén, representan cuantiosos fondos de inversiéa

fen 1a construcci6n de 1a central. Para el caso de 1a central de carbén de 400MM estina~

luna central nuclear de 600M aproximadanente $950

millones. Es

inversiones en una época de escasez de dinero y de reducciéa én 1a denanda por energfa eléctrica son éfficiles de justificar « pesar del rendimiento eco

némico que estas produscasn al substituir e1 aceite combustible come venos de 1a com

Paracién econdaica presentada en 1a figura 3.

Se requiere por 1o tanto una solucién intermedia que resulte on los costos as

dajos de inversién capital para substituir el petréleo utilizande carbén. Lu altema-

tiva que proponeacs va dirigida a 1a mfnina inversiGn posibie para canbios en 1a

calderas existentes en una compaifa eléctrica que esté localizada lejana a las fuentes

de abasteciniento de carbén.

Esta alternatiba consiste en mirar al cacbn como si fuera una forma 1fquida. Le

Alanarenos MAC (Mezcla de agua y carbén).

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SISTEMA MAC

sua y Carbéa)

En un sistena MAC todo flujo de carbén se realizar en una suspensida acuffera.

Gonenzando por 12 transportacién desde un punto seleccionado de eabarque en el pais

de origen, el carbén se pulverizars a eapecificaciones deseadas, se nezclarf con agua

y se hat

fluir a tanqueros de transportes aarinos en su forma Ifquida. £1 proceso

de alaacenaje en el tanquero envolverg una etapa de recirculacién y extracciGn del

agua de forma tal que el carbén a transportarse no estar en forma 1fquida y ms bien

bhimedo. AL Legar al puerto de d

einacién se inyectard agua nuevanente al tanquero

para hacer fluir el carbén en forma Liquids por tuberfas hacia los tanques de alma~

cenamiento. Wo se requiere un puerto especial, ni sistenas de acarreos especial

(conveyors)

De los tanques de alnacenaniento pasar a los tanques de servicio don-

ae

santendr una mezcla de 40% agua y 60% carbén pulverizado que se utilizaré para alinentar 1a caldera directanente.

EXPERIMENTOS MAC

Una serie de experinentos exitosos ya se han realizado con mezclas de agua y carbén en el Pittsburgh Energy Technology Center (PETC). Se ha encontrado que 1a lana de conbustiGn de una nezcla de agua y carbén al 40/60% resulta considerable- mente estable si el aire de combustién sobrepasa 25°F. £1 aire de conbustién de tuna caldera convencional de central eléctrica nornalmente sobrepasa los 500°F.

Rendinientos de conversiGn de carbén a calor en el proceso de cosbustién de una

nezcla de

{te tipo alcanzaron valores de hy

ta 96.1% sin realizar esfuerzos de opti-

mizacién. Estos experimentos fueron realizados en una pequefia caldera de 700H? gene-

rando 24,000 1ibras por hora de vapor saturado a 175 psig y una Liberacién de calor

47,100 stv/te3 far.

La granulaciga del carbén pulverizado se varié en el experinento. Un valor ef

pico fue 89% menor que 200 "sesh". (200 divisiones por pulgada)

Cuando se quenan s6lidos en suspensién es exencial que 1a mezcla de aire-conbue.

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tible contonga una cantidad apreciable de particulas extrenadanente finas para gurar una conbust Por otro lado para obtener 1a eficiencia mixina de com

bustin es necesario que se mantenga a un minino el ndnero de particulas ade gruesas,

Un 3-52 de particulas més gruesas que 50 ?nesh? pueden producir condiciones indesea

bles de "slagging? y pérdidas de eficiencia a pesar de que puedan existir las mejores

condiciones para quemar las partfcules finas.

La figura 4 nos presenta una distribucién de tanaio-partfculas del carbn uti-

Lis

fo en el experinento, £1 carbén utilizado fue Pittsburgh Seam Coal con el and~

Lisis indicado en la Tabla 1.

La reducei6n en eficiencia debido a 1a cantidad de agua envuelta es de alrede-

dor de 5-62. £1 carbén pulverizado se mantiene en suspensin « era

de agitadores

necesarios apropiados y recirculaciGn en los tanques. Se ha encontrado que es una condieién deseable que se mantenga el carbén lo nis Minedo posible para una flama es fable y uniforme. Esta condicién se consigue manteniendo 1a mezcla almacenada por varios dfas 0 acelerando el proceso por medio de 1a adicién de agentes humedecedores, La adiciéa on 0.5% del compuesto Lonar D acta como agente reductor de viscosidad logrando 1 efecto hunedecedor del carbén, En el cas0 que proponemos para Puerto Rico resulta ventajoso los varios dfas de transporte del carbén en tanqueros ya hunedecidos. Oeras fases del experinento concentraron en la determinacién ambiental y distri- bución de cenizas, E1 escape de cenizas hacia 1os supercalentadores de 1a caldera Puede controlarse variando el efecto de ?ciclon" ge le combustiGn, Mientras eayor el efecto de ciclon menor fue el arrastre de cenizas hacia 1a chinenea en los experi- mentos de PETC. Otro paréaetro importante que controla el arrastre de ceniza al ex

terior

4a granulaciGn del carbén pulverizado. Controlando estos factores puede

mininizarse 1a

rosin y depdsito en los tubos del supercaientador de una caldera.

Tgualmente se han realizado experinentos de flujo para determinar las cafdas de

Presign y capacidades de bonbeo. Coeficientes de friccién y ninero de Reynolds para

---Page Break---

6

?flujo laminar han sido detersinados en PETC. Actualmente se est proce-

diendo con experimentacién en flujo de turbulencia (atimero de Reyold mayor de 7100). -

Bh finel uso de carbén en forma de MAC representa un reto para Puerto Rico que

debenos investigar para uso a corto plazo.

ENERGIA NUCLEAR -

1a energia nuclear representa le otra alternativa econémicanente visble para
Puerto Rico ya 1a cual no debe cerrarse le puertas.

Eric Jeffet y otros han reconocido que los problenas de 1a energfa nuclear gon 5
de naturaleze politica y psicolégica. Un grupo 6 élite anti-nuclear polfticanente ao-
tivado y encubriendo sus notivaciones con el manto de 1a ecologfa y utilizando como

?

faporte Las palabras Llaves de conservacién y fuentes renovables ha tenido éxito com

siderable en conbatir las plantas nucleares. Este éxito continGa diciendo Jeffs ha

sido ayudado en gran parte por los efectos de 1s recesién econGnica mundial que ellos
wnimos han ayudado @ acelerar y que ha reducido grandenente 1a denanda por electricidad =
a extreno que muchos pafses se encuentran hoy con un exceso de generacién.

Hoy cada pafs tiene su moviniento o facciéa polftica anti-nuclear. En Suecia es el Partido Central, 1a principal faccin de 1s fuerea goberaante, en Francia es una

facción de los Socialis

1s del nuevo partido de gobierno. Tgualnente en 1a RepGblica

Federal Alenana 3 una facción del Partido Dendcrate Social, en Inglaterra es el Partido

Liberal que tuvo influencia hasta 1979. 4

En E, U. conocenos cono los grupos anti-nucleares se han organizado efectivanente

ara oponerse al estableciniento de centrales nucleares. Este éxito de oposición al desa~

rrollo de centrales aucleares podencs verlo de 1a Tabla 2. Fata nos apunta hacia 1a

ifra de 115,666 MV que no pudieron entrar en operación para 1981 segin planeados. Aun~

que algunas de estas proposiciones pueden explicarse debido a revisiones en pronésticos

de carga, Sstos son quizas nenores.

?Faaceat, Vor 3, Wo. Z. 1982.

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Otro éxito que podenos anotarle a los activi:

anticnucleares puede observarse

on 1a reducida actividad nuclear que ha Mlevado al cierre ge Laboratorio, de consor~ stos de diselo, consultorfs, etc. Como resultado veros ahora a los ant iguos ingenie~

ros mucleares envueltos en actividades de energfa solar y alternativas energéticas

renovables.

No obstante, 1a situacién vivida en estos Gltinos alos conienza a dar mueatras

ue esto va a cambiar. Los pueblos estén despertando debido @ 1a severidad con ue les estén inpactando tos altos costos de energfa. En Austria, luego de haberse ax Probado legislacisn anti-nuclear, ei Canciller Kretsky presionade por nuevos grupos industriales y ciudadanos extén planeando repeler 1a lepislacisn anti-nuclear de

Pic. de 1978. Bn Alenania, ahora el Gobierno Federal después de haber cafdo en una moratoria en la construcciGn de centrales nucleares est planificando un programa Para poner en servicio 25,000 Mi para 1990,

fn Francia, ?1 nuevo gobierno gocialista de Mitterend que cono promesa de can hhabfa prometido eliminar el prograna nuclear est procediendo con pasos cautelosos

¥ Procediendo a transferir el proceso decisional del gobierno central en estos asuntos

los gobiernos regionales, Cinco sitios para centrales nucleares paralizadas en 1981

ahora estén siendo reevaluados y si el nuevo consenso es favorable Estas proseguiréa,

Recfentenente tres nuevos sitios fueron aprobados para centrales nucleares francesas.

fe Bélgica, el prograns nuclear se ha visto enwelto en controversia con el repro-

cesamiento y utilizacién de Plutonio como combustible y se espera que esta controversia

sea debatida prontanente y que el Gobierno tenga que acceder a contratos previanente

establecidos.

En Bélgica, 1a inforssciGn suninistrada indica que el sondeo pr

ate de 1a opinién

Piblica es que existe un reciente endoso para las centrales aucleates y hasta conside=

Factones de substituit caletacci6n urbana centralizada por sistenas nucleares como nedio

fe eliminar el consumo de petréleo.

