X-164 1983 UPDATE: PUERTO RICO ENERGY ALTERNATIVES

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May 1988
CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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In this part, we present some figures and tables that summarize our findings. The competitive conclusions are drawn from our research regarding Puerto Rico's energy alternatives. Questions and answers relevant to the present state of Puerto Rico are presented in APPENDIX 4.

In sections C1, C2, and C3 (C stands for Capital) of this appendix, we describe the main factors that appear in the economic equations which calculate the total $/KWH of any of the energy alternatives. In sections B1 and B2 (B stands for fuel), we calculate the economic equation for the fuel cost on a $/KWH level throughout the life of the plant. In sections OM1 and OM2 (OM stands for operation and maintenance), we calculate the levelized cost throughout the life of the plant.

The total energy cost levelized throughout the life of the plant is then presented in APPENDIX II. In this appendix, we discuss the new assumptions based on some references given at the end, which served to elaborate this work.

RESULTS AND CONCLUSIONS

One of the conclusions is that Puerto Rico's energy situation is primarily due to near complete dependence on oil. Steps should be taken to reduce this dependence in the future. Measures being considered include reducing consumption. The most promising area in reducing oil consumption is electricity.

A program to reduce oil consumption by 50% for electrical generation within the next 18 years can be considered as an appropriate objective. The most promising alternatives for fuels are nuclear or solar, with the optimum solution utilizing both. In addition, there are promising sources of energy in development.

The smaller quantity is available from our sugar cats (industry). This energy source is economically competitive with coal. A commercial enterprise utilizing biomass (energy cane and sugar cane residues, or SCR) developed recently, competes favorably in the energy market. The main restriction to its broader use will be the use of land for production, considering higher value crops. These conclusions are supported by our calculations which are presented in the Table 1. The curves shown in Figure 1 were determined following consistent assumptions. All 1983 costs: Capital, Operation and Maintenance Costs are carried over to 1985 and then, from that year, a 7% inflation rate and 10% interest rate are applied. As we see, the most economic solution is Nuclear with a total levelized cost in 1986 (See Figure 1 and Table 1) of $0.07/KWH. Coal is next with $0.127/KWH. Biomass is very close to coal with $0.191/KWH. The comparative oil cost is $0.168/KWH. Wind and photovoltaic alternatives generate electricity at much higher values, at $0.210/KWH and $6.588/KWH respectively. These figures are calculated from data reported in References 19 and 8 respectively.

PART - 1: QUESTIONS & ANSWERS REGARDING PUERTO RICO ENERGY ALTERNATIVES

Figure: Nuclear, Coal, Biomass, Wind and Photovoltaic - Levelized Cost for the Different Alternatives. All costs are affected by a 7% inflation and 10% interest rate after 1985.

Calculated from Data reported in Ref. 10 and new data reported in Ref. 8.

1. What is the background of Puerto Rico's economic condition?

The economy of Puerto Rico is a section of the USA economy, cycling as follows: In the period before 1973, the Puerto Rican economy was dynamic, growing faster than the United States economy as a whole, propelled by lower labor costs and US government support. After 1973, oil price increases reversed Puerto Rico's oil cost advantage. The economy has grown afterwards at a much slower rate.

1973-80 Growth Comparison: Puerto Rico 14%

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The text "40 DSA 3 25 80" discusses the reduction in employment growth rates. From 1963 to 1970, Puerto Rico experienced a 5% biyearly growth rate. However, as of March 1983, the economy of Puerto Rico continues to be depressed.

Question 2 asks whether the high cost of oil is the only factor affecting Puerto Rico's development. The answer is no, it's one of many. However, it is an area where governmental action can have very direct and positive results. Energy is particularly important to Puerto Rico because the Commonwealth is a high user of energy, as can be seen in the table below reflecting World Bank information.

