| BIBLIOGRAPHIC DATA SHEET | 1. CONTROL NUMBER PN-AAJ-471 | 2. SUBJECT CLASSIFICATION (695) AP00-0000-G326 |
|---|---|---|

3. TITLE AND SUBTITLE (240)

An overview of energy strategies for Jamaica

4. PERSONAL AUTHORS (100)

Palmedo, P. F.; Ashby, W. R.; Doernberg, Andres; Tunnah, Barry; Sherlekar, Vic; Simons, Gary; Yim, Herbert

5. CORPORATE AUTHORS (101)

Energy/Development Int.; Energy Systems Int.

| 6. DOCUMENT DATE (110) | 7. NUMBER OF PAGES (120) | 8. ARC NUMBER (170) |
|---|---|---|
| 1981 | 78p. | JM333.79.P172 |

9. REFERENCE ORGANIZATION (130)

E/DI

10. SUPPLEMENTARY NOTES (500)

11. ABSTRACT (950)

12. DESCRIPTORS (920)

Jamaica
Energy
Assessments
Production capacity
Production methods
Development strategy
Statistics
Energy levels
Energy needs
Demand
Alternative energy
Energy consumption

13. PROJECT NUMBER (150)

598060600

14. CONTRACT NO.(140)

DAN-1406-C-00-1046-00

15. CONTRACT TYPE (140)

16. TYPE OF DOCUMENT (160)

AID 590-7 (10-79)

JM
333.79
P172

PN-AAJ-471

# AN OVERVIEW OF ENERGY STRATEGIES FOR JAMAICA

Energy/Development International
and
Energy Systems International

May 25, 1981

e/di
ENERGY / DEVELOPMENT INTERNATIONAL

# AN OVERVIEW OF ENERGY STRATEGIES FOR JAMAICA

Energy Systems International

Vic Sherlekar
Gary Simons
Herbert Yim

Energy/Development International

Philip F. Palmedo, Project Director
William R. Ashby
Andres Doernberg
Barry Tunnah

May 25, 1981.

Prepared for the Government of Jamaica under
Contract No. DAN-1406-C-00-1046-00 with the
US Agency for International Development

Energy/Development International
505 Main Street
Port Jefferson, N.Y. 11777

TABLE OF CONTENTS


| | | Page |
|---|---|---|
| | Acknowledgements | i |
| A. | OBJECTIVE AND APPROACH | 1 |
| B. | CRITERIA | 2 |
| C. | CURRENT ENERGY DEMAND AND PROJECTIONS | [illegible] |
| D. | RESULTS | 11 |
| E. | CONCLUSIONS | 22 |
| APPENDIX A | Option Work Sheets | |


TABLES


| | | |
|---|---|---|
| TABLE I | Strategies and Options | 7 |
| TABLE II | 1980 Petroleum Demand | 10 |
| TABLE III | Petroleum Demand Projections | 12 |
| TABLE IV | Unit Capital Costs of Options | 14 |
| TABLE V | Unit Production Costs of Options | 15 |
| TABLE VI | Oil Savings from Options | 17 |
| TABLE VII | Foreign Exchange Benefits of Options | 19 |
| TABLE VIII | Foreign Exchange Impacts of Options | 20 |


FIGURES


| | | |
|---|---|---|
| FIGURE I | Option Availability in Jamaica | 13 |
| FIGURE 2 | Total Oil Demand: Reference Case and Strategies | 18 |
| FIGURE 3 | Petroleum Demand by Sector | 21 |
| FIGURE 4 | Energy Resources | 23 |

## Acknowledgements

It was possible to carry out this study in the time available only through the unstinting help and support of a number of people in the U.S. and Jamaica. Jerome Bosken of the US AID Energy Office clarified the concept of the study and facilitiated its implementation. We are also very grateful to Jerome Hulehan, US AID Kingston. His advice and support were very important to our success.

Our debts within the Government of Jamaica are numerous but we would particularly like to thank Winston Hay, Managing Director of the Jamaica Public Service Company and William Saunders, Managing Director of the Petroleum Corporation of Jamaica and their staff for most informative discussions.

This study was very much a collaboration between the Energy Division of the Ministry of Mining and Energy and the two U.S. consulting firms who wrote this report. We are particularly indebted to Dr. Henry Lowe, Director of Energy, for his council and collaboration and to several members of his staff who contributed on matters both technical and logistical. Our thanks go particularly to Winston Boyne, Melody Daley and Claon Rowe. We also appreciate the assistance and advice provided to us by several members of the World Bank staff currently concerned with Jamaica, in particular Ursula Weimper, Ahmed Zia Mian and Trevor Byer.

Finally we would like to express our gratitude to His Excellency Mr. Edward Seaga, Prime Minister of Jamaica for his incisive comments and suggestions at meetings at the beginning and near the end of our study. His personal interest in the issues addressed here augers well for the successful definition and accomplishment of a national energy strategy for Jamaica.

## A. OBJECTIVE AND APPROACH

The objective of this brief project was to place the various energy options available to Jamaica in perspective, in light of the anticipated evolution of energy demand. A total of 20 days was available to carry out the analysis. Thus no original research or detailed analysis was possible. A considerable amount of work on most of the energy options has been carried out over the past few years, however, and this synthesis draws heavily on that work.

The study focused particularly on energy sources and technologies which could reduce Jamaica's virtually complete dependence on imported oil. Thus the study should be looked upon as a preliminary and selective assessment of alternative energy technologies rather than an inclusive study of national energy policy. For example, among the important energy policy issues not addressed here are: oil exploration, contracting for future oil supplies, energy pricing and institutional issues in energy management and planning.

The general approach followed was to start with a projection of future energy - and particularly oil - demand assuming no alternative energy sources were implemented. Particular attention was paid to inland energy consumption, excluding the bauxite and alumina industries. Each alternative energy source or option was then characterized by its cost, potential contribution to the national energy system and other criteria. A primary concern was the role of each option in displacing oil. This was evaluated by estimating the amount of oil used in the particular service for which the new option could provide energy. For example, for solar water heaters, the amount of oil used to produce electricity for water heating was estimated. Then a judgement was made of the rate at which solar water heaters would be

adopted (principally in new buildings). This judgement was based on economic competitiveness and the nature of the market. Generally, a new technology was not introduced into the system until it was considered to be economical vis-a-vis the world price of oil.

In order to include most of the feasible options in our brief analysis and in order to achieve comparability between options, a number of simplifying assumptions had to be made, for example regarding the fixed change rate on capital. Thus the individual option or project analyses can not be used to make definitive investment decisions. Such decisions require analysis at a much more detailed level. Nevertheless such a comparative analysis can give a perspective on the major strategies available to Jamaica if it is to achieve renewed economic growth.

## B. CRITERIA

The choice between energy options is complicated by the fact that there is no single criterion which can be used to make the choice. There are a number of factors such as capital costs, employment effects and environmental impacts, all of which are important but incommensurate. The amount of weight given to each criterion is a judgemental or political question as much as an analytic one. Thus in an analysis of options it is advisable to characterize each option in terms of various concerns or criteria, and to let the decision maker rank the alternatives according to his objectives.

In this project, the following criteria were considered for each option. Note that many of these criteria are overlapping.

1. Oil Savings, Bbl/year

Reduction in oil consumption resulting from the implementation of the option. Three reference years were used to evaluate these and other impacts: 1985, 1990 and 2000.

2. Net Imported Fuel Cost Savings

The reduction in total imported oil cost, corrected for any increase in the cost of fuel imports, such as coal. In these calculations we have assumed that world oil prices, and the real price of petroleum fuels in Jamaica, will increase at the rate of 3 percent per year.

3. Capital Cost

Total capital cost for the units installed since the last reference year, expressed in constant 1980 U.S. dollars.

4. Capital Cost $US/BOE

Total capital costs, in US$ per barrel of oil equivalent of energy produced or saved per year. For electricity generation this is expressed in two ways: cost per barrel or oil saved on the import side, and cost per kw of installed capacity.

5. Foreign Exchange Components

The fraction of the total capital cost which is foreign.

6. Energy Production Cost

For electricity this is expressed as US¢/kwh; for other energy forms the unit is US$/BOE. When calculating the contribution of the capital investment to total energy cost, a total cost of money of 10 percent per year is used. This corresponds roughly to current World Bank rates commercial bank rates could be higher; concessionary loan rates lower.

7. Foreign Exchange Balance

This measures the net annual foreign exchange benefits or costs associated with the implementation of the option. It has three elements, as follows:

FEB = value of reduction in oil imports - value of any fuel import requirement - annualized cost of the foreign exchange component of capital requirements.

This is also expressed in terms of the foreign exchange balance per barrel of oil saved.

8. Employment Impacts

This measures the number of jobs created in Jamaica per unit of energy output. Expressed as high, medium or low impacts.

9. Economic and Social Effects

This identifies economic or social costs or benefits other than those captured in previous criteria. These could involve the development of an export industry or social benefits such as greater electrification than anticipated in a reference case.

10. Environmental Effects

This indicates the potential environmental costs or benefits associated with an option, expressed simply as negative, neutral or positive with some indication of the nature of the effects and the uncertainties involved.

11. Risk and Uncertainty

An indication of the status of the development of the technology, whether it is in the research, development and demonstration or commercial stage. This also measures the uncertainty in the projected impact of the technology in terms of date of introduction, or technical and economic performance.

12. Barriers

The rates of implementation assumed for the various technologies considered primarily economic criteria. A technology was introduced at a reasonably rapid rate as soon as it was cost competitive. Under this heading we identify any barriers of an institutional, financial or infrastructural nature that must be overcome if that potential is to be satisfied.

13. Next Steps

Although this is not a primary focus of the study, important next steps to be taken will be identified where it is possible to do so.

The last 5 criteria are not tabulated for all options. Comments are made in cases where any one of these items are important for a particular option.

In the analysis we distinguish three aspects of national energy policy: strategies, options and projects. By an option we mean a specific combination of resource and technology. Examples would be coal used for central station electricity generation; solar energy used for low temperature water heating; or industrial energy conservation. By a strategy we mean a group of related options. In Table I we list the strategies which we have considered in this study and the options which compose them. Projects are the means to develop and implement options.

Among the options which were considered but not analyzed in any detail were:

- Solar thermal electric power generation ("power towers"): It is very uncertain whether the technology will ever be commercially viable; there appear to be a number of more promising options available for power production in Jamaica; and there is no need for R&D in Jamaica on this technology in the forseeable future. Nonetheless international R&D should be monitored.

- Wind power: Current information indicates that the wind regime in Jamaica is not adequate for economical wind power generation. Nonetheless the wind resource requires better definition before this option can be excluded with confidence.

- Geothermal energy: Although there are some indications of geothermal activity, there is insufficient information available to judge whether there is any geothermal energy potential. Further investigation would be useful.

- Nuclear power: Even at high growth rates, the total installed capacity of the electric system will be no large enough even by the year 2020 to accomodate the smallest commercial nuclear power plant.

## C. CURRENT ENERGY DEMAND AND PROJECTIONS

Current petroleum demand in Jamaica is 15.6 million barrels, of which 8.1 million barrels or 52 percent goes to the bauxite/alumina industry.

