CER-K-196 ENERGY FOR THE CARIBBEAN: THE MEDIUM TERM BY WALLACE C. KOEHLER, JR., Ph.D., AND JUAN A. BONNET, JR., Ph.D. CENTER FOR ENERGY AND ENVIRONMENT RESEARCH, UNIVERSITY OF PUERTO RICO. PREPARED FOR THE VIII CONVENTION OF THE PAN AMERICAN UNION OF ENGINEERS ASSOCIATIONS IN CARACAS, VENEZUELA, OCTOBER/NOVEMBER 1993. CENTER FOR ENERGY AND ENVIRONMENT RESEARCH.

ENERGY FOR THE CARIBBEAN: THE MEDIUM TERM

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Abstract:

Energy use patterns are changing in the Caribbean for a variety of reasons. These include growing populations, increasing urbanization, new industries, increasing energy import costs (over the long run), general modernization, and development, among others. The current status of energy production and consumption are explored. Possible changes in demand and supply are considered, and estimates of demand through the year 2000 are made. The chances of effectively meeting these needs with domestic resources are poor. Given the present state of development of renewable energy technology and the estimated possible contribution of these technologies to the energy mix of Caribbean countries and probable increased demand, the Caribbean will find it necessary to import ever-increasing levels of energy resources. The United States Caribbean Basin Initiative (CBI) and other programs should consider the development of the energy infrastructure of each country, compatible with the development strategy of each.

INTRODUCTION

This paper explores the energy requirements of the insular Caribbean through the year 2000. It must be recognized that the soil and subtropical islands differ from those available to much of the rest of the world. While solar resources (sun, wind, biomass, sea) are relatively abundant, the energy needs and the options open to more conventional fossil resources (oil, natural gas, coal) are produced in only three of the fifty-one inhabited.

Islands of the Caribbean, and only one country, Trinidad and Tobago, is a net exporter. Most of the islands are very small, seriously limiting economies of scale possible in other land masses. Data on the Caribbean are shown in Table 1.

TABLE 1

As Table 1 shows, the size of the countries range from tiny Bermuda (58 sq. km.) to the "giant" Cuba (113,960 sq. km.). Populations too are relatively small, ranging from 6,500 on Anguilla to 9.8 million in Cuba. Per capita gross domestic product (GDP) is low, typical of developing countries, ranging from US $3,172 in Puerto Rico to $260 in Haiti. The governments of many developing countries are taking shifting economic dependencies into consideration as they plan national energy policy. Size limits the potential of large-scale electricity generation schemes. We are told, for example, that Antigua wishes to expand its generation capacity by 6 MWE, and to do so with two 3 MWE units. Only the larger islands have sufficient demand to even remotely justify nuclear power.

The smallest U.S. commercially available power reactor is the 600 MWE pressurized water reactor (PWR). Consider the impact, not even taking cost into account, of such a system in most of the Caribbean, where installed capacity (excluding the larger islands of Cuba, Hispaniola, Jamaica, and Puerto Rico) ranged in 1980 from 14 MWE in St. Kitts - Nevis to 454 MWE in Trinidad and Tobago. Even in Puerto Rico, which has the largest installed capacity of the islands - 4290 MWE in 1980 - one of the smallest units would represent fifteen percent of installed capacity. In fact, the total installed capacity of these small islands is only 1630 MWE (see Table 6 below). A 600 MWE reactor would represent 37 percent of current installed capacity of the small islands. As a rule of thumb, no electric unit should be of a capacity greater than 20 percent of the actual, available installed capacity. One small nuclear reactor represents for most marked excess capacity, very high costs, and very limited use.

Options are available when the reactor is down (6,14). However, once electricity transmission becomes economically feasible across or under water, cooperative arrangements may be possible. These too would face serious institutional, political, and social constraints (16). Only one country, Cuba, is pursuing the nuclear option. There are two 440 MWE PWR units currently under construction by the Soviet Union.

