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FINAL REPORT

BARBADOS NATIONAL ENERGY ASSESSMENT

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1. INTRODUCTION

BACKGROUND

A comprehensive National Energy Assessment began in Barbados during early October 1980 as part of the Caribbean Alternative Energy Systems Project - which is executed by the Caribbean Community Secretariat and the Caribbean Development Bank and funded by the United States Agency for International Development.

Under the project, the CARICOM Secretariat holds responsibility for energy policy planning and assessment along with technical and analytical training. The Caribbean Development Bank has responsibility for energy technology and for the development of a regional energy information and communications system.

The Government of Barbados became the first CARICOM Member Country in which a National Energy Assessment was initiated under the Project. The Energy and Natural Resources Unit of the Ministry of Trade and Industry was originally designated the responsible agency in Barbados for management of the assessment. Responsibility was subsequently transferred to the Ministry of Finance and Planning. Technical assistance has been provided primarily by Energy Development International under contract to the CARICOM Secretariat.

PURPOSE OF THE ENERGY ASSESSMENT

Barbados has gone through a period of rapid development over the last 10 years, producing a sophisticated economy heavily dependent on both imported energy and the international economy. The last 10 years have also produced a dramatic increase in energy intensity of the economy as measured by per capita energy use, and

a shift from traditional fuels such as coal and wood to kerosene, and then LPG and electricity.

Domestic oil and gas exploration programmes have produced up to one-half of domestic petroleum needs, although present production represents only some 20% of that need. Despite domestic production of oil, energy costs have risen dramatically; as a proportion of total goods imported costs rose from 2% in 1970 to 6.4% in 1979. Energy import costs are now about 6% of total foreign exchange earnings, versus less than 2% in 1970. High energy prices have adversely affected all aspects of the economy, in particular the important tourism sector by requiring higher rates and lowering profits, and by increasing the cost of air travel.

The Barbados economy remains in a vulnerable position due to its dependence on imported oil. Unless significant changes occur, Barbados can expect more of a drain on its scarce foreign exchange earnings in the future, and deterioration of its competitive position both in tourism and manufacturing as energy prices rise.

The goal of the Energy Assessment is to gain a better understanding of the national energy system, and by so doing, to permit better design of programmes to conserve scarce energy, manage its supply and use, develop indigenous resources and anticipate energy problems. Specifically, in accomplishing these goals, the Assessment must perform a number of tasks:

- Compile and review historic, current and projected data on energy supply, price and demand;

- Construct current and projected energy balances;

- Identify major energy policy issues;

- Evaluate major policy questions using the base year and projected energy balances;

- Train National Energy Unit Staff in the preparation of energy balances, and energy forecasting and planning; and

- Outline a programme of follow-up for the National Energy Unit, and assist in developing energy policy options for further study.

As part of the National Assessment, staff conducted extensive interviews with public and private sector energy consuming entities, business associations, electric and gas utilities, oil suppliers, Government ministries, the Central Bank of Barbados, the Industrial Development Corporation and responsible individuals and organizations with each major energy or economic subsector. In addition, a Residential Household Energy Use Survey was conducted to ascertain usage patterns and levels of consumption. A similar, but more limited energy survey was conducted in the Hotel Sector.

Several energy specialists were provided by CARICOM under the assessment programme. These included specialists in energy planning, conservation, solar and wind resources, and electrical sector conservation and planning. Numerous corporations, businesses and private individuals assisted in the specialist's work by providing information on energy use, production, and manufacturing processes, as well as their valuable time and ideas. Lastly, CARICOM sponsored a one-week energy planning seminar in October 1980 to initiate the regional assessment programme.

Due to the large body of work already done on the Petroleum and Gas Sectors under a recent UNDP contract, this assessment has given very limited treatment to oil and gas resource development and related pricing issues.

2. ASSESSMENT RECOMMENDATIONS

GOVERNMENT SHOULD DEVELOP A SET OF ENERGY CONSERVATION AND RENEWABLE RESOURCE DEVELOPMENT GOALS FOR INDUSTRY, COMMERCE, TOURISM, GOVERNMENT AND TRANSPORTATION

In the absence of a strong public commitment to achieve potential conservation savings and renewable resource opportunities, these may either be implemented incompletely or only after costly delays. Government should develop these energy goals in co-operation with a public advisory group.

Analysis performed as part of this Energy Assessment, although only preliminary, suggests that the following energy conservation savings and renewable goals are possible:

Sector	Fuel Type	Savings Goals
Industry	Oil and Gas	7.5% by 1983 15% by 1986 25% by 1990
Industry	Electricity	5% by 1983 10% by 1985
Commerce and Tourism	Electricity	15% by 1983 20% by 1986 30% by 1990
Residential	Electricity	7% by 1983 15% by 1986 20% by 1990

- Penetration of solar water heaters in the hotels in existence in 1979: 75% by 1990. 100% penetration for all non-centrally air conditioned hotels built after 1983.

- 50% penetration of solar water heating in existing homes with water heating by 1985, and 75% by 1990. All new homes being built with water heating could be solar as of 1983.

- Bagasse electric power generation of 11 million KWhs by 1985, and 23 million KWhs by 1990.

- Wind electric power generation of 5 MW by 1987.

IMPLEMENT NATIONAL ENERGY EFFICIENCY PROGRAMME

Barbados should immediately begin a programme to develop and publish guidelines for energy efficiency in existing industry and buildings, for new energy-using equipment, and in new construction. In addition, a Building and Equipment Standards Plan should be developed. This activity should be initiated through the CARICOM Standards Committee and Barbados National Standards Institute.

MOBILIZE PUBLIC AND PRIVATE SECTOR ENERGY AUDIT TASK FORCE

Government should, in co-operation with the Barbados Manufacturing Association, Barbados Hotels Association and other business groups, organize an urgent and comprehensive energy audit programme to cover all major businesses within one year. Funding should be provided for the temporary hiring of engineers, conservation specialists and technicians for the energy audit task force. Intensive classroom training and field work would also be required to prepare the team, and should include a programme for managers on implementation. Lastly, a broad public media and education programme should be launched to generate public understanding of the effort and the extent and costs of energy waste.

CREATE CONCESSIONARY FINANCING MECHANISMS AND GRANT OPPORTUNITIES FOR CONSERVATION

Government should convene a meeting of financial institutions including the Central Bank, Barbados Development Bank, Inter-American Development Bank and Caribbean Development Bank to design and initiate a programme of financing for conservation investments at concessionary rates. The program should be designed to enhance incentives to implement energy conservation recommendations. One important action in this area would be to reduce the risks inherent in innovative conservation investments through tax policies (such as loan write-offs for unsuccessful investments, etc.). Similarly, concessionary loans and, in some cases, even grant financing may be considered for certain investments with especially high benefits to the economy as a whole.

ASSIST BARBADOS LIGHT AND POWER TO INTEGRATE WIND AND BAGASSE, AS WELL AS OTHER RENEWABLE RESOURCES IN THEIR SYSTEM

Government should create and/or assist in creating economic incentives and remove the risks of innovation in implementing renewable options for Barbados Light and Power. In addition, further support from donor agencies should be sought to analyze the implementation limits and technical problems associated with maximum use of these renewables. Lastly, BL&P should be urged to ensure that their resource plans be made as flexible as possible to accept these new supply sources.

REEVALUATE THE VALUE OF CONTINUED OPERATION OF THE MOBIL OIL REFINERY AND COMPLETE COMPARATIVE REVIEW OF OIL PRODUCTS IMPORTS UNDER THE TRINIDAD OIL FACILITY

Government should urgently complete its evaluation of a shift to imports from Trinidad, which are not only less costly than

products from the local refinery, but which are available on attractive financial terms as well. Reliance on the small and uneconomic Mobil Oil Refinery appears increasingly problematic. It has been recognized for some time that this refinery produces oil products at higher cost than the same products could be imported. Adding to this higher cost will be a shift in policy by Venezuela (the primary oil supplier) requiring supply sharing of less compatible and higher cost Mexican crudes. Even under the so-called Venezuela-Mexico Oil Facility costs will increase rather than be reduced. Appropriate assistance should be sought to help evaluate and resolve all of the above technical issues.

BARBADOS LIGHT AND POWER SHOULD BE ENCOURAGED TO DEVELOP AN EXTENSIVE CONSERVATION PROGRAMME

Preliminary analysis in this assessment points to the obvious economic and foreign exchange benefits of a strong BL&P conservation effort. Good energy management, customer power factor improvements, more efficient air conditioners, reduced lighting loads, among other areas, present major opportunities for BL&P to reduce its growth rates. Such changes can substantially benefit the ratepayer. However, in order to achieve these savings BL&P will need Government approval and encouragement. BL&P should themselves play a major role in the Government's overall conservation planning.

PREPARE AN ENERGY INVESTMENT PLAN

An energy investment plan should be prepared to identify and evaluate the cost benefits and priorities of potential energy sector planning needs and investment opportunities. This plan should form the basis for defining funding proposals for various donors. Projects which could be included are:

- Development of national or regional building and equipment standards and testing center in Barbados;

- Development of building and equipment standards through:

  (a) Preparation of a set of model building and equipment standards,

  (b) Preparation of an energy-efficient building design manual, and

  (c) Development of architect-engineer education and a training programme both at the University of the West Indies for undergraduates and through an appropriate institution for current practitioners.

- Optimizing use of bagasse for sugar refining and electricity production;

- Development of energy businesses to serve Barbados and the Caribbean in designing and building efficient industrial and commercial energy systems and buildings;

- Short-term energy audit mobilization effort to define immediate conservation needs;

- A study of the energy efficiency in transport and funding of demonstration projects to test new ideas, including traffic control and lights, parking, turn-outs on major roads, alternative staggered work hours, construction of new bus stations, and pedestrian over-crossings.

- Technical and economic evaluation of advanced energy technologies which <u>might</u> be appropriate for Barbados, e.g., solar ponds, ocean thermal and wave energy;

- Redesign of the energy price structure to discourage inefficient energy use, equitably allocate costs, and provide sufficient capital for least cost capacity expansion of Barbados Light and Power.

- Utility conservation programme design, and funding of demonstration projects, e.g. in load management, maintenance, and control of equipment, and survey and analysis of current power consumers.

- Analysis of alternative air conditioner cycling load management programmes, and funding of demonstrations of different devices in Commercial, Government and Hotel sectors.

BARBADOS LIGHT AND POWER SHOULD PROMOTE THE IMPROVEMENT OF POWER FACTORS BY ITS CUSTOMERS IMMEDIATELY THROUGH AN INFORMATIONAL PROGRAMME, AND EXPLORE PROVIDING BOTH FINANCIAL INCENTIVES AND HIGHER RATES FOR POOR POWER FACTORS

Losses due to poor power factors among Barbados' large electrical customers are currently costing some $2.0 million in unnecessary electricity costs. At the rates of growth forecast by BL&P a programme of customer power factor improvement could save some 22,200 barrels of oil per year (roughly 9% of current domestic oil production).[1]

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[1] Power factor refers to the degree of coincidence in voltage and current in an electrical circuit. Usually a power factor of 0.9 or better is considered good, while currently power factors of 0.7 - 0.85 are observed in Barbados.

3. OVERVIEW OF THE BARBADOS ECONOMY

3.1 ECONOMIC REVIEW

In Barbados, the combination of an open economy, small size and narrow natural resource base, have made the economy highly vulnerable to movements in international prices, energy supplies and general economic conditions. Barbados, like most small non-oil exporting developing countries, has been adversely affected by the dramatic rise in oil prices during 1973-4 and in 1979. Barbados' rapidly growing economy will require more and more energy in the future, and ways must be found to ensure secure and reasonably priced supplies; achieve all economically feasible domestic energy conservation, and maximize local oil and gas and renewable resources.

The linkage between economic growth and energy use in Barbados is well established. The rapid growth of commerce, tourism and industry have all required substantial imports of fuels in the past. The extent to which this growth can be maintained, and at the same time energy use reduced, is a paramount energy policy consideration.

This section of the Energy Assessment outlines the economic context in which energy analysis takes place throughout the remainder of this report. The primary focus of this analysis is on examination of the oil import requirements and the balance of payments under different energy policies, as well as on the ability to maintain healthy growth and diminish energy consumption.

Barbados is now dependent on imported oil for over two-thirds of its energy needs. The economy as a result has experienced severe problems of inflation, unemployment and balance of payments as the "energy crisis" developed after 1973. It has been affected in two ways: first, by the direct effect of higher prices on oil import costs, and secondly from the recession in North America and Western Europe following the sharp increases in energy costs. For Barbados, this latter influence has been manifested in lower demand for its export products, decline in its tourist business, and a decreased rate of development of new business in Barbados to service foreign markets.

Several major factors have historically affected the growth and structure of the economy and energy situation in Barbados:

1. Steady growth of GDP and per capita income.

2. Rapid increase in tourism and encouragement of manufacturing.

3. Relative decline of the sugar industry.

4. Governmental policies and strategies to promote a more equitable distribution of income and provision of basic needs, which itself has led to a rise in energy demand and a move away from traditional sources of fuels such as charcoal and kerosene, towards electricty, LPG and natural gas.

5. High density and well-developed public transport leading to relatively low-per capita transport demand.

6. Development of substantial domestic oil supplies beginning in 1974.

Changes in the pattern of energy consumption in Barbados can be directly attributed to a diversification in the structure of production which was marked by the rise of manufacturing.

Three phases have been recognized in the growth of energy consumption. There was a period of rapid growth between 1960 and 1965. This marked the end of the transition from non-commercial to commercial energy for household consumption and the beginning of the industrialization period. During this period consumption of energy grew at 16.2% per annum. From 1966-1977, there was a period of more modest growth averaging 8.7% annually. In the final phase, 1973-1979, there were the sharp increases in fuel prices and the consumption of energy expanded at under 2% after an actual decline in 1974 (Ref. 8).

The structure of economic activity, income distribution and high level of infrastructural development have all led to a pattern of energy consumption heavily dependent on the utilization of imported petroleum products for electricity generation and all major uses.

Since 1973, when petroleum was found in commercial quantities, local production has increased substantially to a peak of 1025 barrels per day with current production about 650 barrels per day. However, while present local production of fossil fuels provides Barbados with about 20% of its energy needs, imported petroleum products still dominate the commercial energy supply in the country. In 1970 imports of crude petroleum and liquefied petroleum gas (LPG) cost Bds $4.3 Million and represented 2.1% of the value of total foreign exchange earnings from the export of goods and services. By 1979, the respective figures have grown to Bds $52.8 million and 5.7% (See Section 4.1 - Table 4.1.1).

