UNITED NATIONS ENVIRONMENT PROGRAMME

Ocean energy potential of the West African region

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PREFACE

Ten years ago the United Nations Conference on the Human Environment (Stockholm, 5-16 June 1972) adopted the Action Plan for the Human Environment, including the General Principles for Assessment and Control of Marine Pollution. In the light of the results of the Stockholm Conference, the United Nations General Assembly decided to establish the United Nations Environment Programme (UNEP) to "serve as a focal point for environmental action and co-ordination within the United Nations system" (General Assembly resolution (XXVII) of 15 December 1972). The organizations of the United Nations system were invited "to adopt the measures that may be required to undertake concerted and co-ordinated programmes with regard to international environmental problems", and the "intergovernmental and non-governmental organizations that have an interest in the field of the environment" were also invited "to lend their full support and collaboration to the United Nations with a view to achieving the largest possible degree of co-operation and co-ordination". Subsequently, the Governing Council of UNEP chose "Oceans" as one of the priority areas in which it would focus efforts to fulfil its catalytic and co-ordinating role.

The Regional Seas Programme was initiated by UNEP in 1974. Since then the Governing Council of UNEP has repeatedly endorsed a regional approach to the control of marine pollution and the management of marine and coastal resources and has requested the development of regional action plans.

The Regional Seas Programme at present includes ten regions[1/] and has over 120 coastal States participating in it. It is conceived as an action-oriented programme having concern not only for the consequences but also for the causes of environmental degradation and encompassing a comprehensive approach to combating environmental problems through the management of marine and coastal areas. Each regional action plan is formulated according to the needs of the region as perceived by the Governments concerned. It is designed to link assessment of the quality of the marine environment and the causes of its deterioration with activities for the management and development of the marine and coastal environment. The action plans promote the parallel development of regional legal agreements and of action-oriented programme activities[2/].

At the third session of UNEP's Governing Council (1975), a number of West and Central African States requested UNEP to study the problems of marine and coastal pollution of their region. As a result of that request, UNEP's exploratory mission visited fourteen States of the region during 1976. The mission's report identified the major environmental problems of the region and recommended the development of a regional action plan for the protection and development of the marine environment and coastal areas of the region.

1/ Mediterranean, Kuwait Action Plan Region, West and Central Africa, Wider Caribbean, East Asian Seas, South-East Pacific, South Pacific, Red Sea and Gulf of Aden, East Africa and South-West Atlantic.

2/ UNEP: Achievements and planned development of UNEP's Regional Seas Programme and comparable programmes sponsored by other bodies. UNEP Regional Seas Reports and Studies No. 1. UNEP, 1982.

After considering the report of the mission, the fifth session of the Governing Council (1977) decided that "steps should be undertaken for the development of an action plan and a regional agreement to prevent and abate pollution" in the West and Central African region.

The preparatory work on the development of the action plan and the regional agreement included several expert group meetings, missions and surveys[3/] leading to the Conference of Plenipotentiaries on Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region (UNEP/IG.22/7) convened by UNEP in Abidjan, 16 - 23 March 1981 as the final stage of the preparatory work leading to the adoption of the (a) Action Plan for the protection and development of the marine environment and coastal areas of the West and Central African Region, (b) Convention for the Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region, (c) Protocol concerning co-operation in combating pollution in cases of emergency, and (d) a set of conference resolutions.

This document is one of the surveys prepared as a contribution to the development of the Action Plan.

3/ For details see:

- Report of the Executive Director on preparatory activities for an action plan for the protection and development of the marine and coastal environment in the West African Region. UNEP/IG.22/4. UNEP, 1981.

- UNIDO/UNEP: Survey of marine pollutants from industrial sources in the West and Central African Region. UNEP Regional Seas Reports and Studies No. 2. UNEP, 1982.

- UNESCO/UNEP: River inputs to the West and Central African marine environment. UNEP Regional Seas Reports and Studies No. 3. UNEP, 1982.

- IMCO/UNEP: The status of oil pollution and oil pollution control in the West and Central African Region. UNEP Regional Seas Reports and Studies No. 4. UNEP, 1982.

- UNDIESA/UNEP: Onshore impact of offshore oil and natural gas development in the West African Region. UNEP Regional Seas Reports and Studies No. 33. UNEP, 1983.

- UNDIESA/UNEP: Environmental management problems in resource utilization and survey of resources in the West African Region. UNEP Regional Seas Reports and Studies No. 37. UNEP, 1983.

CONTENTS

CONTENTS Cont.....

LIST OF FIGURES

LIST OF TABLES

CHAPTER I: INTRODUCTION

Even though the major current utilization of the ocean area as an energy source in the West African region is in the production of oil and gas from the continental shelf, ocean energy from renewable sources, particularly from favorable areas, could be of major local importance. The present profile of commercial energy production and consumption in the region is dominated by oil and gas. During the period 1971-75, the average annual production of oil and gas in the region accounted for almost ninety-nine percent of commercial energy production. Hydropower and coal accounted for the remaining one percent. The distribution of energy production in the region is also very uneven. Though the general prospects for oil and gas on the continental shelf of the region are quite good, at the present time, production is from only eight of the countries with an overwhelming proportion of it originating from Nigeria. Of the eight producing countries, three are net exporters of primary energy while the remainder are net oil importers.

The fourfold increase in OPEC oil prices in 1973-74 was, therefore, a serious blow to most of the oil importing countries in the region. The oil price rises, world economic recession, and lack of deflationary policies in several of these countries have led to large increases in their current account deficits since 1973. Since imported energy requirements at present consist almost entirely of oil, a reduction in imported oil can be achieved in the short term only at the expense of a reduction in energy supply and, in consequence, lower economic growth, because non-productive uses of oil (private transport and residential and commercial cooling) are minimal. For the oil importing countries of the region, the new level of petroleum prices has two principal long term implications:

- The development of domestic sources of petroleum that were regarded as uneconomic at pre-1973 prices now prompt endeavors to expand known oil and gas reserves; and

- the development of energy from alternative sources will lead to the substitution of petroleum-based energy supplies.