In the mid-1970's, Puerto Rico bought a 600 MWE PWR Westinghouse unit, but cancelled it for political, economic, and ecological reasons. Coal-generated electricity is also being considered, especially in the Dominican Republic and Puerto Rico. As there are virtually no local sources, coal would have to be imported, just as oil is. Both the United States and South America, principally Colombia, are major possible exporters to the Region. Once solid fuel reserves and known bituminous coal are identified, they could represent an economic source of coal. Colombia, bordering on the Tennessee-Tombigbee waterway is completed, the United States is well located to export to the Region (9).

The distances involved, transmission across water, and the instability of the Region are impediments to cooperative ventures. This is not to say that there aren't political, economic, and cultural divisions; there have been 10 efforts in this regard. The Regional Energy Action Plan (REAP) of CARICOM (the Economic Community of the Anglophone Caribbean) is a serious attempt to coordinate planning at the national level and to develop regional solutions (5).

Through a grant from USAID, the Caribbean Development Bank (CDB) provides loans for energy and other development R&D in the Region. The Organisation of Eastern Caribbean States (OECS) is seeking solutions for eastern Caribbean states. There are also other international actors in the Region. These include international organizations like the Organization of American States (OAS), the Latin American Organization for Energy (CLADE), and the United Nations and its Specialized agencies. Other countries have taken an active role.

Interest. Among them are regional ones like Colombia, Mexico, and Venezuela. The San José Accords is a regional response to oil prices. The governments of Colombia, Mexico, and Venezuela have provided preferential prices for countries of the Region, low-interest loans to permit them to purchase oil, and incentives to develop alternatives. Canada, France, the Soviet Union, the United Kingdom, and the United States have assisted in identifying various resources and have provided funding to help develop energy and other resources and to build the development infrastructure necessary.

There are no perfect solutions for Caribbean energy problems. We have argued elsewhere that there are at least six important obstacles to progress (17):

1. Shortage of trained personnel
2. Inadequate research
3. Absence of organized markets for indigenous renewable fuels
4. Lack of investment capital
5. Reluctance of regional governments to consider cooperative ventures, as well as the absence of a non-governmental network
6. Subcritical size of national energy systems.

Some of these are already being addressed by various groups. Yet, serious infrastructural problems remain (4,20). However, if the Caribbean is to deal effectively with its energy problems, it will have to grapple successfully with obstacles to progress.

CARIBBEAN ENERGY STATISTICS:

Production and Resources: There are relatively few conventional energy resources exploitable in the Caribbean. As is seen in Table 2, Trinidad and Tobago and to a far lesser extent Cuba and Barbados, produce liquid fuels; Trinidad and Tobago and, again to a far lesser extent, Barbados produce natural gas; and only six generate electricity from hydropower. Several of the islands may possess potentially exploitable oil or gas reserves. These are the Dominican Republic, the Bahamas, Jamaica, Puerto Rico, and the Netherlands Antilles. There are indications of lignite deposits in the Dominican Republic, Haiti, Jamaica, and Trinidad. There are peat deposits in Jamaica and evidence of peat in the Dominican Republic.

Republic and Haiti, geothermal resources exist in Dominica, Montserrat, St. Lucia, St. Vincent and perhaps the Dominican Republic, Haiti, and the Netherlands Antilles (23).

TABLE 2

Some statistics exist for "non-conventional" energy production. Fuelwood is thought to supply 80 percent of rural energy needs. In 1976, Haiti's fuelwood production was twenty times that of its conventional energy production. In the Dominican Republic, it was nine times higher; for Cuba, only 2.5 times higher. In the eastern Caribbean, fuelwood production may be the only source of nationally produced energy (22). It is known that deforestation to provide fuel and building material has been a serious problem throughout parts of the Caribbean, particularly in Haiti. It is estimated that 35,000 hectares are deforested in the insular Caribbean each year while only 10,000 are afforested (11). From the 1920s to the 1970s, forestation fell from 50 percent of the total land area to 18 percent (19). To counter this, governments have instituted programs to plant fast-growing trees such as leucaena, and to offer incentives for doing so. The Dominican Republic, for example, offers a pig for every 2000 government-provided trees planted. That said, forest resources can and do provide energy resources, particularly in the eastern Caribbean.

