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1983 UPDATE PUERTO RICO

ENERGY ALTERNATIVES

By

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May 1988

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é 2 CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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iu bie pati me show some figuses and tables which sunmarize our

stage. Ths 9 nipetive ooneis

fons are drawn from the results of

wore Rega

ding Puerto Rice Energy Alter-

questions ane atiewors reiovant ta the present

Rico are presented

APPESDIN 4 eonomic Bquy

nthe seations C1, C2 and ?3 (C stenda for Capital) of this

Appennia we deseribe the min fuetors wl

?appear in the economic

equevions «hie eulcuinte the total $/KWH of any of the energy alterna-

tives.

tr seotions BL anc £2 G stends for fuel? we calculate the economic

uation far the fuel cost an §7WH Tevelizing throughout the life of

Ye plant

ections CML and OM2 (OM stands for operation and mainten-

ance) se cfotlate the levelized cost throughout the life of the plant.

---Page Break---

The total Bier serty Cos leveuzed throughout the Ife of the plant

1s then

APPENDIN Ih ~ New Duta Source

In this appendix we discuss the new ussumptions, based on some

references given at the end, which served to elaborate this work.

---Page Break---

SULTS ASD CONCLUSIONS

---Page Break---

2 conelusiens is that Puerto Rico's energy situati

primarily

due to nea cor, ete dependence of elt Steps should he taken to

Feduce this dependence te the future

measus es Bemg Hditas ts co

sumption, ** most promising area in redueing off consumption is elec-

2. A program te reduce ii sonsunpticn by 500 for

electrical generation within 1

next 18 yes

2a be cmsidered as an

sppropriste sbjective. The most proms:

we for fuels are

nuclear or vo! with the eptinum solution vtiliziny both, In addition,

promising ruven ef cnergy in smaller quattisien

Is available from

ot oUF sugar cats: ?durtry). ?this energy

Fou ant ers economically competitive with cox. A commercial enter

uring biomass (energy cane and sine: CBR developed rece) most compete favornbly int

oust energy market.

he sein seatrietion to its broader use, will Le the use of land for

ution.

se tagher value ps

?These conclusions are supported by our calculations which resulted

ee Lond table 1, The curves shown in figure 1 were ceternined

owing consistent assumption. All 1983 costs: Capital, vention and Meintenance Costs are orricc over ty 1985 and

then, at chat yeer. « 7% inflation cate and 10% interest este sre allowed.

AS ws Se tue most economic solution ic Nucloar with @ total

level~

> 1996 (See figure 1 end table 1) of &.07/KWH, Then Coal
is next with @.1Z7/KWH. Then biomass very closey to esa with
$0.191/KWH. The comparative oll cost is $0.168/KWII, Wind and photo~
voltaic alivrnatives generate electricity at much higher values, at

$0,.210/KWE and $6.588/KKW respectively.*

?Calewlated from data reported in Reference 19 and # respectively.

---Page Break---

PART - 1

QUESTIONS & ANSWERS REGARDING

PUERTO RICO ENERGY ALTERNATIVES

---Page Break---

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490

Figure b

Nucteor

Sy > Coot

B, = Siomoss

oN

My = Wine

| po + Frotovel-

Levelizec Cost For the Different Alternstives

AML cost are affected ay 7% i

fond 10% interest otter 1985,

PHO) (0)

©) Calculated from Data reported

In Ret. 10

b) Calculated trom new Dote reported

in Ref 8

1990 ty98 000

Y

ear,

---Page Break---

1, What is the bexground of Puerte Kico's eeorumic cond:tion?

The eccnomy of Puerto Rico is a section of the USA economy cycling

fas follows. In the period before 1973 te Puerto Riean economy was

oynamic, growing f

ter than tie United States economy as » whole,

propelled by lower

and labor costs as well as by US government

support.

After 1973, oil price increases reversed Puerto Rico's oil cost

suvantaye:

?he eccomy has grown afteraurds at a much slower rate.

960-73 1973-80 Growth Comparison

Blyear year 8

Puerto Rico 14 Bt 40

DSA 3 25 80

the growth in employment was also reduced.

EMPLOYMENT GROWTH RATES

1963-70

_ biyear

Puerto Rico 5. aa a

usa 212 1s 6s

Puerto Rico's economy continues to be depressed as of March 1983.