Within this context, the need for both national and regional ocean based energy development strategies is unavoidable. The main consideration in setting these strategies is a knowledge of the ocean based energy resource endowments. The countries of the region possess ocean based energy resources that are both renewable and non-renewable in character. These energy resources, however, are often either not proven or not fully developed, but these potential energy resources, if developed, could reduce or eliminate the dependence on imported energy.

It is a prime requirement of energy planning to identify these potential resources and plan for their evaluation as a viable energy source. It is in this connection that this study is undertaken, specifically in regard to renewable ocean energy sources. Though it is not expected that renewable ocean energy will replace fossil energy, the options it offers in the long-term, include the potential of extending the life of nonrenewable fossil and nuclear fuel resources as the power generated from renewable ocean sources may locally substitute for conventionally generated power.

This paper undertakes a general review of ocean energy sources of the region, the state-of-the-art in the development of technology to harness these resources and the potential benefits of ocean energy utilization. The second chapter summarizes the current status of commercial energy production and consumption in the region. Chapters III and IV provide an overview of the region's ocean energy sources and the state-of-the-art in the technology to develop these sources. The final two chapters present proposals for regional action in ocean energy resource appraisal and development.

CHAPTER II. THE STATUS OF COMMERCIAL ENERGY IN WEST AFRICA

Of the 19 coastal countries in West Africa, five are energy surplus countries (Angola, Congo, Gabon, Nigeria and Zaire) while the remainder belong to the class of energy deficient countries. The potential for domestic energy resource development in these countries is considerably diversified. Cameroon, Ghana and the Ivory Coast though not net exporters of oil are all current oil and gas producers. The potential for oil and gas is considered fairly good in Benin and fair in Sao Tome and Principé, Equatorial Guinea and Sierra Leone. Goethermal energy resource potential exists in Cameroon while moderate resources of coal are known to occur in Angola, Benin, Cameroon, Sierra Leone, Nigeria and Zaire. Energy development planning within the region is very recent and in most countries exploration and appraisal of sources other than oil and gas is almost non-existent. In most cases, therefore, knowledge of the actual energy resource endowment is in want.

PRODUCTION OF COMMERCIAL ENERGY

In order of decreasing importance, commercial energy production is dominated firstly by crude petroleum and natural gas liquids (99 per cent of commercial energy production in the period 1971-75), followed by hydropower, natural gas and coal in that order. Table 2-1 compares regional energy production to that of Africa and the world.

Table 2-I. Regional Energy Production in Comparison to Africa and the Rest of the World
(Average of Production in Years 1971-75)
(1971-75 in Thousand Metric Tons of Coal Equivalent)

Region	Total Primary Energy Production	Coal and Lignite	Crude Petroleum and Natural Gas Liquids	Hydro/ Natural Gas	Nuclear Electricity
West Africa	165,341.0	388.0	163,060.0	491.0	1,403.0
Africa	482,350.0	68,350.0	398,887.0	11,195.0	3,917.0
World	8,277,923.0	2,495,191.0	4,015,056.0	1,576,646.0	191,029.0
As percent of Africa	34.3	0.6	40.9	4.4	35.8
As percent of World	2.0	0.02	4.1	0.03	0.7

Source: World Energy Supplies

A summary of commercial energy production in the region by type during the period 1971-75 is presented in Table 2-II. During this period, eight countries recorded no commercial energy production while three more recorded less than 50,000 metric tons of coal equivalent in energy production on average each year. The following is a summary of the energy resources that have been developed.

Oil and Natural Gas

The dominant producers of commercial energy in the region are Nigeria and Gabon (both OPEC members), Angola, Congo and Zaire. The major energy source in all cases consists of oil and natural gas mostly from their continental shelves. Though Ghana, Benin and the Ivory Coast recently joined the ranks of oil producers, they still remain net importers of commercial energy. Prospects for oil and gas production in the region are encouraging. Table 2-III summarizes the potential for further oil and gas discoveries in the region.

Oil and natural gas imports account for the bulk of commercial energy imports in the region. In the cases of Benin, Cape Verde, Equatorial Guinea, Gambia, Guinea-Bissau, Senegal and Sierra Leone, oil imports accounted for all domestic commercial energy requirements while for Ghana, Ivory Coast, Cameroon, Guinea, Liberia, Togo and Zaire, it constitued the major share. Table 2-IV summarizes data on production, trade and aggregate supply of commercial energy in all countries for the period 1971-75.

Table 2-II. Average Annual Production of Commercial Energy (1971-75 in Thousand Metric Tons of Coal Equivalent)

Country	Total Primary Energy Production	Coal and Lignite	Crude Petroleum and Natural Gas Liquids	Natural Gas	Hydro/ Nuclear Electricity
Angola	11,121.0	-	11,025.0	-	96.0
Benin	-	-	-	-	-
Cameroon	137.0	-	-	-	137.0
Cape Verde	-	-	-	-	-
Congo	1,994.0	-	1,966.0	22.0	7.0
Equitorial Guinea	-	-	-	-	-
Gabon	12,185.0	-	12,132.0	53.0	1.0
Gambia	-	-	-	-	-
Ghana	443.0	-	-	-	443.0
Guinea	4.0	-	-	-	4.0
Guinea-Bissau					
Ivory Coast	27.0	-	-	-	27.0
Liberia	36.0	-	-	-	36.0
Namibia	N/A	N/A	N/A	N/A	N/A
Nigeria	138,832.0	280.0	137,909.0	417.0	226.0
Senegal	-	-	-	-	-
Sierra Leone	-	-	-	-	-
Togo	-	-	-	-	-
Zaire	562.0	108.0	28.0	-	426.0
Regional Totals	165,341.0	388.0	163,060.0	492.0	1,403.0

N/A: Not Available
Source: World Energy Supplies

Table 2-III. Potential for Further Oil and Gas Discoveries

Good to Very Good	Good	Fairly Good	Fair	Poor to Moderate
Angola	Cameroon	Ivory Coast (1)	Sao Tome and Principe	
Congo		Ghana (1)	Equatorial Guinea	
Gabon		Benin (1)	Togo	
Nigeria		Chad	Sengal	
Zaire			Gambia	
			Guinea	
			Sierra Leone	
			Guinea-Bissau	
			Cape Verde	

Source: Energy options and Policy issues in Developing Countries. World Bank Staff working paper No. 350 August 1979.