Resources

Much thought has been given to the role of renewable energy for the Caribbean. Table 3 is a catalog of those resources and the degree to which they may and have been exploited.

TABLE 3

Wind and solar energy are judged to provide the best opportunities for economical development in all islands, while biomass, geothermal and hydropower receive mixed results (2,18). Relatively little is known of the impact these resources might make economically, although it has been estimated that bagasse from sugar cane could replace 19 percent of energy needs in the Eastern Caribbean (5). Similarly, Puerto Rico could reduce the oil used to generate electricity by 12 percent and eliminate completely the dependence.

The rum industry has a reliance on imported molasses, which has been addressed through the planting of 70,000 acres of energy cane - 4 species developed to produce additional bagasse (3). Estimates of the potential contribution of both bagasse and rice husks for six countries are provided in Table 4.

TABLE 4

The fifth column of Table 4 indicates the total potential energy contribution of the two agricultural byproducts. Compare this column with column six. Significant contributions appear to be possible for these cases. Column seven indicates the percentage that agricultural byproducts could contribute to displace oil imports. The case for a fruition agricultural program appears compelling.

It should be noted that much of the focus on renewables is on oil substitution for electric generation. It is shown later on that while nearly all electricity in the Caribbean is oil-fired, electricity generation is only a small part of the oil bill. It is also necessary to bear in mind that there do not yet exist adequate solar and wind data for most of the Caribbean, making it difficult to estimate the potential various renewables may have for replacing conventional energy consumption.

As was previously indicated, there exist few statistics on rural energy use in the Caribbean. Vardi (28) estimates that for Haiti, firewood, charcoal, and bagasse represent 80 percent of primary energy consumption, the "modern sector" consumes 91 percent of electricity while only 4 percent of all households have it. According to Vardi, one percent of Jamaica's energy is derived from hydro power, nine percent from bagasse, and the balance from oil.

There are also few statistics on sectoral energy use. Table 5 gives energy consumption by fuel type for each island and per capita.

TABLE 5

Just as Luxembourg has the highest per capita energy consumption in the world because of energy intense industries, two Caribbean islands have greater per capita consumption than the United

States for the same reason. Table 3 makes it clear that liquid fuels, or

Petroleum dominates the Caribbean energy supply. Solid fuels are mainly employed in only three countries: Cuba, the Dominican Republic, and Jamaica; they account for a minute portion of the energy consumption in each. Natural gas, associated with oil production, powers electricity generation in Barbados and Trinidad and Tobago. Hydroelectric power is produced in only six of the Caribbean islands. As indicated in Table 2, eight islands have poor hydroelectric potential, while others have none, limiting its contribution to the Caribbean energy system. It is clear from Table 9 that oil is the primary fuel for thermal electrical generation, since liquid fuels are the only conventional fuel consumed in most Caribbean countries. Moreover, as shown in Table 6, oil-fired electric generation is the predominant source of electricity in the region. Table 6 shows both the net installed “nameplate” capacity for 1980, and the production for that year. Only in Haiti does hydroelectric power more than compete with oil-fired power, accounting for 41 percent of capacity and 70 percent of Haiti's hydropower potential. The production of hydroelectric power for the balance ranged between one percent (Cuba) and five percent (Puerto Rico).

Table 7 attempts to disaggregate the petroleum sector into electrical and non-electrical. Usually, the non-electrical sector is further aggregated into residential, commercial, industrial, and transportation. Table 7 offers a very broad estimate, and caution should be exercised when interpreting it. Most of the petroleum imported into the Caribbean is consumed by sectors other than electricity production. As we have seen, renewable strategies for oil substitution policies will have to be designed for other sectors as well. Research into alcohol motor fuels, solar industrial heat, and high and low-grade hot water, among others, is already underway to varying degrees in the Caribbean. Policies such as limits on automobile engine size and building code restrictions have been implemented by several governments.