---Page Break---

Ba E. U, la Administracién del Presidente Reagan ha dado un viraje a 1a polftica

antinuclear establecida por su predecesor y varios escritores han conenzado a poner

fen su correcta perspectiv:

fel accidente de Three Mile Island, accidente que fue ex-

plotado auy hfbiinente por los grupos anti-nucleares.

funque, quiz:

tun poco lento, el soviniento hacia una activacién del prograna

nuclear a nivel mundial est conenzando @ tomar cuerpo. 8 conveniente que aquf en

Puerto Rico estems atentos y Listos a considerar 1a alternativa nuclear tan pronto

se despeje et panorana de Licencianiento de centrales sucleares. Fl Presidente

Reagan ha indicado que su administracién acelerarS y facilitard los procedinientos

Licenciamiento.

(Q0STOS_DE_GENERACION NUCLEAR EN PUERTO RICO

los costo de generaciGn nuclear en Puerto Rico han sido motivo de examen de~

tallado en CEEA. La figura muestra la funcién de costos de inversiGa en Ske contra

1 tamafo de una central. Le curve de regeesién utilizada para satisfacer le deta

tiene un coeficiente de correlacién de 1002. La Figura 5 ilustra en fora de bloque

?1 cielo de combustible y 1a Tabla 3 muestra un resunen de varias predicciones ée

elemento de costes.

Un pronedio de 1os costos nfs altos fue utilizado dando un valor escalsdo para

1985 de $1.86 por MTU.

os costos de operaciéa y manteniniento fueron correlacionados con el nGnero de eupleados de operaci6n y mantenimiento y con 1a generacién total

EL anflisis indicS que el precio de generaciéa nuclear resulta en el maf bajo

de.todas las alternativas estudiadas.

Una central nuclear economizaré en promedio durante Is vida de 1a central cerea

$900 millones de d6lares anualzente en forma

etualizada comparada con una central

de aceite. Cuando se compara una central nuclear con una de carbéa 1s econonfe resul~

tante es del orden de §350 millones anualmente, en forma actualizada.

---Page Break---

?48 on econonias que se pasarfan directamente a los consun{dores y tendrtan

wn serio impacto en 1a industrislizaci6n y el conercio.

No eseanos discutir en esta ponencia los varios tenas controversiales en contra

Ae 14s ceatrales nucleares, ya que este ha sido tena de varias ponencias anteriores,

Bm resunen creemos que, anbos conbustibles, carbén y centrales mucleares, pueden

venir al rescate de los precios inflados de 1a energ{a eléctrica produciends un nuevo

y

Hludable panorama industrial en Puerto Rico,

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CUADRO ENERGIA MUNDIAL

e+ 10" Bru

FUENTES NO RENOVABLES

FOSILES 213 @

U- 235 70

283 Q

U-238(REPRODUCTORES): 420,000

FUSION (D2): 10,000,000,000 9

GEOTERMICA.: .009 @

FUENTES RENOVABLES

SOLAR : 5190 @/ANO

AEOLICA: 003 a@/aANo

MAREAS : 09 Q/ANO

FUENTE: WESTINGHOUSE 41P4

FIGURA 2

---Page Break---

1o20, Fiera 3

a Costos Totcles Actuolizedos de Vorios

: Alternativos para Producción de

4 Energio Electrice en PR.

= Iflacin SUD

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Costo Tote

K Alternative Ge Viento (Sin Almacenaje de Energfa)

Inicedo pore Propositos Comparotive con ta Curve

Ge Componente de Aceite Combustible

Fuente CEEA x-72

Alo de Arronque

---Page Break---

X de Volumen

100

60

40

T Acwmulative por Volimen menor al tanaio indicade

[>= Jo

° 20 40 60 180 100 120 140

ae 3 um) mw

Figure 4, Diseribuciga de Tanaio de Partfculas Carbén en MAC.

---Page Break---

Figura 5

THE NUCLEAR FUEL CYCLE

| minine

H Reactor

swu FUEL

FABRICATION

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Recovered | Pu |

voy passant

aa--L.

INTERIM

SPENT FUEL

STORAGE

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PERMANENT

wasres _ WASTE

DISPOSAL

---Page Break---

TABLA 1 ~ ANALISTS DEL CARBON

1

vousest 36,

Carbén Fijo 50.

Cenizas 10.

Hide6geno)

Carbono.

Nitrégeno

sulfuro

Oxigeno

Ceniza

Valores Celorfficos (Btu/1b) = Sin Hunedad

Temperatura Inicial de Deformaciéa (°F) 2350

Temperatura de Ablandamiento (°F) 2400

Tenperatura Fase Liquide 2580

Composicién de 1a ceniza (%)

Sioy 52.69

A103, 22.82

e203, i5!67

110), 1.22

cao 140

MgO ona

a0 one

K0 85,

sb, 0.95

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- Exploratory Coal

18

REPERE

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+ Energy Analysis and Socioeconomic Considerations for

Puerto Rico. - M. Iriarte et al May 1980,

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UPADI 82

San Juan, Puerto Rico

?August 1-7, 1982

First Pan American Congress on Energy

1S A NUCLEAR POWER PLANT SAFE?

ey

Néstor Azziz

Department of Physics

University of Puerto Rico

San Juan, Puerto Rico

Agosto 1987

---Page Break---

---Page Break---

TS A NUCLEAR POWER PLANT SAFE?

Néstor Azztz

University of Puerto fico

Mayaguez, Puerto Rico, 0708

Aostract,

In this naner we review sone main {ssues regarding the safety aspects of 2 nuciear power plant. Special constderation 1s given to the possible case of a nuclwar reactor being instalied in Puerto Rico.

---Page Break---

hich are of the order of 2enron/yenr, with a paver plant neorby, thts wil Hncrease to PON + 0,26 (with N.C] aren a year). See Table 7

2, Fuel Nanagenant: Reprocessing and Msposal

Ths 1 one of the protilens which has worrted ost nuclear power Industry a5 well as fevleral nuclear agencies. Its solutton 1s as good as one may choose, ANT denenis un lune ruch fnvestrent is allocated for the fue) management, Mut, as a surary, we ray mention that the Natfonal cadery of Sctence, Forni tter fon tuclear and Alternative Energy Systens (1979), has expresset: The technical groblecs of waste disposal are not considered major, There is an existing so-lution which nffurs storage at reasonable cost and acceptante rish.. Pecently,

2 F111 Sas gone through Senate which establishes 2 Aublic Tocetten in the lint
tee States for the disposal of nuclear este, These sites will he maintained

by tnereasing ?,001/¥U {n taxes. In the spectal case of Puerto co the mole
protle= fs of na?cencern, because tn the case cf having a rower plant, we rautd
Feceive the frech fuel fron the Continent an¢ the burned one (after A'nonths or

® jeer fror. its Instaltatton) should go tack to the mainland for sts renreceseing
ant ?snesal. Thus, the entire problen af reprocessing and dtepesal fe, fe our
eases @ protien nf the country whitch supplies the fuel, ke rev, Iwwevery ast
burselvct wnat tind of risks exist during the trensnortation of the furl to the
Plant and from the plant back to the country supplier, In this recard we ney

Say that casks butlt for the transnortatton (Fig.l) are such that they cnuld stand
?the nest abused treatrent, For instance, the truck which transports the cask,
between the plant end the? ship, may strtfe, at 69 miles/tour a concrete wall, and
a5 Mt vas expertrentally verified, no darage occurr to the cask, The cask will
Sonsist of a thick steel cavity ont a nuch thicker lead shelving sn destanes

25 to withstand the most severe accidents and heat from fire without allouing
escape of raitoactive catertaly

3, Thermal Msclierge from a tivelear Plant.

Any power plant releases heat, ature dons reoutres this, every tine we are

erate power, Thus, we have heat from 9 coal er cil plent, fron a cer engine, a huran body, etc, "The heat rejected frome ructnar newer? plant 1s in the Fors of warm water (about 70*F) and 1ts environmental effect may he goo", or had, oF Famless, according to the way ve ray use It, For dnstence, a nice anount of vara watery (about SAM gals for a Sn sy) electric power olant) could be extras rely useful to grow algae in a pont or to use tn large tattertes which could gene= rite direct current for peripheral rachtnertes of the pant. We should paint out

?at vidle all the heat refected fron a nuclear plant 1s tn the form of men vater, for ozter power plents Ike chal or of] piarts the heat 4s also sent. to the aknosrhere througtout the snake stacket alone vith contustton products. Me.

oxtdes of cerion, nftrocen, and sulphur, net of thom vary Yaretul to the human,

health,

4, Securtty of tuclear Power Plants

There are two types of possttle acctuents that ray accur at a Nuclear Plant:

1) fue to external causes, Tike earthnuates, war, ote,

2) Cue to an interna? mstfunctton

---Page Break---

The only example of som relevance In the last categnry, without any dnuht

45 the Three tes slant Accitent. Let us focus our attention on thts vent

anil postpone the first pofnt for later consideration, ?Thr Tiree Miles Island

Heetdont has taught us a few things, (2) 1, That fn sptte of the lack of inowledge of operators, engineers, and Supervisors, the nuclear desian ts safe. The five safety Inerfers designed to prevent racfoactivity fron: coming tn contact with the public have worker out jin the hest way that one can expect.