(1) Joined the ranks of producers recently.

Table 2-IV. Production, Trade and Aggregate Supply of Commercial Energy (Average of years 1971-75 in thousand metric tons of coal equivalent)

Country	Primary Production	Imports	Exports	Bunkers	Aggregate Supply
Angola	11,121.0	445.0	9,938.0	396.0	1,115.0
Benin	-	141.0	-	-	141.0
Cameroon	137.0	496.0	-	72.0	561.0
Cape Verde	-	362.0	-	343.0	18.0
Congo	1,994.0	251.0	1,939.0	6.0	274.0
Equatorial Guinea	-	28.0	-	-	28.0
Gabon	12,185.0	9.0	11,597.0	N/A	498.0
Gambia	-	37.0	6.0	-	32.0
Ghana	443.0	1,664.0	338.0	57.0	1,578.0
Guinea	4.0	398.0	-	N/A	401.0
Guinea-Bissau	-	37.0	-	-	37.0
Ivory Coast	27.0	1,883.0	181.0	105.0	1,627.0
Liberia	36.0	789.0	2.0	108.0	670.0
Namibia	N/A	N/A	N/A	N/A	N/A
Nigeria	138,832.0	569.0	133,577.0	54.0	4,778.0
Senegal	-	2,195.0	86.0	1,442.0	673.0
Sierra Leone	-	538.0	15.0	207.0	298.0
Togo	-	160.0	-	3.0	157.0
Zaire	562.0	1,843.0	324.0	110.0	
Regional Totals	165,341.0	11,847.0	158,053.0	2,903.0	14,807.0

N/A: Not available
Source: World Energy Supplies

Hydropower

Hydropower sources accounted for only a small proportion of the energy mix in the region. Hydropower is generated in over half of the countries (Angola, Cameroon, Congo, Gabon, Ghana, Guinea, Ivory Coast, Liberia, Nigeria and Zaire) though Cameroon, Ghana, Nigeria and Zaire produce almost ninety percent of regional output. Though data on hydropower capacities are not readily available for all countries, it is generally accepted that the region is fairly well endowed with respect to such sources. Plans are under way to increase hydropower capacities in at least four countries (Angola, Ghana, Ivory Coast and Zaire). Hydropower production from the region amounts to over thirty-five percent of total African production.

Coal

Coal production in the region is limited to Zaire and Nigeria. Though the region is not considered a significant repository of coal at the present time, the degree of exploration for coal in most countries is in no instance satisfactory. The results of the few exploration programs undertaken in the region suggest that moderate amounts of the resource may be found in Nigeria, Angola, Benin, Cameroon, Sierra Leone and Zaire. Coal production from the region amounts to less than one percent of African coal production and represents a miniscule proportion of world production (see Table 2-I).

ENERGY CONSUMPTION

Per capita energy consumption in the region is quite low. It ranges from a little over sixty kilograms per capita in energy deficient Gambia to over nine hundred and fifty kilograms in Gabon. Energy consumption is dominated by liquid fuels, followed by hydropower, solid fuels and natural gas. If the efforts to industrialize in many of these countries is not to be thwarted, the need to radically improve per capita consumption is obvious. Table 2-V summarizes data on commercial energy consumption by energy type for the years 1971-1975.

CAPITAL REQUIREMENTS FOR POWER GENERATION

In a recent study commissioned by the International Bank for Reconstruction and Development (IBRD), required capital expenditures for power facilities commissioned during the period 1977-1990 were forecasted using estimates of system unit costs (including an amount for transmission and distribution facilities) in 1977 U.S. dollars. These estimates which represent the capital costs to electrical utilities indicate that the average unit cost for small installations in scattered systems in West Africa is about $1,572 per kilowatt. Estimates for predominantly hydro systems were determined to be in the range of $2,500 per kilowatt for small installations.[1]

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[1] "Energy Options and Policy Issues in Developing Countries", World Bank Staff Working Paper, August 1979.

Table 2-V: Average Annual Consumption of Commercial Energy
(In Thousand Metric Tons of Coal Equivalent and for Years 1971-1975)

Country	Per Capita Energy Consumption (in Kilograms)	Solid Fuels	Liquid Fuels	Natural Gas	Hydro/ Nuclear Electicity
Angola	184.6	7.0[1]	1,014.0	-	94.0
Benin	47.8	-	141.0	-	-
Cameroon	90.6	1.0	423.0	-	137.0
Cape Verde	65.4	-	18.0	-	-
Congo	214.0	-	245.0	22.0	7.0
Equatorial Guinea	96.2	-	28.0	-	-
Gabon	965.2	-	444.0	53.0	1.0
Gambia	63.2	-	32.0	-	-
Ghana	168.2	7.0	1,127.0	-	444.0
Guinea	95.6	-	398.0	-	3.0
Guinea-Bissau	72.0	-	37.0	-	-
Ivory Coast	349.2	-	1,600.0	-	27.0
Liberia	410.2	-	633.0	-	37.0
Namibia	N/A	N/A	N/A	N/A	N/A
Nigeria	79.6	270.0	3,865.0	417.0	226.0
Senegal	170.0	-	673.0	-	-
Sierra Leone	111.4	-	298.0	-	-
Togo	74.2	-	157.0	-	-
Zaire	81.4	438.0	1,050.0	-	433.0
Regional Totals	113.0	720.0	12,183.0	492.0	1,410.0

N/A: Not Available
Source: World Energy Supplies
[1] Average of Years 1971, 1972 and 1973

SUMMARY

The indigenous and conventional energy resources of the region tend to be concentrated in a minority of countries with the clear majority of countries remaining net importers of energy. The heavy dependence upon fossil fuels have had a great impact on the economies of these net importing countries rendering alternative sources of energy vital components of the future development of these countries. Chapter III identifies the ocean renewable energy resources and technologies available to the West African Region.

CHAPTER III: SURVEY OF ALTERNATIVE OCEAN ENERGY SOURCES FOR THE WEST AFRICAN REGION

INTRODUCTION

This chapter presents the leading technologies that have been developed to exploit the renewable sources of energy in the oceans, as specifically applied to offshore areas in the West African Region. On a daily basis, a tremendous amount of dispersed energy goes untapped, just as it has in the past, but the advent of rising fossil fuel prices and associated environmental concerns have prompted innovative research and development to capture this unharnessed energy resource. History is quite replete of experiments and small scale projects using ocean energy sources, even as far back as the Tenth Century. This survey presents a broad overview of the more appropriate technologies for a West African regional action on ocean energy.