The use of primary energy “Barrel Capacity-Ve” is 20 in Puerto Rico, 38 in high-income countries, 3 in medium-income countries, and 1 in low-income countries. The Puerto Rican economy is susceptible to changes in oil prices. Not only is Puerto Rico a high energy user, but it also depends almost exclusively on oil. In contrast, the U.S enjoys a certain degree of energy source diversification and is moving towards the use of lower-cost energy sources.

Question 4 asks how Puerto Rico's dependence on oil can be reduced. Puerto Rico's use of oil is mainly for transportation (25%), electric production (35%), the chemical industry (20%), and feedstock (10%). Reductions in oil usage are primarily achievable by conservation in the field of transportation and a combination of methods in the chemical industry. These changes are in the process of implementation in response to the high cost of oil and its by-products. In the case of electric production, conservation also results from high prices. However, a better solution is the reduction in the cost of generating electricity by substituting oil with lower-cost energy sources, which can only be done by the Puerto Rican Government.

Question 5 asks whether the price of electricity is higher in Puerto Rico than in the USA. The answer is yes. In 1981, the average prices of electricity were 9.82 cents/KWH in Puerto Rico, 5.00 cents/KWH in the USA on average, and 4.13 cents/KWH in South Carolina. The difference is also getting larger as can be seen from the chart below indicating the average price of electricity from 1973.

1981 Rate of Change (Constant $)
Current Constant Dollars
Dollars cent/KWH
___cent/KWH
__cent/ KWH

Puerto Rico: 2.2t, 8.82, 5.35
USA: 1186, 5.00, 272

6. Have the high prices deterred electrification and therefore reduced the productivity of the economy?

Yes. The price of electricity, while low in the short term, increases significantly with time. The consequences are reflected in the table below.

1960-1973, 1973-1980 Change in Growth Rate
Biyear Siyear

Puerto Rico: 13.9, 7.3
USA: 68, 26

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

The exclusive dependence on oil. It can be seen by the tables below that when comparing prices in different states, the price of electricity declines where less oil is used for electrical production. As a consequence, the electrical utility industry in the US has shifted towards lower cost fuels. In the period 1973 - 1982, the use of decreases increased significantly.

The World Bank advised that developing countries plan to reduce the use of oil for electricity generation from 24% in 1968 to 68% in 1995.

Puerto Rico: 99%

The recent reduction in oil prices revised the magnitude of the impact. Oil prices today are only slightly lower than the 1981 prices used as reference. Further oil price reductions may occur, but they are expected to be short-lived.

The position of the oil producing countries to raise prices will improve when demand increases as a result of leveling oil prices and the end of the recession. The forecast in the long run continues to be for oil prices to increase faster than the general level of inflation. It should be noted that 70% of the oil exports originate from the Arab world, bringing into question the reliability of supply.

9. What are the alternatives to oil for electric generation in Puerto Rico?

Gas, hydro, and geothermal are not in consideration because the island does not have the natural resources. Breeder reactor,

Nuclear fusion and sun power are not in consideration because no commercial technology will be available in the next 30 years. Coal and nuclear are proven sources of possible immediate application, biomass could be used in a limited manner; solar-photovoltaic and wind, while not economical today, could become practical alternatives if their capital cost is significantly reduced by technological development.

10. What are the possible savings from using alternative fuels in Puerto Rico? For a reasonable set of assumptions, the leveled cost of electrical generation for a plant that starts operation in 1990 was calculated to be on 16.8 c/kWh. Biomass and coal 8 c/kWh, Nuclear 8 c/kWh. Biomass (sugar cane or sorghum dried and burned in boilers) could conceivably be competitive with coal. Wind and solar-photovoltaic are not current solutions. The cost of energy with the same assumptions above are: Oil, 10 c/kWh, Wind, 21 c/kWh, Photovoltaic, 48 c/kWh. The cost of the electricity generated by these sources must be significantly 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 alternative fuels, if 80% of the current electrical output of 19 billion kWh were produced by coal or nuclear, the potential savings would be (in 1981 dollars) Coal 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.