Let us first review the meaning of these five barriers: The worst accident that could happen fs the meltdown of the core because the ternerature has reached the relting point of urantum dtoxide (cerarte fuel) (39M"°C),, Normally, this. cox cate fuel pellet, about 1/2" 1 1", fs enough to retain cost of the fission prow Suct. About IF may escape frou the pellet, The second harrier 1s then the elede ing, or long hollow stainless steel tubes, sealed in hoth ents, which pactet. the pellets. The third barrter 15 the closed Cooling Toop vsed in the PY and TUR to rerove the heat fren the core, Ths primary coolant ts filtern* an! purified 0, thet the seal} annunt of radtoacttve rater{al that Teats throughout. the claicing is retatnet in those ffiters, The fourth harrier {2 the ornesure vessel of May stainless steel, sfx to etohth inches thick, The fifth Sarrier is the relnfores Concrete structure which contains the whale reactor, It ts » structure af 1 th 4 feet thch walls, which have an intertor steel Itnings

This tutleing has also a powerful spray Instie, to retuce the pressure of the stean in case of a hireak {n the High pressure coolant systen, ant te nosh cut radioactive fotine from the contatnrent atmosphere, Tue to the effectiveness of these two last harriers, at the THE accident only 17 curies of ractoncttve fotine were released fron the plant, About 7.5 miIIfon curies ere retatned tn the cooling systen and 10,? mflion fn the contatnrent bitline,

If we analyze the sequence of errors hofore ant during the accident we ray understand uhy the nuclear Industry ts one of the safest, arora thnse whter sete ver power,

In fact, at 4:09 am on March 28, 1979, TH1=? ues operating at noreal pouery (2790 1" Wests thermal eneray wore ceftvere? by the core). The prieary cnolant was. {00°F and 2200 psto. Thts primary coolant generated steam which slrove e turhines which in turn grove'a generator 1000 Mi electric output. At thts very sane ronent ?the pup P tripped and the water tm the secondary syster started averchnatina, and the heet at the prinary systen could not be reroved properly. (See Fig. ?)
The serfes of auxtlfary purps that were supposed to start when thts Just ?apncnedy could not operate because the valves V were closed (thay were sungosed to he oper aN} the tire), In about 18 seconds the steam ues Just dry and the neinery, toxpe rature and pressure started to rise so that the pressure relief valve P onened
The pressure then cropped to a point where the relief valve P vse sunposes to he Closed again, fu it did not close and a leakage In the prirary system ecarted,
TMs drought ecergency pumps E's nto the scenery to supply the loss of priory, Eoolant. At ahout 4 hours, £ minutes, the closed valves V¥s were Wisenvrred Chose: and they were opened. This could have heen enouch tn stop the ncefdent, Put the relief valve ® was not detected open until ? hours and 7% minutes pace & ere fh

the problem was now gotng to the primary system since tn the seconcarys thines

---Page Break---

care to be normal, The pucps C's were sunplying water and the valve ® opened,

Thus, we wore having a cysten with ruch lower pressure and water contng fn,

Tis? situation created stean pockets in the prinary systen which produced the

effect of an inercasing level of water tn the reactor, Thts confused the one=

ators sich, In the assumptfon that too much water from C's was supplied

Gen actually there was a nead for nore), they decided to close F's. Andy

That was {t. Before this, to make things worse, the operators opened a high

pressure system to drain even rare water out of the prirary syster throughout,

the ?letesoun line", The punns C started then to cavitete® duc to the large

?ount of gas which oot in the upner part of the core, Traving the fuel clement

ineovered, Tha tenperature rose so high that the cladding material zircatloy

Could react with the steam to produce hydrogen and ztrconfum oxides. These

fon consensahle gases accumulated at the top of the core malting the recircvlatton Very itfficult. At this stage sone fuel cladding explored releasing sone radioe active ratertal which escaped through the relfef valve to the drain tank which Jater overflowed Into the contatnrent hutTdings The sunp punp then carrted thts cacess Hauld into the store tanks of the auxtifary bufldtng, which also overs ?flowed onto the floor of thase tutTéings. About 1:3 pr there vas an explosion of an hydrogen pocket, with no serfous consequences at all. Cfrcutation n the privary systen was recestablishee shout If hours after 4 an and the core was then already denages,

Ftratlyy tet oe refer to the natn Tesson gatned fron THI Acctents Tes cay bel boyisttied tn the folloving ways for pyolfe has never teen aoare of the TEyathg?of thecrower_tenctors utiitttes and sehentists have not Seen alte, to Cone Semterte?on PRIS traortant matter, ?Puslic.tgnorance bas Caused sertoys elsunter= Randingss? The pustte ty confused with regard tothe tosue ant Qonortunist fours tatfte len art Igorance of actsray fave very nericiow etek on nh Mtaypueretanctags GAP gtecTiacelaegt the fuctust tntorretton ves rot, imectate SUANIEETE' 2H okecuEetShs nbeBHeGeT Hass on erony ane iemracarie tacts ites Shysrosen torb®, "clouds of radiations stey Tmlustry end util ictes face the crtetelte tron ineibostncss_ ond ontttechnsiogteal peoples, TF neonte 4ovnot une

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ia'are'in the elocle?of a technological fevotutton es well ay roctaty and sesust

Sesatietone ?if'we donot have?s erally sn responsi te way to, comuntente the

Hicks to'the public ve? are going to face a soclety ich eneeny Starvation Wey

SCicnetaes and engincerty are trying hard? to convey the ressage ty Cetetrattng

HEeMtcat recesses sendin tnternston to the soldier ates fut? fit THe tne

Heeeatean GEvearettu'to ene putt throush the freses? THAG 4g annther storys

Siete oan conctostons anf heed} ines nay rot ayer aevthina ta fo with the fnctuaT

Tenet ?Flnengtve?and' scores energy reanss. taviattons seetal iseortancesy? nigh

setereat ee Caen? the sore we wale to rang tn nore miclent the Tess wilt Re tur

SOHEHTTTTEy OF econdete tecuneratton,?"We'rust rake hierto Sten Cafnrstant tat

1) In 19 years from now Puerto Pico Power futhortty will need Aan st

(lor of ts actual capacity) more to keep up with the present eran,

2) Stace nuctear pover 4s the cheapest eneray source the neaple of Puerto

Rico would he saving atout 3 cents/Ky (aout 27°},

3) tuerfcan and Yocal investors would he willtna to finance the pragect.

---Page Break---

4) Pucrte P¥co could pay thea back ty means of 1ts noma consumption,

'0 SOverMment Investment would be needed. Thus, at the sare tine

?that the consuner would be saving 3 cents/Mi, PLerto Rico could own

the plant fm about IN years after the construction has heen fintshed,

5) The plant could be constructet within 7 years. uring thts perfod

hundrot of workers and Pucrto Mean engineers will be needed,

f) Puerto ico could start its Independence fron foreign of1 exporters.

7) Puorto Mcen inlustrtes would he able to compete with those In the

?nite! States by paying a reascnable price per M=hrs

£) The muclear energy source 15 Tess nollutine? than of and coal.

5) The ?Hsposal of the nuclear waste 4s not a Puerto "ico oroMen since

after ft {5 burned ft will be shtpned tack to the ralaland,

M1 deveTopes countries and some others under the process of develor=

rent vse nuclear powcr to generate electricity, Mhe

QPEOATING ? anER cqusTRACTH

Arguntina

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OPERATING § ? ore enverRNCTYON

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"Sy power Vines, and clectrie

2, Internal contustion engines,

3. Air conditioning snd heating

4, Theory of elusticiyy and structure analysts,

5, Engineering econowy

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Curriculum Vitae ~ Dr. Néstor Azziz (cont.)

3. EMPLOYWENT AND ASSIGWMENTS

Present - 1971 University of Puerto Pico

Duties: Teaching, Research, and fininistration

The Administrative Duties are related to:

1) Office of Research Coordination, director (10%0-present); 7) Meaher of a Task Force tor the feasibility of fuclear Plants in Puerto ico (107m Present); 3) Member of the Comittee for the evelopment of Technoloay at

vaguez Campus to Help Government Actions; #) Yenher of the Conmittee for - the Development of Gratuate Studies sponsores by SF; 5) Graduate School? Representatives 6) Energy Coordinator for fneray Affairs of the schoo! of Arts and Sciences,

1979 = 182 _Uestinghouse Atomic Pouer M'vision, Fellow Physicist, Main Puty: thuclear Reactor Design -

1951 ~ 1959 President of a Private Engineering fnterprise: Air conditionina, radiant heating, ete.

PUBLICATIONS: 40 publications in Physics and Engineering. They are in the field of energy alternatives, nuclear reactor design, and on nuclesr and +| atomic models,

SOME ENGINEERING PROJECTS DIFFERENT FROM NUCLEAR:

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a) Messier of the New York Academy of Science; b) Menher of the Anerican

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UPADI 82

Sen Juan, Puerto Rico

August 1-7, 1982

First Pan American Congress on Energy

ENGINEERING FOR ECONOMIC DESIGN IN ENHANCED OIL RECOVERY

By

Charles W. Perry

Department of Energy

Washington, D. C.

Robert M. Jimison

Consultant

Washington, D.C.

San Juan, Puerto Rico

?Agosto 1982

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ABSTRACT

ENGINEERING FOR ECONOMIC DESIGN IN ENHANCED OTL RECOVERY

Charles H. erry

U.S. Department of Energy

Washington, Dc

and

Robert M. Jimeson

Consuitant,

Washington, DC

One of the most active engineering functions in the United

States is the sophisticated pooling of disciplines required for

the economic design of enhanced oil recovery(EOR) field projects.

The technology is not complete, and the design engineers must make decisions under uncertainty. There are about 300 sizeable EOR pilot tests. The knowledge gaps are thus gradually being filled. Field projects cannot be undertaken, without varying amounts of risks

?The stepwise evaluation of scientific and engineering data leading to the best practical geophysical and geochemical defi- nition of the reservoir project area is described. Concurrently OF subsequently the EOR process design must be undertaken. The engineering skills involved in each step are also described. Tn the multiplicity of BOR pilot fieid tests in the U.S. the purpose is most often to develop design data for expansion to commercial scale. The two key factors in an economic design must always be the determination of the oi1 in place (original or remaining), and how much can be recovered by the chosen EOR process over what period of time.

The three major categories of GOR processes, i.e. thermal, chemical and miscible gas are briefly described, together with their subcategories. The basic reservoir criteria for each proc- 88 are reviewed. A discussion of engineering problems encountered in some of the U.S. Department of Energy cost-shared field tests since 1975 follow

Finally, a review of some BOR economic case histories is

Presented to help focus engineering design on the major cost

factors.

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ENGINEERING FOR ECONOMIC DESIGN IN ENHANCED OTL RECOVERY

by

Charles W. Perry

U.S. Department of Enersy

Washington, Dc

ana

Robert son

?Consultant.