A tremendous volume of technical and economic literature exists on the technologies covered by this paper, but unfortunately very little of the information is site specific, and does not address the prevailing characteristics of the West African Region. However, most of the available research and experience to date can be applied to oceanographic and environmental work that has been performed, and will be performed in the future, concerning the West African Region.

Ocean energy sources encompass quite a few phenomena of the ocean, some that are very obvious to the lay person and some not so obvious. The obvious ocean energy sources would include the tides, waves and wind, while the less obvious would be the ocean thermal gradients exchange, salinity gradient energy conversion process, and oceanic bioconversion. Each of these ocean energy sources and the leading technologies to exploit them will be discussed within this chapter, but it is important to note some characteristics common to all such sources:

- All ocean energy sources are dispersed and are fuel free.
- All require either extensive capital or extensive labor.
- All have either no negative environmental impact or a very minimal one.
- All require limited local infrastructure to either build, operate or maintain.
- All of the sources are renewable and incapable of being restricted, altered or deprived from the user.
- All require either a local management of resource (at a minimum) and ideally, a regional management for the conservation and wise use of the resource.

Finally, it is important to note that the end product of the ocean energy sources may be in the form of either mechanical, electrical, chemical or protein energy, thus serving a wide range of energy needs.

There presently is an estimated $60 million (U.S.$) of research and development being conducted worldwide, predominately by the United States, Japan, the Soviet Union and some European countries. The Developing Countries may anticipate being the initial beneficiaries of this research and development for three reasons. First, as presented in Chapter I, the comparable cost of power ($1500 - 2500/kW) in the West African Region is commensurate with the cost of delivered power that these initial technologies will deliver. Thus, the technology promoters will seek initial locations where their units can be economically competive with existing alternatives. Second, the initial units will be on a much smaller scale than eventually desired for applications in industrialized nations, but this initial small scale represents a commercial scale or operation in many developing countries. Third, some Developing Countries are adjacent to much greater ocean energy resources than the States developing the technology; thus these States will seek to operate the initial units where the oceanic resource conditions are optimal.

OCEAN THERMAL ENERGY CONVERSION

The ocean energy technology that has received the most research and development has been Ocean Thermal Energy Conversion (OTEC). OTEC technology seeks to exploit the thermal differences between the warm surface waters (26°C) and the colder (4.5°C) subsurface waters (at 1000 m) of the ocean. In essence, the renewable energy resource is created by the ocean surface acting as a solar collector to store the daily insolation, while the colder subsurface waters result from the cold and dense polar waters gradually moving towards the equator. Naturally the thermal differences are greatest near the Equator but are still adequate as far south as 10°S and 15°N. Figure 3-1 illustrates the ocean thermal resources zone in the West African Region for the thermal gradients between the surface and a 1000-m depth.

The general criteria for attractive sites would include the following:

- Primarily a high thermal gradient with a mean coldest month of 16.7°C and a mean annual temperature of 20°C.
- Bottom depths of less than 1500 meters for mooring.
- Minimal distance to shore from a depth of 1000 meters.
- Currents sufficient to provide adequate cold and warm water sources and to provide for dispersion of modified water.
- Light winds, minimum sea and swell and the lack of severe storms.

The thermal energy resource for the West African Region is one of the largest in terms of size and thermal gradients and is especially attractive since the necessary thermal gradients can be achieved at a relatively close distance from shore. This is attributed to

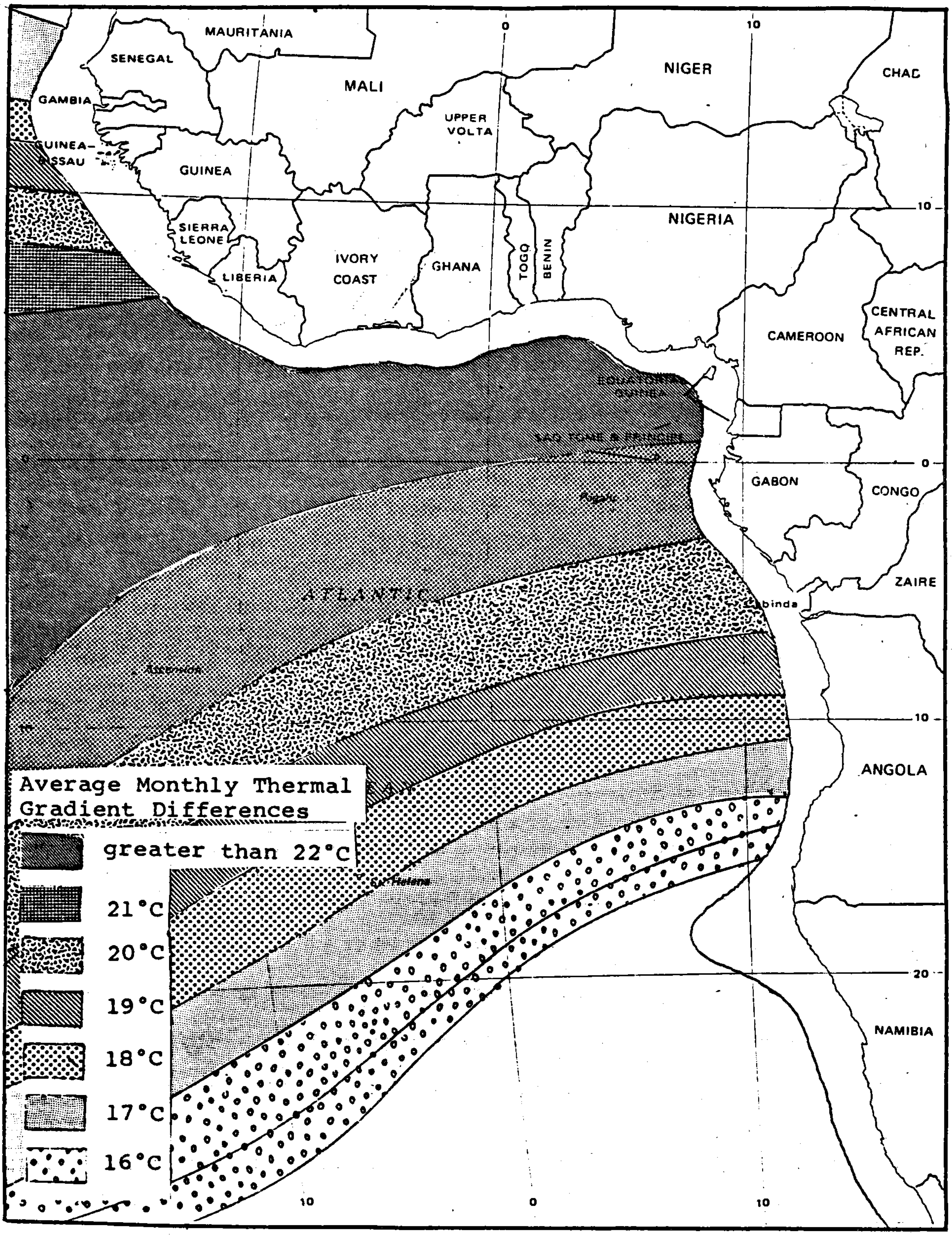
MAURITANIA
SENEGAL
GAMBIA
GUINEA-BISSAU
MALI
NIGER
CHAD
UPPER VOLTA
GUINEA
SIERRA LEONE
LIBERIA
IVORY COAST
GHANA
TOGO
BENIN
NIGERIA
CAMEROON
CENTRAL AFRICAN REP.
GABON
CONGO
ZAIRE
Cabinda
ANGOLA
NAMIBIA
ATLANTIC
Average Monthly Thermal Gradient Differences
greater than 22°C
21°C
20°C
19°C
18°C
17°C
16°C
0
10
20