TABLE I

STRATEGIES AND OPTIONS

| STRATEGY/OPTION | MAIN ASSUMPTIONS |
|---|---|
| Coal/Peat | |
| Central Station Coal Plant | 65 MW in 1987; 65 MW in '89; 100 MW in '92 and '95. |
| Coal Use in Industry | Conversion to coal by Carib Cement by 1985, double capacity by 1990. |
| Peat Electricity Generation | 80 MW by 1989 |
| Energy Conservation | |
| Industry | Various measures to reduce oil use by 20% by 1985, 30% by 1990 |
| Transportation | 5% reduction by 1985, 10% by 1990, 20% by 2000. |
| JPS (slow speed diesel) | 40 MW installed by 1985 |
| Bagasse in Sugar Industry | Replace 50% of oil used in sugar industry by bagasse in 1985, 75% by 1990. |
| Hydropower | |
| Large Scale | Phases I, II, and III of Blue Mt. 22.5 MW in 1990; 45 MW in 2000. |
| Medium Scale | Develop Rio Bueno (0.9 MW) and Great River (7.7 MW) by 1985. Additional 5 MW by 1990 and 7 MW by 2000. |
| Small Scale | 0.5 MW by 1990, 2.0 MW by 2000. |

continuation of TABLE I

| STRATEGY/OPTION | MAIN ASSUMPTIONS |
|---|---|
| Solar and Biomass | |
| Low Temperature Heat | 30,000 households by 1990 and 4% growth between 1990 and 2000. |
| High Temperature Heat | 25% of Industrial Commercial proc heat by 2000, 25% of this achieve by 1990. |
| Crop Dryers | New Use of crop drying - small fuel displacement. |
| Photovoltaics | 500 kw in 1985; 2.5 MW in 1990; 20 MW in 2000. |
| Solar Ponds | 2.5 MW pilot plans by 1990; 25 MW from Yallah's Pond by 2000. |
| OTEC | 10 MW pilot plans in 1990; 80 MW in 2000. |
| Biogass | 2000 households in 1990; 5000 in 2000. |
| Fuels from Sugar, etc. | 25% of sugar acreage by 2000. |
| Fuels from Wood | 100 - 200,000 BOE by 2000. |
| Energy Farm | 2500 acre (3 MW) by 1990; 25,000 acres by 2000. |
| Urban Waste | 1000 ton/day collection; 30MW by 1990. |
| Wood/Charcoal | One third of current kerosene use in households switch to charcoal by 1990. |

Of the remaining 7.4 million barrels, roughly one third is used for electricity generation by the utility, JPS, one third is used for transportation. The remaining third is divided roughly equally between industry-commerce and households and other miscellaneous uses. This allocation omits from the transportation sector about 100 thousand barrels that are consumed by buses and railway (included in "other) and includes the Bunker C oil sales to international shipping (or bunkers) in the "other" category as well. These figures are summarized in Table II.

The basis for analyzing alternative energy options is a "reference case" projection of petroleum demand. In the reference case, energy demand grows at the rate of its historical relationship with GNP growth. No new or improved facilities are introduced except in the electrical sector, in which new capacity is assumed to have an efficiency of 8,500 Btu/kwh (or a thermal efficiency of 40 percent).

In the analysis of energy alternatives we exclude from consideration the bauxite and alumina industries, since their energy consumption does not represent a foreign exchange cost to the Government. We assume the conventional relationship between energy and economic growth as follows:

$$E_t = KG_t^a P_t^b$$

where $E_t$ = Energy use in year t

$K$ = Energy use in base year

$G_t$ = GNP in constant dollars in year t relative to base year

$P_t$ = Energy prices in year t relative to base year

$a$ = GNP elasticity of energy demand

$b$ = Price elasticity of energy demand

TABLE II

1980 PETROLEUM DEMAND

Sector

| Sector | | Demand Thousand Bbls/yr. | Percent of Total Including Al. | Percent of Total Excluding Al. |
|---|---|---|---|---|
| Industry & Commerce | | 1093 | 7 | 16 |
| Cement | 275 | | | |
| Sugar | 200 | | | |
| Other (Industrial & Commerce) | 618 | | | |
| Electricity Generation | | 2677 | 17 | 40 |
| Transportation | | 2287 | 15 | 34 |
| Other Sectors | | 632 | 4 | 9 |
| Total (excluding alumina) | | 6689 | 43 | 100 |
| Bauxite & Alumina | | 8103 | 52 | |
| Aviation Fuel Bunkers | | 765 | 5 | |
| Total Consumption | | 15,557 | 100 | |

Note: Petroleum products are allocated as follows:

- Aviation gas and jet fuel are classified as international bunkers and omitted from the domestic transportation sector.
- Transportation includes all gasoline, service station sales of auto diesel, diesel use by bus, rail and rural transport, and fuel oil use by ship bunkers.
- "Other" sectors are kerosene and LPG sales.
- Cement use includes marine diesel sales.
- Industry and commerce include all fuel oil and auto diesel not allocated elsewhere.

The principal assumptions are given in Table III along with the resultant energy demand growth. The elasticities used are based on international experience. During the 1961-73 period energy growth in Jamaica was characterized by GNP elasticity of about 1.4.

## D. RESULTS

For each of the options listed in Table I we evaluated the various criteria given above. The assumptions used for that analysis and the resulting evaluations for each option are given on the work sheets included in Appendix A. In this section we summarize those evaluations and indicate some aggregate impacts of alternative energy strategies in Jamaica.

Figure 1 indicates the assumptions we have made regarding the commercial availability of the various options in Jamaica. We have also indicated there whether research and development (R&D) and/or demonstrations in pilot plants are required before an option can be implemented commercially.

Table IV summarizes the capital costs assumed for each option. For the options which produce electricity the cost is expressed in constant 1980 US $ per kw installed. For other options the cost is expressed in constant 1980 US $ per unit of energy produced expressed as barrels of oil equivalent saved per year (BOE). Table V gives the cost of the energy produced by each option in constant 1980 dollars. This includes the cost of capital, annualized at 10 percent, as well as the cost of fuel.

TABLE III

PETROLEUM DEMAND PROJECTIONS
(excluding bauxite and alumina)

| Year | GNP (relative) | Reference World Oil Price $/Bbl | Petroleum Demand, Thousand Bbl/yr. Commerce, Industry | Electricity Generation | Other | Total |
|---|---|---|---|---|---|---|
| 1980 | 1.0 | 35.0 | 1093 | 2677 | 2919 | 6689 |
| 1981 | 1.03 | 36.0 | 1132 | 2738 | 3023 | 6893 |
| 1982 | 1.07 | 37.1 | 1179 | 2827 | 3174 | 7180 |
| 1985 | 1.24 | 40.5 | 1379 | 3217 | 3821 | 8417 |
| 1990 | 1.58 | 47.0 | 1713 | 4043 | 5212 | 10,968 |
| 2000 | 2.34 | 63.1 | 2561 | 5873 | 8135 | 16,569 |

Assumptions:

$E_t = KG_t^a P_t^b$

| GNP growth rate: | 1981 | 1982 | 1983-90 | 1990-2000 |
|---|---|---|---|---|
| | 3% | 4% | 5% | 4% |

a =+1.3 for all fuels; = +1.4 for electricity

b = -0.3

Electricity oil demand based on 110 Gwh/yr. from hydro and new capacity added at 8,500 Btu/Kwh heat rate.

Oil demand in the sugar industry is held constant at 200,000 bbl/yr.

## FIGURE I

## OPTION AVAILABILITY IN JAMAICA

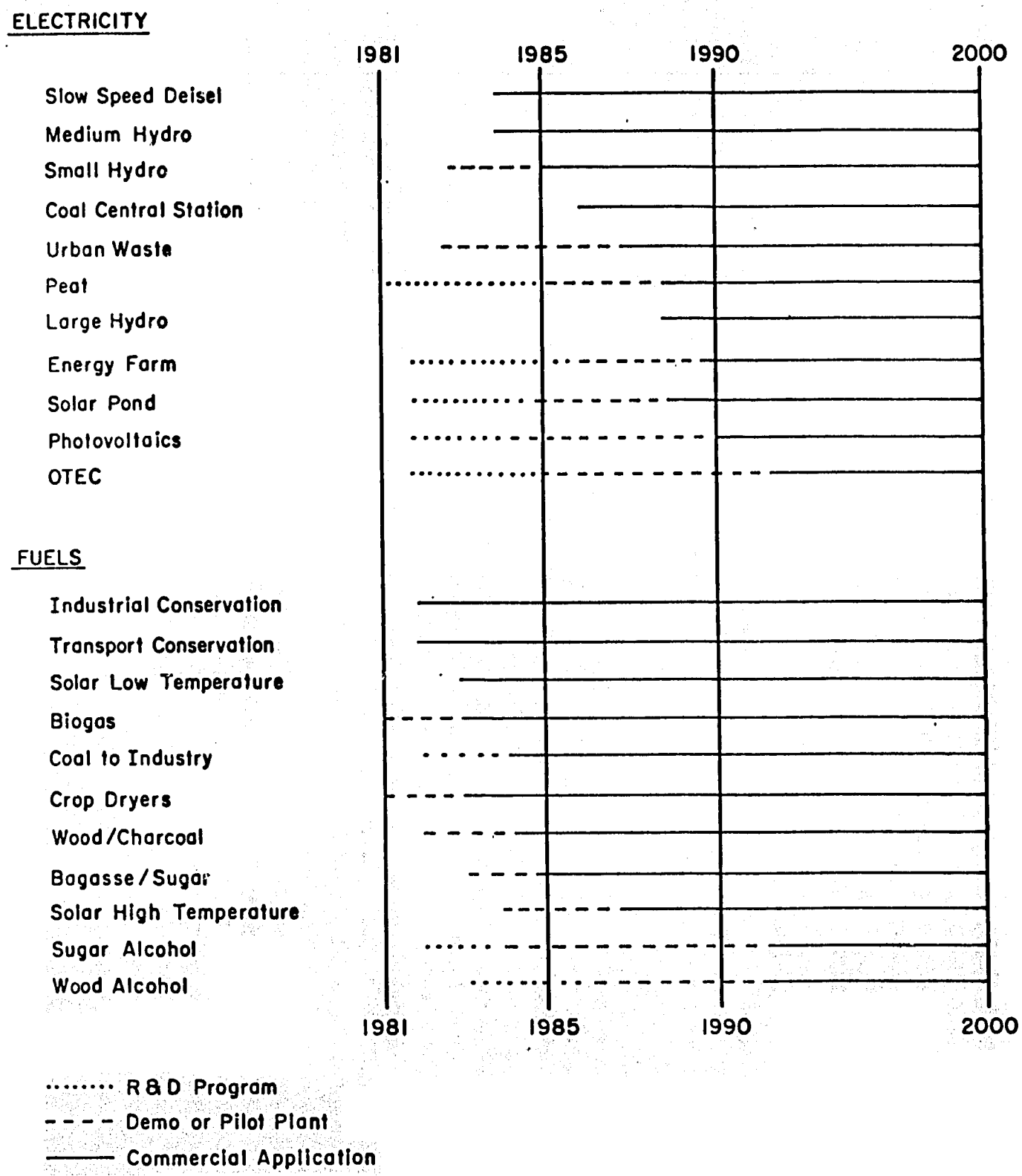


TABLE IV

UNIT CAPITAL COSTS OF OPTIONS

| Strategy:Option | Capital Costs (Per Unit Energy) | | |
|---|---|---|---|
| | 1985 | 1990 | 2000 |
| COAL/PEAT | | | |
| Coal Plant JPS | - | $1350/kW | $1350/kW |
| Coal to Industry | $ 48/BOE | - | $ 79/BOE |
| Peat/Electricity | - | $1910/kW | $1910/kW |
| CONSERVATION | | | |
| Industry | $ 50/BOE | $ 110/BOE | - |
| Transportation | $ 81/BOE | $ 94/BOE | $126.2/BOE |
| Utility (Slow Speed Diesel) | $ 93/BOE | - | 0 |
| Bagasse | $162/BOE | $ 188/BOE | - |
| RENEWABLE RESOURCES | | | |
| Solar: | | | |
| Solar Ponds | - | - | ? |
| OTEC | - | $8000/kW | $5000/kW |
| Photovoltaics | $10000/kW | $3000/kW | $2000/kW |
| Low Temperature Solar | $ 371/BOE | $305/BOE | $288/BOE |
| High Temperature Solar | - | $550/BOE | $467/BOE |
| Crop Dryers | $ 666/BOE | $477/BOE | $409/BOE |
| Hydro: | | | |
| Large Scale | - | $1.40/kWh | 33¢/kWh |
| Medium | 73¢/kWh | 67¢/kWh | 67¢/kWh |
| Small-Scale | 35-70¢/kWh | 35-70¢/kWh | 35-70¢/kWh |
| Biomass: | | | |
| Biogas | $189/BOE | $189/BOE | $189/BOE |
| Energy Farm | - | $1766/kW | $1766/kW |
| Urban Wastes | - | $167/BOE | $167/BOE |
| Fuel Alcohol | $ 79/BOE | $ 79/BOE | $ 79/BOE |
| Liquids (Silviculture) | - | - | ? |
| Wood/Charcoal | small | small | small |