ECONOMIC ACTIVITY SINCE 1970

During the 1970's, economic fluctuations in Barbados have closely followed international events. The 1973-75 world economic recession served to exacerbate a decline in Barbados' real investment which had begun earlier in the decade. Thus at the end of 1974, real G.D.P. fell by 2.3% to $640 million. However by 1980 G.D.P. had increased to an estimated $803 million (see Table 3.1-1). This represents a fairly strong real growth rate of approximately 2.5 percent per annum during the 1970's. Only in 1974 and 1975 was there negative real economic growth. During these two years, the economy was in deep recession, real output declined 3.0 percent, and inflation reached 40 percent in 1974, from 10 percent in 1972.

Since 1975 a major recovery has taken place, with real G.D.P. growth rates between 4.3 - 7.9 percent (see Table 3.1-1). This was achieved through careful demand side management, which included rigid curbs on consumer credit; revaluation of the Barbados currency in 1975, moderate wage increases, appropriate monetary and fiscal policies, and foreign investor confidence. Consequently, foreign exchange reserves have been maintained at respectable levels, totalling $58.3M, $18.1M and $25.1M in 1978, 1979, and 1980, respectively. Unemployment has been reduced to 12.6% in 1980, down from 15.6% in 1976; however, inflation registered 8.4%, 9.5%, 13.1% and 14.4% in 1977, 1978, 1979, and 1980, respectively. Fuel imports as a percentage of foreign exchange earnings have continued to grow, however, to about 6% in 1979 from 2% in 1970 (see Table 3.1-2).

Although all major sectors of the economy recorded real increases, growth has been primarily via the manufacturing sector, wholesale and retail trade, and tourism.

Manufacturing Sector: The major subsectors of the manufacturing sector are food and beverages, garment manufacturing,

ESTIMATES OF REAL GROSS DOMESTIC PRODUCT 1971 - 1980 (CONSTANT PRICES)

BDS $' 000

SECTOR OF ORIGIN	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Sugar	57,800	47,674	49,564	46,831	41,680	43,834	51,093	42,991	48,517	57,602
Non-Sugar Agriculture and Fishing	24,219	21,282	22,835	21,665	24,525	27,146	21,296	29,356	29,789	24,979
Mining & Quarrying	1,133	1,139	944	807	869	1,294	1,104	1,591	1,647	1,989
Manufacturing	55,539	61,300	65,718	62,649	69,289	81,005	83,574	91,217	92,783	98,421
Electricity & Water	8,242	9,362	10,181	9,578	10,095	10,765	12,298	14,213	15,804	16,838
Construction	53,007	52,067	55,484	52,744	44,146	49,949	43,091	46,309	52,744	56,436
Wholesale & Retail Trade	120,041	123,881	124,254	118,337	119,638	122,242	124,609	129,461	142,004	156,678
Tourism	56,150	57,213	58,317	64,085	56,138	57,869	77,094	86,258	107,021	111,059
Transport, Storage & Communications	44,006	44,904	44,949	43,640	43,378	44,382	45,473	46,607	48,266	49,705
Business & General Services	122,719	125,223	125,474	123,014	120,184	118,339	121,291	123,014	126,089	128,057
Government Services	86,946	93,491	96,982	97,050	97,050	97,050	97,050	99,476	102,000	101,999
TOTAL	629,802	637,536	655,702	640,400	626,992	653,875	677,973	710,493	766,664	803,763
Real Growth	0.3	1.2	2.8	-2.3	-3.1	4.3	3.7	4.8	7.9	4.9

Source: Barbados Statistical Service (1971 - 1973)
Central Bank of Barbados (1974 - 1980)

TABLE 3.1-2

IMPORT COST OF CRUDE PETROLEUM AND
L.P.G. 1970 - 1979

	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970
I Import cost of Crude oil and L.P.G. in millions $Bds	$ 52.8	$ 37.8	$ 34.8	$ 29.6	$ 29.3	$ 31.0	$ 10.0	$ 7.9	$ 3.9	$ 4.
II Import cost of all Goods in millions $ Bds	$830.5	$629.6	$545.6	$477.0	$437.7	$418.9	$328.7	$270.5	$243.8	$235.
I as a % of II	6.4%	6.0%	6.4%	6.2%	6.7%	7.4%	3.0%	3.0%	1.6%	1.
III Foreign exchange earnings from Goods in millions $Bds	$264.4	$223.1	$182.4	$152.6	$190.7	$138.1	$ 93.9	$ 72.3	$ 65.6	$ 71.
I as a % of III	19.9%	16.9%	19.1%	19.4%	15.4%	22.5%	10.6%	10.9%	6.0%	6.
IV Foreign exchange earnings from Goods, Services and non factor Services, in millions $ Bds	$933.7	$725.2	$586.7	$468.7	$497.4	$420.0	$323.6	$268.9	$245.9	$218.
I as a % of IV	5.7%	5.2%	5.9%	6.3%	5.9%	7.4%	3.1%	3.0%	1.6%	2.

Sources: Ministry of Trade and Industry;
Central Bank of Barbados; Mobil Oil Barbados Ltd.

assembly of light electronic components, and chemical products and plastics. From the period 1976 to 1980 output in the manufacturing sector has averaged approximately 11.2% of the Gross Domestic Product at factor cost.

This industrial sector showed considerable improvement in 1980. Production in this sector grew by 6.1% compared with 4.2% and 3.8% in 1978 and 1979, respectively. The rise in external demand for electronic components and chemicals and the growth in beverage and tobacco production were the main factors behind the 1980 increase, according to the 1980 Barbados Economic Report.

Tourism Sector: The significance of the tourism industry to the overall economic and social development of Barbados is well known. The industry has been and continues to be a prime generator of foreign exchange, contributing some 12.1 percent to Gross Domestic Product in 1979, is a source of both direct and indirect employment and a stimulant to development of the islands infrastructure.

The trend in the numbers of long stay visitors has been very positive rising from 156,400 in 1970 to 370,900 in 1979. Numbers declined during the years immediately following the Arab oil embargo in 1975 and 1976; and later during the recent recession in 1980 and 1981 in North America and Europe. However, income in the sector maintained a substantial growth even during these later recession years. Cruise ship visitors have been more erratic, and in 1980 for example, rose by 42 percent after a 12 percent decline in 1979, and 21 percent increase in 1978.

The increase in hotel bed capacity has been equally rapid. Luxury hotels have shown a growth in number of rooms of 8 percent per year and apartment hotels 11 percent. Currently there are an estimated 13,360 beds (6,680 rooms) available as compared with

7000 in 1970. There are currently under construction some 1,612 new units (3,224 beds). These are largely in the luxury class.

Growth in tourism over the last 4 years (1977-1980) has been dramatic, some 18 percent per year in real terms. Tourism is expected to remain an extremely important growth factor for Barbados in the 1980s. However, future prospects for the expansion of Barbados' tourist demand are heavily dependent on economic recovery in its major originating markets, as well as improvements in local capital investment resources, managerial capability, training opportunities, linkages between tourism and the rest of the economy, and price competitiveness of the product which has itself become increasingly dependent on the cost of the industry's energy component.

Except for isolated cases, regrettably little attention has been paid by the sector as a whole to its high and increasing cost of energy, the assumption apparently having been made that the energy problem is worldwide and visitors could therefore have no objections to bearing increased energy costs in Barbados.

Agricultural Sector: This sector has experienced a decline during the late 1960s and the 1970s in terms of its contribution to G.D.P. Whereas agricultural contribution to G.D.P. in 1970 was 15%, it had fallen to 10.2% in 1979 and 1980. The main agricultural crop, sugar, which accounts for about 70% of total agricultural output, has also seen a decline following a trend which begun in 1968.

The sector has been beset by numerous problems since the beginning of the 1970s. Unfavorable weather conditions, unavailability of regular labour and relatively high labour cost, rising costs of imported fertilizer and other inputs, reduction in the hectareage under cultivation and an increase in the number of

hectares of sugar cane burnt have all led to the prevailing situation.

Non-sugar agriculture has not fared any better, recording a 0.15% decrease over the 1978-80 period, and the subsector was severely affected by heavy rain in 1980. Cotton production, which reached a peak in 1975 declined in 1979 to about 11% of the 1975 level, and fell again in 1980 by about 50%. However, poultry and milk have made significant contributions to the Agricultural Sector in recent years. In 1979, poultry production increased by 23.3% to 5.3 million kg, while fresh milk production rose by an estimated 10% from 2.9 million kg in 1978 to 3.2 million kg in 1979.

Barbados' agricultural policy continues based on diversification of crop production in order to better provide for local needs and to help check the mounting food import bill. It should be mentioned that substitution of imported food products in the Tourism Sector is a major Government strategy to reduce leakage of earnings. Government intends to place greater emphasis on the agricultural sector through the greater emphasis on the agricultural sector through the greater use of mechanization, the rehabilitation of sugar factories and improving cultivation techniques.

Energy use in the agricultural sector is largely that of the sugar industry. The industry uses solely bagasse (the residue from sugar cane milling) to provide motive power for milling operations and to generate electricity. This use accounts for some 27% of the total energy budget of the country and has been a major relative advantage for the country in lessening reliance on imported energy while maintaining a healthy economy.

3.2 POPULATION

During the period 1970-1980, the resident population of Barbados increased by only 3.4%, from 240.6 thousand in 1970 to 248.9 thousand in 1980.

Table 3.2.1 below summarizes data on population increases, since 1960, and Table 3.2.2 the projected household and population growth figures based on a population growth forecast produced by the Barbados Statistical Service (BSS) in 1979. Growth rates in the resident population were estimated by the Barbados Statistical Service at between 0.7 and 0.8 percent up to the year 2000 (The household populaton forecast was based on the population forecast, using the 1980 Census provisional household size estimate of 3.57 persons/household).

The Labour force, defined as those persons actively seeking employment, as well as those who were working, stood at 90,200 persons in 1970. In 1980, the figure was 114,800 or 65.9% of the total adult population of 174,200. Table 3.2.3 summarizes labour force and employment.

One of the salient features of sectoral employment has been the sharp decline of employment in the Agricultural Sector over the last decade. Agriculture's share of the working population fell from 16% in 1970 to approximately 9.5% in 1978. By comparison, the manufacturing sector employed an estimated 14.9% of the labour force in 1970, increasing to 17.0% in 1978.

Table 3.2-1

POPULATION STATISTICS
1960-1980

P=Provisional

Year	Population at 31st December (000)	Births per 1000	Death Rate per 1000	Rate of Natural Increase Per 1000	Infant Mortality Rate per 1000	Rates of Population Growth %
1960	233.0	33.5	9.1	24.3	60	
1961	232.4	28.9	10.3	18.6	84	-0.3
1962	235.8	29.5	9.1	20.3	54	1.4
1963	238.8	28.4	8.8	19.5	61	1.3
1964	242.6	26.8	8.8	18.1	53	1.6
1965	244.9	26.1	7.8	18.2	39	1.0
1966	248.2	25.7	8.4	17.5	48	1.4
1967	250.6	22.0	8.3	13.9	54	0.9
1968	252.9	22.0	8.2	13.8	46	0.9
1969	253.6	20.9	8.0	12.9	42	0.3
1970	240.6	20.3	8.7	11.6	45	-5.1
1971	242.0 (241.3)[1/]	21.5	8.7	12.8	29	0.6
1972	243.9 (242.0)	21.7	8.2	13.5	35	0.8
1973	245.7 (242.7)	20.8	9.4	11.4	33	0.5
1974	246.3 (243.4)	19.5	8.5	11.0	31	0.5
1975	248.8 (244.0)	18.9	8.4	10.5	33	1.0
1976	251.1 (244.7)	18.3	9.1	9.2	28	0.9
1977	253.3 (245.4)	17.1	8.6	8.5	25	0.9
1978	253.1 (246.1)	17.0	9.1	7.9	27	-0.7
1979	254.3 (246.7)P	16.8P	8.5P	8.3P	24	0.4P
1980	249.0 (249.0)	16.3	8.2	8.1	24.5	-2.1

Source: Barbados Statistical Service

1/ Figures for estimated population in brackets, 1971-79, are adjusted values intended to be consistent with the 1980 Census Provisional Count of 248,983.

P Provisional estimates from the 1980 Census Provisional Count.

TABLE 3.2-2

RESIDENT POPULATION AND HOUSEHOLD FORECAST

	1979	1980	1985	1990	1995	2000
Population	246,770	248,149	255,980	266,400	276,780	286,500
Households	69,125	69,509	71,700	74,620	77,530	80,250

Source: Derived from 1980 Census Provisional Count. Utilizes growth rate from 1979 Statistical Service Population Forecast and household size estimate of 3.57 persons/household.

TABLE 3.2-3

SUMMARY OF LABOUR FORCE AND EMPLOYMENT 1976-1980

	1976	1977	1978	1979	1980
Total Adults	166.8	167.7	168.3	171.0	174.2
Labour Force	104.1	104.6	102.6	109.0	114.8
Employed	87.9	88.2	88.2	95.0	100.3
Unemployed	16.2	16.4	13.8	14.0	14.5
Rate of Unemployment	15.6%	15.7%	13.4%	12.8%	12.6%

Source: Barbados Statistical Service - Barbados 1980 Economic Report

4. ENERGY SUPPLY SOURCES IN BARBADOS

4.1 PETROLEUM AND GAS SECTOR

4.1.1 CRUDE OIL AND NATURAL GAS EXPLORATION AND PRODUCTION

The existence of hydro-carbon deposits in Barbados has been known since the last century and some of these were exploited with the rudimentary technology during the 1870's. More organized exploration and production activities were initiated in 1896 by the West Indian Petroleum Company Limited (WIPCL), and by the British Union Oil Company (BUOC) which took over WIPCL's activities in 1920. The BUOC was active between 1920 and 1928, and between 1934 - 1946. Exploration philosophy was based on the occurrence of seepages and production was established in a few areas, the most important being Turner Hall area on the fringe of the Scotland District. During the 1950's Barbados Gulf Oil Company carried out geological and geophysical exploration, both onshore and offshore, obtaining concession rights over the whole island in 1958. However, Gulf's involvement in Barbados was terminated soon after due to the conviction that no large reservoirs existed. In 1965 the General Crude Oil Company of Texas commenced a programme of exploratory drilling. During the period 1965 - 1973, 16 exploratory wells were drilled and continuous production was established at two Woodbourne wells.

After a development feasibility study was carried out in 1973, it was decided to go ahead with a full scale development programme in the Woodbourne area. In 1974 General Crude relinquished most of the onshore area, electing to retain five separate

blocks in the south of the island, totalling approximately some 35 square miles under production licenses, and in the following year finalized a new exploration agreement for the offshore license area.

Mobil Oil acquired the onshore and offshore Barbados licenses through the purchase of General Crude in 1979 after 33 wells had been drilled in the Woodbourne area. Mobil has concentrated their drilling efforts in the Woodbourne area drilling 10 shallow wells and 6 wells up to 10,500 feet.