Figure 3-1.

the steep continental shelf of the region and the small current speeds through the Gulf. The only site specific OTEC resource assessment found in the literature for the West African Region was prepared for the Ivory Coast; it bears stating here in that it is encouraging for future consideration for the Gulf as a whole.

The mean temperature difference ($\triangle T°$) at 1000 meters is 22°C and a $\triangle T°$ of 20°C can be reached at a depth of only 600 meters. (This means that the cold water pipe, an expensive and challenging subsystem of an OTEC would be 40% shorter and much less expensive.) Waters of 1000 meters are available within 35 kilometers. Sea, swell and currents do not pose any particular problems and strong winds and tropical storms are a rare occurence. There is a problem of less than desirable mixing of the ocean's layer depths, i.e., the depth at which the temperature first becomes colder than the surface temperature by 1°C. This is attributed to the vertical thermal gradient off the Ivory Coast being very strong in the first 50 meters below the surface but, because of light winds and lack of wave mixing from January through March, there is often no mixed layer depth during this period. When an upper mixed layer exists, its depth is generally very shallow. Thus an OTEC would need to reinject its cold water discharge sufficiently below the surface to avoid having it recirculate back to the OTEC intake.

On the whole, the West African Region is ranked as an excellent resource site for OTEC.

OTEC has technically received more research and development attention during the 1970's than any other ocean energy resource. The ocean thermal gradients can be exploited by two different types of engine cycles, using basically the same type of facility. The first engine cycle is the Rankine thermodynamic cycle that has received the predominant amount of research. The Rankine cycle utilizes a working fluid, such as ammonia, which is capable of evaporating and condensing over small temperature ranges. It is often called the closed cycle since the working fluid is constantly retained within the heat exchange cycle. This approach has been chosen because it presents the best balance between economics and technical risks to achieve commercial OTEC performance goals in an early timeframe. The closed-cycle system is shown schematically in Figure 3-2.

In the configuration illustrated, warm ocean surface waters are pumped into the OTEC plant, where ammonia is vaporized in a large evaporator. The expanding ammonia vapor drives a low-pressure gas turbine, which powers electrical generators. The exhaust vapor then passes into a condenser which is cooled by sea water pumped from depths of about 3,000 feet. The condensed ammonia, again a liquid, is pumped back to the evaporator, and the cycle is repeated. The baseload power produced can be transmitted ashore by submarine cable. An alternative to transmission ashore is to manufacture energy-intensive products on or near the OTEC plant. One such energy-intensive production is the production of ammonia