Dominican Republic, Jamaica, and Puerto Rico, among others, have difficult to find sectoral data for the Caribbean. However, according to Vardi (23), in 1980 in Antigua, 10 percent of electricity sales were tourist-oriented, 98 percent commercial, and 17 percent residential. In Barbados, the breakdown of oil and gas consumption is as follows: electricity generation 45 percent, transport 23 percent, sugar industry 4 percent, manufacturing 18 percent, and residential 8 percent. Hotels accounted for 25 percent of electricity sales. The major consuming sectors of the Dominican Republic were: transport 20 percent, domestic 21 percent, government 1.5 percent, and mining varies with international prices. According to Vardi, Radio Antilles is the major consumer of electricity in Montserrat, representing 25 percent of consumption. Household demand is 3 percent, industry 44 percent. Table 8 provides some fairly dated data. Energy end-use patterns vary throughout the region. Compare the data in the table and the more recent Dominican Republic data above. Energy use in the industrial sector rose from 26 percent in 1975 to 44 percent in 1980.

It has been shown that there are limited conventional energy resources in the Caribbean, although there is some potential for development. The possible contribution of renewables for some is unclear yet the degree to which they can contribute and the costs associated with them is problematic. Moreover, like conventional fuels, renewable resources are not evenly distributed throughout the region. The data for rural energy consumption are incomplete. In some cases, renewables already contribute significantly to the national energy system (e.g., Haiti). It also appears that urban areas consume not only more energy per capita but more conventional energy than their rural counterparts. Liquid fuels dominate the energy systems of the Caribbean Islands, almost all of which is imported.

CHANGES IN DEMAND PATTERNS

The status of the present...

The energy situation was outlined above. It is suggested that this situation will undergo significant change, with the demand for conventional energy, including electricity, growing substantially by the end of the century. This change will be driven by several factors, including A. Population increases, B. Increasing urbanization, C. Modernization, and D. Industrialization.

A. Population Increases

As shown in Table 9, the population of the Caribbean is increasing at an average annual rate of 1.5 percent, with intra-regional variation ranging from 0.9 percent in Barbados to 2.8 percent in the Dominican Republic. Given this rate of increase, the 1981 population of 30 million is projected to rise to just over 42 million by the year 2000, a mere fifteen years from now. Assuming that per capita energy consumption remains constant, energy demand will rise from the 1980 level of 0 million metric tons of coal equivalent (MMTCE) to nearly 72 MMTCE (see Table 7).

B. Increasing Urbanization

The urbanization rate of the Caribbean is also increasing, as is shown in Table 9. The overall rate of increase is estimated at just under one percent per year. One observer (1) concludes that the urban Latin American citizen consumes between six and thirty times more conventional energy than his rural counterpart. We estimate that if this trend continues, if urban and rural demand remains constant, and if the disparity between urban and rural consumption rates is 10:1, energy demand will be of the order of 100 MMTCE. This is double the 1980 demand. However, constant per capita demand is unlikely. Despite two oil price shocks and an economic downturn, the region experienced growth in demand at a conservatively estimated annual rate of 2.4 percent in the 1970s. Even without compounding, assuming historical birth and demand rates, energy demand for 2000 can be estimated at nearly 100 MMTCE. If urbanization and the historical 2.4 percent rate are considered, energy demand in the Caribbean will be of the order of 123 MMTCE. We do not believe that energy demand will remain constant.

The text is increasing at an uncompounded rate of 4.4 per cent. We believe it will be significantly higher. There are a number of factors driving this prediction. First, the Caribbean's 9:1 ratio in the electrical sector seems to be a conservative estimate, especially in Haiti. This doesn't even take into account further disparities in oil.

Developing economies are improving. It would be foolish to make a fifteen-year prediction. However, changes are occurring which support this view. Two factors, population and urbanization increases, have been explored to predict future demand. The link between development and energy demand in developing countries has been clearly established (8). As shown in Table 9, the economic structure of the Caribbean is undergoing a metamorphosis. This change is more clearly demonstrated in Table 10. The Caribbean economic structure is transitioning from what was typically "underdeveloped" to a more "developed" model.

The last two entries in Table 10 provide unweighted averages for four developed and three developing countries. These are provided to give an indication of sector importance for these two groups. In three sectors, significant differences can be seen: agriculture represents a significant product (GDP) of developing countries, but only a small proportion of the developed. Similarly, the contribution of the industrial sector was, in 1977, almost twice that of the developing countries in the developed countries. The same is true in the "other" sector, reflecting the diversity of the economies of developed countries.