Washington, De

?oduction

in mature oil producing and consuming nations such as the

United States the depleting reservoirs will at their economic pro

Guction limit sti11 hold from one haif to two thirds oF eee

griginal oil in place. or the 450 billion barrels of erage oi]

gaacevered in the 50 U.S. states (excluding tar sands), roughiy

{eon} d 1402 Parreis remain as the target for enhanced oil recovery

(Bon) «AS the technology of EOR matures in the Us, it beconcs

one of its more viable energy alternatives.

ip has been found in the decade since 1972 that EOR, using

expensive fluids and methods, demands a far more sophisticetss

kechnology than conventional primary and secondary production,

?Thus concurrent vith the growing sophistication in finding ney

reservoirs and defining them, EOR requires a team of sciestiets

and engineers applying @ larger effort over several years foe a

Project to be successful. The pooling of such engineering skizis

and the approaches to EOR fieid testing leading to comerciontzas

Sion is the subject of this paper. It will be related to the ans.

Department of Enersy EOR program for the years 1975-198902

Where We Are--The U.S. Potentia

As stated above, the target in the U.S. is roughly 300 billion

Parrels» and perhaps 30 billion barrels additional ot tar sand

The technology is not complete. With major research efforts under~

fay in Private companies, universities and gavernment laborater ices

however, together with over 300 sizeable field testes the cate ur
is increasing. Thus the technical constraints are graad-

3ily being overcome so that economics then becomes a deciding

Before proceeding further, a brief review of the several
Process variations for EOR is desirable. For each canaidece EOR
Epeervoir there will be usually one optimum process to be deters
mined by intensive investigation, The three broad caresories
Of Processes are 1. thermal, 2, miscible gas, and 3. chemicals
we will consider here only the continuous processes, although
intermittent or cyclical methods are possible,

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A brief reference can be made to the simplified improved water
floods using polymer water solutions to improve sweep efficiency
for remaining mobile oil (after waterflooding) and alkalies to
lower surface tensions, passivate clays and create crude surfact-

ants in situ. Both recover only a few percent of the remaining oii in place.

?Thermal Processes for Heavy Oils

?The viscosity of heavy oils in place in their depositional environment often requires heat in some form to improve flow induced by natural energy or artificial pressure differentials. The most common method is to inject high pressure steam into a normal or inverted five spot pattern and force oi1 plus condensate toward

the producing vells. Usually about one barrel in three of the crude produced must be burned to raise steam. Efficiency is not high, but in the primary or secondary mode as much as 50% of the oil in place may be recovered. Surfactant additives may help.

Thi process is commercial in California.

Steam flooding is economic only to about 900 meters depth, and attention is being given to insulated tubing and downhole Steam generation. The alternative thermal method is firefiooding or partial in situ combustion. Compressed air is injected into ?the appropriate pattern and partial combustion preferentially burns the heavy ends of the crude, creating heat, combustion gases, and a lighter crude. The pressre differential forces these products toward producing wells. The gases and light ends must be separated from the crude oil on the surface.

?This process is difficult to control, and in the U.S. there have been more failures than successes. Nevertheless, it remains a viable candidate, especially in combination with steam or water ?as wet combustion. There have been several successes.

2s Miscibie Gas Processes for Light oin

A common secondary process for decades has been reinjection of associated natural gas and light hydrocarbons produced with

crude oil back into the formation. This may be done for simple Pressure maintenance, but more often as a continuous flooding process, In travelling through the oil sand, crude oil is dissolved, reduced in density and viscosity and entrained so it will flow to producing wells.

In recent years, natural gas and light hydrocarbons have become too valuable when produced, Hence miscible hydrocarbon

gas processing has given way to the rapidly developing commerciali-Zation of carbon dioxide flooding. The effort is based largely on transporting large quantities of natural carbon dioxide via pipe line to the carbonate reservoirs of West Texas

Carbon dioxide behaves similarly to natural gas, and its mobility (leading to viscous fingering) is a problem. It is controlled by alternating carbon dioxide injection cyclically with water injection. This permits reduction of carbon dioxide use

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3

gown to 6 or 7 thousand standard cubic feet per barrel net, includ-

ing recycle. This process is becoming commercially active in the us.

3 Chemical Flooding--Light and Medium 042;

?The preferred method for this process is to first inject perhaps a 10% pore volune of a surfactant slug. This slug 12 most often a complex microemulsion of a surfactant such as petroleum sulfonates, a cosurfactant such as a higher alcohol, bydrocarbon oil and water or brine. This serves to mobilize or ?bank? the residual oil by solubization, lowering of interfacial tension, coalescence and release of oi1 from pores. The banked o11 1s? then moved toward producing wel1s by injection of several pore volume Of 1a l0zcentipoise dilute polymer solution using polyacrylamides gnd other carefully screened polymers. Finally conventional werer flooding finishes the EOR treatment

The chemical fiooding process is one of the most versatile

for light and medium oils. It suffers at this time from hh

Chemical costs, such as 10-15 pounds of surfactant and 1-2 pounds

Of polymer per barrel,

Technical Constraints to EoR

Before proceeding with the engineering of EOR field projects,

a brief look at the major technical constraints to successful On

Projects by process is desirable. These are summarized in Figure 1.

In the thermal processes, heat inefficiencies and poor sweep

efficiencies vertically and horizontally are principal proplens,

Tt has been found that insulated tubing will reduce heat losses

Such that depths greater than 900 meters is economic, The Doe

downhole steam generator and its offspring appear promising.

Gravity override of uncondensed steam also subteaces efficiency

and often leaves the center part of the oil sand between werre

untouched. Surfactant additives are helpful in this respect.

In in situ combustion the greatest problem is first trying to control it. It is thought that dipping formations are best? gone Progress in developing new instruments to help with this probles is underway.

With miscible gas, mobility contro or prevention of viscous fingering is the major problem. The water-aiternating gas proces gure can heip greatly in this respect. Interesting research is being sponsored by DOE in using surfactants and/or polymers as G02 additives as an alternate way to control mobility. C0) supply has been solved at least for the very large West Texas carfonace fields, where two thirds of the U.S. action will take place, fy tapping large natural Coz deposits in Colorado and New Mexico,

The greatest amount of remaining research needed is in chemi- gal flooding. Workable surfactant fluids are in hand, but chemical efficiency is low for many reasons. The chemicals will react or absorb on clays and reservoir rocks. The viscosity of polymers

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can be destroyed by divalent ions. The chemicals must be directed to the residual oil. Bacteria can destroy chemical eftectivenes:

Figure 2 shows the DOE estimates of recoverable BOR in bil-
Lions of barrels from the processes just discussed. The bottom

ction in each process bar is the estimated recovery by today's technology. The top part is the added increment using advanced technology now under development or on the horizon. Several innovations vere briefly mentioned under process descriptions above.

?The summary bar on the chart shows our belief that by today's technology roughly 18 billion barrels of incremental EOR oil can be recovered in the U.S. and by the sum of todays plus advanced technology up to 52 billion barrels is possible, This chart does not show when this will take place, and Figure 3 vill help in this respect. This figure suggests that much of the Figure 2 potential can be recovered by the year 2000. This leaves 250 billion barrels as a target for future technologies, gerhaps microbial. Figure 4 Shows U.S. EOR production as of 1980.

Predictability in Design

At diggerent stages in the development of a commercial EOR fie1d project, the design team consisting of geophysicists, ceolo-gists, chemists, reservoir engineers, geotechnical, mechanical and electrical engineers will need mathematical or modéling predictions , to determine its technical or economic feasibility. Early in the development, empirical short-cut models such as developed by Lewin? or Intercomp may be useful, using averaged field data. These will give useful approximations. As more information develops the larger 2D and 3D simulation models will be used.

?The history of accuracy of predictions by large simulation models has not been very good for several of the DOE cost-shared field tests. An example is given in Figure 3 for the completed Phillips micellar-polymer flood in the North Burbank Unit in Oklahona.© Admittedly, this exercise is a few yoars old, and progress has been made since. Simulation is not yet an? exact Science, hovever. It is under these circumstances of residual uncertainty that the EOR field project design tean must operate.

The Sources of BOR Uncertainty

?The great advances in geology, geophysics and reservoir engineering have not eliminated ali areas of ignorance in EOR. Te'mist be concluded that not all reservoirs are EOR candidates, even if all of the necessary or desirable information is available. A major source of uncertainty often is the distribution Of residual oil in place. Tt cannot be assumed to be uniform, and bypassed areas will often be present.

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The degree of heterogeniety between injector and producer wells vill always be incompletely known, in spite of the pest efforts from coring, logging, pressure fall-off tests, nigh resolution seistography etc. Beginning efforts are undervay fo apeiy statistical and probability methods to these problems,

Faults mist be located. Large channels must be blocked,

fae injected fluids mast be contained in the target areas Finally not aii is mown about the chemistry and physics of injected fiaias and the reservoir components of oil, gas, brine, rock and clays,

In spite of this, a competent design team, given adequate gesign information, can proceed with certainty, ?Seldon dese it happen that no oi1?is recovered.

of BOR Eieid projec

Figure 6 presents the normal logical approach to the con- eptyative design of a commercial EOR field project. once having chosen a reservoir, or part of one, asa candidate, a first ste will be to screen the possible processes by applying know core Seria to known reservoir facts. In the majority of cases primary and/or secondary production will have taken place in the reuse Yours and much will be known about it. It will not be enousne and averaging of data will constitute a hazard. ?old date guna be suspect. The biggest single factor in the technical and ose nomic success of an EOR ficld project will be the snout ned distribution of residuat oi1 in place. Extra coring and logging will be indicated.

The laboratory data must include core flooding, PVP phase gquilibria, rock/fluid interactions, and choice of stimulating fluids. The laboratory test phase will take one or two years and can include the design of a mini-field tests Foliowiey this ap intensive field pilot test vill take two to five years. During the latter part of the pilot test the design of a field expension can begin, if the prognosis is positive.

A more detailed stepwise and specific procedure is given in

Figure 7.? This was a prescription provided by a leading perros

}eun service laboratory, Core Laboratories, Inc. of Dallas, Texas,

for a proposed project in a specific Wyoming field, Ail ot tht

Professional disciplines previously mentioned are involved in che

Steps, including the preliminary laboratory evaluation,

The pooling of engineers and scientists during the same

sepTaastd Phase for FOR, but applied more generally to evaiuaging

any new planned oi! reservoir operation is shown in Figure 8.