2, Is the high cost of oll the only factor affecting Puerto Rico's de~

velopment?

No, it is only one of many. However, it is an aren where govern-

mental action will have very direct and positive results. Energy is

Particularly important to Puerto Rico because the Commonwealth is a

---Page Break---

relative high user of energy

be seen by the Luble below refect=

ing World Bank inforination.

Ye of Primary Ener

?Barrel Capity-Ve

Puerto Rico 20

High Income Countries 38

Med income Countries 3

Low Ineone Countries

prices?

© Puerto Ricans economy se susceptible te changes in oil

Puerto Rivo 3s not only # high cvergy wser,

it depends almost

Glusively on oi, In contrast, the US not only enjoys a certain

we Of enerzy source diversification, but it is aise moving toward

he use of lower cost energy sources.

---Page Break---

4. How can Puerto Rico's dependence on of! be reduced?

Puerto Rico's use of oil is mainly for

?Transportation 258

Electric. Production 358

Chemical Industry 208

Feedstock Lo8

Oil usage reductions are wchievable primarily by conservation in the

field of tronsportation, an

by © combination of methods in the chemical

Industey. ?These changes are in the process of implementation in res~

ponse to the high cost of oil and its by-products.

In the case of electric production, conservation also results from

high prices. However @ better solution is the reduction in the cost of

kenerating electricity by substitution of olf by lower cost energy sour-

ces. This can only be done by the Puerto Rican Government.

5. Is the price of electricity higher in Puerto Rico than in USA?

Yes, in 1981 the average prices of electricity were

Puerto Rico

USA (Average)

South Carolina

9.82cents/ KWH,

5.00cents/ KWH

4)13conts/ KWH

The difference is also getting larger as can be seen from the chart

below

AVERAGE PRICE OF ELECTRICITY

1973. 1981 Rate of Change

(Constant $)

Current Constant

Dollars Dollars

cent/KWH ___cont/KWH __cent/ KWH

Puerto Rico 2.2t 8.82 5.35

usa 1186 5.00 272

---Page Break---

6. Have those high prices deterred electrification and therefore re~

duced the procuctivity of the veonomy?

Yes ~ The price of electricity while low in the short term increases

significantly with time, The consequences are refteciea fa tte tab below.

1960-1073, 1973-1980 Change in Growth

Rate

Biyear Siyear a

Puerto Rico 13.9 Ls 7.3:

ISA 68 26 zie:

What is the reason for the high cost of electricity in Puerto Rico?

?The exclusive dependence on ol). It can be seen by the tables below

that when comparing prices in different states, the price of electricity

celines where less oll is used for the electrical production.

AS a consequence, the electrical utility industry in the US has

shifted toward the lower cost fuels. In the period 1973 - 1982 the use

of

decreases

increased

increased

Increased

338

2

42¢

2208

?She World Bank advised that the developing countries plan to reduce

the use of oll for electricity generotion from 24% in 1968 to 68 in 1995,

---Page Break---

---Page Break---

te

wot

:

Urtre

ou

puerro 99% %

nico \

---Page Break---

recent seduction in oil prices revsce tne magnitude of the

Oil prices today are only skehtly lower than the 1981 prices used

as reference.

Further oil price reductions may occur but they are expected to be

short tiveé. ?The position of the il producer countries to rise prices

will improve when the demand increases as # consequence of the leveliz~

ing in of! prices and

he end of the recession

The forecast in the long run continucs to be fer cil prices to

increase faster than the general level of inflation

Ni shoula be noted that 70% of the oil exports originate from the

Arab sorid, bringing inte question the reliability of supply.

9, What ane the alternatives to ofl for electric generation in Puerto

Rico?

Gas, hydro and geothermal are not in consideration because the

Island docs not have the natural resources. Breeder reactor, nuclear

fusion

and sen power are not itv consideration because no conmerclal

technology will be available in the next 30 years.

Coal and nuctear are proven sources of possible immediate applicw-

ton, biomass could be used In # limited manner; solur-photovoltaie and

wind, while not economies! today, could becone yractical alternatives if

their capital cost 4s significantly reduced by technological development.

oe

---Page Break---

10, What ure the possible savings from using alternative fuels in

Puorte. Rico?