TABLE V

UNIT PRODUCTION COSTS OF OPTIONS

| Strategy:Option | Energy Production Costs | | |
|---|---|---|---|
| | 1985 | 1990 | 2000 |
| **COAL/PEAT** | | | |
| Coal Plant JPS | - | 6.2¢/kWh | 6.5¢/kWh |
| Coal to Industry | $22.7/BOE | $23.5/BOE | $37.5/BOE |
| Peat/Electricity | - | 4.8¢/kWh | 4.8¢/kWh |
| **CONSERVATION** | | | |
| Industry | NA | NA | NA |
| Transportation | NA | NA | NA |
| Utility (Slow Speed Diesel) | 7-8¢/kWh | 7-8¢/kWh | 7-9¢/kWh |
| Bagasse | $16/BOE | $18/BOE | $18/BOE |
| **RENEWABLE RESOURCES** | | | |
| **Solar:** | | | |
| Solar Ponds | - | - | NA |
| OTEC | - | 14-17¢/kWh | 14-17¢/kWh |
| Photovoltaics | $0.4-$1.0/kWh | 11-22¢/kWh | 6-11¢/kWh |
| Low Temperature Solar | 4-8¢/kWh | 4¢/kWh | 4¢/kWh |
| High Temperature Solar | - | $10/MMBtu | $7/MMBtu |
| Crop Dryers | 5¢/kWh | 3¢/kWh | 3¢/kWh |
| **Hydro:** | | | |
| Large Scale | - | 13.5/kWh | 7.0¢/kWh |
| Medium | 7.2¢/kWh | 7.2¢/kWh | 7.2¢/kWh |
| Small-Scale | 5.4-8.8¢/kWh | 5.4¢-8.8¢/kWh | 5.4¢-8.8¢/kWh |
| **Biomass:** | | | |
| Biogas | 10-20¢/kWh | 7-12¢/kWh | 7¢/kWh |
| Energy Farm | - | 15¢/kWh | 15¢/kWh |
| Urban Wastes | - | 5-8¢/kWh | 5-8¢/kWh |
| Fuel Alcohol | $62/BOE | $62/BOE | $62/BOE |
| Liquids (Silviculture) | - | - | NA |
| Wood/Charcoal | <1¢/kWh | <1¢/kWh | <1¢/kWh |

We have evaluated the rate at which each option can be implemented in the Jamaican energy system and, in particular, the amount of imported oil it can replace at different time periods. These figures are summarized in Table VI. These numbers can now be used to estimate the aggregate oil savings resulting from the implementations of the various strategies. These results are shown in figure 2.

Although reduced oil consumption is a convenient measure of the success of an energy strategy, a more complete measure is the net foreign exchange savings. As defined above, this measures both the annualized foreign exchange component of a capital investment and the net fuel import savings. These net foreign exchange savings for each option for the three reference years are given in Table VII. In Table VIII those savings are given per unit of energy saved.

The various strategies discussed above are clearly not exclusive. On the contrary, a national energy strategy would include at least elements from all the individual strategies. It is thus germane to ask what the maximum contribution of all of the options combined could be to the national energy balance. In performing this analysis it was found that, by the year 2000, there was an overabundance of options for non-oil electricity production. In all other cases, however, a combined strategy could be composed quite straight-forwardly through a combination of all the options assumed to be available in the various years analyzed. The results of that analysis are shown in Figure 3. Also shown in that figure are rough estimates of the consumption of oil by the major energy sectors: electricity, industry/commerce, transportation and other (mostly households). These sectoral estimates are <u>very</u> approximate depending as they do on very simplistic assumptions about proportional sectoral growth.

TABLE VI

OIL SAVINGS FROM OPTIONS

| Strategy:Option | Oil Savings (Thousand Bbls/yr) | | |
|---|---|---|---|
| | 1985 | 1990 | 2000 |
| COAL/PEAT | | | |
| Coal Plant JPS | -- | 1,480 | 3,480 |
| Coal to Industry | 275 | 550 | 840 |
| Peat/Electricity | -- | 830 | 830 |
| CONSERVATION | | | |
| Industry | 157 | 254 | 254 |
| Transportation | 176 | 352 | 1,099 |
| Utility (Slow Speed Diesel) | 348 | 331 | 278 |
| Bagasse | 100 | 150 | 150 |
| RENEWABLE RESOURCES | | | |
| Solar: | | | |
| Solar Ponds | -- | 30 | 296 |
| OTEC | -- | 130 | 1,170 |
| Photovoltaics | 2 | 10 | 80 |
| Low Temperature Solar | 35 | 190 | 281 |
| High Temperature Solar | -- | 50 | 200 |
| Crop Dryers | 0.3 | 3.2 | 5.1 |
| Hydro: | | | |
| Large Scale | -- | 98 | 273 |
| Medium | 67.8 | 113.8 | 178 |
| Small-Scale | 0.5 | 3.8 | 15 |
| Biomass: | | | |
| Biogas | 4.5 | 9.8 | 21 |
| Energy Farm | -- | 35 | 350 |
| Urban Wastes | -- | 370 | 555 |
| Fuel Alcohol | -- | 33 | 330 |
| Liquids (Silviculture) | -- | -- | 150 |
| Wood/Charcoal | 10 | 100 | 100 |

FIGURE 2

TOTAL OIL DEMAND: REFERENCE CASE AND STRATEGIES

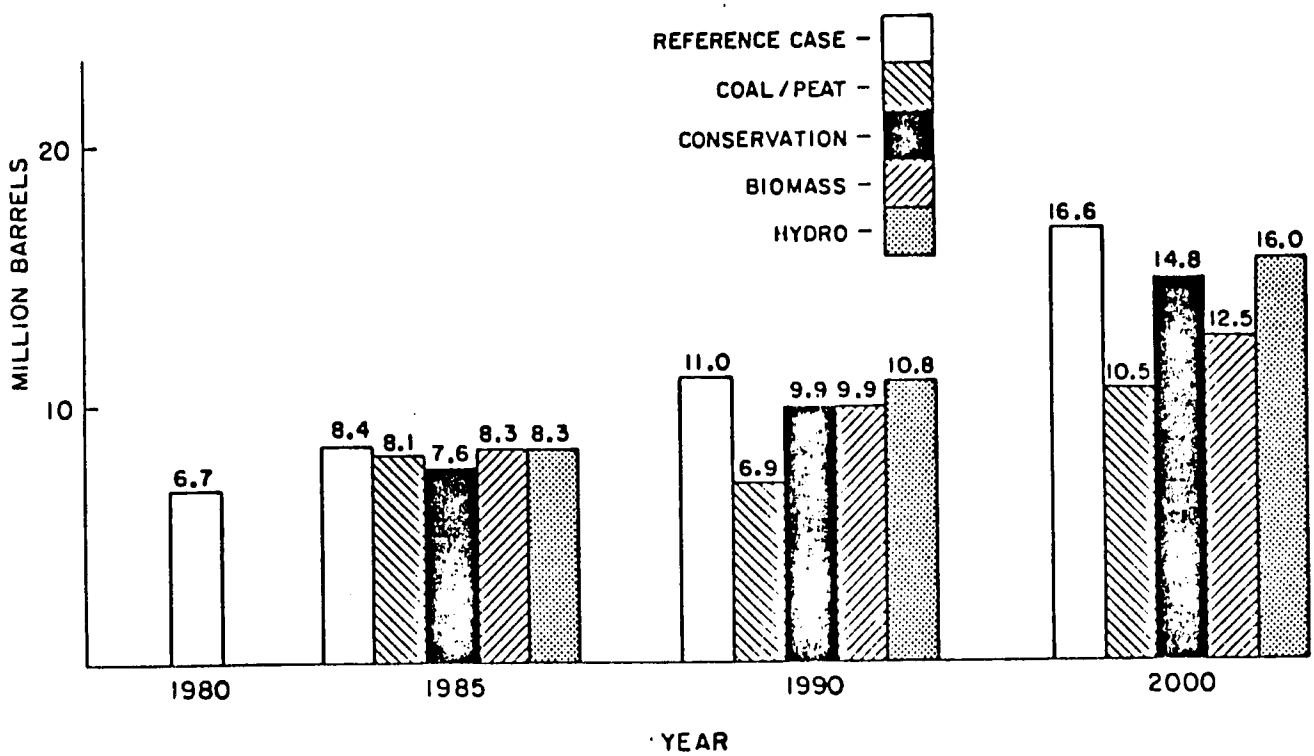


TABLE VII

FOREIGN EXCHANGE BENEFITS OF OPTIONS

| Strategy:Option | Foreign Exchange Benefits $, Million | | |
|---|---|---|---|
| | 1985 | 1990 | 2000 |
| COAL/PEAT | | | |
| Coal Plant JPS | -- | 30.7 | 114 |
| Coal to Industry | 5.3 | 13.4 | 27 |
| Peat/Electricity | -- | 28.3 | 42 |
| CONSERVATION | | | |
| Industry | 5.8 | 10.9 | 15 |
| Transportation | 7.0 | 16.2 | 68 |
| Utility (Slow Speed Diesel) | 10.8 | 12.3 | 14 |
| Bagasse | 3.3 | 5.8 | 8 |
| RENEWABLE RESOURCES | | | |
| Solar: | | | |
| Solar Ponds | -- | -- | ? |
| OTEC | -- | 6.1 | 46 |
| Photovoltaics | -0.4 | -0.5 | 2 |
| Low Temperature Solar | 0.8 | 6.5 | 14 |
| High Temperature Solar | -- | 0.2 | 3 |
| Crop Dryers | -0.1 | -0.2 | 0 |
| Hydro: | | | |
| Large Scale | -- | -0.9 | 10 |
| Medium | 0.9 | 4.6 | 6.7 |
| Small-Scale | 0 | 0.1 | 1 |
| Biomass: | | | |
| Biogas | 0.2 | 0.5 | 1.3 |
| Energy Farm | -- | 1.2 | 18 |
| Urban Wastes | -- | 10.6 | 15 |
| Fuel Alcohol | -- | -0.9 | -4 |
| Liquids (Silviculture) | -- | -- | ? |
| Wood/Charcoal | -- | 4.7 | 6 |