Actual international experience gives a 40% advantage to nuclear 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 the USA because of increased prices for transportation and handling. Finally, The US estimates reflect implementation schedules that are much longer than necessary.

11. What would be the benefits to Puerto Rico of reducing oil dependence in electrical production to 50%? The benefits would be more than 1 billion dollars per year.

What will be the source of the capital required to carry out the investment needed to achieve the above objective? The financial community will be willing to advance the necessary funds both for capital cost and for interest during construction, if the investment is warranted by the Commonwealth. As soon as a plant is in operation, the savings in oil imports will permit repayment of the loan, as well as the operating expenses and fuel, leaving a large surplus that will allow for a reduction in the price of electricity.

14. What will happen to the competitiveness of coal-generated electricity if the assumptions utilized in the estimates do not materialize? The estimates of coal power costs are sensitive to:

1. The relative cost of coal vs. oil. The abundance of coal and the consequence of using oil determines that coal prices are driven by those of oil. Furthermore, coal-generated electricity will be cheaper even if the coal to oil price ratio increases by 50%.
2. The availability factor of the coal power units. The availability of large units with strict environmental controls has been low, of the order of 60%. It may increase as the technology is better understood. Coal power is competitive even with an availability as low as 50%.
3. The assumed rate of inflation. Because of its higher capital investment, coal power has an edge against inflation and will be penalized if deflation occurs after plant completion. Coal continues to be competitive with oil.

Even after deflation rates of 3008.15, the question arises: What are the environmental effects resulting from the use of coal? The most significant effects result from the huge mass of material to be transported, handled, and disposed of. If generation facilities produce half of the current Puerto Rican electricity output, the following flows result:

Coal Transportation: 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_2 Released to Atmosphere: 4 million tons/year

While most of these result in expenses and nuisance rather than danger, the effects of the release of CO_2 is currently a widespread concern of the scientific community because of its potential effects on world weather conditions.

16. What will happen to the competitiveness of nuclear generation if the assumptions utilized in the estimates do not materialize?

The estimates of nuclear power competitiveness are sensitive to the future cost of oil. However, to become competitive, the price of oil in constant dollars must go down to $10 a barrel, the price of coal to $25/ton. The availability of the nuclear plant also impacts competitiveness. The availability of 600MW nuclear plants has historically been high and should be

even higher (above 75%). In any case, nuclear will retain its economical advantage over oil even if it is utilized at only 25% of its nominal rating. The advantage over coal still exists for an availability factor of the order of 33%.

3. The initial capital investment assumes the use of a proven design and the execution of the project by a competent team under a streamlined NRC regulatory review. These are necessary conditions for the options to be a practical alternative. However, capital costs must be four times greater before it loses its advantage over oil, and 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 is that because electric consumption in Puerto Rico is not growing, we do not need new power generation. Electric consumption has not grown due to the general recession of the economy and as a reaction to the increase in electricity prices. Demand will increase again once the recession ends and as the price of electricity stabilizes. Furthermore, new generation facilities with alternative fuels will result in large savings even if the demand does not grow because of the high operating costs of the existing oil burning units.

A second objection raised against nuclear power is that the commercial 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 load demand to Puerto Rico. The smaller reliable nuclear units available today are rated at 600 MW. They can be competitive with oil even if operating at 200 MW, and with gas at 300 MW. Adequate reserves to permit satisfying the electrical demand during refueling and maintenance of the nuclear unit will be provided by the existing oil facilities (4200 MW).

Is nuclear power risky? Worldwide, there are about 260 reactors in operation and about 220 under construction. Thus, humanity has lived through about 2000 reactor-years with no fatalities resulting from the nuclear portion of the plant. This contrasts with the numerous accidents and fines that result when using oil for power generation, including transportation of oil, its refinement, equipment failure such as boiler explosions, fires like that of TOCOA, and pollution from oil leaks and combustion products. There is a potential risk that an accident in a nuclear power plant could result in the loss of hundreds of lives. However, this risk is extremely low, less than one case in 100,000 years.