For @ versonable set of assumptions the lvellzed cost of electrical

Kenerntion for @ plant that starts operation in 1990 was calculated to be

on 16.8 ockwH

Biomass awed cokWH

Coal 8 evkWH

Nuclear a cokWH

Biomass (sugar cane or sorghum dried and burned in boilers) could

bbe conceivaoly competitive with coal

Wind nnd solar-photovoltaic are not current solutions. Cost. of

energy with the same assumptions above are:

ou, ies ookwn,

Wine! > 210

Photovoltaic! as

?The cost of the electricity generated by these sources must be

ignificuntly reduced before they become competitive for Puerto Rico conditions. This is not likely before the end of the century.

To set in perspective the savings possible with the use of alter native fuels, s? 808 of the current electrical output of 19 billion KWH

were produced by coat or nuclear the potential savings would be (in

1981 dotters)

Coat 166 million dollars/year

Nuclear 397 million dollars/year

?The cost of electric power shown gives nuclear a very substantial

advantage. This is contrary to estimates in the USA, that show much

less advantage for nuclear power over coal power.

YAS CalGilted from data reported in Ref. 10.

») As cwloulated from data reported in Ref, 8.

---Page Break---

Actus! international experienc: gives a 40 advantage to nucleer ?over coal. This advantage increases where sophisticated environmental controls are required for coal. Also the cost of coal is higher in Puerto Rico compared with USA becsuse of increased prices for transportation ané handling. Finally the US estimates reflects

implementation schedules, much longer then necessary.

11, What would be the benefits to Puerto Rieo of reducing oil depend~ ence in electrical production to 508?

More than 1 billion dollars per year.

What will be the source of the capital required to carry out the investment required to achieve the above objective?

?The financial community will be willing to sdvance the funds neces~ sary both for capital cost and for interest during construction, if the investment is warranted by the Commonwealth.

?As soon as 9 plant is in operation, the savings in ofl imports will

permit repayment of the loan, as well as the operating expenses and

fuel leaving @ large surplus that will permit a reduction in the price of

el

ricity.

?16

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x 09 yvayoaszeug

x ow porn,

x xx 82 ssesoyg

x z eoto0N

x xox x x x 1 809

x x x x mm 10

Sfwraodsvest eyo 9UsuA woFI¥TpeY Tesod aenp yu FavETN angdTng LDITS wI/SOIDE

aapaoe yt699 sre THO paszaba

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uo jwopsDafa 40J [Ho Jo asn ayy 0} Saaneusoyly yueL93;p oy) q PayDayJa aq yuoWLOAAUD OM)

TIM MON ?ET

a

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14, What _will heppen tothe competitiveness of coal generated elec

trlety If the Wastumptions Utized in the estates do not materia

The estimates of co#l power costs are sensitive to:

Relative cost of coal vs. oll. The abundance of coal and the consequence of using oil determines that coal prices are riven by those of oil. Furthermore, coal generated electric= ity will be cheaper even if the coal to oit price ratio inerenses by 508.

?The availability factor of the coal power units. The avail~ ability of large units with strict environmental controls hi been low, of the order of 608. It may increase as the techn- ology is better understood. Coal power is competitive with even with an availability as low as S08.

3. The assumed rate of inflation. Be

use of its higher capital

investment, coal power has an edge against inflation and will

be penalized if @ deflation will occur after plant completion.

Coal continues to be competitive with oil even after deftation

ates of 3008.

15. What are the environmental effects resultant from the use of coal?

?The most significant effects result from the huge mass of material

to be transported, handled and disposed. If generation facilities pro~

@uce half of the current Puerto Rican electricity output, the following

flows result:

---Page Break---

Coal Trensportetion 1.8 million tons/year

Ashes to be Buried 150,000 tons/year

Particulates Released

to Atmosphere 4,000 tons/year

Sulphur Removed 20,000 tons/year

Sulphur Slurry 100,000 tons/year

Sulphur Oxide Released

to Atmosphere 10,000 tons/year

CO, Released to Atmos-

pifere 4 million tons/year

While most of them result in expenses and nuisance rather than danger,

the effects of the release of CO, is currently « widespread concern of

the scientific community because of its eventual effects on world weath-

er conditions.