The Caribbean's metamorphosis is most clearly evidenced in the agricultural sector. In almost every case, there has been a consistent decrease in the contribution of agriculture to the GDP, despite the fact that agricultural production has risen in most cases (see Table 9). The contribution of industry to GDP has, for most, also consistently risen, approaching and sometimes exceeding the developed average. The same can be said of the "other" sector.

Sector. In addition, as Caribbean societies continue to modernize, their populations will consume more energy-intensive goods. Table 10 illustrates this trend, evident in the increase in the number of automobiles, trucks, televisions, telephones, and so on throughout the Caribbean (see Table 9). The Caribbean Basin Initiative, by opening the U.S. market and through other incentives, may further expedite Caribbean development. These changes in economic structures and demand patterns will affect energy demand in the Caribbean. The change will be from labor-intensive to energy-intensive: witness the increase in the number of tractors, for example, replacing human and animal energy with diesel.

Table 11 provides estimates of demand rates and predictions for the year 2090. The table includes estimates of demand increases both worldwide and in the developing world. These estimates provide a prediction of total Caribbean demand. Estimates of increases in annual global energy demand are relatively low, ranging between 1.2 and 2.4 percent, as are the resulting demand predictions. It is unlikely, however, that Caribbean demand will be as low as global demand, and that too is reflected in Table 11. Estimates of increasing demand for developing countries range between 1.8 percent and 7.1 percent. Three of the figures are population-driven, and are explained above. The 7.1 percent figure is the actual growth in energy demand in developing countries from 1960 to 1980. This provides an interesting benchmark because this growth was unimpaired by the energy price shocks of the 1970s. Also provided is the actual growth rate for the Caribbean from 1972 to 1980. That growth rate was impaired by the 1970s economic recession. We believe that the increase in annual energy demand from the present to 2000 will lie somewhere between 2.4 and 7.1 percent. We accept 7.1 percent as the upper limit for several reasons. Although the Caribbean is benefiting from the end of the recession in the developed world, the

The structure of growth in the next fifteen years will be different from that of the 1960s. There is a greater awareness of the benefits of conservation.

New infrastructure will be more efficient. There will be some development of a low energy demand service sector. And, finally, there are already in place highly energy-intensive industries such as city refining and aluminum smelting. These will expand as the global economy improves, but we do not expect the degree of growth experienced in the 1960s. For these same reasons, we believe 2.4 percent to be the lower limit. And because of economic and industrial expansion should be above that of the 1970s, energy demand should also be higher. These upper and lower limits provide a wide range of possible demand in 2000, 80.5 MNMTCE and 197.5 MNMTCE, the larger figure is more than double the smaller. The actual 2000 demand will be somewhere between these two figures. Goldemberg has recently suggested a growth rate for Latin America (1980-1990) of 5.2 percent (12). If that number applies to the Caribbean, 2000 demand will be 198.1 MNMTCE.

The Caribbean differs from the rest of the world. Table 12 presents energy demand by primary fuels. Oil provides nearly 46 percent of global demand, almost 7 percent of Latin American demand, but 90 percent in the Caribbean. If this pattern continues, oil demand, almost all of which must be imported, will exceed 124 MNMTCE in 2000 (lower case: 71 MNMTCE, upper case: 177 MNMTCE).

That will be a difficult economic burden for the Caribbean to bear.

TABLE 12

But there are few options, for most other conventional fuels will likewise be imported. And while oil is more expensive to import than other conventionals at present, their relative prices in fifteen years cannot be accurately predicted. Nuclear power might displace some oil or other fuels in the Caribbean import menu. Yet, there are serious problems of scale,

technical problems associated with transmission must be solved, and the economics appear to be worsening.