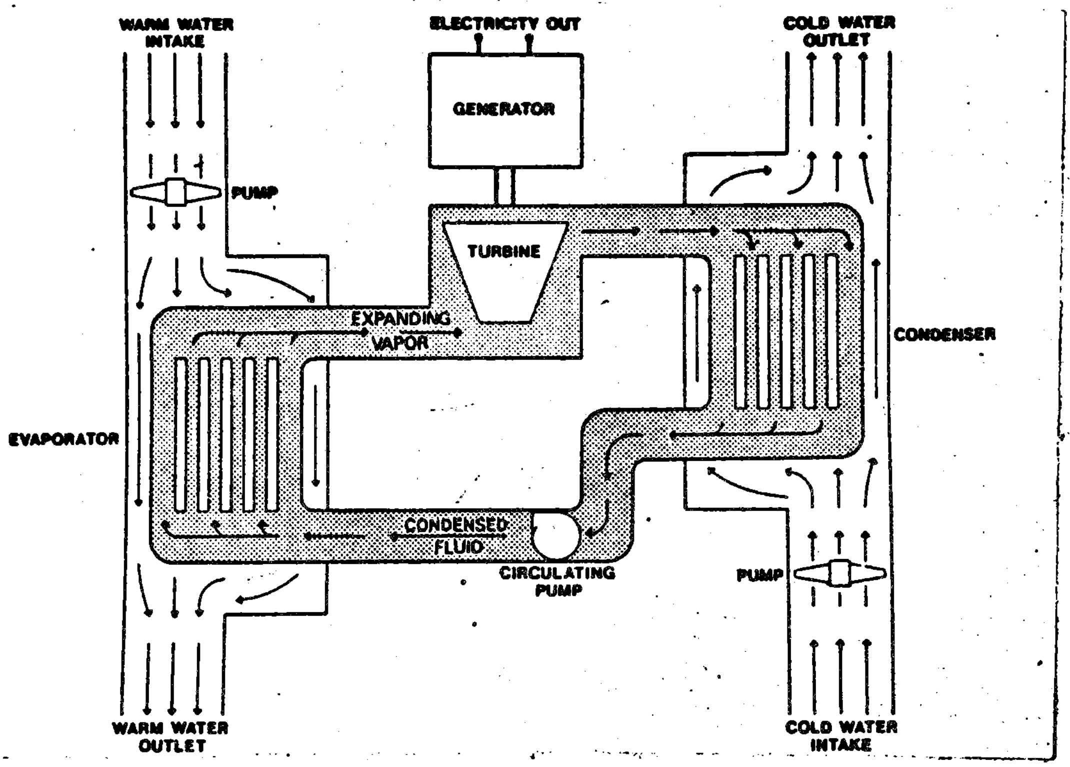

Figure 3-2. OTEC Closed Cycle System Schematic (For Electric Power Generation)

by electrolysis of seawater to produce hydrogen and then adding nitrogen from the ambient air to produce ammonia. This product could be used in the production of nitrogenous fertilizer for agricultural purposes.

The other major technology, the open cycle, lacks a similar technological advancement, but is of particular potential interest to the West African Region. A natural byproduct of the open cycle system is fresh water in significant quantities, in addition to electricity.

This cycle uses the principle of flash evaporation to generate the working fluid, water vapor, at 0.43 psia. The cycle begins with the warm seawater being drawn into a deaerator and passed successively through a flash evaporator (where over 95% of the warm water is rejected to the sea); the evaporated water then passes through a steam turbine and is condensed by direct contact in a barometric condenser. The condensing medium is again cold water from 1000 meters. The cold water and condensate mixture is returned to the sea, thus the working fluid is freely exchanged; thus the term open cycle is used.

Both the closed and open cycles would employ the same basic components of a 1000m cold water pipe, mooring and transmission cables, and a superstructure, as depicted in Figure 3-3. Most commercial plants would be sized from 80 to 350 megawatts of power and would cost from $2,300 to $3,200/kW (U.S.$), but the free fuel aspect of OTEC makes it competitive on a life cycle basis. The life cycle cost in this case refers to the total capital costs and operations and maintenance that the plant would incur over the life of the powerplant.

On August 2, 1979, a privately funded 50-kW OTEC project off the Hawaiian Islands became the first working closed-cycle, continuously running OTEC project in the world. The purpose of the project, called "Mini-OTEC" (shown in Figure 3-4) was to demonstrate the feasibility of the technology. The U.S. government will have a 1-megawatt at-sea facility in November of 1980. The European consortium of EUROCEAN has initiated design studies to pursue a proposal for a 10-megawatt facility in 1979. This is in addition to the Centre National pour L'Exploitation des Oceans (CNEXO), which has a program underway for completing a pilot plant (1 to 10mW) before 1985. The Japanese have reviewed designs for

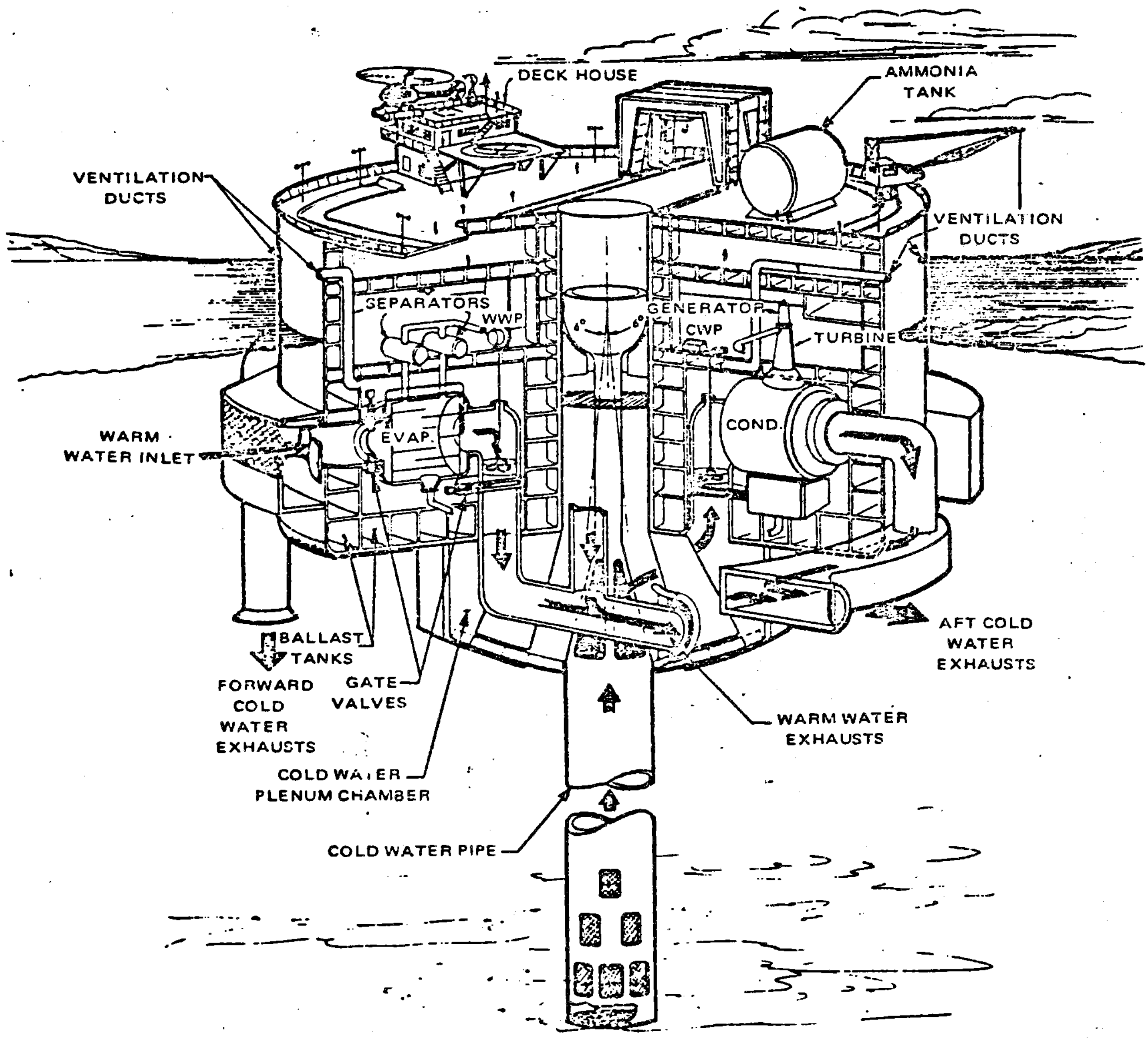
DECK HOUSE
AMMONIA TANK
VENTILATION DUCTS
VENTILATION DUCTS
SEPARATORS
WWP
GENERATOR
CWP
TURBINE
WARM WATER INLET
EVAP.
COND.
BALLAST TANKS
FORWARD COLD WATER EXHAUSTS
GATE VALVES
COLD WATER PLENUM CHAMBER
COLD WATER PIPE
AFT COLD WATER EXHAUSTS
WARM WATER EXHAUSTS