16. What will happen to the competitiveness of nuclear generation if

the assumptions utilized in the estimates do not materialize?

The estimates of nuclesr power competitiveness are sensitive to

Future Cost of oil. However to become competitive, the price

of ol in constant dollars must go down to $10 8 barrel, the

price of coal to $25/ton.

The aveilabitity of the nuclear plant. The availability of

600MW nuclear plants has historically been high and should be

---Page Break---

even higher (sbove 758). In any case, nuclear will retain its

economical advantage over oil even if it is utilized ut only 258

of its nominal rating. while the advantage over coal still exists

for an availability factor of the order of 338,

3. The initial cupital investment a

mes the use of a proven design and the execution of the project by s competent team under « streamlined NRC regulatory review. These are necessary conditions for the options to be « practical alternative. However capital costs must be four times greater before it

looses its advantage over oil, 2 1/2 times for the case of coal.

17, Which objections have been raised to preclude considerations of nuclear power?

Several objections have been raised:

One of them

that because electric consumption in Puerto Rico is not growing, we do not need new generation power.

Riectric consumption has not grown because of the general reces~ sion of the economy and as ® reaction to the increase in electricity prices. Demand will increase again once the recession ends and as the price of electricity levelizes. Furthermore, new generation facilities with alternative fuels will result in large savings even if the demand oes not grow because of the high operating costs of the existing oil burning units.

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A second objection raised against nuclear power is that the commer-

ial units currently available are too large to fit the size of the Puerto

Rican system.

Nuclear power has been introduced in other electrical systems of

similar lond demand to Puerto Rico.

?The staller reliable nuclear units available today are rated at 600

MW. ?They cun be competitive with oil even if operating at 200 MN, and

?ith cos at 300 MW. Adequate reserves to permit satisfying the elec-

?ical demand during refueling and maintensnee of the nuclear unit will

be provided by the existing oll facilities (4200 MW).

18. But is not nuclear power risky?

In the world there are about 260 reactors in operation and about

220 in construction. Thus, humanity has lived through sbout 2000

Feactor-years with no fatality resultant from the nuclear portion of the plant.

This contrasts with the numerous accidents and ines that result When using oll for power generations, including transportation of oil, fits refinement, equipment failure such as befier explosions, fires like that of TOCOA, and pollution from the off leaks and combustions pro- duets.

There is @ potential risk that an accident in a nuclear power plant

However this risk i

will result in the loss of hundreds of liv

extremely low, less than one case in 100,000 yeas

---Page Break---

counTRY OPERATING

Argentine

Austria

Belgium

Brezil

Bulgaria

Canada 1

Crechosiovak?

Finland

France

Germany (GDR)

Germany (FR)

Hungary

Ineie

italy

Japan 2

Korea

Nexico

Netherlands

Pakistan

Philippines.

Poland

Rumanie -

South Africa

Spain

Sweden

Switzerland

Taiwan,

United Kingdom 32

nited States 4

USSR x

2

1

4

2

1

4

8

1

0

22

---Page Break---

18. Does the public have to be protected for thousands of years from

the nuclear waste generaied Ly nuclear power?

Most of the waste from « nuclear plant is low level, as 1

ated fa ® hospital, and its dsposul will follow proven a

in use in Puerto Rico.

?The spent fuel, in contrast, is highly radioactive and must be

handled safely. This will be done either through reprocessing outside

the island or in the national waste repositories that will result from the

application from the high-level waste policy act

Storage and transportation of spent fuel nes not resulted in ac-

cidents in the 2000 reactor-years of nuclear operations to date.

The spent fuel generated from a nuclear plant is only @ minute

fraction of the waste resultant of fossil combustion and therefore the

problems resultant from its disposal are simplified,

2. Cost and schedule of nuclear plant construction in the USA has

risen ?out of control during the last decade, How will this be

avoided in the case of Puerto Rico?

?The increases in cost and schedule of US nuclear construction ean be explained by a combination of s period of extruordinary expansion in the nuclear industry in the USA, its fragmented nature, and the nature

of regulation in the USA.