At the end of 1979, Mobil finalized an agreement with the Barbados Government, allowing it the exclusive right to conduct geological and geophysical surveys offshore and onshore Barbados, excluding areas already held under license. Under the agreement Mobil completed a comprehensive offshore and onshore seismic programme on December 31, 1980, and June 30, 1981, respectively. Mobil has the exclusive right up to December 31, 1981, to negotiate with the Barbados Government for onshore exploration license, and has the right of first refusal up to December 31, 1982. Table 4.1-1 shows hydrocarbon production in Barbados from its beginnings in 1972 of 50 thousand barrels to the current 300 thousand barrels.

The source and reserves of hydro-carbons on Barbados has long been a puzzle to petroleum researchers. The most recent estimates of Barbadian potential oil reserves have ranged from 30 million to 72 million barrels, and gas reserves estimates have ranged from 25 billion cu.ft. to 120 billion cu.ft. The estimates of the Woodbourne field and Barbados potential are listed below:

1978 - 79	British Technical Assistance Team; Under Professor Gill. (Imperial College London).

TABLE 4.1-1

PRODUCTION OF CRUDE OIL AND NATURAL GAS IN BARBADOS 1965 - 1980

	Crude Oil in US Barrels	Natural Gas M.C.F.
1965	-	-
1966	45587	29388
1967	-	-
1968	-	-
1969	-	-
1970	-	-
1971	-	-
1972	49678	35247
1973	57389	44986
1974	19891	120717
1975	122813	217590
1976	143379	229054
1977	124241	206386
1978	271647	450919
1979	283472	547139
1980	305454	618360

Source: Mobil Oil (B'dos) Ltd.

Woodbourne Field:

Oil reserves (proven). 2-3 Million bbls. (over 10 years.)

Gas reserves (proven). 2-5 Billion cu.ft. (over ten years.)

Barbados:

Possibly 10 similar Woodbournes in southern Barbados.

1978 - 79 UNDP. "A Study for Preliminary Energy Policy Plan for Barbados." - Van Meurs and Associates. (Ref. 32)

Woodbourne:

Oil reserves (proven)	9 Million bbls.
Gas reserves (proven)	15 Billion Cu.Ft.
Oil reserves (Estimated Potential)	18 Million bbls.
Gas reserves (Estimated Potential)	30 Billion Cu.Ft.

Barbados:

Oil reserves estimated	72 Million bbls.
Gas reserves estimated	120 Billion Cu.Ft.

Van Meurs suggested that four (4) Woodbourne fields could exist and that these estimated figures could be achieved with better operational procedures.

1980 NORCONSULT: "UNDP Oil and Gas Project Report." (ref. 19)

Woodbourne:

Oil reserves (proven)	4.5 Million bbls.
Gas reserves (proven)	7.5 Billion Cu.Ft.
Oil reserves (probable)	9 Million bbls.

1981 MOBIL:

Woodbourne

Oil reserves (proven)	3 Million bbls.
Gas reserves (proven)	4.4 Billion Cu.Ft.

Geological Problems and Prospects.

All the researchers agree on the fact that the Woodbourne field (the only operational oil field at present) is complex: the limits are yet undetermined; the oil and gas reservoirs are generally small, and are highly faulted and folded.

Present production rates total about 650 barrels oil/day, and 0.95 million cubic feet gas/day. Prospects are that with increased drilling at least to 1000 ft. above which producible hydro-carbons have been proven, the island energy needs can be supplied for at least 15 years.

The prospects of large finds in deeper reservoirs (approximately 18,000 ft.) still remain promising, and exploration activity is continuing, being conducted by Mobil, the sole local operator, and the Barbados Government.

Legislation.

At present Mobil holds a license to conduct geological and geophysical investigations on the entire island (onshore) and offshore, over the entire Exclusive Economic Zone, (200 mile limit or medium line). In terms of offshore exploration Mobil had until July 1st, 1981 exclusive right to negotiate with the Barbados Government. Also from 1st July 1981 - 1st July 1982, Mobil has right of first refusal. In terms of onshore exploration Mobil has a 12 month right of refusal period ending December 31, 1982.

Current Legislation, covers a concession type agreement, with 12.5% royalty and taxes. At present the revised Petroleum Act has only reached the draft stage. It is hoped that both Act and regulations will be complete by year end.

Current Legislation in force is:

1980 Petroleum Mining Operations Act.
1980 Petroleum Drilling and Production Regulations.

4.1.2 PETROLEUM PRODUCTS

Until 1976 when domestic production of crude began, all petroleum requirements were met by imports. Around 1950, petroleum replaced gas derived from coal as the principal fuel in Barbados; thus coal was also imported.

Barbados meets all of its inland demand for gasoline, kerosene, diesel and gas oil from the production of its refinery. In addition, jet fuel and marine fuels are imported directly for re-export (i.e., sold as bunkers to airplanes and ships). LPG is also imported directly.

Reconstituted crude and reformate are imported from Venezuela as feed into the refinery. Imports of crude and reformate amounted to 928.7 thousand barrels in 1979 which added to the domestically produced crude oil yielded approximately 1200 thousand barrels of petroleum products (including asphalts). Tables 4.1-2 and 4.1-3 show the volumes of imports and production for the period 1970-80, and the value of the imports in current $BDs. Table 4.1-4 shows that LPG imports have hovered between 7000 and 8000 tonnes throughout the decade. Even less of a trend can be discerned for the import and re-export of marine and aviation bunkers (see Table 4.1-5), whose demand depends on tourism trends and the prices of fuel in foreign airports and harbors.

Barbados refinery has a capacity of 3200 B/D and is owned by Mobil Oil Barbados, Ltd., a subsidiary of the Mobil Oil Corporation. The facility started as an import terminal in 1919, while the present refinery was built in 1962, the same year Mobil took over concessions from the original owner, the British Union Oil Company. Its imports have always been tailor made so as to avoid re-export of products.

The products from the refinery are distributed by the four marketing companies operating in Barbados, Mobil, Esso, Shell and Texaco. While Mobil has the exclusive right to supply all petroleum products required for inland consumption, the other three marketing companies are allowed to import products for re-export.

TABLE 4.1-2(a)

Volume of Imported Crude Oil and Reformate 1970 - 1980 in Barrels

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Crude Oil	603,894	454,243	835,852	813,379	851,257	749,205	764,309	831,507	766,920	721,626	736,890
Reformate	N.A.	N.A.	155,999	152,632	165,344	188,082	167,359	238,816	253,089	207,118	228,451
Total	N.A.	N.A.	991,851	966,011	1016,601	937,287	931,668	1070,232	1020,009	928,744	965,341

Source: Mobil Oil Barbados Limited

N.A. = Not available

TABLE 4.1-2(b)

Value of Imported Crude Oil and Reformate 1970 - 1980 (in 000 $BDs)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Crude Oil	2,917.3	2,748.0	5,564.0	7,377.5	21,143.4	18,829.8	20,424.4	22,982.4	22,578.2	31,881.4	44,225.7
Reformate	N.A.	N.A.	1,394.6	1,830.3	7,174.0	6,917.3	5,750.4	8,491.1	11,242.5	15,487.9	18,417.8
TOTAL Import Cost	N.A.	N.A.	6,958.6	9,207.8	28,317.4	25,747.1	26,174.8	31,473.5	33,820.5	47,369.3	62,643.5

Source: Mobil Oil Barbados Limited

N.A. = Not available

TABLE 4.1-3

Gross Production of Petroleum Products 1973 - 1980 (in Barrels)

YEAR	GASOLENE	KEROSENE	AUTOMOTIVE DIESEL	INDUSTRIAL	FUEL/GAS	ASPHALT
1973	320,595	74,286	383,000	32,000	251,000	27,595
1974	297,833	62,000	348,861	33,162	245,214	24,071
1975	304,756	67,997	402,944	27,488	222,263	30,690
1976	311,187	70,625	322,563	32,385	302,665	32,978
1977	327,691	61,770	107,275	31,405	528,662	29,812
1978	322,820	59,846	216,543	35,827	513,482	28,527
1979	348,230	59,303	232,059	37,032	591,050	30,993
1980	346,476	48,413	268,324	43,912	613,860	33,798

Source: Mobil Oil (Barbados) Limited

TABLE 4.1-4

L.P.G. IMPORTS 1970-1980

Year	Tonnes	Value (CIF) BDS$
1970	3260	$ 347,117
1971	4810	$ 579,377
1972	7748	$ 968,847
1973	5675	$ 807,379
1974	7030	$2,705,163
1975	8542	$3,553,533
1976	7516	$3,436,918
1977	7625	$3,425,481
1978	7828	$4,011,358
1979	8016	$5,474,353
1980 P	7905 P	$7,988,323 P

P = Provisional

Sources: Overseas Trade Statistics, DaCosta & Musson Co. Ltd. (Texgas) and Shell Antilles and Guianas Ltd. (Shellane)

TABLE 4.1-5

Re-Export Demand for Refined Petroleum Products 1970 - 1978 in BBLS

(Marine and Aviation Bunkers)

	Aviation Gasoline	Jet Fuel	Bunker "C" Fuel Oil
1970	4,677	151,893	13,116
1971	9,242	456,353	13,696
1972	4,951	394,314	12,554
1973	8,643	519,101	227,947
1974	10,926	537,290	808,794
1975	4,044	193,010	435,378
1976	-	144,698	363,913
1977	9,584	308,356	227,412
1978	5,368	807,989	307,329

Source: Annual Overseas Trade Statistics Reports 1970 - 1978

1979 data not available

4.2 ELECTRIC UTILITY SECTOR

ELECTRICITY SUPPLY AND DEMAND

The sole supplier of electrical energy to the public in Barbados is the Barbados Light and Power Company (BL&P). At the present time BL&P services some 61,000 domestic and 6,445 other customers and has an installed capacity of 95.3 MW. Sales in 1980 were about 284.8 million KWh with Domestic sales accounting for some 29 percent and Commercial and Government the remaining 71 percent. Sectoral sales over the past 10 years are shown in Figure 4.2-1.

Rapid electrification in Barbados over the past fifteen (15) years has produced a very high rate of growth in demand for electricity from BL&P. Table 4.2-1 presents levels of historic sales and annual growth rates. Prior to 1973 the rate of growth in sales was about 16 percent per year (from 1965). Table 4.2-1 shows that following the 7.0 percent decline in 1974, the average growth through 1980 was about 8 percent. BL&P projects a continued high rate of growth, 7.6 percent at least through 1985.

Dependence on Oil for Electricity Fuel. The electrical generation facilities of BL&P are composed entirely of oil-fired generation capacity[1] sited at two locations The Garrison and Spring Garden. Figure 4.2-2 shows the relative size and age of the various sets of generating capacity. Two main features are illustrated, these are: first, the large size of the two 20Mw steam units relative to the other installed capacity (40 Mw out of a total of 96.9 Mw): and second, the old age of the diesel

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1 Natural gas has recently been introduced into the steam turbine units displacing some percent of normal oil use.

Figure 4.2-1

ELECTRICITY SALES BY SECTOR IN BARBADOS
300
250
200
150
100
50
0
(Million kwhs)
Total
Other
Domestic
Industry - Commerce
1968
70
72
74
76
78
80
YEAR

TABLE 4.2-1

Barbados Light and Power

Sales, Peak Demand and Installed Capacity

	1972	1973	1974	1975	1976	1977	1978	1979	1980
Sales (GWh)	170.5	189.6	176.3	187.9	199.7	223.0	244.0	272.8	284.8
Growth Rate (%)		11.2	-7.0	6.6	6.3	11.7	9.4	11.8	4.4
Peak Demand (Mw)	34	35.8	33.5	35.8	40.4	43.2	47.8	51.0	53.2
Growth Rate (%)		5.3	-6.4	6.9	12.9	6.9	10.7	6.7	4.4
Installed Capacity (Mw)	47.4	64.4	63.5	57.5	97.5	96.5	96.5	95.9	95.3
Growth Rate (%)		35.9	-1.4	-9.5	69.6	-1.0	0	-.6	-.6

facilities at The Garrison - varying from 16-32 years in age. Both of these features adversely affect system reliability.

Another characteristic of the BL&P system is the heavy utilization of cheaper Bunker 'C' oil in the two 20 Mw steam turbines. Since 1975 when these units were installed they have bourne some 70 - 80 percent of system load, substantially reducing costs by permitting greater use of Bunker 'C' oil, and decreasing demand on older less reliable diesel generation sets. Figure 4.2-3 demonstrates both the relative generation by type of plant, and fuel consumption for 1980. In addition, this figure shows the substantially lower fuel costs per kWh of the steam units, $0.10 versus $0.15 for diesel plant and $0.31 for the single 18 Mw gas turbine.

Implications of Growth for Needed Utility Revenues. Previous growth in electricity demand at the very high rates experienced by BL&P, and as now projected, imposes a severe strain on the financial capability of a utility. This results from the fact that the relative size of the existing stock of fixed assets upon which the utility earns a return (to be applied to new capital and repayment of past debt) becomes smaller and smaller in relation to required new investments. Figure 4.2-4 demonstrates this phenomenon, showing the Bds $191.2 million investment requirements to support the BL&P expansion plan through 1985, versus the $166.7 million value of total fixed assets in 1980.

The rapid development of Barbados tourism, manufacturing, and commerce, all suggest that continuing pressure on the electrical capacity and financial resources of BL&P is likely to continue. This pressure can only mean higher rates and increased oil imports without concerted action by Government, the private sector and BL&P, to lower growth and conserve electricity.