In the 25 approximately DOE cost-shared field tests tabulated

in Figure 10, the approaches to design descrined avove were followed.

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?These vere contracted in the period 1975-1979, and generally the

best available data and methods were followed. In spite of this

there were failures as well as successes. Some of the principle

lessons leatned are tabulated in Figure il.

BOR Economics

As stated above, the rate of progress in developing EOR technology in the U.S. ig rapid. It is an evolutionary process which

has been gathering momentum particularly in the last decade, and

it will take another decade to more fully mature. Nevertheless, -
?stimulated by over 300 active field tests, as shovn in Figure 12,
commercialization is progressing.

BOR appiicatiog is currently slowed by World Oil pricing, As
shown in Figure 13, the approximate estimated cost ranges for
EOR recovery from three good U.S. candidate reservoirs for each of
five processes are generally borderline, especially at the high
ends. Another way of saying this is that, except for California
steam flooding, and except for the best candidate reservoirs for
other processes, EOR is generally not cconomic today. This will
change as the world price for crude oil increases, and as EOR
process efficiencies improve with experience gained from todays
Fesearch and development.

conclusions

1. EOR requires mich more scientific and engineering sophis-
tication than primary or secondary oil productions -

2. The U.S. EOR potential is large and known to be available.

3. The three principle processes of thermal, miscible gas

and chemical all have technical constraints remaining:

4, ?The U.S. EOR potential for production by the year 2000

is 18 to 52 billion barrels out of 300 in place.

5. The accuracy of prediction by mathematical modeling is

not precise, and adds to the uncertainty under which a design

team operates. 4

6. The logical steps for developing a conservative design for

an BOR project requires a team of geologists, geophysicists and

reservoir engineers supported by chemists and other engineers,

working together for several years.

7, Sources of uncertainty are many and must be recognized.

8. Many valuable lessons have been learned from the 25 DOE

cost shared field tests.

9. EOR economics are favorable for the best fields. 7

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UPADI 82

San Juan, Puerto Rico

?August 1-7, 1982

First Pan American Congress on Energy

GASIFICATION OF COAL IN PUERTO RICO

ey

Donald A. Huber

Burns and Roe

Hamilton 6 Glasgow Synthetic Fuels, Inc.

?San Juan, Puerto Rico

Agosto 1982

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ABSTRACT

"GASIFICATION OF COAL IN PUERTO RICO!

DONALD A. HUBER

BUS AO ROE-MIPHREYS §GLAScOW STHTHETIC FUELS, INC

BRIG:

Puerto Rico possesses no proven resources of ofl, gas, or coal, and only modest resources of water power. Since Puerto Rico currently depends almost totally on inported of] to mest its energy requirements, the iapact of sharply higher of] prices has, and will, present difficult probiens for the continued industrial development of the isiand.

One means of circumventing the situation is the importation and con version of coal to a medium Btu gas in a centrally located facility. ?the medium Btu gas can then be utilized on-site or off-site to yield electricity, Steam, Tiquid fuels and/or chemical feedstocks depending upon market needs and ?conditions. Coal is a cheaper source of energy then oll, end its gasification fs a viable technology which produces fuel that ?can be utilized directly in Industrial botters without down-rating and {nan environmentally acceptable manner.

BRHG has studied the technology and economics of producing this medium Btu gas in plants with capacities ranging from 20 to 40 billion Btu per cay (1000-2000 tons of coat) for distribution to industrial users within? the Tange of 100 ailes from a centrally located gasification facility. The study indicates that medium Btu gas could be produced at approximately &.50. to $8.00 per million Btu. This compares with current of] prices of $4.60 to $5.70 ber million Btu. In the future, oll prices are expected to escalace more rapidly than coal prices, thus resulting in the-cost advantages of hnedium Btu gasification.

Sensitivity analyses were also performed during the study to indicate the influence of the price of coal, capital cost growth, load factor, erans-

Imission distance, and the degree of gas treatment required to satisfy clean

?air regulations on the cost of producing medium Stu ges.

TMs paper discusses the concept of central gasification, gasification technology, botler modifications, and possible economic scenarios related to the island of Puerto Rico,

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INTRODUCTION

The energy outlook for Puerto Rico is not the most promising. It possesses no proven resources of of1, gas, or coal, and only mocest Fesources of water power. Since Puerto Rico currently depends, almost, totally on imported of1 to meet its energy requirements, the impact of sharply higher of1 prices has, and will, present difficult probiens for fhe continued industrial development of the island. Today, there is an immediate need to find innovative and environmentaily acceptable ways. 40 use, the western hemisphere's most abundant energy source = coal. The District Gasification concept provides such an innovative response for an alternative energy resource to lessen Puerto Rico's reliance on imported oil, In a centrally located facility, integrated to make the most efficient yse of energy inputs and waste heat, coal is converted into gaseous forn. It can then be utilized on-site or off-site or processed to yield elece tricity, Mautd fuels, or chemical feedstocks, depending upon market needs and condi tions. This paper concentrates primarily on the production of intermediate or medium Btu fuel gas manufactured from coal However,

?Some comparisons are made to coal derived low Btu ges.

?THE coNcePT

The District Gasiffeation concept consists of a centrally located facility integrated to make the most efficient use of energy inputs and waste heat. Sy gasifying coal in a central location, the econanice oF scale makes the project more financially attractive when compared to diverse small units. In addition, load following capab!Tity will be {m= Proved on a large unit supplying a wide variety of industrial customers

Residue from the gasification process will be recovered as nonleach-

able vitreous stag, while sulfur will be recovered in its elemental. form,

Both the vitreous $1ag and elemental sulfur are expected to have sone commercial value. Sulfur recovery values of 99% and higher are achtevable using commercially available processes. Figure I filustrates the basic concept.

?The first step ts coal pre

acceptable particle size as we!

upon the gasification process

ration, which tnvolves crushing coal to

's drying or slurrying the coal depending

Particle size can range fron 200 nesh (2.5 Cn) for entrained bed gasifiers, up to over one-inch for fixed bed gasitlers. ?Gasitveation can be acconpitshed ina variety of units wnich are discussed tater ts sore detail. Gasifier? tenperatures can range from IS00°F (2139) for Fluvetzed bed units to over 30008F (1650°C) for units where the ath 19 removed molten siag, ?Gperating pressures can range. fron near senosehenne se

1500 psig {i025 HPs) depending? upow?toemeetonen

Following gasification, the hot gas 1s generally quenched and treated {o,renove fines, tars, and Sulfur compouncs. In most systems, the byprocuct hheat 1s recovered in & waste heat recovery boiler.

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From the treatment systen, the gas can be piped to conbined cycle power plants, to steam generators, to industries for chemical feedstocks for other industries dependent upon clean gaseous fuel. These industries include metal treating, glass manufacture, food processing, cenent plants, ate. Factiity byproducts may also be used on-site. These include low pressure stean or hot water for space heating.

GASIFICATION AND GAS CLEANUP SELECTION

The production of gas fron coal has been practiced in various countries of the world for more than 150 years. The principles of coal gasification are relatively simple. When coal {s heated in the absence of air, it Undergoes decomposition (pyrolysis) into a mixture of gaseous, 1iquid, and sole components. The gaseous components consist mainly of methane, hydrogen, carbon monoxide, hydrogen sulfide, ammonia, and nitrogen. The liquid compo-nents are vaporized at the tenperature of the pyrolysis, but condense, when cooled, to yield a mixture of light and heavy hydrocarbons. The solid com onents known as coke, or char, consist of the original ash in the coal together with unreacted carson. In traditional gas-naking processes, coke (char) was discharged fron the pyrolysis retort, cooled, and then conveyed to a further process vessel known asa producer where 1t was subjected, alternatively, to currents of air and steam.

This converted the unreacted carbon in the coke to a mixture of hydrogen and carbon monoxide which, together with the original nitrogen in the air, formed a mixture known as producer gas which could be Used for heating the pyrolysis retort, ors alternatively, for biending with the pyrolysis ges, to ive a Finat mixture? khonn as towns gas? which Rad a higher Reating value {hey ?ranging between 300" and 500° Btu/ScF {12 and: 20°MI/Rd). ine ash fron the coal was discharged continuously fron the base of the producer:

After 1920, considerable effort was devoted to tnoroving the effictency ?and simplifying coal gasification. Modern coal gasification processes employ the same principles as the traditional process, but in most cases, gasifi- cation of char and pyrolysis takes place within the sane reaction systen, often within the same reactor vessel. The modern coal gasification process Tequires a balance of the endotheraté and exothermic reactions s0 that the external application of heat, other than that contained in the gasification Steam, 1s not necessary. In'general, the more air or oxygen consuned per

ton of coal gasified, the greater wiil be the heat released and the higher will be the gasification temperature. The higher temperature leads to fever Ofls and tars in the effluent gases. However, the more oxidant consuned, a greater amount of the heating value of the original coal appears as "sensible" heat in the product gas, resulting in lower overall thermal efficiency. If ?this "sensible" heat can be utilized to generate steam for use in the gasification process or for other purposes, the efficiency will be improved.

The composition of the product gas varies with the type of gasification Process as well as with the steam and oxidant consumed. The principal aif- ference anong gasifiers is the way coal is contacted with the steam/oxidant mixture. The basic types of gasifiers are the fixed bed type, the fluidized bed type, and the entrained bed type. These are illustrated in Figure 2

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The choice of oxidant, air or oxygen, also has a significant effect

fon the composition of the product gas. Since nitrogen in tir passes. through the gasifier as an inert gas, it will dilute on the product, It is difft= Gult to obtain a product gas of WHV greater than 160 Seu/ScF (6.4 MJ/Mo) after ter and sulfur removal with air as an oxigant, in cograst, heating values for cold clean gas in excess of 350 Btu/SCF (14 MJ/MS) can be cotained Using oxygen.

Table 1 {Tlustrates sone of the proprietary comercial and near-comer- cfal processes which have been developed. Although certain oF the noner gasification processes have been mentioned for Illustrative purposes. there are several other competitive second and third generation technologies under development which show equal pronise.