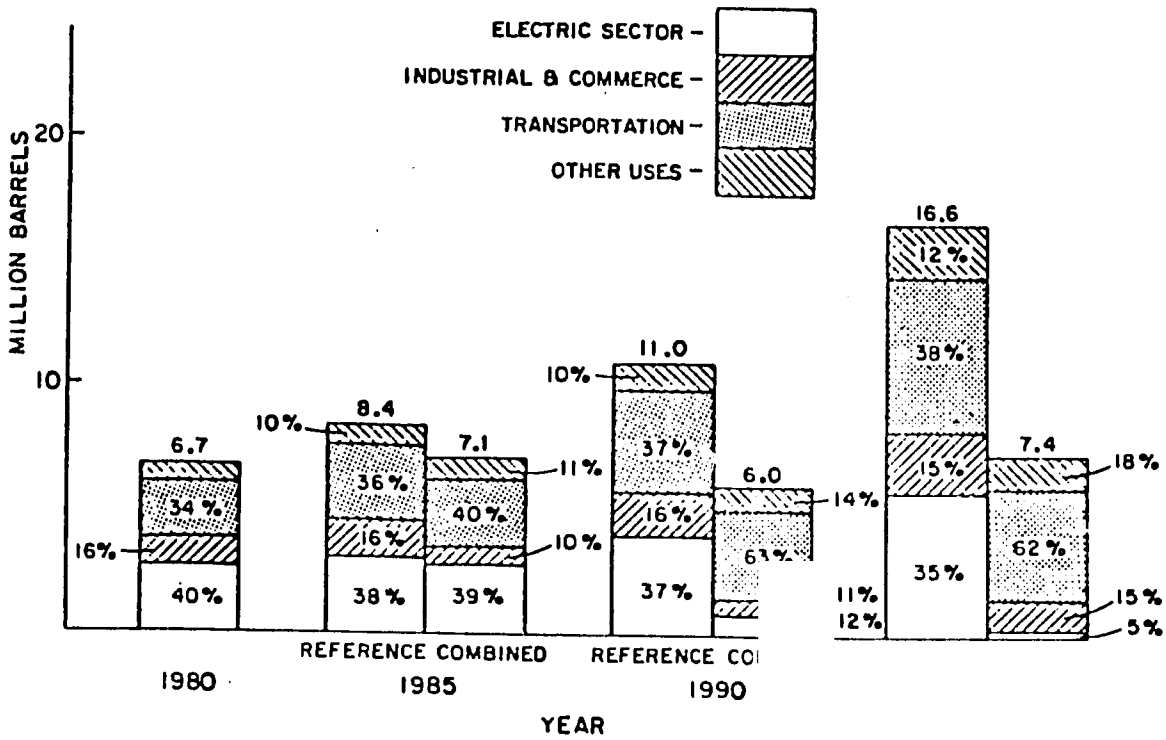
TABLE VIII

FOREIGN EXCHANGE IMPACTS OF OPTIONS

| Strategy:Option | Foreign Exchange Savings ($/BOE/Yr) | | |
|---|---|---|---|
| | 1985 | 1990 | 2000 |
| **COAL/PEAT** | | | |
| Coal Plant JPS | -- | 20.7 | 32.1 |
| Coal to Industry | 19.3 | 24.4 | 31.5 |
| Peat/Electricity | -- | 34.1 | 50.1 |
| **CONSERVATION** | | | |
| Industry | 37 | 43 | 59 |
| Transportation | 40 | 46 | 62 |
| Utility (Slow Speed Diesel) | 31 | -- | -- |
| Bagasse | 32 | 38 | 55 |
| **RENEWABLE RESOURCES** | | | |
| **Solar:** | | | |
| Solar Ponds | -- | -- | ? |
| OTEC | -- | 47 | 38 |
| Photovoltaics | -- | -- | 25 |
| Low Temperature Solar | 22 | 34 | 51 |
| High Temperature Solar | -- | 3 | 16.4 |
| Crop Dryers | small | small | small |
| **Hydro:** | | | |
| Large Scale | -- | -9.5 | 35 |
| Medium | 14 | 41 | 38 |
| Small-Scale | 26.5 | 18.8 | 33.7 |
| **Biomass:** | | | |
| Biogas | 40 | 47 | 62 |
| Energy Farm | -- | 34 | 53 |
| Urban Wastes | -- | 27 | 27 |
| Fuel Alcohol | -33 | -26 | -11 |
| Liquids (Silviculture) | -- | -- | ? |
| Wood/Charcoal | 40.5 | 47.0 | 63.1 |

FIGURE 3

PETROLEUM DEMAND BY SECTOR
REFERENCE CASE AND COMBINED CASE



In Figure 4 we show the distribution of resource consumption in the combined case as compared to that for the reference case. This figure also indicates the reduction in total energy use brought about by conservation measures.

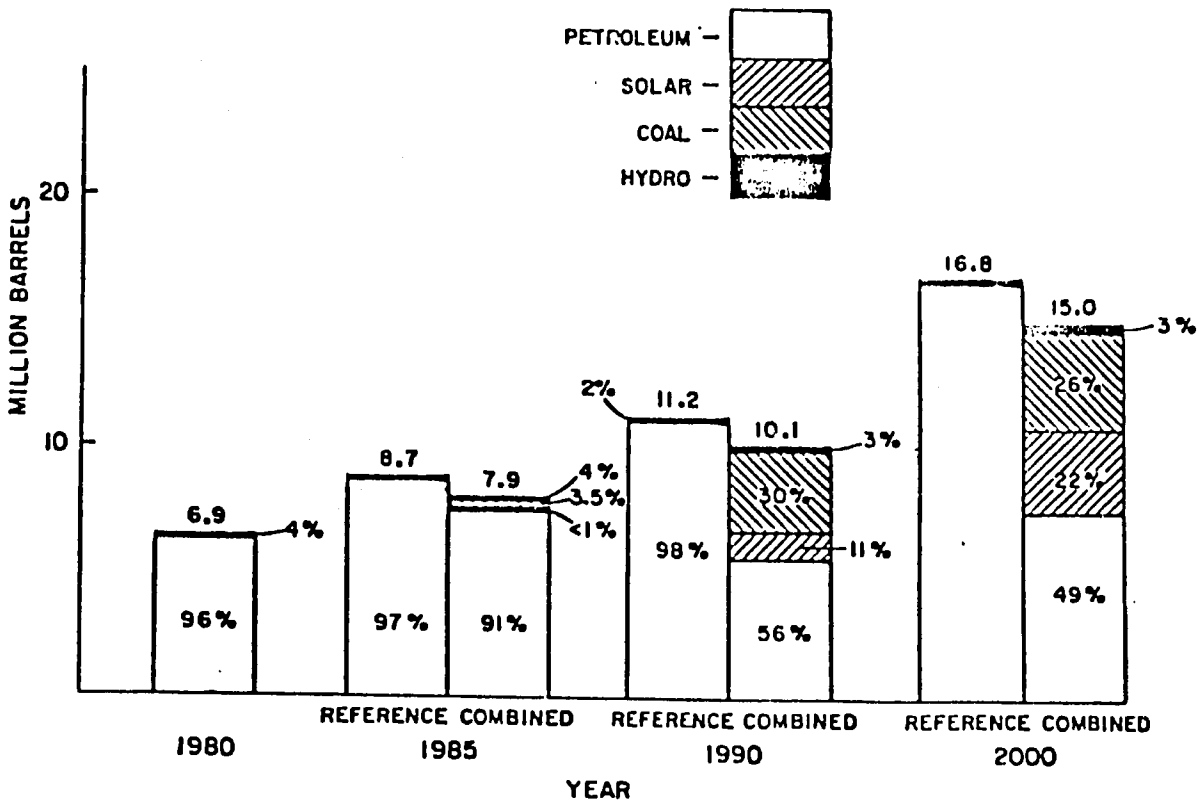
## E. CONCLUSIONS

The analysis summarized above leads to a number of observations and conclusions. These should be prefaced, however, with a strong statement of qualification; the data base on which the analysis was based is, in many cases, very uncertain. There are very large uncertainties in some of the economic characteristics of the technologies, particularly those such as photovoltaics, OTEC and wood-based liquid fuels which are still in the research stage. Both the future world price of oil and the world price of coal are highly uncertain as is the future growth rate of the Jamaican economy. Because of the very short length of time available for the study a number of simplifying assumptions had to be made in the analysis and this brief study should be looked upon as indicating an approach to policy analysis rather than arriving at definitive recommendations. Nonetheless, the general picture of alternative energy use in Jamaica which has emerged from this analysis is believed to be valid and one can frame the following conclusions with some confider

1. Unless concerted action is taken, renewed economic growth implies significant increases in oil imports. If the economy grows as envisioned by the government, oil demand and thus imports could increase by 60 percent in the next 10 years. Such implied imports, in an era of rising world oil prices,

FIGURE 4

ENERGY RESOURCES
REFERENCE CASE AND COMBINED CASE



cast doubt on the economic growth assumptions used.

2. It should be possible to maintain or reduce oil imports from current levels over the next 5 - 10 years, despite a rapidly growing economy (see Figure 3). Despite an anticipated growth of energy demand of around 50 percent by 1990, a combined alternative energy strategy could reduce oil as a fraction of total energy consumption from its current level of 97 percent to 64 percent by 1990. Anticipated growth in the economy between 1990 and 2000 may make it difficult to reduce the oil fraction below 50 percent even by the end of the century.

3. Alternative assumptions regarding economic growth (3 percent per year rather than 5), and the relationship between energy and economic growth (elasticity of 1.2 rather than 1.3) would lead to somewhat different conclusions. Petroleum demand in 1990 would be lower by as much as 25 percent but the fractional dependence on petroleum would still be greater than 50 percent in that year.

4. In the short term the most effective measures in reducing oil imports are (see Table VI):

- implementation of the slow speed diesel option in the JPS system
- industrial and transportation energy conservation
- use of coal by JPS (by 1986 or 1987).

Other options that could be significant in the next five years are:

- more efficient use of bagasse by the sugar industry
- solar water heaters for domestic and commercial use
- medium scale hydro power (the Great River and Rio Bueno systems).

5. In the intermediate term, the most beneficial strategies relative to oil imports remain the use of coal (with peat used for electricity generation an additional possibility) and energy conservation. In addition the following options could be important:

- Ocean thermal energy conversion systems (OTEC) (note, however, there are large technical/economic uncertainties).
- Large scale hydropower (the Blue Mountain Project).
- Urban waste use for power generation (which depends on the viability of garbage collection).
- Wood/charcoal use.

6. Over the longer term (to the year 2000) a number of other options could play a significant role. Many of these, however are at the present very uncertain regarding technical performance, economic viability, environmental implications and social acceptability. Of particular importance, <u>if they prove viable</u> would be:

- OTEC
- Solar ponds for electricity generation
- High temperature (concentrating) solar collectors
- Wood-based electricity generation ("energy farm")
- Urban waste use for electricity generation
- Liquid fuels from crops such as sugar, casava, tropical grasses or fast-growing trees.

7. The various alternative energy options have quite different implications in terms of foreign exchange costs (See Table VII). In general, despite the requirement of importing coal, the Coal/Peat strategy and energy conservation (including slow speed diesel for JPS) are the most beneficial from a foreign exchange perspective. Some options which appear attractive from a superficial oil savings perspective do not appear favorable under this more inclusive criterion. For example, large scale hydropower, photovoltaics and alcohol fuels from sugar appear to have unfavorable foreign exchange implications, at least in the intermediate term.

8. The use of coal both in industry and in the utility appears to be a very attractive alternative for Jamaica. Such use, however can not be decided upon on an individual plant basis because of the need to develop port and transport facilities and other infrastructure. The viability of the coal option thus also depends on the use of coal by the bauxite/alumina sector. A high priority should thus be given to a coal feasibility study of broad compass including all possible uses of coal, alternative suppliers and infrastructure requirements. In examining the future use of coal consideration should be given to the possible regional availability of very heavy crude oils, particularly from Venezuela. There may be, for example, a significant advantage of dual-fired capability in new electricity generation capacity based primarily on coal.