FIGURE 4.2-2

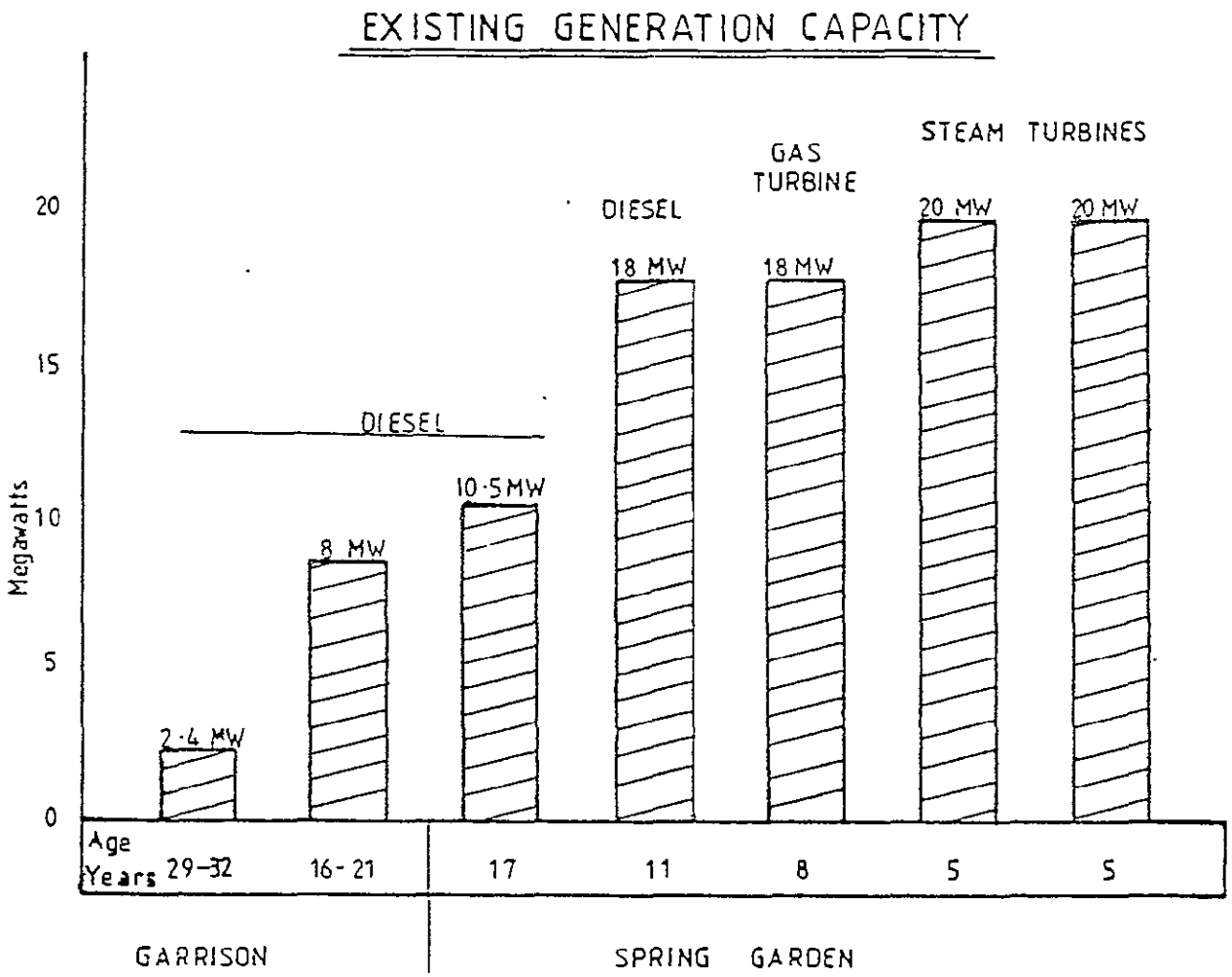

EXISTING GENERATION CAPACITY
Megawatts
20
15
10
5
0
DIESEL
2·4 MW
8 MW
10·5 MW
DIESEL
18 MW
GAS TURBINE
18 MW
STEAM TURBINES
20 MW
20 MW
Age Years
29-32
16-21
17
11
8
5
5
GARRISON
SPRING GARDEN

FIGURE 4.2-3

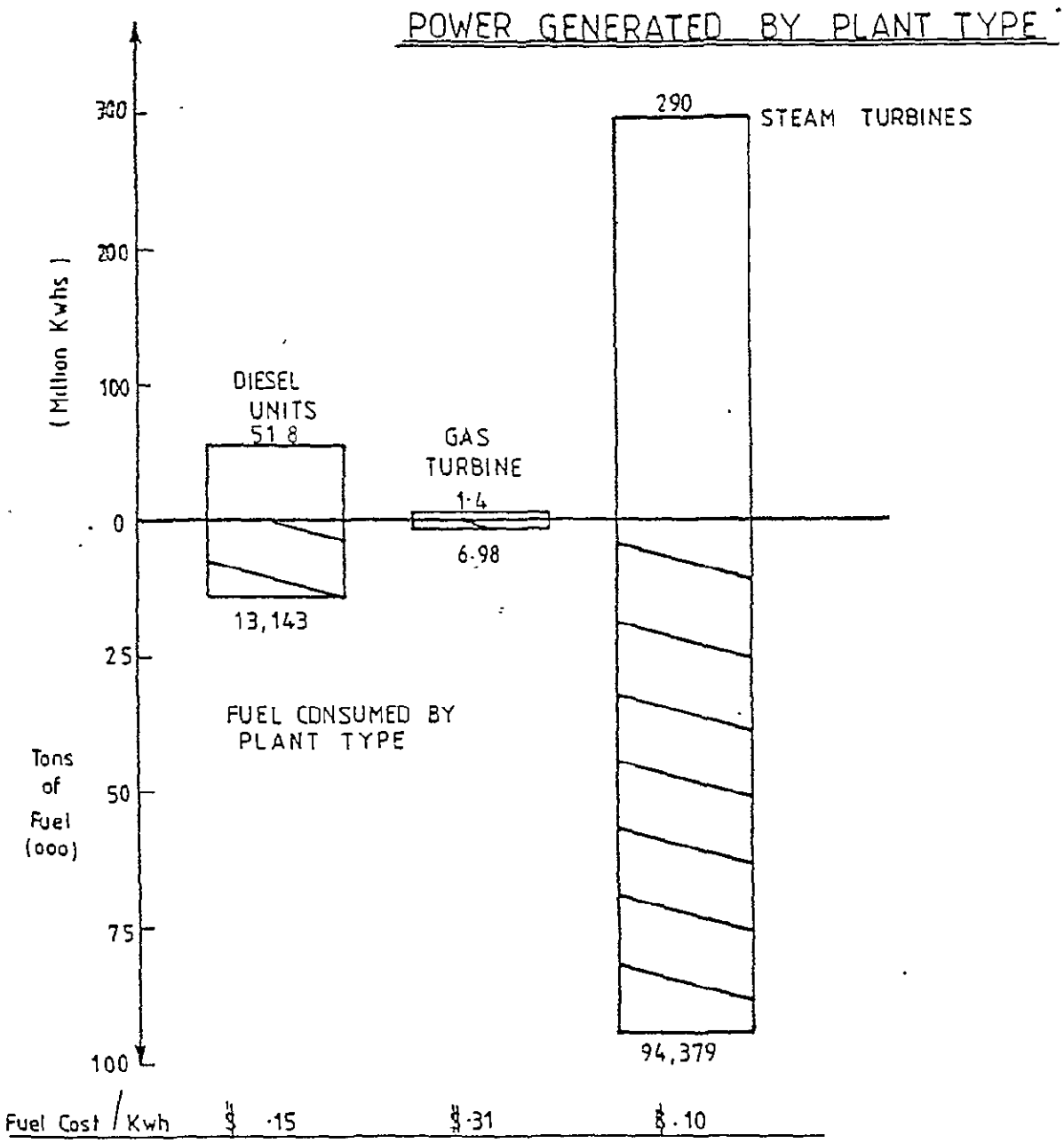
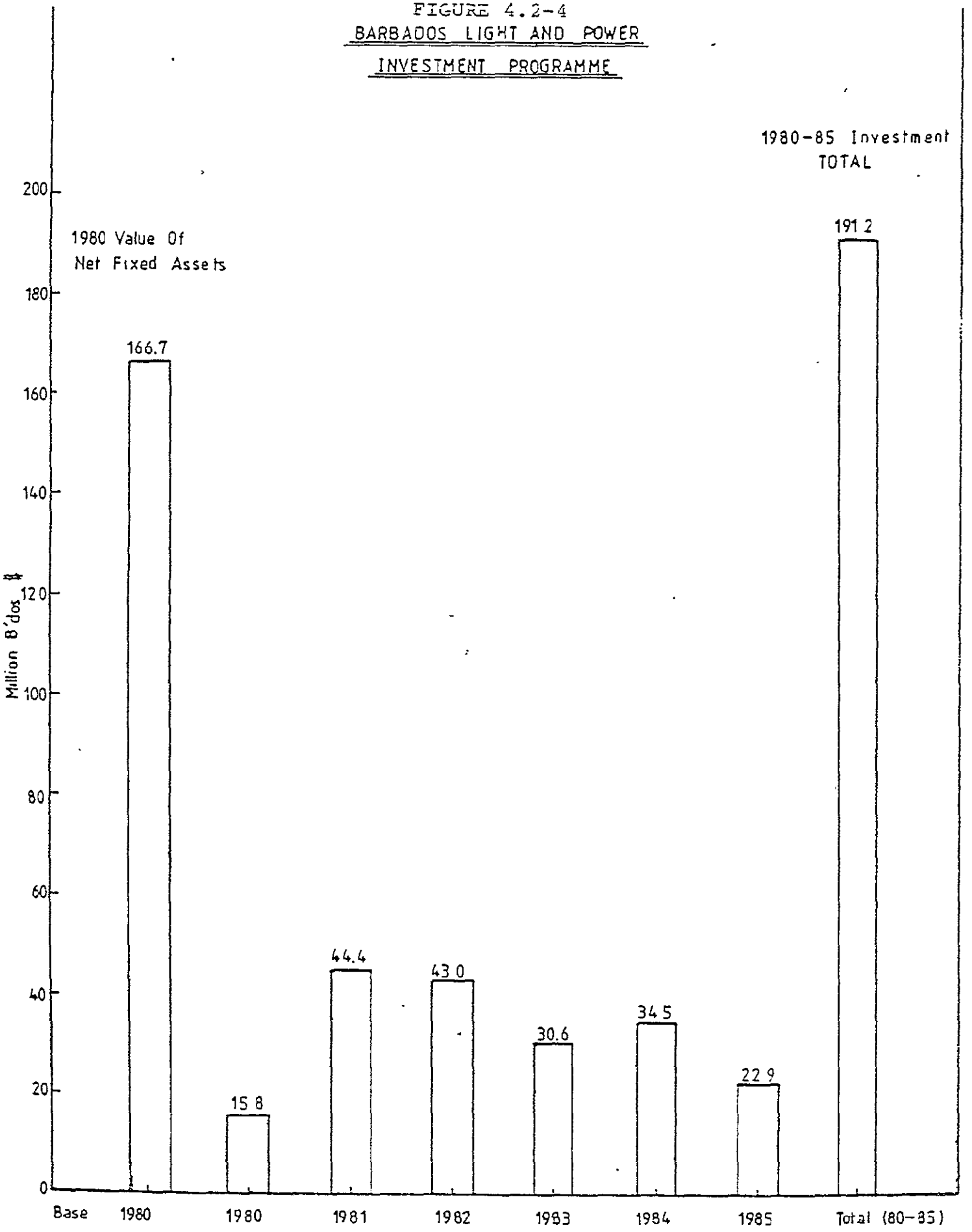

POWER GENERATED BY PLANT TYPE
300
200
100
0
25
50
75
100
(Million Kwhs)
Tons of Fuel (000)
DIESEL UNITS
51.8
GAS TURBINE
1·4
6·98
290
STEAM TURBINES
13,143
94,379
FUEL CONSUMED BY PLANT TYPE
Fuel Cost / Kwh
$ ·15
$·31
$·10

FIGURE 4.2-4
BARBADOS LIGHT AND POWER
INVESTMENT PROGRAMME



Reserve Margins. Another important characteristic of the BL&P system is its small size in relation to economic types of generation capacity. Large and efficient base-load power generation is simply not feasible. Most costly however, is the requirement for high reliability which in effect leads to a large and costly capacity reserve margin.

This reserve requirement essentially calls for BL&P to maintain stand-by capacity equal to size of their two largest units to protect against outages. That is, protecting against the contingency that a 20 Mw steam unit is out on scheduled maintenance and another 20 Mw steam plant break downs. This reserve requirement produced a reserve margin of about 72 percent in 1980; compared with the standard rule of thumb for large interconnected utilities in the United States of 15-20 percent.

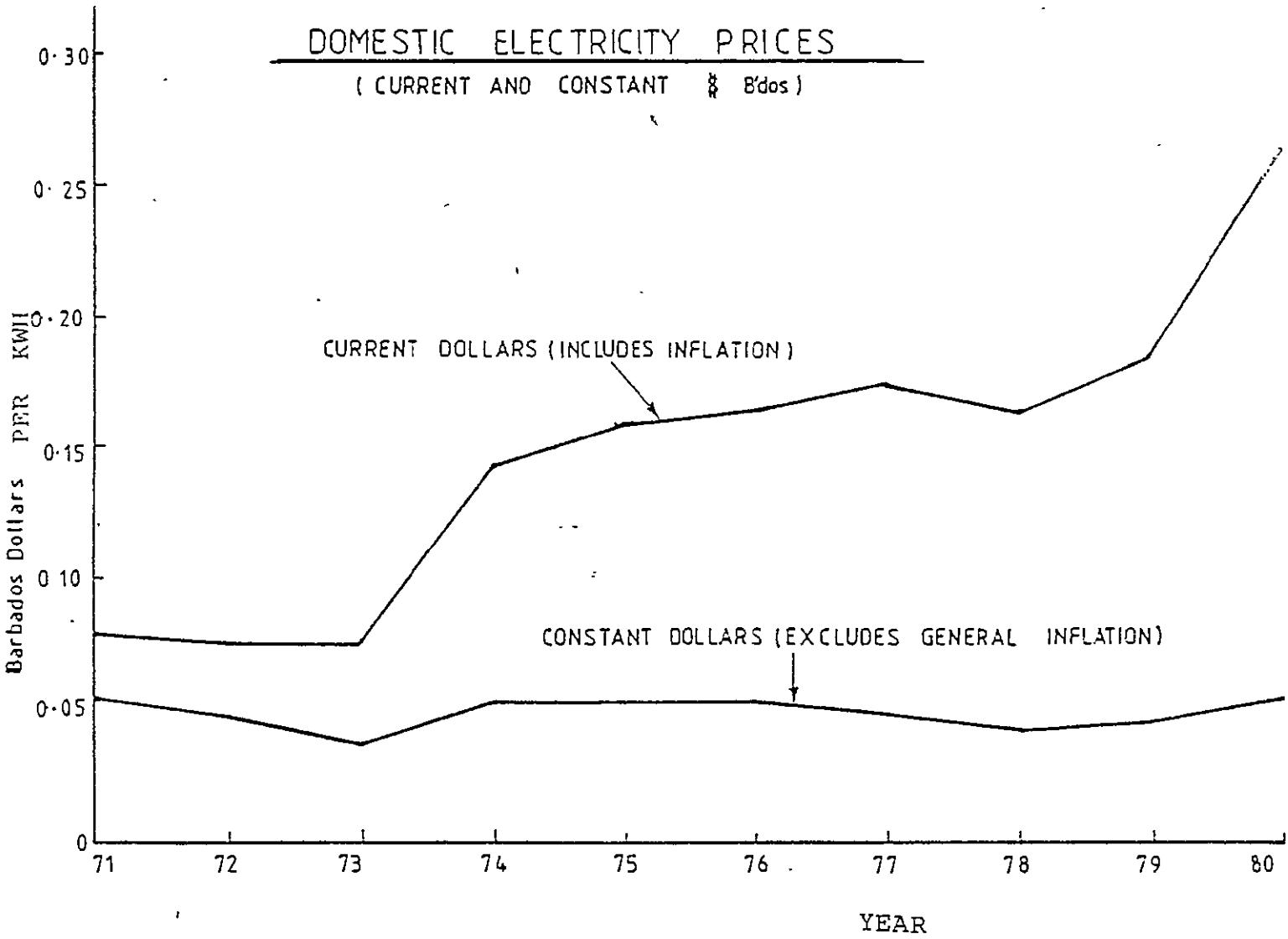
Reduction of this large percentage reserve will naturally occur as the BL&P system grows. More attention however needs to be urgently given to reduction of peak demand both by conservation and load management. In combination, these measures can both decrease the level of expected peak demand and provide a more effective means of managing loads in the event of plant outages.