Moreover, facilities must be built, requiring significant up-front investment. Even if construction began today, it would be at least eight years before they would begin to produce. Oil will continue to be imported into the Caribbean. If governments, the private sectors, and universities of the region cannot work to find economic substitutes for oil, to reduce the rate of increase, the cost of those imports will continue to cause serious balance of payment problems and in all likelihood, will badly impact the societies of the Caribbean. This could render further development impossible. There are two obvious alternatives to energy imports: greater efficiencies and renewable energy. Much of the work done on renewables has focused on the substitution of oil (or other fuels) in the electricity sector. That will help. But because much of the oil consumed in the Caribbean is not consumed in the electricity sector, even more research into those areas is clearly needed. Goldemberg has distinguished between two types of energy planners which he labels "geneticists" and "teleologists". A geneticist sees plan goals as constrained by historical situations and the inherent, objective tendencies of the country. For a teleologist, the purpose is to modify existing structures in order to meet plan objectives. To understand and plan for the Caribbean is to be of both minds. The constraints are massive, the options limited. Yet we know that energy demand must be targeted, and that the target will be a difficult one. It is crucial that talent be brought to bear on current and future problems; that cohesive recommendations reflecting Caribbean realities be made; and that those in authority to act, do act.

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TABLE 1 The Caribbean Countries Population Data:
Anguilla (U.K.) 6,500
Antigua (1981) 17,226
Bahamas (1973) 209,503
Barbados (1966) 252,000
Belize (1981) 146,000
Bermuda (U.K) 72,000
Cayman Islands (U.K.) 17,035
Cuba (1902) 9,771,000

Dominican (1978) 74,100
Dominican Rep. (1844) 5,762,000
Grenada (1974) 107,000
Guadeloupe (France) 317,000
Guiana (France) 66,000
Guyana (1965) 793,000
Haiti (1804) 6,000,000
Jamaica (1962) 2,225,000
Martinique (France) 312,000
Montserrat (U.K.) 12,036
Netherlands Antilles (Neth.) 243,000
St. Kitts/Nevis (1983) 46,408
St. Lucia (1979) 122,000
St. Vincent (1979) 115,000
Suriname (1975) 388,000
Trinidad/Tobago (1962) 1,176,000
Turks/Caicos (U.K.) 7,436
Virgin [Islands] (U.K.) [Population Data Not Available]

Tel. (0.K.) 33 BL 28.588 _2,45eHm 721,421 35, 806.6 - Total: United States, Puerto Rico, and U.S. Virgin Islands total 3,240,000, 98,307, and 226,306,825 respectively. 9,372,623 and 8,897 were the figures for others.

Source: Caribbean/Central American Action, Department of Commerce, Bureau of the Census. The data may vary. The population was 2,626,1008 in Myanmar in 1983. For the U.S., the figures were 1,536, 3,001, and 4,788 respectively.

Table 2 presents data on 1980 commercial energy production in metric tons coal equivalent x 10° for various countries.

For example, Barbados, Cuba, the Dominican Republic, Haiti, Jamaica, Puerto Rico, St. Vincent and the Grenadines, and Trinidad and Tobago had figures as follows: N/A, 13, 6, N/A, 18, 10, 2, and 1,932,159,833,369 respectively.

Source: UN Statistical Yearbook, 1979/80, Table 180.

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TABLE 1 ESTIMATES OF COMMERCIAL ENERGY DEMAND IN THE INSULAR CARIBBEAN, IN THE YEAR 2000

Percent Annual Level Increase MICE x 10°

GLOBAL
Iglesias (ref. 15) 12 63.6
Hafele (ref. 13) 21 15.9

High Sea) s 1s 615
World Bank (ref. 24) 24 80.5

DEVELOPING COUNT

Developing Countries 1960 =" 1970 (Actual) (ref. 7) fa 197.5
Caribbean 1972 - 1980 (Actual) 24 60.5
Goldemberg (ref. 12) 5.2 138.1
Iglesias (ref. 16)

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Table 12: Energy Demand by Primary Fuel in Percent

Oat: 45.8%
Coat: 69.5%
Gas: 90%
Others: 29.9%

X0 Ana: 62%
Fiyaro A7: 63%
Nietour OG: 2.8%

Sources:
* World Bank (ref. 24)
* Goldener (ref. 12)
* SUN Stat. YB. Get. (ref. 21)