9. Energy conservation measures would rank very high under virtually all the criteria used in this study. They are the principal source of oil replacement in the near term. Indeed, unless vigorous conservation actions are pursued in the industrial and transport sectors, oil demand may well grow to unacceptable levels over the next several years. The price structures for fuels and electricity are important determinants of energy demand. Rational pricing is a key to the implementation of new technologies and conservation measures.

10. Several alternatives exist for backing oil out of the electric sector. Very few secure options exist, however, for direct fuel use in households and, particularly, for the transport sector. This results, for example, in transportation accounting for 60 percent of petroleum use by 1990, under a combined alternative energy strategy compared to 36 percent currently. Thus considerable attention should be paid to the following:

- increased energy efficiency of the transportation sector, including freight transport, urban mass transport and private vehicles
- alternative liquid fuels from biomass including crops such as tropical grasses and from fast growing wood varieties
- household fuels such as charcoal from tree plantations and dead coconut trees.

11. Although the bauxite and alumina industries have been considered to be external to this assessment, they can not be excluded from any complete analysis of the energy situation. Clearly they are critical to the economic future of the country and, just as clearly,

energy costs are critical to their future viability. National policies, for example on the development of a coal infrastructure, can have a significant impact on those industries. Similarly, opportunities for electricial generation within the bauxite/alumina industries feeding the national grid could be of mutual benefit.

12. This project has underscored the importance of a tightly coordinated national energy planning and analysis activity which extends to project planning, investment analysis and implementation. The analysis suggests that major changes are required in the future patterns of energy resource and technology use. A substantial effort is required if the necessary transition from petroleum to non-petroleum based fuels is to be accomplished in time.

# APPENDIX A

## OPTION WORK SHEETS

| | Page |
|---|---|
| ASSUMPTIONS | A 1 |
| Coal/Peat | |
| Central Station Coal Plant | A 2 |
| Coal Use in Industry | A 4 |
| Peat Electricity Generation | A 6 |
| Energy Conservation | |
| Industry | A 8 |
| Transportation | A10 |
| JPS (slow speed diesel) | A12 |
| Bagasse in Sugar Industry | A14 |
| Hydropower | |
| Large Scale | A16 |
| Medium Scale | A18 |
| Small Scale | A20 |
| Solar and Biomass | |
| Low Temperature Heat | A22 |
| High Temperature Heat | A24 |
| Crop Dryers | A26 |
| Photovoltaics | A28 |
| Solar Ponds | A30 |
| OTEC | A32 |
| Biogas | A34 |
| Fuels from Sugar, etc. | A36 |
| Fuels from Wood | A38 |
| Energy Farm | A40 |
| Urban Waste | A42 |
| Wood/Charcoal | A44 |

# ASSUMPTIONS & REFERENCES:

## Assumptions

All computations on the enclosed sheets are preliminary and are based on best available information. The purpose of this four-week study effort is to provide a relative comparison of energy strategies from an overall national perspective. Hence, the individual values by themselves are of less significance.

- Economic Growth
  - 3% 1981
  - 4% 1982
  - 5% 1983-1990
  - 4% 1991-2000
- Energy strategies exclude bauxite/alumina sector
- Oil prices escalate 3% annually in real terms
- All costs are in U.S. dollars
- A 10 percent fixed charge rate is used to compute annual foreign exchange capital costs of imports
- Capital costs per unit energy and foreign exchange balance are stated as U.S. dollars per barrel of oil saved.
- Capital costs in item (2), evaluation criteria, are not accumulated for year 1990 and year 2000. These include capital costs incurred only in that time frame.
- In the electric sector, near-term options are evaluated against 13,500 Btu/kWh heat rate, while for mid-and long-term options a 10,500 Btu/kWh heat rate is used.
- The costs and projected production quantities of options which are in research and development stage are highly uncertain. These estimates should be used with caution.

STRATEGY: Coal/Peat

SECTOR: Electricity

YEAR OF COMMERCIAL CONTRIBUTION: 1987

OPTION:

JPS - Public Power. This option assumes the installation of a 65 MW coal power plant in 1987, a second 65 MW unit in 1989, and 100 MW units in 1992 and 1995.

| EVALUATION CRITERIA | NEAR TERM 1985 (87) | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | 830 | 1,480 | 3,480 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | 92.3+ | 87.7 | 269.8 |
| PER UNIT ENERGY Per BOE oil saved | 111/BOE $1420/kW | 135/BOE $1350/kW | 135/BOE $1350/kW |
| FOREIGN COMPONENT (%) | 70% | 70% | 70% |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | 16.0 | 30.7 | 113.8 |
| PER UNIT ENERGY Per BOE oil saved | 19.4/BOE | 20.7/BOE | 32.7/BOE |
| 4) ENERGY PRODUCTION COSTS | 5.7¢/kWh | 6.2¢/kWh | 6.5¢/kWh |

COMMENTS:

- Harbor costs might be high; a joint coal harbor with alumina companies might be attractive
- Technology is proven
- Maintenance requirements are high
- Feasibility study needed

+ Does not include harbor and infrastructure costs

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHARGE

RATEGY: Coal/Peat SECTOR: Electricity YEAR OF COMMERCIAL CONTRIBUTION: 1987

TION: JPS-Public Power

## ASSUMPTIONS & REFERENCES:

### Assumptions

1. A 65 MW plant is installed in 1987, a second 65 MW plant in 1989, and 100 MW units in 1992 and 1995. These dates and sizes are appropriate for a major system conversion to coal.

2. Capital costs are updated values from a 1979 study and include JPS interface costs and interest during construction.

3. Coal costs based on 1980 prices of $53.60/metric ton + $15.00/metric ton for transport. Coal cost is escalated at 1% per year; coal transport at 2%.

4. Second collocated plant 5% less expensive than first plant.

5. Operation and maintenance costs of .2¢ per kWh.

### References


1. "Coal as a Possible Alternative Source of Energy for Jamaica," Dr. Henry Lowe, February 1981.

2. "Preliminary Energy Sector Assessments of Jamaica - Coal Prefeasibility Study", Energy Systems International, January 1980.

3. Mr. Walter Williams of Stone & Webster Engineering Corporation, personal communication.

STRATEGY: Coal/Peat

SECTOR: Industrial

YEAR OF COMMERCIAL CONTRIBUTION: 1985

OPTION:

Industrial (Non-Alumina). This option assumes a conversion to coal by Caribbean Cement by 1985, a doubling of cement production by 1990, and small additional facilities by 2000.

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | 275 | 550+ | 840 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | 13.4++ | minimal | 14-30 |
| PER UNIT ENERGY Per BOE oil saved | 48/BOE | - | 76/BOE |
| FOREIGN COMPONENT (%) | 80% | 80% | 80% |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | 5.3 | 13.4 | 26.5 |
| PER UNIT ENERGY Per BOE oil saved | 19.3/BOE | 24.4/BOE | 31.5/BOE |
| 4) ENERGY PRODUCTION COSTS | $22.7/BOE | $23.5/BOE | 37.5/BOE |

COMMENTS:

- Coal conversion is part of a plant expansion and modernization program
- Coal infrastructure would improve economics
- Other industries should be examined

+ This savings might be achieved b

++ Coal conversion costs only

FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHARGES

RATEGY: Coal/Peat

SECTOR: Industrial

YEAR OF COMMERCIAL CONTRIBUTION: 1985

TION: Industrial (Non-Alumina)

## ASSUMPTIONS & REFERENCES:

Assumptions

1. The modernization and expansion of the Caribbean Cement plant is carried out.

2. A 17 metric ton per hour coal unit is installed.

3. This unit is run at 45% capacity in 1985; 90% capacity in 1990. (The system might be running at 90% capacity in 1985).

4. 1980 costs of $53.60/metric ton for the coal and $15.00/metric ton for its transport escalate at 1% and 2% a year, respectively.

References

1. "Caribbean Cement Company Expansion and Rehabilitation Study," SNC/CEM/Joint Venture, March 1981.

STRATEGY: Coal/Peat SECTOR: Electricity YEAR OF COMMERCIAL CONTRIBUTION: 1988-89

OPTION:

Peat - Development of a 80 MW peat plant using peat from Negril and from Black River.

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | - | 830 | 830 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | - | 153+ | 153+ |
| PER UNIT ENERGY Per BOE oil saved | - | 184/BOE $1910/kW | 184/BOE $1910/kW |
| FOREIGN COMPONENT (%) | - | 70% | 70% |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | - | 28.3 | 41.6 |
| PER UNIT ENERGY Per BOE oil saved | - | 34.1/BOE | 50.1/BOE |
| 4) ENERGY PRODUCTION COSTS | - | 4.8¢/kWh | 4.8¢/kWh |

COMMENTS:

- Mining and Burning operations must be tailored to peat
- Environmental consequences are potentially serious
- Test and/or prototype operations needed

+ Does not include environmental costs

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHARGE

RATEGY: Coal/Peat SECTOR: Electricity YEAR OF COMMERCIAL CONTRIBUTION: 1988-89

TION: Peat

## ASSUMPTIONS & REFERENCES:

Assumptions

1. Power plant cost of U.S. $118.6 million; harvesting equipment cost of U.S. $22.4 million; land preparation cost of U.S. $11.2 million

2. 80 MW facility burning 500,000 tons of peat a year and producing 455 million kWh

3. Production and O&M costs of U.S. $6.6 million annually

References

1. "Prefeasibility Study Report on the Production and Utilization of Peat at Negril and Black River Morasses," Ewbank Engineering Consultants, June 1979.

2. "Interim Report. Environmental Feasibility Study of the Jamaica Peat Resources Utilization Project," The Traverse Group and the National Resources Conservation Department. July 1980.

3. "Report by Olle Uddgren", January 1981.

STRATEGY: Conservation SECTOR: Industry YEAR OF COMMERCIAL CONTRIBUTION: 1982

OPTION:

Industrial Energy Efficiency.+ Reduce oil conservation in industry through various measures ranging from "housekeeping" to investment: up to 4 years payback.

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | 157 | 254 | 254 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | 7.9 | 10.7 | - |
| PER UNIT ENERGY Per BOE oil saved | $50/BOE | $110/BOE | - |
| FOREIGN COMPONENT (%) | 70% | 50% | - |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | 5.8 | 10.9 | 14.9 |
| PER UNIT ENERGY Per BOE oil saved | 37/BOE | 43/BOE | 59/BOE |
| 4) ENERGY PRODUCTION COSTS | n.a. | n.a. | n.a. |

COMMENTS:

- Beneficial employment impacts
- Reduces cost of output increasing competitiveness of export industry
- Possibility of export market for conservation equipment and services.
- Beneficial environmental impact
- Repairs vigorous government program, and price structure change and capital availability.

+Excluding cement and sugar industries

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHAR

TRATEGY: Conservation SECTOR: Industry YEAR OF COMMERCIAL CONTRIBUTION: 1982

PTION: Industrial Energy Efficiency

## ASSUMPTIONS & REFERENCES:

Assumptions

1. By 1985 20 percent reduction in fuel use can be accomplished with measures having payback periods of 0-2 years.

2. Oil consumption in industry accessible to this program is 1985: $784 \times 10^3$ bbl; 1990: $973 \times 10^3$ bbl

3. By 1990 an additional 10% reduction from measures with paybacks of 2-4 years.

These are conservative assumptions and require a continuing government program

References

1. Frank Beveridge, "Technical Report on Jamaica Energy Conservation Scheme," National Industrial Fuel Efficiency Service, February 1980 (based on visits made in October 1979)

2. Wallace K. Pryke, "Energy Conservation in Jamaica, Report No. 2" UK Department of Energy, June, 1980

3. B. Tunnah "Energy Conservation, Industrial Sector, Jamaica," E/DI memo April 13, 1981.

STRATEGY: Conservation SECTOR: Transportation YEAR OF COMMERCIAL CONTRIBUTION: 1982

OPTION: Transportation Conservation

Rehabilitate transport fleets
Introduce operating standards
Restrict mpg. of vehicle imports

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | 176 | 352 | 1,099 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | 1.43 | 3.3 | 13.8 |
| PER UNIT ENERGY Per BOE oil saved | 81/BOE | 94/BOE | 126/BOE |
| FOREIGN COMPONENT (%) | 70% | 70% | 70% |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | 7.0 | 16.2 | 68.0 |
| PER UNIT ENERGY Per BOE oil saved | 40 | 46 | 62 |
| 4) ENERGY PRODUCTION COSTS | n/a | n/a | n/a |

COMMENTS:

- The numerical estimates are rough assumptions as no adequate data base exists.
- Several studies need to be made on optimal transportation modes, especially for public conveyance and commercial freight, before morerealistic projections can be made.