Electricity Prices. The level of electricity prices in Barbados has historically fallen when compared to the level of consumer prices in general. Current prices for the residential consumer (in constant dollars) are about 13 percent below the real price in 1970 (see Figure 4.2-5). In current dollars the price of electricity went from 7.89¢ to 26¢ per kilowatt-hour (Figure 4.2-5).

There are three elements to utility prices which might be influenced to lower the rate of growth of electricity prices. We discuss each in turn below:

BEST AVAILABLE

FIGURE 4.2-5


DOMESTIC ELECTRICITY PRICES
(CURRENT AND CONSTANT $ B'dos)
Barbados Dollars PER KWH
0·30
0·25
0·20
0·15
0 10
0·05
0
CURRENT DOLLARS (INCLUDES INFLATION)
CONSTANT DOLLARS (EXCLUDES GENERAL INFLATION)
71
72
73
74
75
76
77
78
79
80
YEAR

The first, the basic rate of return on rate base, which is partially comprised of the utilities rate of return times its rate base. Historically, this rate of return has been about 7 percent, but declined to under 5 percent in 1978. Second, the fuel charge which largely reflects the cost of imported oil, but is affected by the efficiency of power production and the cost of domestic oil refining. Last, the investment cost of adding new capacity to meet growth which must be built into the basic rate to ensure earnings are sufficient to finance expansion, and attract investors, and to repay debt incurred to build new capacity.

Of the various elements of utility prices fuel costs are largely beyond the control of the utility. However, efficiency improvements are now and have been a major area of BL&P concern. Current system losses are about 9%, which are reasonable by conventional standards. The cost of fuel from local refining is addressed elsewhere in this assessment report.

The basic rate of return of BL&P is determined by the Public Utilities Board after a hearing and is not likely to diverge significantly from that required to maintain financial soundness of BL&P. If anything, the rate of return itself can be expected to increase as a result of the large investment programme of BL&P, and the necessity to generate internal funds to finance a part of the programme and attract investors to purchase BL&P stock.

The major area where cost control may be successful is in demand management and conservation. For example, current customer power factors[1] in the commercial and industrial sectors vary from 7.5 to 8. This compares with cost effective power factors of 9.5. An increase from 8 to 9.5 produces a significant decrease in

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1 Power factor refers to a ration relating the degree of coincidence of voltage and current.

energy demand. Similarly, some 45 percent of hotel electrical energy is consumed for air conditioning. Most of this air-conditioning is supplied by room air conditioners with very low energy efficiency. Replacement of these units by more efficient units now available could decrease this demand by some 30-40 percent. Central air conditioning would be even more efficient in new hotels, and use of waste heat for water heating from these units could replace most fossil fuel for water heating as well.

As we have explained above, the costs of new generation capacity are likely to add substantially to utility bills for all BL&P consumers. Current power rates kilowatt demand however do not reflect these high marginal costs which reflect the cost of building new generation capacity. The current utility demand charge of Bds $3.00 per KVA is far below the annualized cost of new generation of some $198.00.[2]

A combination of Government regulations and incentives, BL&P conservation and education efforts, and marginal cost demand charge pricing, would help mitigate the pressure on utility bills due to new capacity additions. Specific options in conservation are discussed in Chapter 7.

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2 $1800 kW for low-speed diesel capacity times the capital recovery factor 11.0 (for 10% discount rate and 25 a year amortization period).

4.3 ALTERNATIVE ENERGY RESOURCES-WIND, SOLAR, BAGASSE

4.3.1 WIND POWER PROSPECTS

Considerable interest is now being shown in the wind electric power generation potential of Barbados. In order to determine the potential for wind, we must consider how much power is theoretically available from the wind profile in Barbados, technical achievability, economics and marketability. Each of these questions is addressed in turn below.

WIND RESOURCES IN BARBADOS

Barbados is fortunate in having fairly good long-term wind measurement records. These records strongly suggest that large potential exists for exploitation of this resource, and supported further studies as noted below.

Figure 4.3-1 shows the average wind speed at two locations in the Springhead area of Barbados for a single summer and winter day, respectively. Both profiles show excellent wind velocity, above 8 meters per second (m/s) with a maximum of about 9.5 m/s. Wind speed data from a 1968 study by Florida State University confirms this pattern. Long term records are available for three stations in Barbados, the Airport, Codrington Agricultural College and the Caribbean Meteorological Service, and all basically confirm the above conclusions (See Table 4.3-1).

It is important to point out the importance of wind speed data for machine choice and siting. At one Northeast Coast site a wind speed of 10m/s is exceeded 34% of the time. At another site on the West Coast this speed would be exceeded 3% of the time. For a reference 200 Kw machine rated at 10.7 m/s, power generated

FIGURE 4.3-1

MEAN HOURLY WINDSPEED AT 55' AGL FOR SPRINGHEAD

---WINTER DAY
——SUMMER DAY

Wind Speed	# Hrs./Day	Hrs./Yr
10 - 10.33	1.0	360
9.66 - 10.0	3.2	1170
9.33 - 9.66	2.5	910
9.0 - 9.33	2.1	770
8.66 - 9.0	2.9	1060
8.33 - 8.66	8.3	3030
8.0 - 8.33	4	1460
		8760

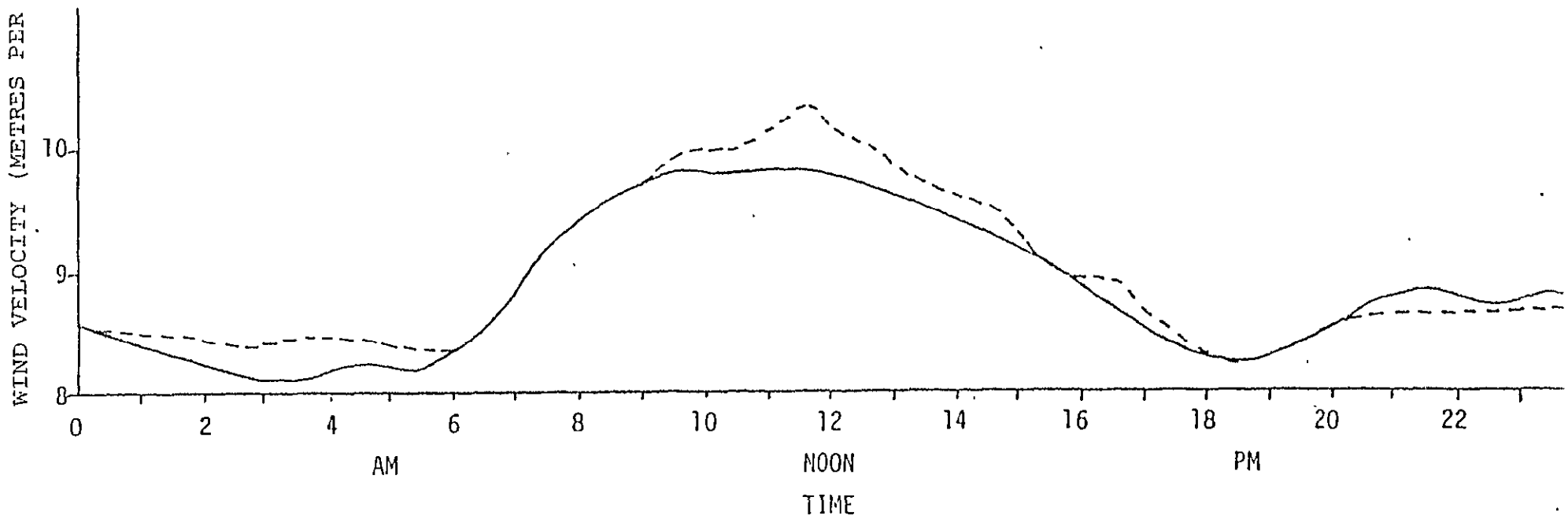

TABLE 4.3-1

MONTHLY AND SEASONAL VELOCITY STATISTICS IN METERS/SECOND FOR SELECTED PERIODS AT WIND MEASUREMENT STATIONS IN BARBADOS

	Codrington (1903-1960)				CMI (1971-79)		Airport (1971-78)	
Month	Hi	Low	Month Ave.	Season Ave.	Month Ave.	Season Average	Month Ave.	Season Average
Dec.	7.3	3.8	4.4		3.7		6.3	
Jan.	7.3	3.4	4.9	4.8	4.1	4.3	5.3	5.8
Feb.	9.1	3.7	5.1		4.5		5.8	
Mar.	8.5	4.0	5.2		4.4		6.1	
Apr.	8.86	3.6	5.1	5.2	4.4	4.5	5.5	6.0
May	7.9	3.6	5.3		4.7		6.3	
June	9.4	3.8	5.6		5.2		6.8	
July	9.1	3.8	5.1	4.9	4.7	4.6	6.0	5.9
Aug.	6.8	2.8	3.9		4.0		4.9	
Sept.	5.4	2.4	3.4		3.6		4.5	
Oct.	5.2	2.5	3.3	3.5	3.6	3.5	4.6	4.7
Nov.	6.6	2.9	3.6		3.3		5.0	
AVERAGE			4.6		4.2		5.6	

at the first site would be .81 million kWh and at site two, only one-quarter of this energy, or about .21 million kWh.

At the present time, a major wind and solar energy resource assessment exercise is under through the Caribbean Meteorological Institute under the sponsorship of the Caribbean Development Bank. This study is designed to collect data on wind regimes at the most probable wind generator sites, identify good prospective wind generator sites, and assist in monitoring and evaluation of installed wind turbine generators. Data from the first phase of this effort should be available for Barbados within 6-8 months.

TECHNICAL AND ECONOMIC FEASIBILITY

The technical feasibility of wind power generation of electricity is well established at a relatively small-scale. At this time a large number of demonstrations and small commercial tests are underway in the United States and elsewhere, with machines ranging in size from a few kW's to 3500 kW's. Successful previous applications of several of these designs indicates probable favourable technical results, with estimated costs in the range of US$800 to US$600 per kilowatt after large scale implementation.

The technical and economic feasibility of wind generation in Barbados is complicated by three major factors. First, the presence of the threat of hurricanes; second, the presence of high levels of in the air, with associated corrosion problems; and third, the relatively small market. The only way to satisfactorily address these issues is through experience. Therefore, the current Inter-American Development Bank Wind Turbine Demonstration Project (9200-300 kW's) in Barbados is a critical milestone in wind power development. Plans call for purchase and construction by mid-1983, and thereafter tests in cooperation with BL&P.

Payments by utilities for electricity from wind generators are most often set in relationship only to the operating or fuel cost savings to the utility from wind energy. Wind is thus not credited with a firm power capacity "credit" which essentially is a payment for reducing utility needs to build capacity in order to meet peak demand.

In many systems more recent studies now show fairly substantial capacity benefits, however these results are highly system specific and depend on:

- size of the utility, and daily, weekly and seasonal load variations;

- wind speed and duration;

- reliability, type and size of wind machines;

- number and location of wind machines;

- availability of storage (e.g. water, battery, etc.)

Our study is conservative and does not add any capacity credit. Table 4.3-2 below displays the capacity and operating costs of various generation options, with the last row a comparison of existing facility, fuel and O & M costs versus wind.

Table 4.3-3 further refines the figures in Table 4.3.1 for the various wind machines at specific reference sites (and with associated power outputs). It is obvious from the data in Table 4.3-2 and 4.3-3 that:

(a) Given utility financial assumptions (a capital charge rate of 0.12/year); all but the 2000 kW and vertical

TABLE 4.3-2

WIND POWER BASED COST ESTIMATES

(1981 US Costs, Except as Noted, Delivered to Major Consumers)

Fuel/Generator Type	Capital Cost 1981 $/kw	Fuel Cost ¢/kwh	Total Power Cost ¢/kwh
Small Decentralized Diesel			
(1980)	800	10.9	13.2
(2000) (a)	800	13.5	15.8
Large Coal-Fired Central Station	1000	2.7	5.2
Large Imported Oil Fired Central Station			
(1980)	800	5.5	7.5
(2000)	800	8.0	-
Single Small Nuclear Unit	2200	1.0	7.4
50 Kw Wind Turbine (b)	900	1.35 (c)	9.2
200 Kw Wind Turbine (b)	800	0.9 (c)	8.1
Central Grid Electricity (d)	-	8.5	17.0

(a) Crude oil prices taken as $70/bbl in 2000.

(b) Calculations made using existing wind turbine prices for the 50 kw machine. The 200 kw machine price was taken from a recent proposal by a major wind system supplier. Because the price was for a U.S. system FOB factory and was not a quote, it may not be an accurate estimate of actual costs.

(c) O&M costs of $15,00 per year for 50 kw and $5,000 per year for 200 kw; there is no fuel.

(d) Current (May, 1981) fuel adjustment and electricity charges for domestic customers in Barbados.

TABLE 4.3-3

COST OF VARIOUS WIND TURBINES (US $/kWh)[1/]
AT SITES IN BARBADOS

WIND PLANT & TYPE (KW)	SITE 4 (EAST COAST)		SITE 10 (NORTH COAST)		SITE 12 (MID-ISLAND)		CURRENT FUEL COSTS (BL&P)
	A[2/]	B[2/]	A	B	A	B	
100	.06	.08	.07	.09	.07	.09	
500	.06	.09	.08	.11	.08	.12	
1,000	.05	.08	.06	.08	.06	.08	
1,500	.07	.11	.09	.14	.10	.15	
2,000	.08	.12	.11	.16	.13	.19	
3,000	.04	.06	.05	.08	.06	.08	
500[3/]	.11	.17	.11	.23	.17	.25	.09

Notes:

1/ Cost calculation as in Table 4.3-2, footnote b/.

2/ Capital charge rate of 0.12 in column A, 0.18 in column B.

3/ Vertical Axis - all others - horizontal axis type

4/ Methodology. This table was derived by using data from 14 stations around the island from which wind speed/duration curves were derived.

Curves were estimated for a standard 10 metre height and extrapoted to 50 meters. Next design parameters of various turbines were combined with wind duration data to estimate annual Kwh output. Ref. 8.

axis 500 kW machine are cost competitive with existing oil generation fuel costs at US$0.076/kWh.

(b) At 50% higher fixed charge rates (0.18), wind is still competitive at the 100 kW, 1,000 kW and 3,000 kW size.