There fs @ recognition in all segments of the industry that it must come back to shorter schedules and lower costs. This can be accom= plished if the following clements are available for now plant construc- tion:

--+ a well studied site

~ @ proven design with a good level of definition

---Page Break---

--+ 8 competent ond experienced implementation teum review and agreement with the site anc design by the owner

and by the NRC before start of construction

in the case of Puerto Rico, the Islote site is well studied aod

Proven 600 MW design is available which will mect all current NRC

requirements. Only @ Probabilistic Risk Analysis remains to be made to

permit review by the NRC.

21, What is the feasible schedule for implementing @ program that will

reduce Puerto Rico dependence on oil?

aed Decision to proceed

198 Preparation of a plan with specific proposals for

approval and release for implementation:

1985, Start of program implementati

ry9i-2 Start_of operations of first generating facility

utilizing alternative fuel

1995, Achieve goal of reducing ofl share in electrical power generation to 50%.

22, The effects of the proposed program to reduce dependence on vil will only reduce electricity prices In 1990's, Which are the imme- Giate benefits of the program?

A program as proposed will result in immediate benefits as the result of the implementation process,

Local direct construction expenditures will be in the order of 600

million 1981 dollars and its multiplication factor will resi

it on an

economy incentive of 2 to 3 billion dollars of added circulation. ?This represents around 25,000 man-years of direct employment and 100,000 man-year of indirect employment during implementation of the

project.

---Page Break---

These effects will increase with w higher nuclear share in the

program, will decrease if the nuclear share is lower.

23, What ore the advantages and disedvantages to result from the use

of biomass as a source of power?

Primary advantages are

=~ fuel is native

-= it generates agricultural employment

?at the same time it generates power it my yield some molasses

The disadvantages are:

-- extensive land requirement (40,000 acres are required to

satisfy about 108 of current power demand). However for

simall plants like 20MW Plant, the land is available in the sugar

cane fields of the government of Puerto Rico.

~~ high mechanization of operations required to reduce costs reducing employment with reference to other possible uses of the land.

~- economies require efficient combination in large size units.

Only small, inefficient units are currently available. Tech ology must be developed to the commercial operations phase before generation costs can be established.

It is interesting to note that in 1935 Eng. Luis A. Ferré had already made a detailed study of the use of bagasse to generate elec

tricity in Puerto Rico (reference 13).

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APPENDIX A

ECONOMIC EQUATIONS.

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Copital Investment

C1. The initial Capital Investment © can be calculated given

1. CO: Basie cost calevintoc in dollars per kilowatt correspond-

ing to the base year of investment (BYI) and

Ks Special adders for » particular site und utility organization

CO in general decrease with increasing plant output power.

For instanee CO may be given by # exponential form of the

following type

cos Ac B®

where A and B are constants and W output power. In case of

coal the bose cost CO includes the cost for FGD (Flue Gas

Desulfuration) which is needed since most of the coal which

may come to Puerto Rico from Colombis or U.S. have more than

0.58 of sulphur, The total base cepital cost in BY1 dollars is

c= (CO+K) = (AC PM 4 Ky

C2. Inflation and Interest

?The base capital cost (CO + K) should be multiplied by:

1. a factor which includes the effect of inflation from the date

where the ©

imations are done (Base Year of Investment) up to the

Gate when the plant construction starts. (Starting Yeur of Construc~

tion = SYC). This factor is given by

y,

aig?

where jg is the inflation rate end

y, = syc - BYI

---Page Break---

2, by @ factor which akes into acount, the inflation during

construction of the uncomplete | portion of the work, that is. the inflation on the material to be acy tired at that given time during construc-

tion in order for the whole ps ject to be finished. This factor is given

by

a= ays,

where Y, is the construction period in years and ?a? the integral of the

money to be spent during con: truction,

. £ (My = Dae/Otyza0n)

whore,

Osta,

and dz is the increment of expenditure at the time t during construc-

tion, The inflation rate ip may change between the BYL and BYI + ¥2 =

FYOCO = First Year of Commeveial Operation

3. by @ factor which takes into account the interest of the dollars

spent during construction. This factor is given by:

a igs

where ig 18 the interest rate during construction.