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHARG

RATEGY: Conservation SECTOR: Transportation YEAR OF COMMERCIAL CONTRIBUTION: 1982

TION: Transportation Conservation

## ASSUMPTIONS & REFERENCES:

### Assumptions

10% of transportation fuel (excluding aviation fuel and fuel oil to ship bunkers, can be saved by 1990, and 20% by 2000, through measures having a 2-year payback period.

### References

"Economic and Social Survey Jamaica 1979", National Planning Agency, September 1980.

STRATEGY: Conservation SECTOR: Electricity YEAR OF COMMERCIAL CONTRIBUTION: 1985

OPTION:

Slow Speed Diesel. Install 40 MW of slow speed diesel replacing 70 MW of Hunts Bay A and possibly some smaller units.

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | 348 | 331 | 278 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | 32.5 | - | - |
| PER UNIT ENERGY<br>Per BOE oil saved | 813/kW<br>93/BOE | - | - |
| FOREIGN COMPONENT (%) | 100 | - | - |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | 10.8 | 12.3 | 14.2 |
| PER UNIT ENERGY<br>Per BOE oil saved | 31/BOE | 33/BOE | 37/BOE |
| 4) ENERGY PRODUCTION COSTS | 7-8¢/kWh | 7-8¢/kWh | 7-9¢/kWh |

COMMENTS:

- Currently available technology
- Next steps: review economics, specifications and performance
  financing analysis
  contracting

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHARG

STRATEGY: Conservation SECTOR: Electricity YEAR OF COMMERCIAL CONTRIBUTION: 1985

OPTION: Slow speed diesel

## ASSUMPTIONS & REFERENCES:

### Assumptions

Capacity = 40MW
Capital cost = $32.5 million
Heat rate = 7700 Btu/kWh ($K$ 90 unit)
Operation: 8250 hrs/yr.
Heat rate of replaced capacity = 13,500 Btu/kWh
(Note heat rate of plants to be retired first is approximately 20,000 Btu/kWh).
Plant utilization decreases by 5% in 1990; 20% in 2000.
Diesel fuel cost below as $40/bbl.

### References

1. Personal Communication from W. Hay, April 17, 1981.

2. Letter from Hugh M. Shannon of Oresundsvarvet AB to W. Hay, "New Power Generating Facilities at Hunt's Bay", March 7, 1980.

3. Oresundsvarvet AB, "Report on Economy for Diesel Power Station Investment for JPS", November 17, 1980.

STRATEGY: Conservation SECTOR: Industry YEAR OF COMMERCIAL CONTRIBUTION: 1983

OPTION:

Sugar Industry. This option involves the replacement of most of the oil used in the sugar industry with bagasse.

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | 100 | 150 | 150 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | 16.2 | 9.4 | - |
| PER UNIT ENERGY Per BOE oil saved | 162/BOE | 188/BOE | - |
| FOREIGN COMPONENT (%) | 50% | 50% | - |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | 3.3 | 5.8 | 8.2 |
| PER UNIT ENERGY Per BOE oil saved | 32/BOE | 38/BOE | 55/BOE |
| 4) ENERGY PRODUCTION COSTS | 16/BOE | 18/BOE | 18/BOE |

COMMENTS:

- Increased bagasse use could improve the economics of sugar production
- A study of ways and costs to increase bagasse utilization is needed.

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHAR

STRATEGY: Conservation SECTOR: Industry YEAR OF COMMERCIAL CONTRIBUTION: 1983

OPTION: Sugar Industry

## ASSUMPTIONS & REFERENCES:

Assumptions

1. 1985, 1990, and year 2000 reference case oil use by the sugar industry is 200,000 barrels per year.

2. 75% of that oil could be displaced by bagasse by 1990; 50% by 1985.

3. The average oil displacement measure will have a four year payback, and a 50% foreign exchange component.

References

1. "Economic and Social Survey Jamaica 1979," National Planning Agency, September 1980.

STRATEGY: Hydropower SECTOR: Electricity YEAR OF COMMERCIAL CONTRIBUTION: 1989

OPTION: Large Hydro. The following assumes the deployment of Phases I, II, and IIIA of the Blue Mountain Multipurpose Scheme.

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | - | 98 | 273 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | - | 75.8 | 32.9 |
| PER UNIT ENERGY Per BOE unit saved | - | 773/BOE<br>140¢/kWh | 188/BOE<br>33¢/kWh |
| FOREIGN COMPONENT (%) | - | 73% | 68% |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | - | -0.9 | 9.5 |
| PER UNIT ENERGY Per BOE unit saved | - | -9.5/BOE | 35/BOE |
| 4) ENERGY PRODUCTION COSTS | - | 13.5¢/kWh | 7.0¢/kWh |

COMMENTS:

- Acceptability of water component investment ($491 million) must be established
- Technology is proven
- Construction schedule particularly susceptible to delays

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHARG

'RATEGY: Hydropower SECTOR: Electricity YEAR OF COMMERCIAL CONTRIBUTION: 1989

TION: Large Hydropower

## ASSUMPTIONS & REFERENCES:

Assumptions

1. Phases I, II, and IIIA of the Blue Mountain Multipurpose scheme are carried out.

2. The total project costs of $616 million are partitioned between water ($491 million) and power ($125 million).

3. Phase II (56 million kWh) is completed in 1989; Phase IIIA (100 million additional kWh) is completed in year 2000.

4. Maximum power output is 55 MW.

References

1. "Co-ordinating Committee Report, Blue Mountain Multipurpose Scheme", Petroleum Corporation of Jamaica and Ministry of Mining and Energy, March 1981.

STRATEGY: Hydropower SECTOR: Electricity YEAR OF COMMERCIAL CONTRIBUTION: 1985

OPTION: Medium to small Scale Hydropower. This includes the development of the Great River (7.7 MW, 33.1 GWH) and Rio Bueno (0.9 MW. 5.6 GWH) hydropower systems by 1985. Additional 5MW Capacity Additions of medium to small systems by year 1990 and 7MW by year 2000 (Total of 20 MW by year 2000).

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | 67.8 | 113.8 | 178.2 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | 27.9 | 17.5 | 24.5 |
| PER UNIT ENERGY Per BOE unit saved | 412/BOE 73¢/KWH | 380/BOE 67¢/KWH | 380/BOE 67¢/KWH |
| FOREIGN COMPONENT (%) | 65% | 65% | 65% |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | 0.9 | 4.6 | 6.7 |
| PER UNIT ENERGY Per BOE unit saved | 14/BOE | 41/BOE | 38/BOE |
| 4) ENERGY PRODUCTION COSTS | 7.2¢/kWH | 7.2¢/kWH | 7.2¢/kWH |

COMMENTS:

- Energy Contribution is moderate
- 1978 Mid and Western Jamacia study must be updated
- Other potertial projects should be examined.

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHARGE

:ATEGY: Hydropower SECTOR: Electricity YEAR OF COMMERCIAL CONTRIBUTION: 1985-1986 A19

'ION: Medium Scale Hydropower

## ASSUMPTIONS & REFERENCES:

Assumtions

1. The Great River and Rio Bueno projects will be developed by 1985 or 1986.

2. The 1978 cost estimates of $18.5 million and $2.6 million have been inflated to $24.5 million and $3.4 million in 1980 US $.

3. Additional hydroprojects could be operational by 1990 and 2000 using other rivers in Jamaica. These are estimated to be 5MW capacity additions by 1990 and 7MW by 2000. Total medium scale hydro potential is approximately 20MW by 2000.

4. Average capacity utilization: 60 percent; Capital Costs $3.5/Watt

5. A heat rate of 10,500 Btu/kWh has been used to compute oil savings.

References


1. "Appraisal Report on the Mid and Western Jamaica Hydro-electric Feasibility Study, 1978 report", Norconsult A.S., September 1979.

2. "A Survey of Alternative Energy Possibilities in Jamaica," Petroleum Corporation of Jamaica, July 1980.

3. Preliminary assesments by Canadian Energy Development Systems Internationl; verbal communications with David Henry

STRATEGY: Hydropower

SECTOR: Electricity (rural)

YEAR OF COMMERCIAL CONTRIBUTION: 1985

OPTION:

Microhydro. This option assumes that 2 MW of capacity could be installed by the year 2000.

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | .5 | 3.8 | 15.3 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | .075 - .15 | .70 - 1.35 | 2.25 - 4.50 |
| PER UNIT ENERGY Per BOE unit saved | 34¢ - 68¢/kWh | 34¢-68¢/kWh | 34¢-68¢/kWh |
| FOREIGN COMPONENT (%) | 70% | 55% | 40% |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | .013 | .071 | .515 |
| PER UNIT ENERGY Per BOE unit saved | 26.5/BOE | 18.8/BOE | 33.7/BOE |
| 4) ENERGY PRODUCTION COSTS | 5.4¢-8.8¢/kWh | 5.4¢-8.8¢/kWh | 5.4¢-8.8¢/kWh |

COMMENTS:

- Costs are highly uncertain
- Ultimate potential is unclear
- Detailed survey of potential sites and cost evaluations are needed

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHARG

RATEGY: Hydropower

TION: Microhydro

SECTOR: Electricity (rural)

YEAR OF COMMERCIAL CONTRIBUTION: 1985

## ASSUMPTIONS & REFERENCES:

Assumptions

1. 2 MW of installed capacity by 2000; .5 MW by 1990; .05 MW by 1985
2. Capital costs of $1.50-$3.00 per watt
3. An average 50% utilization factor
4. 2¢ per kWh for O&M, setting up lines, etc.

References

1. "A Survey of Alternative Energy Possibilities in Jamaica, Petroleum Corporation of Jamaica, July 1980.
2. "The Contribution of Renewable Resources and Energy Conservation as Alternatives to Imported Oil in Developing Countries," Energy/Development International, February 1980.

STRATEGY: Solar

SECTOR: Household
Industrial
Commercial

YEAR OF COMMERCIAL CONTRIBUTION: 1981-82

OPTION: Hot Water

Solar hot water heating in households, industry and commercial sectors. Aggressive program to achieve potential by 1990.