(c) A 20 percent higher capital cost was tested at the higher fixed charge rate of 0.18°. Costs at the best site for the 3,000 kW machine were still roughly equal to current utility fuel oil costs (US $0.076 kWh).

(d) Prospective real oil price escalation of 2-3 percent per year will tend to raise costs for existing oil power generation, while capital costs for wind power should drop as "mass" production and commercialization proceed.

If the present wind demonstration in Barbados proves technically successful then the overall picture for economic wind potential is very favourable. It should also be stressed that the benefits of reducing dependence on foreign oil and reducing capital outflows, although difficult to quantify, should be considered to be additional benefits further adding to the attractiveness of this option.

CONSTRAINTS AND OPPORTUNITIES

The major constraints to the further development of wind power in Barbados are likely to be the availability of skilled manpower and capital resources. These problems are manifested in the following areas:

First, assuming the successful demonstration of a WTG in Barbados; further system generation expansion, transmission and

reliability, and engineering feasibility studies will be required. BL&P neither has the current available manpower or funds to undertake or fully finance this work. At the same time the utility is likely to be slow and conservative in its approach to WTG development. This is normal for a private company in the face of uncertainty, but may not be desirable from the broader public perspective of reducing oil imports. Thus, it is likely that public sector capital and influence would be necessary to get the most out of wind power for Barbados.

Secondly, given the large investments required for any new capital expansion BL&P is likely to be hesitant to bear the full risk of wind-power development. Government should consider various schemes to minimize such risks, including assisting in securing low-interest loans from the World Bank, Inter-American Development Bank and/or Caribbean Development Bank; guaranteed purchase of wind power output on a cost plus basis; and/or direct financial support.

Thirdly, a more detailed implementation plan will be required to indicate Government policy and goals for wind, as well as other alternative resources. Present experience shows us that the long lead-time inherent in major capital developments, acting together with decreasing expectations of peak load growth, will delay the implementation of significant wind generation. Even when new wind is more economic than utilizing existing oil generation, it is likely to prove very difficult to make new investments for wind generators when existing or newly authorized capacity is sufficient to meet peak load.

Finally, a combination of the advanced state of BL&P planning on new low-speed diesel units for 1984 and 1986-7 to meet capacity needs, and possible conservation impacts on new demand could push the implementation date for substantial wind generation into the

late 1980's. Priority attention should be given to providing a "window" for wind before any other than the most critical fossil plant commitments are made. Availability of wind energy could very well influence what type of new capacity should be added, as wind will tend to reduce its needed energy output.

4.3.2 SOLAR ENERGY PROSPECTS

Past efforts to measure and record basic weather information in Barbados have resulted in the compilation of data on hours of sunlight, cloud cover, temperature and rainfall, among others. There exists only one year of solar radiation measurements, however given the high level and low variability of radiation, there is clearly a high quality resource. The recorded annual radiation average of 463 langleys equals about 5.4 kWh's/square meter per day (Further discussion of resource potential may be found in Ref. 28).

The good current economics of solar hot water heating systems also supports the other evidence that indicates solar radiation is a substantial and reliable resource.

The potential for solar energy use in Barbados is large. The major possible areas of solar energy development are:

- Solar hot water heating
- Solar assisted space conditioning (air conditioning and freezing)
- Photovoltaic (PV) electrification.

The task of estimating the rate of application of these technologies is more difficult tnan for wind. This is because the major

barriers to solar assisted space conditioning and PV electrification are technological and economic and are outside the control of local institutions. The potential for solar hot water heating is easier to estimate than for these other solar technologies.

Solar Air Conditioning. There are now two solar thermal powered air conditioning demonstrations underway in in Barbados. These are being instituted because space cooling is one of the largest electricity uses on the island. If solar powered cooling is shown to be reliable and economical, its adoption could result in substantial fuel and operating cost savings for a wide range of public and private users. These two demonstrations should provide a substantial amount of information on this application during the next several years (Ref. 28).

A third solar powered air conditioning demonstration is being planned for the Central Agronomic Laboratory when it is conducted. The Planning and Priorities Committee of the Ministry of Agriculture, Food and Consumer Affairs (MFACA) has approved a PV powered vapor compression chiller system for the laboratory. Specific designs have not yet been prepared and an exact date for construction or startup has not been set.

Solar Hot Water Testing. The Barbados National Standards Institution is planning to build a simple solar flat plate collector test stand. The project, financed by CDB and developed with the assistance of the UWI, will be completed in approximately six months. The purpose of the project is to develop performance and installation standards for locally produced solar collectors. Initially, the testing will be voluntary and later a more formal mandatory certification program may be implemented. This service will provide information to prospective buyers on what they should expect from solar hot water heating systems.

Wave Power. In December 1980, a two month preliminary study on the potential for wave power for Barbados was initiated (Ref. 14). The study concludes that there is reason to believe that wave power can be important to Barbados and suggests further data collection on offshore wave height and power and on sites for wave power installations. The Government is considering these recommendations. A substantial amount of further study is necessary before any definite answer is available. There is no commercial size wave power plant anywhere in the world, and until one is commissioned there may be hesitancy to approve even a demonstration for Barbados.

In addition to the above, there have been some solar and wind research projects at UWI and basic solar crop drying experiments by the MAFCA.

SOLAR ENERGY MARKETS

The use of solar hot water systems in Barbados is now widespread in the residential and hotel markets. It is estimated that the two larger solar manufacturers have installed about 160,000 gallons of solar hot water heating capacity. This comes to roughly 2,500 individual systems.

There have been a number of solar hot water market estimates prepared in the past (Ref. 28). Additionally, in a recent study done for CDB (Ref. 26) solar hot water systems were compared with central air conditioning waste heat use for hot water and potential markets were examined. In the cases analyzed, all showed simple cost recovery in five years (and for the more complex calculation scenarios, the majority showed payback of less than five years).

The market for solar hot water heating has three components; the Domestic Sector, the Commercial (including Tourism and Institutions) Sector, and the Industrial Sector. It is possible to jointly consider the Domestic and Commercial Sectors, but since industrial hot water needs frequently require temperatures greater than 140 degree Fahrenheit, a different type of system is required.

In the Residential Sector we have examined two market cases, with the results summarized in Table 4.3-4.

In the Hotel and Tourist Sector, the growth is expected to be larger. In 1979 there were approximately 5,922 rooms available for visitors. A mail survey conducted as part of the National Energy Assessment showed that 8.2 percent of those responding, or 181 rooms (2200 rooms were represented in the responses) already had solar hot water heating. Data in Ref. 28 indicates that over 1000 rooms currently have solar hot water heating (about 15 percent). We believe this latter estimate to be more reliable. Table 4.3-5 presents estimates of the growth in Tourist Sector solar hot water heating.

The quantity of moderate-low temperature hot water used today is by far the greatest in the Hotel Sector. Utilizing an estimate of 40 gallons of hot water per day per tourist and an estimate of 2.6 million tourist days, it is estimated that roughly 104 million gallons of water and 2.6 million barrels of oil equivalent are used annually for this purpose. With 70 percent of systems using

TABLE 4.3-4

DOMESTIC SOLAR WATER HEAT PENETRATION

1979-2000

	1979	1985[2]	1990[2]	1995[2]	2000[2]
Total Dwellings	69,125	71,700	74,620	77,530	80,250
Saturation[1]	.02	.05	.083	.113	.15
No, of Solar Units	1,475	3,656	6,193	8,761	12,038

Notes:

1 Saturation estimate from Barbados National Energy Assessment Household Survey (Ref. 16), derived as 2000 in 1980 minus 525 for future years, estimated saturation rates are from this study (see Chapter 16).

2 No. of dwellings assumed equal to number of household.

TABLE 4.3-5

ESTIMATED GROWTH OF SOLAR HOT WATER SYSTEMS FOR HOTEL AND RENTAL UNITS (Base Case)

Year	Total Rooms[1]	Rooms with Solar Hot Water Heating[2]	% of Total Rooms	Total Installed Gallons[3]
1979	5,922	750	15	40,000
1985	7,849	3,140	40	120,000
1990	9,574	6,510	68	256,000
2000	11,556	8,089	70	256,000

Notes:

1 For growth rate assumptions see Projections in Tourism Sector

2 Assumes 75% of existing rooms with solar water heat by 1990, and one-half of all new rooms go solar.

3 An average of 40 gallons capacity per room is assumed.

solar in the year 2000, oil savings would be roughly 3.6 bbls per year.[1]

The industrial market for solar hot water is much more difficult to estimate because:

- Hot water temperature requirements exceed flat plate delivery capability;
- Other methods such as heat exchangers on compressors and improvements in boiler operation may be able to supply hot water at cheaper costs than a new solar system;
- Estimates of hot water requirements in the industrial sector are not available.

Presently there are no solar systems supplying process water or pre-hearing boiler feed water. However, in our study of the Queen Elizabeth Hospital, dairies, and poultry operations, (Ref. 15 and 22) there appeared to be several good candidates. The rate of adoption and absolute magnitude of industrial hot water heating is assumed to be small. Since no on-island manufacturers now handle concentrating collectors or systems tailored to industrial temperature needs, the market will be very small until 1985. After this date, even if those conditions change, the total size of the market is not expected to be as large or as profitable as either the domestic or the commercial market. There will likely be some systems installed, but no estimate can be made at this time. There are no data on current hot water use in industry..

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1 Note that water heating is also now done by LPG and natural gas, as well as by large boilers which may not be converted due to economics.

The estimated total market for solar hot water is impressive, however, in terms of absolute number versus the present manufacturing capacity on Barbados, it is not so large. Manufacturers currently feel that the domestic market will not support even one more manufacturer over the long term.

The market for other solar technologies is presently very small. However, two technologies may have large potential markets. The first is solar powered air conditioning and the second is photovoltaic powered stand-alone electricity systems. The first technology must be demonstrated and the economics must be more favourable than they are today.

In the industrial sector, there are also many hundreds of tons of existing air conditioning. The amount of this space conditioning market which can be supplied by solar power is not known. The up-coming Barbadian solar air conditioning demonstrations, increases in worldwide demand, and technology and manufacturing improvements will determine the size of the solar and solar-assisted air conditioning market.

The PV-power systems market is presently only for powering emergency lights in homes, offices and factories, and for supplying small electricity demands. The future of the market depends on improved economics and the willingness of BL&P to permit stand-alone systems. Because of this and the fact that wind seems to be economical now, we have not estimated any major market for PV. If this market develops it will develop after 1990 and into 2000.

In summary, there is a large market for solar technologies on Barbados especially in hot water, and air conditioning. Additionally, the solar hot water heating market is not large enough to support other manufacturers or an expansion of manufacturing to include additional components or new technologies. If this type

of expansion is to be possible, the size of the market must be increased. One way to do this is to service other Caribbean countries. If this were possible, of other islands and countries also were to have excellent solar resources, and if markets for existing technologies were in existence, the possibility of Barbados' serving as a manufacturing center would be much larger.

IMPLEMENTATION

At the present time there are a number of incentives and/or penalties favouring the solar manufacturer and distributor in Barbados. These include:

- All water heating devices except for solar are now subject to a 30 percent consumption tax. This measure was specifically introduced to protect local manufacturers and encourage production and use of solar water heating.

- Solar water heating installation costs may be deducted by the purchaser from income taxation.

- Caricom regional import preferences and tax holidays are currently being used by local solar heat water manufacturers.

Several major difficulties remain even in the face of the favourable treatment of solar hot water systems at the present time. Most importantly, solar systems remain significantly more costly to originally install. For example, a gas water heater installed now costs some Bds $1,300; and a 30 gallon electric water heater Bds $1,100. While the installed cost of a solar system is about Bds $2,300. Obviously this first cost may weigh heavily on the decision, even though the operating costs of the other systems are much higher. For example, for natural gas Bds

$600/year, electric Bds $1,080/year, and solar perhaps Bds $30/year (assuming a heating requirement annually if two barrels of oil).

The problem of high first cost may need to be addressed by creation of readily available financing programmes, tax credits or other means. An important policy question should be considered however before offering such incentives. That is, to what extent does Government wish to stimulate water heating use in the domestic market? Current practice is to use tap water for bathing and clothes washing, and there seems to be little dissatisfaction with this practice. Stimulation of water heating even if by solar energy involve a substantial initial foreign exchange commitment for equipment.

Also very important are the fiscal incentives which today permit the duty-free import of equipment for construction of new hotels. This in effect removes the extra incentives which Government has attempted to apply. Clearly the operating cost savings of solar hot water are still great. However, though businesses might be expected to be more conscious of the life-time cost, as opposed to first cost, numerous examples exist of choice being made to heat water with fossil fuels and <u>even electricity</u>. Clearly further review of incentives for this sector and possible elimination of duty and consumption tax exemptions on certain energy using equipment should be undertaken.

<u>Development of an Implementation Plan</u>. Development of a solar (and wind and bagasse) implementation plan could produce a substantial benefit in stimulating growth in use of each of these sources. Such a plan could establish goals and note markets, recommend incentives, identify need for economic assistance, and

establish the Government's priority by providing a budget for implementation and further analysis.[1]

A Renewable Resource and Conservation Conference and Technology Show in Barbados to demonstrate equipment, explain economics and share information on experiences elsewhere, could be very useful as well. Such a show could potentially reach the regional CARICOM market and include wind and conservation devices and approaches appropriate to the smaller countries with needs similar to Barbados.

4.3.3 BAGASSE AS AN ENERGY SOURCE

Bagasse, the sugar cane waste after removal of cane juice, has historically been the primary fuel used for the refining of sugar in Barbados. During the sugar cane harvesting season (15 - 20 weeks from February - June), eight sugar factories operate 5-6 days per week 24 hours per day. Bagasse provides the fuel for the generation of steam to drive mill machinery, boil the sugar and generate electricity.

Sugar production remains a major economic sector in Barbados, accounting directly for some 7% of GDP in 1980. Production has varied significantly, however, over the last nine years from a high of 134.6 thousand tonnes in 1971 to as low as 96.9 thousand in 1975. 1980 production was very good, about 130.0 thousand tonnes. Government and the Sugar Industry have set a target goal of 150.0 thousands tonnes per year through the end of the century.

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1 The Ministry of Finance and Planning Energy Unit currently employs no engineer, nor does it have a clear assigned responsible for renewable energy technology (nor conservation for that matter).

This use of bagasse for the production of electricity has stirred considerable interest as a possible substitute for imported oil in the last few years. In order to explore this concept, a study was undertaken in 1980 to ascertain the availability of surplus bagasse as a potential electricity generation fuel.

The study found that over a 12 year period from 1968 - 1980, average surplus was about 20,950 tonnes (roughly 6% of total bagasse produced) (see Table 4.3-6). It was further found that various measures could substantially expand this surplus, most notably:

- Drying bagasse by use of a roller system
- Combustion air preheating
- Reduction in factory stops when no grinding is occurring
- Overall factory energy efficiency improvement.