Countries Operating:

Argentina, Austria, Belgium, Brazil, Bulgaria, Canada, Czechoslovakia, Finland, France, Germany (GDR), Germany

(FR) Hungary, India, Italy, Japan, Korea, Mexico, Netherlands, Pakistan, Philippines, Poland, Romania, South Africa, Spain, Sweden, Switzerland, Taiwan, United Kingdom, United States, USSR x 2 1 4 2 1 4 8 1 0 22.

18. Does the public have to be protected for thousands of years from the nuclear waste generated by nuclear power? Most of the waste from a nuclear plant is low level, similar to that generated in a hospital, and its disposal will follow proven methods 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 of the high-level waste policy act. Storage and transportation of spent fuel has not resulted in accidents in the 2000 reactor-years of nuclear operations to date. The spent fuel generated from a nuclear plant is only a minute fraction of the waste resultant of fossil combustion and therefore the problems resultant from its disposal are simplified.

2. The 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 can be explained by a combination of a period of extraordinary expansion in the nuclear industry in the USA, its fragmented nature, and the nature of regulation in the USA. There is a recognition in all segments of the industry that it must come back to shorter schedules and lower costs. This can be accomplished if the following elements are available for new plant construction: a well-studied site, a proven design with a good level of definition.

A competent and experienced implementation team review and agreement with the site and design by the owner and by the NRC before the start of construction. In the case of Puerto Rico, the Islote site is well studied and a proven 600 MW design is available which will meet all current NRC requirements.

Requirements: Only a Probabilistic Risk Analysis remains to be conducted to permit review by the NRC.

21. What is the feasible schedule for implementing a program that will reduce Puerto Rico's dependence on oil?

The decision to proceed was in 198. The preparation of a plan with specific proposals for approval and release for implementation started in 1985. The start of program implementation was in 1989-1992. The first operations of the first generating facility utilizing alternative fuel started in 1995. The goal to reduce the oil share in electrical power generation to 50% was achieved.

22. The effects of the proposed program to reduce dependence on oil will only reduce electricity prices in the 1990's. What are the immediate benefits of the program?

A program as proposed will result in immediate benefits as a result of the implementation process. Local direct construction expenditures will be in the order of 600 million 1981 dollars and its multiplication factor will result in an economic incentive of 2 to 3 billion dollars of added circulation. This represents around 25,000 man-years of direct employment and 100,000 man-years of indirect employment during the implementation of the project.

These effects will increase with a higher nuclear share in the program and will decrease if the nuclear share is lower.

23. What are the advantages and disadvantages resulting from the use of biomass as a source of power?

Primary advantages are: the fuel is native, it generates agricultural employment, and while it generates power it may yield some molasses.

The disadvantages are: extensive land requirement (40,000 acres are required to satisfy about 10% of current power demand). However, for small plants like a 20MW Plant, the land is available in the sugar cane fields of the government of Puerto Rico. High mechanization of operations is 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. Technology must be improved.

The text has been developed to the commercial operations phase before generation costs can be established. Interestingly, Eng. Luis A. Ferré made a detailed study of the use of bagasse for electricity generation in Puerto Rico as early as 1935 (reference 13).

APPENDIX A: ECONOMIC EQUATIONS

Capital Investment C1: The initial capital investment can be calculated given 1. CO: Basic cost calculation in dollars per kilowatt corresponding to the base year of investment (BYI) and Ks: Special adders for a particular site and utility organization. CO generally decreases with increasing plant output power. For instance, CO may be given by an exponential form of the following type: $CO = A * B^W$ where A and B are constants and W is output power.

In the case of coal, the base cost, CO, includes the cost for FGD (Flue Gas Desulfurization) which is needed since most of the coal that may come to Puerto Rico from Colombia or the U.S. contains more than 0.5% sulphur. The total base capital cost in BYI dollars is $C = (CO+K) = (A * B^W + K)$.