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | 35 | 190 | 281 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | 31 | 45 | 23 |
| PER UNIT ENERGY Per BOE unit saved | 371/BOE | 305/BOE | 288/BOE |
| FOREIGN COMPONENT (%) | 50% | 40% | 40% |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | 0.77 | 6.48 | 14.36 |
| PER UNIT ENERGY Per BOE unit saved | 22/BOE | 34/BOE | 51/BOE |
| 4) ENERGY PRODUCTION COSTS | 4.8¢/kWh | 4¢/kWh | 4¢/kWh |

COMMENTS:

- 2.5% of Nonbauxite energy consumption saved
- Technology available today; Local industry exists but needs expansion
- Incentives needed for conversion of existing rental households
- Elimination of water heater tax for new construction; Low interest loans and other incentives
- Strengthen technological base
  - solar radiation data base
  - standards development
  - technician training

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHA

ATEGY: Solar

SECTOR: Household
Industrial/Commercial

YEAR OF COMMERCIAL CONTRIBUTION: 1981-1982

'ION: Hot Water

## ASSUMPTIONS & REFERENCES:

### Assumptions

Potential of 190,000 barrel savings achieved by 1990; 159,000 barrels/year household; 24,000 bbl/yr. commercial; 7,000 bbl/yr. industrial

Present 30,000 households with hot water double by 1990; 50% retrofit & 50% new units. Year 2000 projection assumes 4% growth rate from 1990.

| | 1985 | 1990 | 2000 |
|---|---|---|---|
| Capital costs $/sq.ft. | 40 | 35 | 30 |
| Total Square Ft. installed (not cumulated) | 326,000 | 1,284,000 | 772,000 |

Current hospital hot water system costs (reference 2)

| | |
|---|---|
| with retrofit | $65/ft$^2$ |
| without retrofit | $50/ft$^2$ |

Potential contribution by 1985

| | | |
|---|---|---|
| household | 10% | |
| commercial | 75% | of 1990 savings |
| industrial | 25% | |

### References


1. "Preliminary Energy Sector Assessments of Jamaica," Volume III Renewable Energy, Energy Systems International, January 1980 - Projections updated as required;

2. Cost summary sheet - hospital retrofit, MME

STRATEGY: Solar

SECTOR: Industry/Commercial

YEAR OF COMMERCIAL CONTRIBUTION: 1990

OPTION:

Process Heat

Intermediate temperature heat systems for solar cooling, process hot water and other applications. Assumes 25 percent savings by 2000 in Industrial/Commerce sector.

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | | 50 | 200 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | | 27.5 | 66.0 |
| PER UNIT ENERGY Per BOE unit saved | | 550/BOE | 467/BOE |
| FOREIGN COMPONENT (%) | | 80% | 80% |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | | 0.15 | 3.27 |
| PER UNIT ENERGY Per BOE unit saved | | 3/BOE | 16.35/BOE |
| 4) ENERGY PRODUCTION COSTS | | 60/BOE | 42/BOE |

COMMENTS:

- High performance collectors not produced in Jamaica (Evacuated Tubes/Concentrators)
- Concentration require mirror manufacturing capability & tracking systems
- Systems could be deployed if sufficient demand exists for intermediate temperature process heat (100°C to 300°C)
- Assess the process heat potential in industry/commerce

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHA

:ATEGY: Solar

SECTOR: Industrial/ Commercial

YEAR OF COMMERCIAL CONTRIBUTION: 1990

'ION: Process Heat

## ASSUMPTIONS & REFERENCES:

Assumptions

- 25 percent of industrial and commercial process heat/intermediate temperature applications are converted to solar in year 2000.
- Approximately 50,000 barrels/yr. or 25 percent of year 2000 potential is obtained in 1990.
- Collector costs: $25/sq.ft. in 1990; $20/sq.ft. in 2000 with conversion efficiency of 45 percent.
- 1.1 million square feet of concentrating collectors installed by 1990; additional 3.3 million square feet collectors installed by year 2000.
- A direct normal insolation level of 600,000 BTU/ft.$^2$yr. is assumed.

References

"Solar Energy-Program Summary Document FY 1981" U.S. Department of Energy, August 1980.

STRATEGY: Solar SECTOR: Agriculture YEAR OF COMMERCIAL CONTRIBUTION: 1983

OPTION: Agricultural Crop Drying

Grain drying, agricultural product drying such as peas, beans, coffee, tumeric, cassava, timber, etc.

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | 0.3 | 3.16 | 5.1 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | .200 | 1.31 | .581 |
| PER UNIT ENERGY Per BOE unit saved | 666/BOE | 477/BOE | 409/BOE |
| FOREIGN COMPONENT (%) | 50 | 20 | 20 |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | -0.088 | -0.212 | -0.138 |
| PER UNIT ENERGY Per BOE unit saved | - | - | - |
| 4) ENERGY PRODUCTION COSTS | 3-5¢/kWh | 2-3¢/kWh | 2-3¢/kWh |

COMMENTS:

- Contribution to energy supply and foreign exchange balance is minimal
- Major benefits not quantifiable: food preservation for nonharve seasons; minimize post harvest loss of local production (estimated at 43-52 million dollars); increased efficiency
- Air collectors not manufactured in Jamaica
- Steps for implementation
  - Determine characteristics of agricultural products
  - Develop cost effective designs
  - Investigate local manufacture of collectors
  - Economic incentives for solar use

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHA

TRATEGY: Solar SECTOR: Agriculture YEAR OF COMMERCIAL CONTRIBUTION: 1983

PTION: Agricultural Crop Drying

## ASSUMPTIONS & REFERENCES:

### Assumptions

The potential of 3160 barrels/yr is achieved by 1990. This potential is derived from preliminary assessments made by Energy Systems International. Of the 3160 barrels saved, 10% is achieved by 1985. Escalation to year 2000 assumes a 5% growth each year. This saving may be conservative.

| | 1985 | 1990 | 2000 |
|---|---|---|---|
| Capital costs $/sq. ft. | 20 | 15 | 15 |
| Total square ft. installed (not cumulated) | 10,000 | 87,600 | 38,700 |

### References

"Preliminary Energy Sector Assessments of Jamaica" Volume IIIb Renewable Energy, Energy Systems International, January 1980

STRATEGY: Solar

SECTOR: Household (rural & urban) Industrial/Commercial Electricity

YEAR OF COMMERCIAL CONTRIBUTION: 1985-90

OPTION: Photovoltaics

500 kW in remote & agricultural use by 1985
2.5 MW in household/industrial/commercial use by 1990
20.0 MW in household/industrial/commercial utility use by 2000

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | 2.0 | 10.0 | 80.0 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | 5.0 | 6.0 | 35 |
| PER UNIT ENERGY Per BOE unit saved | 10,000/KW 2500/BOE | 3000/KW 750/BOE | 2000/KW 514/BOE |
| FOREIGN COMPONENT (%) | 90% | 70% | 60% |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | -0.369 | -0.470 | 2.0 |
| PER UNIT ENERGY Per BOE unit saved | - | - | 25/BOE |
| 4) ENERGY PRODUCTION COSTS | 40¢-100¢/kWh | 11-22¢/kWh | 6-11/kWh |

COMMENTS:

- Suited for rural and agricultural applications of electricity in the near-term. If prices decline substantially (factor of 10), an option for household and industrial/commercial (onsite) electricity. In the long run, an option for electricity generation by JPS
- Current costs too high; only economic for remote/stand-alone applications
- High foreign exchange component
- Potential for local component manufacture and assembly
- Systems modular, clean and reliable

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHA

RATEGY: Solar SECTOR: Electricity YEAR OF COMMERCIAL CONTRIBUTION: 1985-87

TION: Photovoltaics

## ASSUMPTIONS & REFERENCES:

### Assumptions

Modest contribution to energy supply assumed by 1990. This includes remote, agricultural and household uses. One half of year 2000 contribution is assumed to come from a 10 MWp utility plant if the costs are substantially reduced.

Total installed capacity in year 2000 is 20 MWp.

| | 1985 | 1990 | 2000 |
|---|---|---|---|
| Installed capacity MWp | 0.5 | 2.0 | 17.5 |
| Cumulative capacity | 0.5 | 2.5 | 20.0 |
| Price* | $10/ Wp | $3/Wp | $2/ Wp |

*prices are expected to be achieved if the goals of U.S. Department of Energy's Photovoltaic Program are met.

### References

National Photovoltaics Program Plan, U.S. Department of Energy, September 1980.

STRATEGY: Solar

SECTOR: Electricity

YEAR OF COMMERCIAL CONTRIBUTION: 2000

OPTION: Solar Pond
2.5 MW electrical generation by year 1990
25 MW electrical generation by year 2000

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | | 30 | 296 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | | ** | ** |
| PER UNIT ENERGY Per BOE unit saved | | | |
| FOREIGN COMPONENT (%) | | | |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | | ** | ** |
| PER UNIT ENERGY Per BOE unit saved | | | |
| 4) ENERGY PRODUCTION COSTS | | | |

COMMENTS:

- Yallahs Ponds offer a promising resource of approximately 1300 acres ; Potential of several other ponds needs to be investigated
- Ponds may be subject to dilution with fresh and sea water
- Await results of US and Israel Project Experience
- Perform small studies on salt gradients and their stability fallowed by a demonstration plant

** Costs are entirely dependent on the stability of ponds

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHAR

RATEGY: Solar

SECTOR: Electricity

YEAR OF COMMERCIAL CONTRIBUTION: 2000

TION: Solar Ponds

## ASSUMPTIONS & REFERENCES:

### Assumptions

Yallah's Ponds as a naturally existing resource

Big Pond has 1090 acres at 14 feet deep; Small Pond has 216 acres @ 4.5 feet deep
Several other ponds are available and need to be investigated
2.5MW capacity obtained by year 1990; 25MW by year 2000

Suitability of Yallah's ponds is in question due to its location and environment. Economic viability of their operation has to be determined. Ponds subject to dilution with fresh and sea water. Sealing may be necessary.

### References

1. "Feasibility Study of Yallahs, Companie des Salins du Midi et des Salines de l'Est.," Jamaica Alkali Ltd., 1974.

2. "A Survey of Alternative Energy Possibilities in Jamaica," W.R. Ashby, July 1980.

STRATEGY: Solar

SECTOR: Electricity

YEAR OF COMMERCIAL CONTRIBUTION: 1988

OPTION: OTEC

10 MW land-based, hybrid or floating plant by 1988
80 MW of capacity by 2000.

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | - | 130 | 1,170 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | - | 80.3 (total)<br>14.2 (Jamaica) | 350.0 |
| PER UNIT ENERGY Per BOE unit saved | - | $8,000/kw<br>617/BOE | $5,000/kw<br>336/BOE |
| FOREIGN COMPONENT (%) | - | | 80 |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | - | 6.11 | 4.58 |
| PER UNIT ENERGY Per BOE unit saved | - | 47/BOE | 38/BOE |
| 4) ENERGY PRODUCTION COSTS | - | 14-17¢/kWh | 10-12¢/kWh |

COMMENTS:

- Large potential for Jamaica
- Technology commercially unproven; experiments conducted at 50 kW and 1 MW scale
- 10 MW pilot plant first-of-a-kind to be built at this scale; High uncertainties in various components--large heat exchangers, cold water pipe, corrosion and biofouling; costs could escalate substantially
- Jamaican investment should follow, if first unit is successful
- Seek 100% international funding with JPS buying electricity at agreed-upon rates and by providing local assistance.