At the present time there are approximately 13.3 Mw of installed-generating capacity at the eight sugar factories. The Sugar Producers Association has estimated that approximately 17.5 million kWh's* of electricity are now produced, with a peak load of about 7.3 Mw (This assumes 16 weeks of production operation and 150 hours plant operation per week).

In order to demonstrate the theoretical potential for electricity generation from surplus bagasse we have examined three scenarios below: First, use of 20,950 tonnes surplus bagasse to produce electricity; secondly, use of 20,950 tonnes surplus

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* Ref. 13

Table 4.3-6

Bagasse Use 1970 - 1980

YEAR	TONS CANE	% FIBRE* CONTENT	TONS BAGASSE PRODUCED	SURPLUS BAGASSE
1970	1,355,151	14.42	415,878	20,584
1971	1,147,354	15.19	370,910	23,474
1972	1,045,354	15.38	342,240	21,272
1973	1,073,808	16.22	370,673	23,511
1974	940,763	15.62	312,734	17,795
1975	831,669	16.05	284,079	18,437
1976	904,537	15.92	306,466	19,975
1977	1,028,886	16.47	360,640	23,603
1978	880,726	15.78	295,775	18,822
1979	1,036,537	15.42	339,860	13,433
1980	1,208,622	15.67	371,168	26,561
TOTAL	11,453,533	-	3,770,423	227,467
AVERAGE	1,041,230	15.64	342,766	20,679

* Fibre % is largely a function of the level of rainfall

Source: Study to determine the amount of excess bagasse in Barbados by D.M. Simpson and Co. (1969) ltd. (Ref. 12)

bagasse plus 18,087 tonnes (saved by combustion air preheating); and thirdly, use of the 39,037 tonnes of bagasse as in 2), but with a roller system to reduce moisture by 4 percent. The results of these examples is shown below:

1. $$\frac{(20{,}950 \text{ Tonnes} \times 2200 \text{ lbs}) \times 3{,}460 \text{ Btu/lb}}{14{,}500 \text{ Btu/kWh}^{3}} = 11.0 \text{ GWhs}$$

2. $$\frac{(39{,}037 \text{ Tonnes} \times 2200 \text{ lbs}) \times 3{,}460 \text{ Btu/lb}^{1}}{14{,}500 \text{ Btu/kWh}} = 20.5 \text{ GWhs}$$

3. $$\frac{(39{,}037 \text{ Tonnes} \times 2200 \text{ lbs}) \times 3{,}809 \text{ Btu/lb}^{2}}{14{,}500 \text{ Btu/kWh}} = 22.6 \text{ GWhs}$$

The effective capacity required to produce the above energy (assuming operation for only 16 weeks, 5 days per week and 24 hours/day) is about:

1. 6 Mw
2. 11 Mw
3. 12 Mw

To place these figures in perspective, Barbados Light and Power currently generates some 343 million kWh's per year, so that the bagasse generation would be 3 - 7 percent of generation in the scenario above. We have not specified in the above numbers the contribution which the existing 13.3 Mw of sugar factory generation might make if assigned to produce electricity from surplus bagasse.

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1 Heat content of bagasse at 48% moisture.

2 Heat content of bagasse at 44% moisture.

The figures above refer to the dedicated capacity required to fully utilize surplus bagasse, whether entirely new or partially made-up of existing generation. It should be noted that capacity requirements are halved if bagasse is stored and the power generation is extended (for example) for a period of an additional 16 weeks. In this approach even less new generation would be added as existing capacity could be more heavily used when the sugar refining season ends.

Present Prospects

Following the successful demonstration of sales of electric power from the Foursquare Sugar Factory last year, a purchase agreement has been signed with Barbados Light and Power, and prospects appear favourable for electricity sales and plant modifications. From both economic and technical prospective, the further use of surplus bagasse looks desirable and feasible. Preliminary estimates, as noted elsewhere in this report, place present prospects to generate and sell power to Barbados Light and Power at some 2.5 Mw - 3 Mw by the year 1984. Assuming a 16 week season and 5 days operation per week, this would yield some 4.8 - 5.76 million kWhs.

As far as other biomass is concerned, a study of the feasibility of ethanol production from biomass in Barbados has been commissioned with results due at the end of 1981. The National Council for Science and Technology has been a proponent of at least assessing economic feasibility.

4.4 MEXICO-VENEZUELA AND TRINIDAD AND TOBAGO OIL FACILITIES

Barbados is now encountering difficulty in keeping its refinery adequately supplied with crude. Venezuela which is the traditional major supplier served notice that in February 1981, it would reduce its crude supply by one-half and that Mexico was willing to make-up this amount. There were a number of technical difficulties with this proposal which were pointed out by Barbados authorities, resulting in a postponement in any crude supply shift. These technical problems were primarily due to the lack of flexibility of the existing small refinery to handle Mexican crude, in combination with the needed mix of domestic product demands, more specifically:

- Quantity of low octane gasoline yield versus requirements;
- Sulfur content limits in diesel and fuel oil which limit the amount of Mexican crude by type and require higher products import;
- Asphalt demand cannot be met using Mexican crude, necessitating additional higher cost asphalt purchase;
- Required additional reformate imports;
- Transport costs from Mexico would be higher, as well as, subject to greater hazard of delay, requiring more trips and smaller volumes.

At this time Venezuela continues to supply all of Barbados' crude supplies (excluding reformate from Trinidad). The Government of Barbados is continuing high level discussions with the Venezuelans and Mexicans, and with Trinidad and Tobago as a

possible substitute supplier of products, in order to reach a satisfactory resolution to this problem.[1]

The issue of most direct relevance to this Energy Assessment however, has been the examination of potential energy sector investment needs which might be met from the Venezuelan Oil Facility (or potentially in the future from either a joint US Mexico-Venezuela fund), or the Trinidad and Tobago Oil Facility.

The only immediate potential source of oil facility benefits for energy project funding could come from the Mexico-Venezuela Oil Facility. The terms of this facility provide that 30% of the purchase price of oil (FOB) could be placed in an account under the control of Barbados with interest charges levied by Venezuela of 4%/year. This concession is intended to apply only to the half of crude oil supplied by Venezuela (as required by Venezuela's San-Jose agreement with Mexico), until Mexico has begun supplying Barbados. Future oil price increases are unaffected except that 30 percent of the increase qualifies for the special oil facility treatment.

The above 30% concession may be converted to a long-term (20 year) loan at 2% interest for approved projects. The average available funds would be on the order of approximately $3.0 million/year. However, since the cost of refinery feedstocks would go up by about 5% or $4.8 Million Bds/year (excluding several hundred thousand dollars additional for asphalt purchases), there

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1 This issue is discussed in more detail in a recent NORCONSULT report to the Government of Barbados. (Ref. 19)

would be a net increase in cost of roughly $1.8 million Bds per year.[1]

The Trinidad and Tobago Oil Facility has several essential differences from the Mexico-Venezuela proposal. First, Trinidad and Tobago would base their arrangement on the supply of petroleum products - not crude. This raises the issue of the relative advantages and disadvantages of Barbados continuing to operate the small Mobil Oil refinery. This issue is discussed later in more detail, but our basic conclusion based on economic and security of supply considerations is that the refinery is a substantial net loser. This loss is magnified if one includes the higher cost of its continued operation under the Mexico-Venezuela proposals, as opposed to the Trinidad Facility as explained below.

Secondly, the Trinidad and Tobago proposal intends to maintain Caricom payments at the level applying on January 1, 1979, with subsequent price increases taken up as a loan. Given current prices this amounts to loans on the order of 50% of current prices (for the four major products). This proposal provides for 100% of future petroleum price increases to be taken up as loan aid.

Third, the terms of the Trinidad and Tobago loans would be to provide 15 years for repayment with a three year grace period and interest rates of 3%, based in Barbados' status as a More Developed Country.

At this time apparently only the LPG imports from Trinidad and Tobago appear to qualify under this facility, amounting to

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1 Ministry of Trade and Industry, internal report estimate, 27/4/81.

approximately $2.4 million in potential facility loans. Reformate does not qualify as a petroleum product under the facility.[2]

Urgent evaluation of the benefits of switching to Trinidad and Tobago Oil product imports, phasing out of the Mobil refinery and sales and export arrangements for domestic crude (or direct utility firing of crude), among other matters, is called for.

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2 Letter from Permanent Secretary, Ministry of Caribbean Community Affairs, Trinidad and Tobago, April 28, 1981.

5. ENERGY SUPPLY-DEMAND BALANCES

5.1 CURRENT ENERGY CONSUMPTION

An energy balance presents an integrated view of energy supplies on the one hand, represented by domestic production of fuels and electricity as detailed in Chapter 4, and of energy demand on the other, obtained from sales information furnished by major distributors of liquid fuels, LPG and natural gas, and sales records of the public utility. In addition, a better understanding of the use of energy resources by major consumers was obtained during the course of this assessment, via a survey of residential energy use, numerous interviews with large industrial and commercial energy consumers and analytical work done by the assessment team. (See Appendices F, G. I and J.)

The differences between total fuels consumed internally by end-users and that supplied by domestic sources and imports fall into three main categories: re-exports (which in the case of Barbados mostly consist of sales of aviation and marine bunkers), changes in stocks (either at the refinery or with the fuel distributors) and lastly, energy losses that occur at any of several points in the energy system: refining of crude oil into petroleum products, production of electricity, distribution of fuels and natural gas, and in the transmission and distribution of electricity. In the case of natural gas, production in the last four years has surpassed sales to customers and other users such as the refinery and the utility by a factor of three. The remainder is reinjected, flared or used in production.

Table 5.1.1 is an energy balance that has been constructed for 1979 in the OECD Energy Balance Framework. An energy supply sector shows production, imports, re-exports and changes in stocks for all fuels, including biomass (bagasse, wood and charcoal) and solar energy. Final use is disaggregated into the following categories: agriculture, sugar cane industry, manufacturing, transportation, hotels, commercial, residential, public, other and non-energy use of petroleum products (asphalts for road paving). The energy transformation sector consists of energy inputs and outputs to refining, electric generation and oil and gas production. The tabulated information is shown in a Reference Energy System format in Figure 5.1-1. This format is a configuration of the flows of energy for the year 1979 from resource to end-use, in which energy conversion and other losses are indicated by efficiencies. Thus the total inputs to the electric utility of 95.9 thousand toe and linked to utility sales of electricity of 23.5 thousand toe by the conversion efficiency of the generation equipment of 0.28 and the transmission and distribution efficiency of 0.86.

Total domestic consumption in 1979 amounted to 256.41 thousand toe (excluding reexports), of which 72 percent are oil products, 25 percent the bagasse used in sugar mills and the remaining 4 percent natural gas, wood (and charcoal) and solar. As shown in Table 5.1-2, the largest consumer of energy at the end-use is the agriculture/sugar milling sector at 37% of total energy, most of which is bagasse. The transportation sector uses 32% of total final demand, all of which is gasolene and auto diesel. The residential sector consumers 14% (part of which is wood and charcoal), manufacturing 7 percent, commercial/government 6 percent and tourism (directly via hotels and restaurants only) 4 percent. The second column tabulated shows the breakdown of oil and natural gas use by sector of economic activity; in this case, demand for electricity is added in terms of the oil required in

Figure 5.1-1

ENERGY BALANCE-BARBADOS (THOUSAND TOE)
YEAR 1979

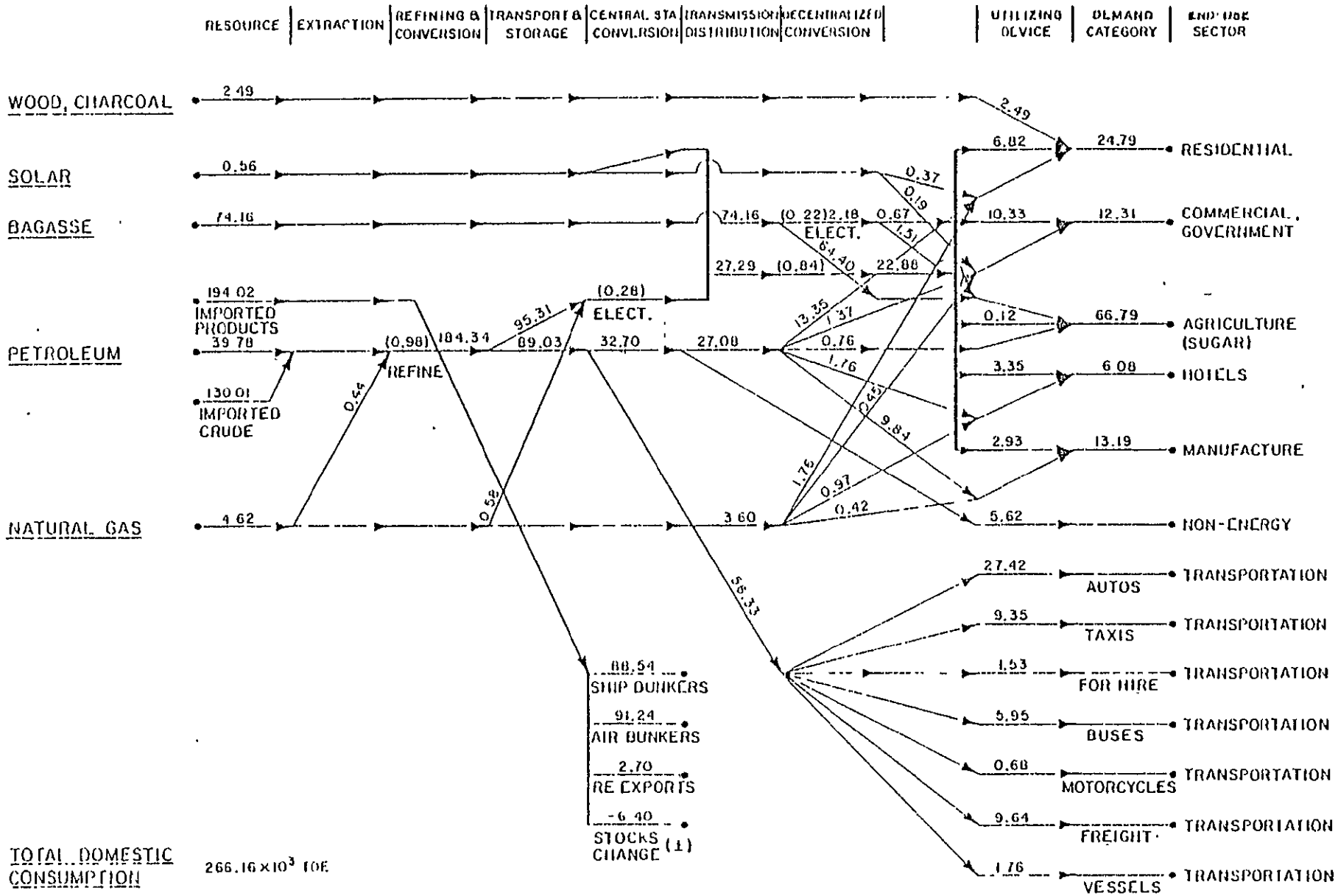

TABLE 5.1-1 BARBADOS ENERGY COMMODITY BALANCE 1979
(T. O. E.)