C2. Inflation and Interest: The base capital cost (CO + K) should be multiplied by:

1. A factor that includes the effect of inflation from the date when the calculations are done (Base Year of Investment) up to the date when the plant construction starts (Starting Year of Construction = SYC). This factor is given by $Y = SYC - BYI$.

2. A factor that takes into account the inflation during construction of the incomplete portion of the work, that is, the inflation on the material to be acquired at that given time during construction in order for the entire project to be finished. This factor is given by $A = Y * a$, where Y is the construction period in years and “a” is the integral of the money to be spent during construction.

The inflation rate may change between the BYI and BYI + Y = FYOCO = First

Year of Commercial Operation 3. This operation is determined by a factor which takes into account the interest of the dollars spent during construction. This factor is represented as: a * igs, where 'ig' is the interest rate during construction. Thus, the total capital investment cost 'C' is given by: a = BW oY, a, 2a + igs. This capital investment cost 'C' is expressed in $/KW.

The previous total capital investment 'TC' must be recuperated during the life of the plant. A fixed charge rate will allow the utility to recuperate all the investment and some profit. The investment recovery factor may include amortization on a sinking fund type of account, property insurance, which is a function of the capital investment, plant depreciation, a percentage to cover property taxes, composite income taxes, charter licensing taxes, etc.

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 depreciation of investment. This helps to build up capital in order to provide an adequate safety margin to pay the debt. Such safety margin is calculated by dividing the net revenues (revenues less operating expenses) in a period of a year by the yearly committed payment of the debt. This ratio should be not less than 1.5. Thus, this safety margin, sometimes called "coverage", should be greater than or equal to 1.5.

Coverage = Net Revenue/Year / Debt Payment/Year

This is necessary for the corporation to assure a good market for its bonds with a 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 bond interest plus the amortization in a sinking fund or the capital recovery factor (CRF) plus insurance (INS). CRF is given by one = a - p" .

Where 'i' is the annual interest and 'n' is the plant life in years (30 to 35, in most cases). Obviously, the annual cost of the KWH will depend strongly on this fixed charge rate (F.C.) and also on the number of equivalent hours where the plant is operating.

At full capacity, to take into account this last important fact, a capacity factor (C.F) is included in the calculation of the actual investment charge or cost/KWH. The Investment Charge (I.C) equation may be written as: y = wy, av (C0 + &) d+ p*L G+ ip) 20 + igg)"¥2 (P.0) TBC. CO = base Capital Cost X= Capital adders aig’ + account for inflation from the time of study to the beginning of construction a+ ip Ore + account for inflation for the non expended money during construction 2, + igo + account for interest during construction. -C.) = Fixed charge rate = (CRF + INS.) 8160 = No. of hours/year.

Fuel (F.L) Cost: The fuel cost in $/KWH depends very much on the type of fuel for the following reasons: The cost ($/KWH) is calculated from the product of the following = Price of fuel/unit = $/lb or $/barrel, etc. + Heat value = MBTU/unit and heat rate of the plant BTU/KWH. For the same type of fuel, different sources may result in different cost values, since this depends on the impurities and chemical compositions. We note also that for the same type of fuel, different qualities may require different adders whose costs are included in the term K of the initial capital C. For instance, F.G.D system, land transportation facilities, port facilities etc., all these are elements to be considered and they should be part of the Value of K described in the section C of Capital Cost. It is also interesting to note the great difference in Heat for the different types of fuel. The following approximated figures may give us an idea of such differences. Fuel (Heat Value in BTU/lb) Coal 10,000 to 20,000 Nuclear 40,000,000.