?Thus the total capital investment cost C is given by:

ae BW oY,

a,

2a + igs

re

siptiasiy G7

+e a +ipti asip

TC is expressed in $/KW

oa

---Page Break---

?The previous total capital investment TC must be recuperated

curing the iife of the plant. A fixed charge rate will allow the utility

to ree!

rute all the investront and some profit. The investments

recovery factor may include amortization on a sinking fund type of

aecount, property insurance, which is function of the capital invest-

+ plant Gepreciation; @ pereent to cover property taxes, composite income taxes, charter licensing taxes, ete. In the case of PREPA the Trust Indenture requires that the electricity rate covers the cost of interest on bond issues plus amortization, plus a straight-line depre- lotion of investment. This helps to build up capital in order to pro vice un adequate safety margir to pay the debt. Such safety margin is calculated by dividing the net revenues (revenues less operating expen- ses) in a period of @ year by the yearly committed payment of the debt, This ratio should be not less than 1.5. Thus, this safety margin, sometime called "coverage" should be greater than or equal to 15,

Coverage _ Net Revenue/Year

?Debi Payment/Year 1S

fn order for the corporation 16 assure ® good market for its bonds with low interest rate. In the case of PREPA (see discussion in I - 24 of reference 1) the fixed charge rate (F.C.) will account for bonds Interest plus the amortization in sinking fund or the capital recovery

factor (CRF) plus insurance (INS). CRF is given by

one =~ ?_

a-p"

---Page Break---

Where i is the annual interest and nthe plant life in years. (30 Yo 35, in most cuses). Obviously the annual cost of the KWH will depend then strongly on this fixed charge rate (F.C) and also on the number of equivalent hours where the plant is at full capacity. To take into necount this last important fact a capacity factor (C.F) is included in

the ealculution of the actual

Wvestment charge or cost/KWH. The

investment Charge (1.C) equatvon may be written as:

y os wy, av

(C0 + &) d+ p*L G+ ip) 20 + igg)"¥2 (P.0)

TBC

CO = base Cupital Cost

X= Cupital adders

aig? + account for inflation from the time of

study to the beginning of construc

tion

a+ ip Ore + eccount for inflation for the non ex-

Pended money during construction

2,

+ igo + neeount for interest during construct

-C.) = Fixed charge rote = (CRF + INS.)

8160 = No. of hours/year

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VEL

FL. Fue! Cost

The fuel cost in $/KWH cepends very much on the type of fuel for

the following reasons:

The cost (S/KWH) is

ted from the produet of the following

= Price of fuel/unit = $/1b or $/barrel, ete:

+ Heat value = MBTU/unit and

~ "eat rate of the plant BTU/KWH.

For tho same type of fue! different sources may result in different jest vallios, since this depend on the impurities and chemical composi- tions, Me note also thet for the same type of fuel different qualitites nay require different adders whose costs are included in the term K of the initial capital C. For instance F.G.D system, land transportation fnckities, port facitities ete., all there are elements to be considered and they should be part of the Value of K deserted in the section C of

?pital Cost, It is also interesting to note the great difference in Heat

the different types ef fuel. The following approximated

figures may give us an idea of such differences.

Fuel (Heat Voise in BTU/ID)

Coat 10,000

on 20,000

Nuclowr 40,000,000

---Page Break---

The fuet during the Ife of the plant may be subject to snfation.

th order to compare the fuel ost and the capital cost both costs have

lw be reduced to the same Deuis. This is done by levelizing the fuel

cost, that is calculating the constant cost which present values is the

sume es the integrated varint ie cost resultant from inflation process.

Fy = Fook = Fuel Cost at the beginning of construction) . (levetizing

factor)

where

Por Ff ca ae ep * ¥)

Se = Fuel Cost in $/HR= Heat Rate in BTW/KWIL

1+ ep Op * ¥y) + factor wlich secount for the inflation which occurs from the year of study to the first year of commer-

?ial operation.

?The Levelizing factor L is given by:

iasyh

ae

2 = life of the plant in years

discount rates usually equsl to the interest peid on bonds for public

corporations

jeu

ra

= total average yearly inflation rate of the fuel

1

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OPERATION # SD MAINTENANCE COST

OM. OAK Cost

The total O&M Cost inciudes those expenses resultant from the

staff cost, fixed and Verisbic maintenance. fix and variable supplies

vd expenses, insurance anc fees, and administration and general

expense

2. Staff Cost

Phe yearly OuM Cost of the plant nt the FYOCO (First year

?of Commercial Operation) is given by:

?TSC = Total Staff Ccst = M.Pm. (4 ©)'¥1 + Yay

where,

M = Number of regular employees at the plant

Pm = Average annua! cost per employee at the busic year of

investment (BYI)

© © Average annual eseaiation rate

Y, + Yg= Number of years between the base year of invest

ment BYI and the Grst year of commercial opera-

tion of the plant, FYOCO.