Figure 3-3.

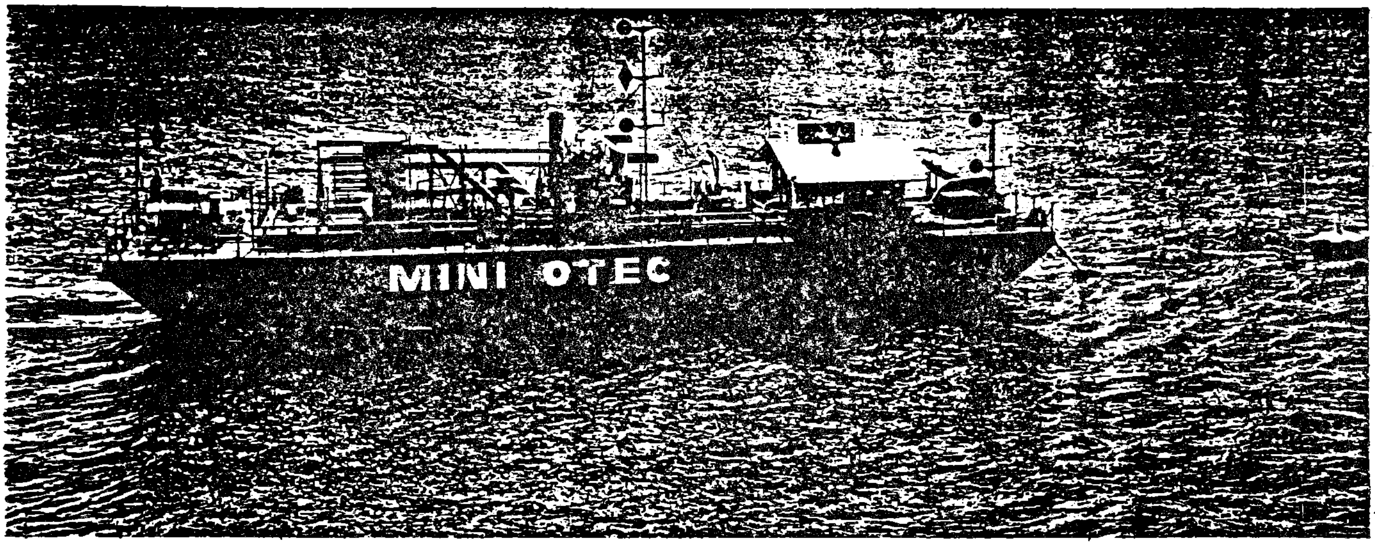

Figure 3-4

OTEC's and they are pursuing research directed at both electrical power transmission to shore and at-sea industrial plants producing energy-intensive products. In summary, the industrialized nations of the world are pursuing OTEC on the basis that future R&D will result in reduction of the proposed $2,700/kW (U.S.$) capital costs and that rising fossil fuel prices will soon make OTEC competitive. The greatest hope for OTEC on a widespread commercial basis appears to be in the early 1990's, but technological innovation or changing world events could accelerate this projected date.

In conclusion, the West African Region has an exceptional resource for OTEC, but the extreme capital intensiveness limits the immediate application. The West African Region does exist as a potential site for initial demonstration units and thus would receive the delivered products of OTEC, whether it be electricity or ammonia for fertilizer. The open cycle holds particular future promise, being far less capital intensive because of the elimination of expensive heat exchangers and the production of fresh water as a natural by-product. OTEC is an ocean energy technology that should definitely be studied further and closely followed in the near and mid-term.

OCEANIC BIOCONVERSION

One of the most promising and least capital intensive ocean energy sources is oceanic bioconversion. Oceanic bioconversion is the process whereby marine plants are grown and harvested either for human consumption, or as substitute natural gas and industrial products. There are a number of marine plants that are candidates for ocean cultivation, e. g., Macrocystis and Thalassia. These species are preferred for their high growth rate and survivability with moderate temperature or nutrient changes in the marine environment. Macrocystis and Thalassia are capable of producing 1,100 to 2,000 and 500 to 1,500 grams of carbon per square meter of plant surface (gC/m^2), respectively. This would equate to the following for a 1-acre plantation's annual production:

- Food energy of 16 x 10^6 Btu (food energy requirement for 4 or 5 people).
- Substitute natural gas of 160 million Btu.

The considerations for an oceanic bioconversion plantation's size and efficiency would include the nutrient supply, environmental conditions, seeding, mooring, harvesting and processing.

The technology for oceanic bioconversion is not unduly complex; if anything it is low technology, labor-intensive energy production. One of the most important aspects in ocean farming is securing the species in question to a stationary area or platform, since a non-stationary plant may drift into potentially harmful environmental conditions and will eventually be washed ashore. Macrocystis and Thalassia attach themselves naturally to rocky bottoms with their holdfasts. Some success has been achieved by American researchers in inducing the reproductive spores of the plants to settle on polyurethane lines in a laboratory culture to a juvenile stage; the young plants are then transported to and transplanted in kelp farm platforms. The success factor of this process has been high, and once the kelp reaches maturity, its life becomes quite long, even with harvesting. The kelp farm is susceptible to storms, diseases and grazing by marine mammals and some types of sea urchins.