For application as botler or gas turbine fuel, the principal character= istics affecting gasifier selection are the HAV and pressure oF the clean {uel gas. For other applications (e.9., petrochemical feedstocks). the chemical composition, particularly the fydrogen/cO ratio, and the content OF C02, methane, and?nitrogen also have a significant effect on gasification Process selection.

In addition to the differing characteristics of various gasification processes in respect to the gas composition, pressure, anc overall thermal efficiency, the various processes also have significantly dsferent character- istics in regard to the energy configuration of the total gasification system, For exampte, the Lurgi gasifier has a very high process steam demand, relatively high oxygen denand, and minimum heat avatlable for steam generation, By contrast, the Texaco Process has a high oxygen denand, zero stean require: ment and a large availability of waste heat from which high pressure steam can be generated,

?The complete coal gasification system, from receipt of coal to discharge of cold clean fuel gas consists of a number of inportant subsystems including coal preparation, gas cleaning and tar recycle, sulfur removal or recovery, air separation, and primary effluent treatment. Gas cleaning and tar recycle subsystems are?usually supplied on a proprietary basis integral with the gasification process. The other subsystems are generally besed on technology which fs well proven'in other applications and ts directly. transtarrabte:

BOILER CONVERSION/RETROFIT CONSIDERATIONS

The centralized District Gasification concept represents the simplest gption where boiler conversion or new coal fired factiities are not feasisle. The major considerations in the conversion of botlers designed for cost oe Of] to gas firing are listed in Table 2

Teble 3 shows some of the principal parameters relating to the combustion of 11 and gaseous fuels. As indicated by Table 3, the sedtun Btu fuel ges flame temperature would be expected to be as hot or hotter than thas of efther natural gas or fuel of). Tt would, therefore, be expected shay padiant heat transfer would not be reduced if a bofler is fired with medium Btu fuel gas.

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Heat transfer in the convective section of a boiler is dependent upon its inlet temperature and the flow of combustion products. Although the inlet temperature may be conparabie, Table 3 shows. that the products of conbustion flow may be slightly higher. It, therefore, appears that with mediun @tu gas firing, the heat transfer in the convective section should be comparable with natural gas or of] firing,

Table 4 shows the potential bofler modifications or replacenents re- quired to burn Tow or medium Btu gas in 2 boiler originally designed to burn of7, natural gas, or coal

Larger fuel gas headers and associated piping would be required to retrofit a natural gas boiler for medium Stu fuel gas. Natural gas burners may be satisfactory for mediun Stu gas firing, although this should be reviewed with the burner manufacturer. For coal and 11 fired botlers, medium Btu fuel gas burners, headers, and piping have to be added. Controls and protective equipment may also have to be modified.

In contrast to medium Btu fuel gas, low Stu fuel gas retrofits could require extensive modifications. Careful review with the manufacturers of ?the boiler and main auxilfary equipment is needed before low Btu fuel gas retrofit is considered.

Medium Btu fuel gas retrofit of natural gas and fuel of! fired boi ters would not be expected to require more than a minor derating (of the order Of 5-108) of the boilers, if any. Necessary plant modifications would De minor.

In contrast, retrofitting for low Btu fuel gas presents a number of serious problens including derating the boiler and the need for extensive modifications to the boiler and main auxiliary equipment.

Econorcs

As stated earlier, the Puerto Rico's of} situation is particularly troublesome because of ?dependence on imports. The supply and price of imported of1 fs not only controlled by market conditions, but by OPEC, consequently, political considerations tend to play an important role

Future coal prices can be expected to reflect market condi tions and be based upon production costs and those market conditions. Preliminary economic and engineering investigations indicate that the prices ?of medium Stu gas will be highly competitive on a Btu basis with prices projected for imported of

fn the late 1980s.

Table 5 presents capital cost estimates in 1980 dollars for gasification plants with inputs of 1000 and 2000 tons/0 (908-1818 ¥s/0) of coal located near San Juan Harbour.

Table 6 presents the production costs of a medium Stu gas from a 2000 ton/day (1818 Mo/D) gasification piant including an estimate for the dedicated transmission and distribution network (in 1987 dollars) necessary to deliver the gas 20 potential custoners. ?The Tevelized gost of medtun gu ges fn the late {98's elon Frame was estiaated to s8-62/108 Btu (85-52/100 WO}

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The cost of coal is the major factor in the cost of producing gas. in Table 6, coal priced at $67/ton ($.066/Ma) contributed approximately? 60x fo, the cost of the product gas. For a change of $1/ton ($-001/Ma) in the Price of coal, the cost of gas changes approxinately S¢/M Btu ($-7/108 Md)

Other factors affecting the cost of product gas are capacity factor of

fhe gasifier plant and plant size. Reducing the capacity factor from 80 to

50% Increases the cost by approximately 15-20%. There 1s a substantial. drop

?in gas cost as the plant size increases which ievels out as the plant ape

roaches 100 B11lion Btu/D (106 trillion MJ/o) capacity,

?CONCLUSION

In conclusion, although it 1s apparent that the production of clean

fuel gas from coal wit) not be inexpensive, preliminary economic and engtne=

tring investigations indicate that the prices of mediun Stu gas can be Sighly

competitive on a heat content basis with prices from imported oi! and offers

2 means of energy independence. In addition, a reliable source of ?uel gas

can foster economic expansion into other areas via the direct gest fication

concept.

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FIGURE 1 ~ DISTRICT COAL GASIFICATI

NN PLANT CONCEPT

GASIFICATION

PLANT

of

PREPARATION

F

COMPRESSION

Hy and CO | Medium Btu Gas

Pipeline up to | 100 mites (161 Kn)

LOCAL DISTRIBUTION SYSTEM

Evectrie om. PeTRO- METALS oTHER

UTILITY REFINERIES CHEMICALS (ALUMINUM INDUSTRY

~STEEL)

PROCESSING

(Fuet) (Hy, Fuel) (H,00, Fuel) (Fue1) (Fuel)

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TABLE 2 - CONSIDERATIONS IN CONVERSION TO GAS FIRING

~ LOAD FOLLOWING ABILITY OF GASIFICATION SYSTER

= COMBUSTION CHARACTERISTICS OF THE GAS

= BOILER EFFICIENCY AND PERFORMANCE

= BOILER RATING WITH LOW AND MEDIUM GAS

= BOILER MODIFICATIONS AND OUTAGE TIME

~ SITE ADAPTATION

= OPERATING SAFETY OF GASIFICATION & POWER PLANTS

~ ENVIRONMENTAL CONSIDERA

KS,

= CAPITAL AND OPERATING COSTS

= ECONOMIC EVALUATION

= REGULATORY ANO FINANCIAL ASPECTS

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TABLE 4 - COAL GASIFICATION - BOILER RETROFIT

BOILER MODIFICATIONS

MINOR MODIFICATIONS

Low Tu GAs

BURNERS

© WIND Box

© coNTROLS

© FUEL PIPING/FEED SYSTEM

MAJOR MODIFICATIONS

(© INTERNALS

© 1D FANS

© REINFORCING

MeorUM atu GAs

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contrat

FUEL PIPING/FEED SYSTEM

NONE

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TABLE § - COAL GASIFICATION PLANT -

CAPITAL COST ESTIMATES

(1982 Dotiars)

Plant Size

Tons /Day (Ng/0)

000 (7820) 1000 (910

x 1000 x 1000

A) Gasification Plant

Gasifier, Heat Recovery, Gas Scrubbing 34,800. 23,200

Air Separation 32,500 18,700

Acid Gas Removal 113600

Sulfur Recovery 9,300

Coal Grinding & Slurry 8,100

Plant Water, Cooling Tower, 15,100

Wastewater Treatment

?Sub-Total T400

8) Support Facitities

Coal Handling Fact tity 4,000

Utility Piping - Potable Water, +400 140

Dentneralized Water, Cooling Tower

Make-up Mater

Gas Piping 130 130

Piles no vio

Access Road 0 30

Electrical Feeders 520 300

Storage Ash Bins, Pneumatic Conveyor 950 550

esfiten, Foundations

iineralizer with Tank 50 500

Sub-Total T50 5760

Total 121,030 74,460

Contingency @ 15% 18,200 11,200

Grand Total 139,200 85,660

Does not include costs of Tand interest during

Construction, royalty allowances, startup, or

working capital estimates.

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TABLE 6 - ECONOMIC ANALYSIS OF COAL GASIFICATION

FOR INDUSTRIAL SALES

2000 T/D (1820 Mg/O) GASIFIER AT SAN JUAN, PUERTO RICO

LEVELIZED ANNUAL 1987-2009 COSTS AT 1982 PRESENT WORTH

(AIT Costs are in $x10%)

GASIFICATION PLANT

CAPACITY FACTOR 80%

Capital Costs: Gasification Plant - Installed Cost, 1987 $ 209,600,

AFDC (165 CIF), 1987 §

Total investment, 1987 §

Annual Carrying Charge (13.22), 1982 $ 14,700

Distribution Pipelines - Installed Cost, 1987 $ 30,000

AFDC (.165 CCIF), 1987 $ 3,600

Total investment, 1987 § 35,600

Annual Carrying Charge (13.24), 1982 $ 1,980

Total Annual Carrying Charges, 1982 $ 16,680

Operating and Maintenance Costs

Gasification Plant

Fuel

Labor

Materia?

Total

Total Annual Project Costs, 1982 $ 61,990

Annual Gas Production, 106 Btu's (109 MJ's) = 10,640 (11,225)

Levelized Annual Cost of Gas Produced, $/108 Btu ($/103 Md) =

83 (5.52)

AFDC - Allowance for funds during construction.

CCIF = Construction Conpound Interest Factor.

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UPADI 82

San Juan, Puerto Rico

?August 1-7, 1982

First Pan American Congress on Energy

FEASIBILITY STUDY FOR AN ATMOSPHERIC FLUIDIZED

BED COMBUSTION COAL FIRED POWER PLANT IN BRAZIL

by

William J. Bradley

Burns & Roe, Inc.

Newton G. Watts

Foster Wheeler ?Boller Corp.