The fuel during the life of the plant may be subject to inflation. In order to compare the fuel cost and the capital cost, both costs have to be reduced to the same basis. This is done by leveling the fuel cost, that is calculating the constant cost which present values is the same as the integrated variable cost resultant from the inflation process. Fy = Fook = Fuel Cost at the beginning of

Construction. (Levelizing factor) where Pf = fuel cost in $/HR, HR = heat rate in BTU/KWHR, 1+ ep Op*¥y) + factor which accounts for the inflation that occurs from the year of study to the first year of commercial operation. The levelizing factor L is given by: iasyh ae 2 = life of the plant in years, discount rates are usually equal to the interest paid on bonds for public corporations, jeu ra = total average yearly inflation rate of the fuel.

OPERATION & MAINTENANCE COST OM. OAK Cost. The total O&M cost includes those expenses resulting from staff cost, fixed and variable maintenance, fixed and variable supplies and expenses, insurance and fees, and administration and general expenses.

1. Staff Cost. The yearly O&M cost of the plant at the FYOCO (First Year of Commercial Operation) is given by: TSC = Total Staff Cost = M.Pm. (1+ Yay) where, M = number of regular employees at the plant, Pm = average annual cost per employee at the basic year of investment (BYI), Yay= number of years between the base year of investment BYI and the first year of commercial operation of the plant, FYOCO.

2. Fixed and Variable Maintenance Costs. The fixed portion of the maintenance costs usually holds a linear relationship with the staff cost. Thus, FMC (Fixed Maintenance Cost) is related to S.C (Staff Cost). P.M.C = (a(S.C) +b) * (1+ ed) where a and b are constants to be calculated at the BYI (base year of investment).

3. Variable Maintenance. In general, the variable maintenance cost (V.M.C) can be written as a linear equation similar to that of fixed maintenance. Thus V.M.C = (a' (S.C) +b') * (1+ oY) where a' and b' are constants.

4. Fixed and Variable supplies and expenses. This cost includes all materials and expenses that are expendable such as chemicals, lubricants, make-up fluids and gases, records, contract services, etc. The fixed supplies (F.S) are generally proportional to the nominal power output (W) supplied. FS = a'' (W+e) * (1+ Yo) where a'' is a constant.

Constant. 'The variable supplies depend very much on the particular characteristics of the system.

5. Administrative and General Expenses (A&G)

This cost is generally proportional to the total fixed cost of operations. Thus, 'vy, amcr.c) + ey a ¥2) where again a! is a constant and F.C is the total fixed cost of the plant.

OM2. Levelized Operation and Maintenance Costs

Operation and maintenance costs are, like fuel, subject to inflation during the lifetime of the plant. In order to compare all costs, capital, fuel etc., all of them should be on the same basis. For that, we divide O&M cost calculated at the first year of commercial operation (FYOCO) by the number of equivalent hours of operation per year and multiply by the levelizing factor I, defined in the fuel cost section,

oun, oun (CoP) 8760) "C.F = Capacity factor

8760 = hours per year

Gen iasi ra+n® a+yay re

u = average inflation rate during the lifetime of the plant

@) average interest during the life of the plant.

Life of the plant in years

APPENDIX B NEW DATA SOURCE

A. Coal Plant References

2-4 were the main references used to update the coal study. The main differences with regard to the data used in reference 1 are the following:

- The base 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 7%
- The average interest rate is now 10% instead of 8%
- The value of K (additions to the basic capital investment CO) was increased 30% with respect to the value 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 at a price which is of the order of the one mentioned above. Its characteristics are approximately, sulphur 1.5%, ashes 10%, heat value 10000 BTU/Ib

B. Nuclear Plant

References 2 and 3 were the main source of information for the

Updated study of the Nuclear Plant. The main variations with respect to the old study, reference 1, were as follows:

- The value of A in the formula for the basic Capital Cost was increased by 56.68 over the 1978 value of reference 1. This assumption is based partially on the study made by United Engineering and Construction in 1981 (reference 2). In this study, the base cost of 1139 MWE PWR Plant is estimated at $1,135,361,396, which is about 46.8 higher than the estimated cost of $760,215,000 given in 1978 dollars by the same group in 1979 for the same plant (see reference 1 and reference 6). However, the EPRI group (reference 8) gives a cost of $1,116,000,000 for a 1000 MWe LWR plant, which is about 56.68 higher than the 1978 cost of reference 1. We have considered this more pessimistic estimation in our calculations. Consequently, the base year of investment is now 1981 instead of 1978.