2, Fixed and Variable Maintenance Costs

Fixed portion of the maintenance costs hold in most cases

linear relationship with the staff cost. Thus FMC (Fix

Maintenance Cost) is related to $.C (8

(P.M.C) = (a(s.c) +b) G+ ed

where 2 and are constants 10 be calculated at the BYI (base year of

investment).

---Page Break---

2. Variable Maintenance

In general the variable maintenance cost (V.M.C) could be

written as # Linear equation similar to that of fixed maintenance. Thus

VeM.C = (a (S.C) +5 + oY

where a! and b' are constants.

4. Fixed and Variable supplies and expenses

#8 cost includes al! materials an expenses that are expend-

ble such as chemicel, lubricunts meke up fiuids and gases, records,

contract services, ete.

?The fixed supplies (F.S) are generally proportional to. the

nominal power output (W) supplied

FS = a wa +e) 1 * Yo)

where a" is @ constant.

?The variable supplies depend very much on the particular characteristic

of the system.

5. Administrative end General Expenses (AtG)

?This cost is generally proportional te the total fixed cost of

ou.

Thus,

vy,

amcr.c) + ey a ¥2)

where aguin a! is @ constant and F.C is the total fix cost of the

plant.

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OM2. Levelized Operation and Maintensce Costs

Operation ané maintenare costs are, like fuel, subjects to inf

tion during the life time of ie plant. In order to compare all costs,

capital, fuel Oatt all of them should be on the s:

ve basis. For that we

divide O&M cost calculated at the first year of commercial operation

(FYOCO) by the number of euivalent hour of operation per year and

multiply by the levelizing factcr I. defined in the fuel cost section,

oun, oun

(CoP) 8760)

"C.F = Capacity factor

8760 = hrs per yeur

be Gen iasi

ra+n® a+yay

re

u = average inflation rate during the fe time of the plant

@)

average interest during the life of the plant.

life of the plant in years

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APPENDIX B

NEW DATA SOURCE

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A. Coal Plent

References 2-4 were the main references used to put up to date

the cou study. The main differences with regurd to the date used in

reference 1 are the following:

the

ase year of investment (B.Y.1) is now 1983 instead of 1978

the inflation rate is taken constant over the whole period from

the B.Y.1. to the FYOCO (first year of commercial operation)

and equal to 78,

the average interest rate is now 108 instead of $8.

~-the value of K (adders to the basic cupits! investment CO) was

Increased 308 with respect to the valuct used in reference 1 where costs were calculated in 1978 dollars.

-~-The fuel cost was taken as $62/(metric Ton) FOR. At present coal originated in Colombia is sold to the Ponce Cement Co. in the Island et @ price which is of the order of the one mentioned above, Its characteristics are approximately,

sulphur 1.58

ashes 108

heat valve 10000 BTU/Ib

B. Nuclear Plant

References 2 and 3 were the main source of information for the update study of the Nuclear Plant. The main variations with respect to the old study, reference 1, were the following:

> The value of A in the formula for the basic Capital Cost was increased in 56.68 over the 1978 value of reference 1, This

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assumption is based partially on the study made by United Engineering and Construction in 1981 (rwerence 2). There, the base cost of » 1139 MWE PWR Plant is estinnted in $1,135,361,396 Which is about 46.8 over the estimated cost of $760,215,000 given jn 1978 doltars by the same group in 1979 for the same plant (see reference 1 and reference 6). However EPRI group (refer fence 8) give @ cost 1,116,000,000 for a 1000 ME, LWR plant, which is about 56.68 over the 1978 cost of reference 1. We have

ronsidered in our calculations this more pessimistic estimation

The base year of investment is therefore 1981 instead of 1978.