San Juan, Puerto Rico

?August 1982

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FEASIBILITY STUDY FOR AN

ATMOSPHERIC FLUIDIZED BED COMBUSTION

COAL FIRED POWER PLANT IN BRAZTL

W. J. Bradley, Burns and Roe, Inc.

N. G. Wattis, Foster Wheeler Boller Corp.

ABSTRACT

The feasibility of retrofitting one of three, existing oi) fired

boilers to a coal fired atmospheric fluidized bed combustion

{avec} system is currently being assessed by a team of secce

gad Roe, Inc., Foster wheeler Boiler Corp., and Internacional

Qe Engenharia's/A. This study is being managed by the U.S,

Pehstiment of Energy on behalf of the U.S. Trade and Develop~

ment Program,

The study assesses the technical and economic feasibility of

converting one of three 88,000 ihs/hr steam boilers locetes

at the NUTEPA Power Station in Porto Alegre, Srasit.

This paper presents the engineering, environmental and economic

gyigerta and design considerations used in thie study, proc

Himinary results of combustion tests performed on thice

Brazilian coals, and preliminary plant modification schemes.

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FEASIBILITY STUDY FOR AN

ATMOSPHERIC FLUIDIZED BED COMBUSTION

COAL FIRED POWER PLANT IN BRAZIL

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N. G. Wattis, Foster Wheeler Boller Corp.

wrRopucTioN

The objective of this study is to assess the technical and economic

feasibility of ?retrofitting one of three existing oil fired soriecs

toa coal fired APEC system. The boilers are each 88,000 ibyhe

units in the NUTEPA power plant located in the industzial ccdtor

of Porte Alesre, Brazil. The study consists of an inspection of

the existing equipment and a feasibility engineering and cose

estimate for the retrofit and demonstracion®

Successful operation of this deronstration plant could lead to retrofit of the two remaining boilers, installation oF s sew fourth unit, as well as additional industrial and utility fluid-ized bed steam generators in Brazil.

Fluidized Bed Combustion

A fluidized bed is defined as a gas-solids system composed of granular particles supported by an upward flow gas, with curticient Yelocity to separate and suspend the particles above a gas diss tribution grid. This highly agitated material behaves Soke a fluid, hence the name fluidized bed (sce Figure 1).

The fluidized bed combustion process offers a feasible and effective solution for burning high sulfur fuels and iow quality fuels with high ash content, while maintaining S09 and Noo stack gpissions within the environmental pollution limits. "py firing

the S02 emissions will be controlled without the need for a large. sagensive flue gas scrubbing system. Noy emissions are greatly

iuced by virtue of the low combustion temperature (about 160°) sociated with the fluidizea bed combustion process. The potene tial for slagsing, gas side tube fouling and corrosion problons are also reduced since the combustion temperature is lees then the ash fusion temperature of most fuels.

Zhe study reviews the possibility for incorporating the fluidized bed method of combustion of the Brazilian coals and retrofitting an existing unit to demonstrate the unique systen,

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site

?The site under consideration is the NUTEPA oil fired power plant located in an industrial center of Porto Alegre, the capital of the State of Rio Grande do sul, Brazil (see Figure 2). This plant contains three inactive boilers which are capable of being fired on oil, The boilers are about 12 years old and were operated on 041 until about two years ago. Presently, power is purchased from other grids to make up for the shortage from this plant. The three boilers are located inside a building, side-by-side with good spacing. A bay is available for a future fourth unit.

The power plant is suitable for coal use as it has installed cement bunkers ?and about 12 feet of open space available below the boilers for ash removal systens. The boiler size of 88,000

Ib/nr is about right for utilization of existing U.S. PBC designs

with a minimum of retrofit. the plant is located ona river and

has a wharf which could be used for coal barge unloading. Suffi-

Gient space is available at the site for ground storage and handling

Coal_and Limestone Res

?The following fuels are evaluated in this study:

(4) Run of mine coal from the Leao Mine (57% ash)

(i) Washed coal from the Leao Mine (408 ash)

(id) Run of mine coal from the Charqueadas Mine (538 ash)

?The proposed limestone assessed in this study will be obtained

from a local mine

Scope of Work

?This study is being performed by a team composed of Burns and

Roe, Inc., as prime contractor, and Foster wheeler Boiler

Corporation (Fwsc) and Internacional de Engenharia S/A (IESA),

as Subcontractors. The following tasks are being performed:

I. Technology Selection

1. site/oiler Retrofit Analysis

2. Brazilian Coal and Limestone Test Program Planning

3. Combustion Testing

4. Assess Test Results

II, Preliminary Design Engineering

1. Process Design

2, Facility Design

3. Environmental Considerations

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III, Project Costs and Economic Assessment

1. Preliminary Cost Estimate

2. Economic Assessment

3. Sensitivity Analysis

IV. Project Management Plen

V. Institutional rssues

VI. Documentation

1. Monthiy Letter Reports

2. ?Interim Report (Test Results),

3: Presentation of Study Results

4. Final Report

This paper presents the results of Tasks T and 17

date.

perforned to-

STUDY APPROACH

Burns and Roe, Foster wheeler and Internacional visited the NUTEPA

Plant, inspected the existing equipment and space avarlabi lity,

Feceived copies of general arrangement drawings, and discoseey the

study with Companhia Estadual de Energia Electrica (CEEE) personnel.

Qn the basis of this site visit and these discussions, the following

study approach was adopted:

¢ An environmental analysis to determine soz and particulate capture requirements will be performed on the basis of Fesulting ground level concentration (Le)

% Samples of the three coals and one limestone to be con- gigered in this study will be shipped to the Foster wheeler FEC test facility where analyses and combustion teste will be performed

© Proposed boiler and plant modifications will be presented in ?an Interim Report and discussed with CREE. The Intecim Report will also present the proposed methodology for determining project capital and operating costs

© Upon CEEE's concurrence of the Interim Report, the pro- Ject costs, economic assessment, environmental assecement, Project managenent plan, institiitional issues and fice! report will be prepered.

ENVIRONMENTAL CONSIDERATIONS

Environmental pollution control standarés utilize two types of criterii

3

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(4) Impact criteria, i.e. the ground level concentration

resulting from the operation of a facility

(44) Performance standards, i.e. emission limitations based

on the size of the facility, such as allowable pounds

of pollutant per million Beu heat input~

Based on discussions with CEEE, it was agreed to utilize impact

criteria as the basis for environnental pollution control for

this study. Specifically, the U.S. EPA 3-hour Class II Prevention

of Significant Deterioration (PSb) allowable increment (Ref. 1)

will be utilized to determine $02 capture requirements. This

criteria specifies that the amount of increased S02 concentration

?at ground level during any 3-hour period may not exceed 512

milligrans/cubic meter {ug/m3) .

?The operation of the NUTEPA Plant Unit 3 boiler (88,000 Ibs/hr) will not produce any significant pollution quantities per se.

However, in order that the conversion of this unit provide operating @ata applicable to larger units, emission control standards suitable for such large units will be observed. For this purpose, a 150 Me plant firing 255,000 ibs/hr of coal was considered.

Dispersion Modelling

It should be recognized that a detailed dispersion analysis requires site-specific meteorological data taken over an extended period of time. ?For the purpose of this preliminary estimate the methodolocy used is based on a sirple technique for determining the maximum ground level concentration of an elevated gaseous release (Ref. 2).

?The parameters used in this analysis and the results obtained are preseni.d in Table 1. The analysis was performed for coals with ¥arious percent sulfur content and for both 400 and 500 foot stacks. The rerniting ground level concentrations (GLC) and sulfur capture requirements are also presented in Table 1.

on the basis of these results, a 60% sulfur capture requirement has been specified for the base case analysis for this study.

COAL AND LIMESTONE TESTING

Preliminary Laboratory Analysis

Samples of the Leao No. 1 Mine run-of-mine (ROM) coal, Leao No. 1 Mine washed coal, and Charqueades Mine ROM coal were analyzed. Tables 2, 3 and 4 present a partial listing of this analysis, including proximate analysis, ultinate analysis, calorific value, Hardgrove grindability index'and ash fusion terperature, for these

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No,unusual characteristics were encountered in reviewing the coal as gaghpMmalyses. The ash fusion tenperature appears very nigh (s7800rt) 1 thereby indicating that ash agglomeration should peesent no problem in the fluidised bed,

Crucible ashing tests were performed on the three coals to deter= Jane the physical characteristics of the coal ash. All tires Samples produced ashes which contained significant quanticics of Ghale type residue. the results of this test suggested thae the Inte ehetugavi}l reauize crushing to small sizes prior to reedneg inte, the bed because of the potential for oversize ash Scccmuraron in the steam generator bed.

Combustion Tests

S Were crushed prior to testing to approximately

Kr 2,0;, Initiatly molochite, an inert fired clay sremeine

Raterial, was used for the fluidized starter bed, ?This material

was cglected for its attrition integrity and chemically sacse

RrgPertios. Tests had to be haltes after several hours, hovever,

gue to severe bed agcioneration. examination of the etinnen

formed in the bed revealed eutectic melts vhich occurved berween

ERE Molochite and the coal ash. Substitution of quasts send fon

the molochite in subsequent tests eliminated the frobiom®

?The coals appear to burn well at 2 bed temperature of 1600°%F

(870°),

PROPOSED BOILER MODIFICATIONS

he NS basis of the combustion tests and the environnental criteria,

the following design features were determined:

© fhe basic criteria in establishing plant modi ficatios

is to minimize the costs of system changes yet meintein

full load capacity. Alternative system medi ficacions

may be considered if increased boiler turndown and final

steam temperature control range are desired,

© Apnounatic incbed fuel feed system will be utilized to

minimize the elutriation of unburned fuel from the boa

and to enhance sulfur capture performance. The fue?

will be crushed to k" x 0.

¢ A Limestone (dolomite) over-bed feed system will be

Provided to achieve sulfur capture performance.

2,gsione dust collector and/or a fabric filter baghouse

will be provided to achieve particulate capture reuiree

Rents.

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Existing Boiler

Figure 3 presents a schematic of the existing NUTEPA oil fired boiler.

Air from the forced draft fan flows across two passes in the lower air heater, across one pass in the upper air heater and out to the burners for combustion air.