	Crude Oil	Reformate	Gasoline	Kerosene	Auto Diesel	Ind. Diesel	Fuel/Gas Oil	Asphalt	L.P.G.	Natural Gas	Elect.	Biomass	Other
Domestic Production (+)	39779	-	-	-	-	-	-	-	-	14340	-	76918	809
Imports (+)	103,914	26097	-	91109	2766	33685	54893	1465	10104	-	-	-	-
Exports (-)	-	-	-	-8	--	-2695	-2	-	-	-	-	-	-
Marine/Aviation Bunkers (-)	-	-	-	-91237	-	-30997	-57543	-	-	-	-	-	-
Stocks (+/-)	5138	1613	318	-163	316	-5	-1265	-486	-68	-	-	-267	-
T.E.R. (1+2-3-4±5)	148,831	27710	318	-299	3082	-12	-3827	979	10036	14341		76651	809
Statistical Discrepancy	2,734	508	-44	-135	-30	-86	-71	-145	-	-	-	-	-
Electricity Generation	-	-	-	-	-19505	-	-75809	-	-	-579	29458	-9765	-
Refinery	-151,566	-28217	42122	7280	30474	4863	85146	4787	-	-441	-	-	-
Energy Sector Use and Loss	-	-	-73	-	-17	-	-	-	-	-9745	-4492	-	-
Final Use	-	-	42323	6846	14004	4765	5439	5620	10036	3596	24966	66886	809
(I) Agriculture	-	-	-	4	-	740	-	-	-	-	9	-	-
(II) Sugar Cane Milling	-	-	-	-	-	16	-	-	-	-	1528	64397	-
(III) Manufacturing		-	-	798	-	3335	4763	-	948	421	2933	-	-
(IV) Transportation		-	42323	-	14004	-	-	-	-	-	-	-	-
(V) Hotels	-	-	-	-	-	220	63	-	1474	967	3354	-	440
(VI) Commercial	-	-	-	-	-	156	-	-	11	37	5959	-	-
(VII) Residential	-	-	-	6028	-	-	-	-	7322	1763	6820	2489	369
(VIII) Public	-	-	-	9	-	264	613	-	280	408	3026	-	-
(IX) Other	-	-	-	7	-	29	-	-	-	-	1337	-	-
(X) Non-Energy Use		-	-	-	-	-	-	5620	-	-	-	-	-

TABLE 5.1-2

SUMMARY OF DOMESTIC ENERGY USE BY SECTOR
(TONNES OF OIL EQUIVALENT - T.O.E.)

	Total Energy at End-Use	% of Total	Oil and Natural Gas Consumption	% of Total
Residential	24,791	14	42,142	23
Tourism	6,328	4	16,390	9
Commerce/Govt.	10,763	6	37,718	21
Manufacturing	13,198	7	21,997	12
Agriculture	66,690	37	6,904	4
Transport	56,327	32	56,327	31
Other				
Total	178,097	100	181,478	100
Electric Utility Losses	74,803			75
Refinery Losses	5,111			3

1 This column includes only fossil fuel use; electricity is converted to the equivalent amount of oil consumed to generate it at the rateof 4 toe of oil = 1 toe of electricity.

its generation (i.e. "oil equivalent"). This shows that the transport sector consumes 31 percent of oil resources, the residential sector 23 percent and commerce/government 21 percent (reflecting the large component of electricity in this sector's end-use energy demand). Manufacturing and tourism consume 12 percent and 9 percent of oil resources respectively, and agriculture/sugar milling 4 percent (reflecting the large portions of its energy needs met by bagasse, excluded from this computation.)

5.1.1 RESIDENTIAL ENERGY USE

Relative to other developing countries, the share of commercial fuels used by the residential sector in Barbados is quite large. A number of factors contribute to this fact: small average household size (due to population growth rate of less than 1% per year) means there are more households, and consequently higher energy use for a given population; high per capita income and population density has led to electrification of over 90% of households; finally, traditionally heavy energy use sectors (such as industry) are not as energy intensive in Barbados as in many other nations. The household sector, excluding private transport, accounts for about 23 percent of total domestic oil consumption (Table 5.1-2). Recent trends in electrification of households (now about 92 percent - Ref. 16) and shifts from traditional fuels such as kerosene and charcoal and wood, have also increased energy requirements substantially. While only 26% of households, for example, used LPG or natural gas in 1970, some 70-80 percent now use these fuels (primarily for cooking and water heat). Refrigeration is now widespread, as are televisions, electric irons, and electric lights.

Information from our Residential Household Survey clearly shows the predominance of refrigeration (43%), lighting (17%), and television (15%), as major electric energy users. (Table 5.1-3

TABLE 5.1-3

PROFILE OF "AVERAGE" ELECTRICITY USER

APPLIANCE	NUMBER PER HOUSEHOLD (SATURATION)	ELECTRICITY USE PER AVERAGE HOUSEHOLD
Stove	0.02	29
Refrigerator	1.00	565
Frost-free	(0.07)	(137)
Large	(0.33)	(213)
Small	(0.60)	(215)
Water Heat	0.04	97
Lighting	0.92	225
Television	0.66	205
Electric Irons	0.73	81
Radio Stereo	0.40	44
Food Freezer	0.02	36
Air Conditioners	0.00	0
Vacuum Cleaners	0.11	37
Washing Machine	0.08	7
Sewing Machine	0.09	2
		1328

illustrates the saturation of different electricity using devices in the household, (see Appendix G for details.)

The overall mix of fuels used in this sector is shown in Table 5.1-4. Electricity, taking into account losses in power generation and distribution, accounts for 61% of residential fuel use; LPG 16%; kerosene 13%; natural gas 4%, and wood and charcoal 6%. Fuels other than electricity are used primarily for cooking and lighting, and in water heating.

The combination of a high level of electrification, growing income and ready availability of electricity using consumer products, makes potential future growth in energy use an extremely serious energy policy problem in this sector. Even given the relatively high proportion of total end-use energy accounted for by the residential sector, average elecrical usage per household (1328 KWH's in 1979) is still modest by international comparison.

5.1.2 COMMERCIAL AND TOURISM ENERGY USE

Tourism, Commerce and Government combined, accounted for some 30 percent of oil and gas consumption in 1979. (Table 5.1-2). The predominant use in these sectors was for air-conditioning and lighting, with a large use of electricity for water pumping in the Government Sector. Electricity constitutes a large proportion of total oil and gas derived energy use, 82% for Tourism and 95% in Commerce/Government. Table 5.1-5 summarizes this information (for details, see Appendix I).

Energy is used in this sector primarily as a source of space conditioning and lighting, with refrigeration, water heating and cooking also contributing, but at fairly low levels. The growth of this energy use is dependent largely on the number of new buildings constructed, the energy intensity of these buildings,

TABLE 5.1-4

RESIDENTIAL FUEL USE

DISTRIBUTION BY FUEL AND END USE (T.O.E.)

Year 1979

	Electricity[1]	Natural Gas	LPG	Kerosene	Wood or Charcoal	Solar	Total
Cooking	828	1,294	6,470	4,031	2,489	-	15,062
Refrigeration	11,364	-	-	-	-	-	11,364
Water Heat	2,768	469	830	-	-	369	4,436
Lighting	4,559	-	-	1,961	-	-	6,520
Other	7,764	-	-	-	-	-	7,764
Total	27,280	1,763	7,300	5,992	2,489	369	45,146
	61%	4%	16%	13%	6%	-	

1 Expressed in oil equivalent assuming 1 toe electricity = 4 toe of oil.

TABLE 5.1-5

COMMERCIAL, GOVERNMENT AND TOURISM

ENERGY USE (TOE) 1979 [2]

	Electricity[1]	LPG	Diesel & Fuel Oil	Natural Gas	Solar
Commercial					
Air Conditioning	10,432				
Refrigeration	1,864				
Other	14,836	11	156	37	NA
Government					
Water Pumping	8,444	--	--	--	--
Public Works			964	--	--
Other	2,776	--	--	--	--
Hotels	13,416	1,462	271	967	NA
	51,768	1,473	1,391	1,004	NA

1 Expressed as fossil fuel equivalent.

2 Source: Energy Balances for commercial sector, government sector, tourism/hotels sector. There are slight discrepancies between those sources and the Energy Commodities Balance in Table 5.1-1.

and the usage of the overall stock of buildings as measured by tourist visitors and government employment.

5.1.3 MANUFACTURING AND AGRICULTURAL ENERGY USE

Manufacturing in Barbados is made up primarily of light-medium energy intensity type activities. Very rapid growth in this sector has caused a relative increase in its size, but it still accounts for only some 7 percent of total final energy use, and 12 percent of oil and natural gas resources consumed.

A major energy consuming subsector is Food and Beverages production, which consumes 49 percent of the total, in the form of fuel oil, 53 percent, diesel, 25 percent, gas and LPG, 4 percent, and electricity, 17 percent (see Table 5.1-6). There are an estimated 44 plants in this category in Barbados, with alcoholic beverages and dairy products of particular importance.

The Electronic Products sector is the fastest growing subsector, mainly as enclave or export enterprises with foreign ownership numbering about 18 firms. It uses 20 percent of the electricity used in the manufacturing sector, or 10 percent of the "oil equivalent" total used in the sector.

The Construction industry also grows very rapidly, with the public sector expenditures in construction growing by nearly 40 percent in 1980. Major government projects included the Bridgetown Sewage Plant, the Samuel Jackman Prescod Polytechnic, the new General Post Office and the National Housing Corporation housing projects. Private Sector construction is estimated to have increased by about 20 percent during 1980, based on the Ministry of Housing Quarterly Survey of Private Contractors.

TABLE 5.1-6

ENERGY USE IN MANUFACTURING AND AGRICULTURE 1979

	Electricity[1]	Ind Diesel	Fuel Oil	Natural Gas	Bagasse	Other[2]
Food & Beverages	1117	1643	3411	202	--	47
Construction	--	1297	477	--	--	213
Chemicals	404	149	--	219	--	100
Textiles	403	--	490	--	--	--
Electronics	576	--	--	--	--	--
Metal & Machinery	36	228	--	--	--	43
Other Manufacturing	397	68	385	--	--	1343
Sugar & Other Agriculture	123	706	--	--	64,397	45
		4091	4763	421	64,397	1791

1 Electricity purchased from BL&P

2 Kerosene, LPG etc.

Applications approved by the Chief Town Planner for erection of new buildings totalled 613 during 1980. Accommodation in the hotel industry grew by some 692 beds in 1980. Of this amount 304 were created in the Apartment/Hotel sub-sector and 388 in the Apartment subsector.

The construction industry consumes 15 percent of total energy of this sector, mostly industrial diesel fueling industrial equipment. Appendices F and J contain detailed information on the manufacturing sector energy use.

Agriculture energy use is dominated by bagasse use for process heat and electricity generation in sugar refining. The energy content of the bagasse amounts to 25 percent of total domestic consumption from all energy sources on the island. The sugar industry uses bagasse as a fuel for the generation of steam to provide motive power to drive equipment for milling, generate electricity and provide heat for boiling the cane juice to produce sugar. In addition, oil products used by the sugar industry and the rest of the agriculture sector amount to 4 percent of total oil use, mostly in the form of electricity purchased by the sugar industry.

5.1.4 TRANSPORTATION SECTOR ENERGY USE

Transport is the largest energy using sector in the economy, 32%, when one considers only oil and gas fuel use. Transport therefore constitutes an important area for energy policy. Very little energy policy consideration however has been given to this sector to date, although various implicit government energy policies impact it.

Table 5.1-7 shows the distribution of fuels by different types of users in transport. One can see the dominate role of

TABLE 5.1-7

TRANSPORT SECTOR

1979 ENERGY USE

DEMAND CATEGORY	UTILIZING DEVICE	GASOLINE TOE	DIESEL TOE	TOTAL TOE
Private Cars & Vans (1)	Gasoline Engine	27,424		27,424
Govt/Commercial Cars & Vans (2)	"	2,688		2,688
Rental Cars (3)	"	1,527		1,527
Motorcycles (4)	"	682		682
Minibuses (5)	"	1,042		1,042
Taxis (6)	"	9,353		9,353
Buses (Transport Board) (7)	Diesel Engine		4,904	4,904
Lorries & Trucks (8)			5,808	5,808
Other Vehicles (Misc.) (9)			1,539	1,539
Fishing Boats (10)			1,764	1,764
TOTALS		42,323	14,004	56,327

(1) Assumes $1508 (Bbds)/yr average household expenditure on gasoline (source pilot household survey). This implies 395 gals/yr. per vehicle at $3.82/gal. Total vehicle stock of cars and vans as reported in registration statistics is 25,005 of these 124 are minibuses, 1194 Govt/commercial vehicles and 995 rental cars (all figures approximate). Estimated average fuel consumption is 23 mpg; estimated average distance traveled is 9000 miles/yr.

(2) Assumes that [illegible]% of registered cars and vans (excluding minibuses) fall in this category. Estimated 23 mpg and 20,000 miles/yr.

(3) Assumes that 4% of registered cars and vans (excluding minibuses) fall in this category. Estimated 24 mpg based on survey data. Estimated 12,000 miles/yr, also based on fleet owners survey size of rental fleet estimated from Wilburn Smith & Associates Transport study.

(4) Assumes 6000 miles/yr at 70 mpg. average. Motorcycles registered in 1979 were 2598.

(5) Approx. 40,000 miles/yr per minibuses (estimated from Wilburn Smith & Associates Report); 13 mpg average estimated from typical vehicle size, load, driving conditions. 124 minibuses - from transport data.

(6) 1979 registered taxis - 1413 Estimated additional 10% unregistered (sources: Wilbur Smith Report; Transport Department). Total fleet 1554. Average distance of 35,500 miles/year based on fleet owner survey, slightly adjusted to reflect higher average distance for non-fleet taxis. 18 mpg average fuel consumption derived from fleet owner survey data.

(7) 282 buses; 6.4 mpg average fuel consumption; 34,860 miles per year (average). All data provided in writing by Transport Board.

(8) 1452 lorries and trucks registered in 1979. We have breakdowns, by fuel consumption, but not by vehicles (source oil company reprots/questionaire response). Retail stations 769,398 gals; Industry 571,326 gals; Sugar Plantations 450,324 gals; Commerce/other: 59,556 gals; Govt 359,646 gals (of which approximately 100,000 gals for miscellaneous vehicles category).

(9) Mainly construction, farm and similar vehicles (excluding sugar). Few details available. Have used some new estimates and residuals; assume 300 gals/yr/vehicle.

(10) No breakdown of size of fleet yet available. Fuel consumption data as reported by suppliers.