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHARG

RATEGY: Solar

SECTOR: Electricity

YEAR OF COMMERCIAL CONTRIBUTION: 1988

TION: OTEC

## ASSUMPTIONS & REFERENCES:

Assumptions

10 MW pilot plant operational 1987-1988 time frame, operating at .65 plant factor.

Additional 2-3 plants of 70 MW capacity are added by year 2000

References

1. "OTEC as a Jamaican Energy Resource - Swedish Involvement," Position Paper, Petroleum Corporation of Jamaica, January 1981

2. "OTEC--A Jamaican Source of Energy," Swedish OTEC, September 1980

3. "Ocean Thermal Energy Conversion," Draft Summary, undated

STRATEGY: Biomass

SECTOR: Household (rural)
Agriculture
Industrial/Commercial

YEAR OF COMMERCIAL CONTRIBUTION: 1983

A34

OPTION: Biogas**

500 household, 50 medium units in 1985
2,000 household, 60 medium units in 1990
5,000 household, 100 medium units in 2000

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | 4.5 | 9.75 | 21 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | .85 | 1.0 | 2.30 |
| PER UNIT ENERGY Per BOE unit saved | 189/BOE | 189/BOE | 189/BOE |
| FOREIGN COMPONENT (%) | 0 | 0 | 0 |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | .18 | .45 | 1.3 |
| PER UNIT ENERGY Per BOE unit saved | 40/BOE | 47/BOE | 62/BOE |
| 4) ENERGY PRODUCTION COSTS | 10-20¢/kWh | 7-12¢/kWh | 7¢/kWh |

COMMENTS:

- Simple Technology, suited for agriculture sector, small rural communities and sugar industry
- Local manufacture and installation
- Experimentation needed for determining appropriate digestor design
- Need animal waste collection system for small communities

** Household size 100 cu.ft./day; medium size-2000 cu.ft./day

)REIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHAR

STRATEGY: Biomass

OPTION: Biogas

SECTOR: Household
Agriculture
Industrial/Commercial

YEAR OF COMMERCIAL CONTRIBUTION: 1983

## ASSUMPTIONS & REFERENCES:

### Assumptions

Aggressive program to replace kerosene use in household, agriculture and industrial/commercial sectors.

| | 1985 | 1990 | 2000 |
|---|---|---|---|
| Biogas Units | | | |
| Household | 500 | 2000 | 5,000 |
| Medium | 50 | 60 | 100 |

Cost assumed to be approximately $5.7/cu.ft. capacity
Household digestor to cost $570 for 100 cu.ft./day
Medium digestor with capacity of 2000 cu.ft./day
Assumes 10 year life at 10% cost of capital

### References

"Preliminary Energy Sector Assessments of Jamaica" Volume IIIc, Energy Systems International, January 1980.

STRATEGY: Solar

SECTOR: Transport

YEAR OF COMMERCIAL CONTRIBUTION: 1990

OPTION:

Fuel Alcohol. The production of fuel alcohol from 25% of sugar acreage is assumed by 2000.

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | - | 33 | 330 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | - | 2.7 | 24.1 |
| PER UNIT ENERGY Per BOE unit saved | 79/BOE | 79/BOE | 79/BOE |
| FOREIGN COMPONENT (%) | 75% | 75% | 75% |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)*+ | | | |
| TOTAL (MILLIONS) | | -.85 | -3.6 |
| PER UNIT ENERGY Per BOE unit saved | -33/BOE | -26/BOE | -11/BOE |
| 4) ENERGY PRODUCTION COSTS | 62/BOE | 62/BOE | 62/BOE |

COMMENTS:

- At current prices, sugar is a more attractive foreign exchange product than alcohol
- New developments in cellulose technology may make alcohol more attractive
- Marginal lands, alternative feedstocks need to be identified

+ Critically dependent on price of sugar

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHARGE

'RATEGY: Solar

SECTOR: Transport

YEAR OF COMMERCIAL CONTRIBUTION: 1990

'TION: Fuel Alcohol

## ASSUMPTIONS & REFERENCES:

### Assumptions

1. Economics based on plant producing six million imperial gallons of alcohol (equivalent to 171,430 barrels of oil) from 384,000 tons of sugar cane.

2. Plant capital costs of $13.65 million

3. Sugar value set at $330/ton; 0.092 tons of sugar from one tone of cane; loss of sugar exports included in the calculation of foreign exchange balance.

4. Per gallon cost of alcohol assumed as $1.02 for cane, 0.21 for chemicals, 0.17 for salaries, 0.23 for capital charges, 0.15 for distribution; total is $1.78/IG.

### References

1. "Sugar By-Product Utilization in Jamaica, Vol. II, Alcohol," Organization of American States, 1978.

2. "The Potential of Sugarcane Derived Alcohol as a Fuel in Jamaica," Dr. Ian Sangster, SIRI, November 1979

STRATEGY: Biomass SECTOR: Transport YEAR OF COMMERCIAL CONTRIBUTION: 1995

OPTION: Liquid Fuels

Conversion of wood to liquid fuels using biochemical or thermochemical processes

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | | | 100-200 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | | | ** |
| PER UNIT ENERGY Per BOE unit saved | | | |
| FOREIGN COMPONENT (%) | | | |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | | | ** |
| PER UNIT ENERGY Per BOE unit saved | | | |
| 4) ENERGY PRODUCTION COSTS | | | |

COMMENTS:

- Fermentation, gasification and liquefaction technologies under development in United States and other nations
- Currently in R&D stage, further development needed
- This could be a longer-term option for transport solar with silviculture

** Costs are highly uncertain

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHAR

RATEGY: Biomass

SECTOR: Transport

YEAR OF COMMERCIAL CONTRIBUTION: 1995

TION: Liquid Fuels

## ASSUMPTIONS & REFERENCES:

References


1. "Biomass Energy Systems Program Summary," Biomass Energy Systems Division, Department of Energy, 1980.

2. "Biomass Potential in 2000 Put at 7 Quads," Chemical and Engineering News, February 1979.

3. "Fuels from Biomass: Integration with Food and Material Systems, E.S. Lipinski, Science, February 1978.

STRATEGY: Biomass

SECTOR: Electricity Household

YEAR OF COMMERCIAL CONTRIBUTION: 1990

OPTION:

Energy Farming

2500 Acre - 3 MW by 1990
25,000 Acres - 30 MW by 2000

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | - | 35 | 350 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | - | 5.3 | 48 |
| PER UNIT ENERGY Per BOE unit saved | - | 151/BOE | 151/BOE |
| FOREIGN COMPONENT (%) | - | 0% | 80% |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | - | 1.22 | 17.86 |
| PER UNIT ENERGY Per BOE unit saved | - | 34/BOE | 53/BOE |
| 4) ENERGY PRODUCTION COSTS | - | 15¢/kWh | 15¢/kWh |

COMMENTS:

- Offers biomass resource for electricity and potential conversion to liquids (transport sector)
- Total potential acreage large (275,000 acres)
- Labor intensive technology
- Technology experimental stage
  - Conduct research on optimum species for growing on farm
  - Growth characteristics and short rotation farming
  - Project economics of farming and conversion to energy

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHAR

TRATEGY: Biomass

SECTOR: Electricity Household

YEAR OF COMMERCIAL CONTRIBUTION: 1990

TION: Energy Farming

## ASSUMPTIONS & REFERENCES:

### Assumptions

A 2500 acre plantation provides enough wood for a 3 MV wood-fired steam plant. The rotation cycle of the crop is 4 years. One 3 MW plant with associated plantation assumed to be operational by 1990, with 0.60 plant factor. Total estimated land availability is approximately 275,000 acres. About 14 sites with a total of 59,000 acres are short listed in reference 1. 250,000 acres with 30 MW electrical generation capacity realized by year 2000. Capital costs of Power Plant = $5.3 million. Operation and maintenance costs of power plant = $300K per year. Annual Plantation costs = $1.59 million/year.

### References

1. "Pre Study and Estimates for Dendrothermal Complex," Scientific Research council, January 1981

2. "Fast growing species for community development," Ministry of Agriculture, January 1981 (F.A.O. Project Paper)

3. "A Survey of Alternative Energy Possibilities in Jamaica," W.R. Ashby, July 1980.

STRATEGY: Biomass SECTOR: Electricity YEAR OF COMMERCIAL CONTRIBUTION: 1986

OPTION:

Urban Waste

Urban Waste Collection system 1000TPD
New incineration steam generation capacity 30 MW

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | | 370 | 555 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | | 12.0 collection<br>50.0 conversion | 6.0 collection<br>25.0 conversio |
| PER UNIT ENERGY Per BOE unit saved | | 167/BOE | 167/BOE |
| FOREIGN COMPONENT (%) | | 83% collection<br>80% conversion | 83% collection<br>80% conversion |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | | 10.0 | 15.0 |
| $ PER UNIT ENERGY Per BOE unit saved | | 27/BOE | 27/BOE |
| 4) ENERGY PRODUCTION COSTS+ | | 12-18¢/kWh<br>5-8¢/kWh | 12-18¢/kWh<br>5-8¢/kWh |

COMMENTS:

- Improved sanitation and health; benefits poorer groups; elimination of illegal dumping of waste; encouragement of tourist trade

- Feasibility study for phased implementation
  - institute urban waste collection system
  - evaluate effectiveness of waste collection with projections
  - install conversion system, if cost-effective in the next phase

+ Top cost is for collection and conversion; bottom cost is for conversion o

FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHAR

RATEGY: Biomass SECTOR: Electricity YEAR OF COMMERCIAL CONTRIBUTION: 1987

TION: Urban Waste

## ASSUMPTIONS & REFERENCES:

### Assumptions

ERL/Option 2, considered for urban waste collection. Collection by standard fleet of smaller, simpler, side-loading vehicles. Conversion system with waterwall incineration.
Assume: 1000 TPD collected & converted to steam by 1990.
1500 TPD collected & converted to steam by 2000.

### References

1. "Solid Waste Management in the Kingston Metropolitan Region," Environmental Resources Limited and Wallace Evans and Associates, July 1979.

2. "Preliminary Energy Sector Assessments of Jamaica Volume IIId, Renewable Energy," Energy Systems International, January 1980.

STRATEGY: Solar SECTOR: Household YEAR OF COMMERCIAL CONTRIBUTION: 1982-198

OPTION: Wood/Charcoal

Direct burning of wood or production of charcoal
Assumes an aggressive switching from kerosene to wood or charcoal

| EVALUATION CRITERIA | NEAR TERM 1985 | MID TERM 1990 | LONG TERM 2000 |
|---|---|---|---|
| 1) CUMULATIVE OIL SAVINGS IN THOUSAND BOE/YEAR | 10 | 100 | 100 |
| 2) CAPITAL COST (U.S. $) | | | |
| TOTAL (MILLIONS) | small | small | small |
| PER UNIT ENERGY Per BOE unit saved | - | - | - |
| FOREIGN COMPONENT (%) | 0 | 0 | 0 |
| 3) FOREIGN EXCHANGE BALANCE (U.S. $/YEAR)* | | | |
| TOTAL (MILLIONS) | .450 | 4.7 | 6.31 |
| PER UNIT ENERGY Per BOE unit saved | 40.5/BOE | 47/BOE | 63.1/BOE |
| 4) ENERGY PRODUCTION COSTS | less than 1¢/kWh wood burning | less than 1¢/kWh wood burning | less than 1¢/kW wood burning |

COMMENTS:

- Large Resource Base exists (4.5 million dead coconut trees) or 7 million BOE
- Considerable fuel switching required aided by removal of kerosene subsidies; consumer/producer acceptance of low density charcoal
- Benefits: Reduced use of logwood, pimento, etc. for charcoal production
  Reduction of dead trees and insect infestation
- Foster charcoal production/wood burning
- Reafforestation needed

*FOREIGN EXCHANGE BALANCE = OIL SAVINGS - IMPORTED FUEL - FOREIGN CAPITAL CHA

RATEGY: Solar

SECTOR: Household

YEAR OF COMMERCIAL CONTRIBUTION: 1982-1983

TION: Wood/Charcoal

## ASSUMPTIONS & REFERENCES:

Assumptions

Household sector consumes 360,000 barrels/yr of kerosene wood resources (with dead coconut trees) amount to $7 million barrels of oil equivalent

Assumes one third of kerosene fuel switching to wood or charcoal under an aggressive program

References

"Charcoal/Wood/Reafforestation," Project Profile, Ministry of Mining and Energy, undated.

"Wood to Fuel," A Summary; Forestry Development Project - New Zealand Technical Assistance, undated.