Combustion gases from the of1 furners travel dounvara between the front waterwall and the partition wall. The gas flow then reverses and travels upward between the partition wall and the rear wall. The gases leave the furnace enclosure through the rear wall screen and travel across the superheater enclosure, turn downward and continue across the upper economizer, through the upper air heater, across the lower economizer and through the air heater. (Inthe air heaters the gases flow inside the tubes). From the lower air heater the combustion gases enter the induced draft fan and then to the stack.

Feedwater enters the unit at the inlet of the lower economizer and after passing throuch the upper economizer, the heater feedwater enters the steam drum to replenish the boiler system,

Boiling occurs in the waterwalls and partition wall of the furnace enclosure by radiant heat transfer between the con-bustion gases and the walle. The boiler system is a natural Circulation loop.

?The superheater tubing forms its own gas pass enclosure roof

and floor. Steam temperature control is achieved using @ sub-

Merged attenperator, which is loca the lower drum.

Attenperation occurs between the and finishing super

stages.

te Boiler Modifications

?wo design alternatives for modifying the furnace for FBC com

bustion were considered:

© Alternate 1 - with recycle of fiyash

@ Alternate 2 - without recycle of flyesh

Both design alternates are based on using the Leao No. 1 Mine

OM coal operated to achieve 60? sulfur capture. The furnace

Would be modified t> accept the operation of @ one cell fluid

bed with all the gases in the furnace flowine in an upward direction. The 4.5 ft high fluidized bed would be supported

by an ais aistributor g1{d properly attaches to the furnace

»

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The first design alternative (with recycle of flyash) is to locate the fluid bed in the area bounded by the front wall, the tho side ELDESgE she, furngce partition wall, ?the plan area of the ¢iuig pee asz ft x 28-3 fe or 170 ft? (a6 me). the flusdising velo- city is determined by the amount of gases raquied to achieve Raximun continuous rating (MCR) output of 82,000 Ib/hr of steam oe ee reat? (522 PSig. This results in a fluidizing velocity of oak flee, G22 R/sec). Fines recirculation was used to give a Combustion efficiency of 97% at a bed temperature of 160008. oA galcium to sulfur ratio (Ca/s) of 1.71 is required to achieve eO¥ sulfur capture and an excess combustion air of 224 wes ures an the evaluation.

Pe gnalveis of Alternate 2 results in # boiter efficiency of

£2-8%1 ,2 fuel feed rate of 20,369 Ib/ar and a limestone fteq rate Of 4,748 W/hr. The ratio of recirculated fines to conbuseion air is nearly 0.7 which is considered too high. An sneracioe Geantity of combustion air would be diverted fiom tuiaising

Siz fo Fueunatically convey the fiyash. In adéition, the fiyash yas found to contain 75% esh which is considered too hign sek justifying recirculation to achieve improved csrbon and sincstone utilization.

The second design alternative (wichout recycle of flyash) is to expand the plan area of the fluid bed by removing the frenace

wall and extending the bed to the rear wall of the furnace, The, plan area of the fluid bed is 17.5 ft x 15.3 ft or 270 £2 (25 92). The resulting fluidizing velocity is 7 ft/sec (2 m/sec) and che C2/8 mole ratio is 2. In order to improve the carson vonhast ion giticiency on a one pass besis through the bed, the bed temeerscure is raised to 1650°F (700°C) -

he enalvgis of alternative 2 sesults in a boiler efficiency of 06-58, 2 fuel feed rate of 22,084 Ib/ar and a limestone feos sate Qf 6,027 lb/hr. The lower boiler efficiency is prinarily aue ts increase in unburned carbon losses from 38 to 94"

The results of these analyses are summarized in Table 5. Although the recycle alternative hes economic advantages in terms of borien Rfficiency (and subsequent fuel and waste disposal savings) the Aigh dust loading resulting from? the recycle of such high ash fuel makes this alternative proaibitsve.

PROPOSED PLANT MODIFICATIONS

Brglininary analysis indicates the following equipment changes and

Adgitions will be required to convert the NUTSPA Plant Gries ee FBC firing:

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© Forced draft fan

@ Induced draft fan

Flues and ducts

© Tubular airheater

© coal feed system

@ Limestone feed systen

?© Spent bed material renoval system

© cyclones and/or baghouse filters

'¢ Coal handling and storage system

@ Limestone handling and storage system

¢ Waste disposal system

Electrical and instrumentation

A brief description of some of these modifications is presented

below.

Forced Draft Fan

?he forced draft fan and motor drive will have to be replaced due to the higher static discharge pressure required to overcome the air distributor and bed pressure drop in this system.

Induced Draft Fan

Although the induced draft fan may be marginally acceptable under the new operating conditions, it is recommended that the fan and motor be replaced to insure feliable performance for start-up and full load operation.

Coal Feed system

An in-bed pneunatic coal feed system will be added with multiple feed points being investigated.

?Limestone Feed system

A single over-bed feed point will be utilized for limestone feed. The limestone feed rate is regulated as a ratio of the coal rate with the ratio adjusted by the autonatic control system to control 50, emissions at the stack.

sD

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tA

Spent Bed Material and cooling system

single seameterial wild be withdrawn from the fluidized bed at a

Fron fesgoe? bites the material leaving the bad aust be socted

Sram, ESOC? £0 & temperature at which it can be hannitd ens with-

SERED St 2 zate to match the inslux of material 1ereteejteY a

Tensval cued ScFew can be used to reguiace the bed sarreins

3o0cr. | ?*t* 8 Well as to cool the material to approxiestely

3000P.

Gyclones and/or Baghouse Filters

ceniee eeesenELY Feviewine the need for a mechanical cyclone dust

SRIrPSEL aE the outlet of the boiler for ehe pasere SE collecting

systen So Gust Particles entrained with the five oes oeceuteream

WET be receeton, fO,date indicates that 9 fabric Fleer Lerhourt will be recommended for the retccrit?

NESE RtepOses Bod tications will be presented in the project

GEEeg eemert and Will be discussed wish ceee. ?uses PECSECE oy

Sapien enmerts the croject will continue with the sonar eesion,

mene aresete eemates, economic assessment, envi ronsentet eacesse

report pees management plan, institutional issues asa sinet

report being prepared.

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INON ONIIOS V ayIT SIAVHIG

?LNSINGUNL G39 'ALIOOTIA ?a3aNadsns

ONIZIOIN IS WAWININ SAWILE 3G !ALIOOIIA ONIZIGINT ~??G3aUNASIONA a3a !ALIQOT3A

ATBLVWIXOUddY ALID073A SVD. WAWININS ALID07AN SVD ONIZIGINTS> ALIDOTIA SVD

VNAWONSHd NOILVZIGINIS

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TABLE 1

ENVIRONMENT:

ASSESSMENT.

Plant Size - 150 swe

Fuel Fired ~ 255,000 1bs/he

Flue Gas Flow Rate - 1,991,000 tbs/nr

Flue Gas Terperature - 25°F.

Flue Gas Velocity - 60 ft/sec

asuuns

SEACK Metahe (st) Suitur content exe ua/a?) 4 SOS

400 2.98 wan soe

400 Le no 208

00 ao ae ov

00 2.98 1102 ses

500 Lm 646 aun

500 Los 380 o

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TABLE 2

LABORATORY [UCL ANALYSIS

SANPLE DESCRIPTION: Leae No. 1 Run of Mine Coal

Sample total moisture prior to shipment to U.S. ~ 11.0%

ALR ORY LOSS 5: 5.28

EQUILIBRIA MOISTURE Sz 20-1

AROGROVE ?INDE n

AS RECEIVED ey,

PROXIMATE ANALYSIS

Fixed Carbon 23.00 25.17

Vol. Hatter wn 29.60)

Ash 50.48 55.23,

Moisture 8.61

Total 100.00 100.00

ULTIRATE ANAL StS,

Carbon 34.24 37.47

Hydrogen 2.79 3.05

Oxygen 0.37 0.42

?trogen, ot 0.66

Sulfur 230 3.7

asi 50.08, 99.23

Moisture 8.61

Total 100.00 100.00

HoH. Vey Btu/2b, 6,236 6,023

ASH FUSION TEMPERATURE Doo. F

Reducing Dxidizing

Inatial Deformation 2800+ 2800+

Soft Tenp Spherical 2800+ 28006

Soft Temp Hemisphericel 2800+ 000+

Fluid Tenp 2800+ 20006

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TABLE 3

LABORATORY FUEL ANALYSIS

SAIPLE DESCRIPTION: Levo No. 1 Mine Washed Coal

Sample total moisture prior to shipment to U.S. - 17.50%

AIP ORY LOSS ?i: 6.18

Cour iariu riorstuRe ss 11.50

HaROGROVE INDEX: 3

aS AECEWED pay

PRORINATE_ ANAL YSIS

Fixed Carbon 29.41 32.88

Vol. Netter 22.43 25.09

Ash 37.58 42.03

10.58

Total 100.00 100.00

Carbon 36.72 41.07

Hydrogen 2.58 2.08

Oxygen 10.79 12.08

Nitrogen 0.68 0.77

Sulfur 1.07 1.20

sh 37.58 42.03

Moisture 10.58)

Total 100.00 100.00,

He He Vey Btusab 6,970 2,995

ASH FUSION TENPERATURE Deg

Reducing Oxidizing

Initial Deformation 2000+ 28006

Soft Teap Spherical 2800+ 2800+

Soft Temp Hemicpherical 2800 2800+

Fluid Teap 2600+ 2000+

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TABLE

LABORATORY FUEL ANALYSIS

TABLE 5

COMPARISON OF ALTERNATE

Description

ca/s .

Bed Temperature, °F

Fluidizing Velocity, fps

Excess Air, *

Combustion Efficiency, &

Boiler Efficiency, ¥

Fuel Feed Rate, 1bs/nr

Limestone Feed Rate, ibs/hr

Alternative 1

with recycle

an

1600

10.5

2

97

22.9

20,369

4,785

Alternative 2

without recycle

2.0

1650

7.0

22

8

76.5

22,084

6,017

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