~The OAM Staff members were almost double. The source of these data is the report of U.B, & C (reference 2). It reflects the new Nuclear Regulation Commission Policy after the Three Miles Island Accident. There, the security personnel are changed from 5¢ to 94, administrative services from 13 to 49, technical engineers from 22 to 50, maintenance crafts from 16 to 55 ete, These dramatic changes have obviously increased the Maintenance Cost.

We also increased the average yearly cosi por person from $24000 to $3000.

~ The inflation rate has been taken constant over the life of the

plant and equal to 78.

~ The annual interest was also constant anc equal to 108.

= The fuel cost were updated using reference 2 and reference 7

It is interesting to note that the item which increased most was

the "spent fuel ship and disposal" respect to the 1978 prices,

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however the ore cost was about heif of sc 1978 price. for this,

reason the price per Million BTU rennes in the range of $0.7 ?

$0.8.

Oi! Plant

The main variations in the oil estimations with respect to the study

done in reference 1, were the oil price which vos taken as a varisble ranging from 27 to 30 dollars/barzet in 1983.

It is interesting to note that at $30/barrel the cost of of only, in

SIKWH, is almost double of the total cost for « nuclear plant. In fect

he cost of olf without any other item as operation and maintenance und

capital is ubout $0.120/KWH while the total cost of

nuclear plant

?fuel + OWN and Capital) is about $0,050/KWH. The value of the oil

must Gecrease to about $13/berrel for the oil to be competitive with

nuclear. At this point if no increasing in power is required in the

Island, no new alternative is needed to be considered. The value of

s13/berrel is obtained in the following way:

The levelized fuel cost (L.F.C.) is given by:

L.F.C = 9200,

6 108

where P is the price of oll per barrel and 1 the levelizing factor.

Assuming the interest = 108 and the inflation rete = 7% and 36 years of

plant fe, then L = 2.3, If L..C is equal to $0.047/KWH, which is

the total cost of the nuclear plant (see figure 1) minus about $0.03 of

?operation and maintenance for the ol plant, then P is equal to:

6

p= 0.087 x 6 108

9200 x 2.3

$13/barrel

oe

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= In all estimations, the interest rate und the inflation rate were

taken equsl to 108 and 78 respectively,

Photovoltaic

One of the references for the update study of the Photovoltaic

Alternative was # 1983 price list of Duane's Solar Energy Co. (reference

8) according to which the peak-watt of @ Solarex electric panels is sold st approximately $12.00, According to reference 9 Arco Solar had submitted » bid for a 1.2 MW photovoltaic station at Sacramento with a pesk-watt cost of about $6 and the same Solerex Co. has completed 2340 mi photovoltaic system rated at 200 KW a: $8.5/peak-watt. This Company predicts that in 10 yesrs the price wil) come down to about StT/peak-watt. These data and the same reference 1 were used to estimate the following peak-watt price-schedule from 1982 to 1992,

Fear Jose [aes [ian flows fase [tot [ioe | aes [sso [van |e] fans @ reliable source.

We should remark that this table is by no

But we feol that at this time, with the scarcity of data, is as good as

any other prediction.

?The base constent A for the Capital Cost wes estimated from the

work of John M. Perkins and Wendy L. Runsle (reference 10). It

resulls equal to $1750/KW which is about double from the 1978 price

sed in reference 1.

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?The fuel cost of $1.85/Million BTU was obtaines from the work of Alex

G. Alexander (references 11 and 12). This price includes all costs:

land rental, cultivation harvest expenses und transportation. Since

biomass requires & much

larger and less efficient boiler than coat the

heat rate for the boiler was increased from 10000 as used in reference 1

to 15000 RTU/KWH which is more in agreement wi

h reference 10.

To obtain the curve B, of figure 1 (an also the values given in

table 1) we have assumed that O&M costs are equal to those of a coal

plant with FGD. Actually the burning bagasse will not rise any sulphur problem, however this assumption has been taken as a criterium to

account for the extra staff and storage snd « wuch heavier transpor-

tolion required in the managing of the biomass fuel,

Wing

?The base cost of 1755.83 of reference 1 for # 1.5 MW plant in 1979

dollars, was increased to $2000/KW, much in agreement with reference

10 which was published in 1983. Most other itesis were left unchanged

respect to those of reference 1, except that we used # constant infla~

tion rate of 1% and interest rate of 10%.

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