- The O&M Staff numbers almost doubled. The source of this data is the report from U.B. & C. (reference 2). This report reflects the new Nuclear Regulation Commission Policy after the Three Mile Island Accident. In this report, the number of security personnel increased from 5 to 94, administrative services from 13 to 49, technical engineers from 22 to 50, and maintenance crafts from 16 to 55. These dramatic changes have obviously increased the Maintenance Cost. We also increased the average yearly cost per person from $24,000 to $30,000.

- The inflation rate has been taken as constant over the life of the plant and equal to 7.8.

- The annual interest was also constant and equal to 10.8.

- The fuel costs were updated using reference 2 and reference 7. It is interesting to note that the item which increased most was the "spent fuel shipping and disposal" compared to the 1978 prices. However, the ore cost was about half of the 1978 price. For this reason, the price per Million BTU remains in the range of $0.7 — $0.8.

Oil Plant: The main variations in the oil estimations compared to the study done in reference 1 were that the oil price was taken as a variable.

The cost ranged from $27 to $30 per barrel in 1983. It is interesting to note that at $30 per barrel, the cost of oil alone, in KWH, is almost double the total cost for a nuclear plant. In fact, the cost of oil without any other items such as operation, maintenance, and capital is about $0.120/KWH while the total cost of a nuclear plant (fuel + operation, maintenance, and capital) is about $0.050/KWH. The value of the oil must decrease to about $13 per barrel for the oil to be competitive with nuclear energy. At this point, if no increase in power is required on the island, no new alternative needs to be considered. The value of $13 per barrel 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 oil per barrel and 1 the levelizing factor. Assuming the interest = 10% and the inflation rate = 7% and 36 years of plant life, then L = 2.3. If L.F.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 oil plant, then P is equal to: 6 p= 0.087 x 6 108 9200 x 2.3 $13/barrel.

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In all estimations, the interest rate and the inflation rate were taken equal to 10% and 7% respectively. One of the references for the update study of the Photovoltaic Alternative was the

1983 price list of Duane's Solar Energy Co. (reference 8) according to which the peak-watt of Solarex electric panels is sold at approximately $12.00. According to reference 9, Arco Solar had submitted a bid for a 1.2 MW photovoltaic station at Sacramento with a peak-watt cost of about $6 and the same Solarex Co. has completed a 2340 m² photovoltaic system rated at 200 KW at $8.5/peak-watt. This company predicts that in 10 years the price will come down to about $7/peak-watt. These data and the same reference 1 were used to estimate the following peak-watt price schedule from 1982 to 1992. Please note that this table is not a reliable source.

At this time, with the scarcity of data, this is as good as any other prediction. The base constant A for the Capital Cost was estimated from the work of John M. Perkins and Wendy L. Ransley (reference 10). It results equal to $1750/KW which is about double from the 1978 price used in reference 1.

The fuel cost of $1.85/Million BTU was obtained from the work of Alex G. Alexander (references 11 and 12). This price includes all costs: land rental, cultivation, harvest expenses, and transportation. Since biomass requires a much larger and less efficient boiler than coal, the heat rate for the boiler was increased from 10000, as used in reference 1, to 15000 BTU/KWH which is more in agreement with reference 10.

To obtain the curve B, of figure 1 (and 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 of bagasse will not raise any sulfur problem, however, this assumption has been taken as a criterion to account for the extra staff and storage and much heavier transportation required in the managing of the biomass fuel.

The base cost of 1755.83 of reference 1 for a 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 items were left unchanged with respect to those of reference 1, except that we used a constant inflation rate of 1% and an interest rate of 10%.

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Energy Analysis and Solutions for Puerto Rico. This reference is in reference 1. CEER.

\-Economic considerations in the test.

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