The supply of nutrients in the water and the temperature of the area are critical factors in the rate of growth of kelp farms. The ability to alter the ambient temperatures of the ocean water is limited; thus it is necessary to select sites having the appropriate temperatures. It is possible though to influence the amount of nutrients in the seawater. Natural ocean upwelling is a phenomena where colder and nutrient-rich bottom water rises to the surface and in essence fertilizes the area with additional nutrients. Such areas are often premium fishing areas as well. Thus one would seek to locate an ocean farm near upwelling sites. The West African Region has three such sites and a major one off the Senegalese Coast and less important ones in between the Ivory Coast and Daliomey. In the absence of natural upwelling, a second means of supplying additional nutrients to the water is by pumping the nutrient-rich colder subsurface waters (from about 300 m) to the surface. Naturally, the cost of pumping this volume of water would have to be offset by the additional productivity of the kelp farm. It has been suggested that part of the cold water drawn from 1000 meters for OTEC could also be used for ocean farming, thereby eliminating much of the cost of obtaining the additional nutrients. A third method for supplying nutrients, which is still experimental, involves having the kelp farm adjacent to the outfall of sewage treatment or waste cannery plants. The effluents then become a source of nutrients for the area. The ability to fully utilize this technique should first be observed in experimentation and only later advocated for commercial use.

The kelp is harvested by specially designed ships that cut the surface layers of the kelp fronds. The cut fronds are placed onboard, dewatered and then transported to shore for processing. Harvesting assists the growth of the kelp by removing the surface area and allowing more sunlight to penetrate greater than normal areas of the kelp bed. The reproductive ability of kelp requires a harvesting every three months.

The dewatered kelp is processed into substitute natural gas, i.e., methane, by either digestion, pyrolysis or hydrogasification. Anaerobic digestion costs the least of the three, since pyrolysis and hydrogasification require removal of water before the thermal treatment. Processes presently exist as well for utilizing the kelp in additional byproducts: ethanol, fiber and fertilizers, as well as feed in the food-chain of a mariculture project.

The entire West African Region contains sufficient and ideal ocean space for oceanic bioconversion, but there is a need for cooperative research and resource management in order to have a successful venture. There exists a number of ecological, botanical, industrial and managerial research areas that need only be conducted once in order to generally apply their results to the entire West African Region. One successful and coordinated research effort is all that is needed before each individual state could embark on separate kelp projects.

ENERGY FROM OCEAN TIDES

Tides are the ebbing and flowing of the ocean due primarily to the gravitational forces of the moon and sun and secondarily by the rotation of the earth and ocean basin geometry. The local characteristics that amplify this tidal action are the proper combination of hydrological and topographical conditions in relatively shallow estuaries and gulfs. Less than 100 estuaries and gulfs in the world possess the conditions necessary to create an amplified tidal motion resulting in a mean tidal range of 5.5 meters or greater. This tidal range is considered to be the minimum standard to support a technically feasible tidal energy plant.

Areas with such sites have both experimented with and installed commercial tidal energy plants. The most notable is the single large tidal plant on the Rance Estuary in France, where 240,000 kilowatts of power are produced. The Soviets and Chinese are known to have had some smaller units installed for experimental and production purposes.

Technology has progressed over the years to a point where a number of different techniques exists, depending upon the characteristics of the site. These techniques are classified on the basis of whether single, double or triple basins are involved in the estuary or gulf and further subdivided as to whether power is generated on just the ebb tide or on both the ebb and flood tides. At the present time, both the single basin-two direction and the single basin-one direction are being planned. The overhead layout would be as depicted in Figure 3-5 having a dam or barrage across the mouth of the estuary or gulf with a powerhouse located at its midpoint. A number of powerplant techniques are available, employing turbogenerators with either vertical shafts, horizontal shaft bulbs, sloping shafts or rim type units, or sluice gates. Figure 3-6 shows a horizontal shaft bulb.

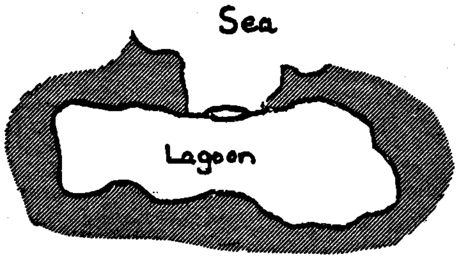

Figure 3-5

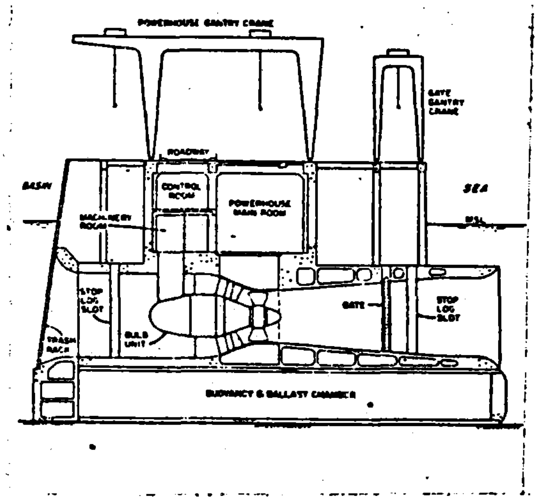

Figure 3-6

The two main drawbacks to a tidal energy project are its capital intensiveness and the fact that tidal is a peaking cycle and will not always produce electrical power in conjunction with normal human working hours. This is due to the fact that the tides are caused by the solar and lunar cycle which occurs at a frequency of 24-hour-and-50-minute instead of the 24-hour solar only cycle. The tides are just as predictable as the sun, but unfortunately their cycles do not coincide. If an application for electricity can be found which is independent of normal working schedules, then tidal energy represents an alternative.

In a recent worldwide survey of potential tidal energy sites (Figure 3-7), four sites were located in the West African Region at Porto Gole, Guinea Bissau; the Niger Delta, Nigeria; near Mocamedes, Angola; and near Walvis Bay, Namibia.[1] Other sites may exist since tidal action data is not necessarily kept on all

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[1] Stone and Webster, 1978.

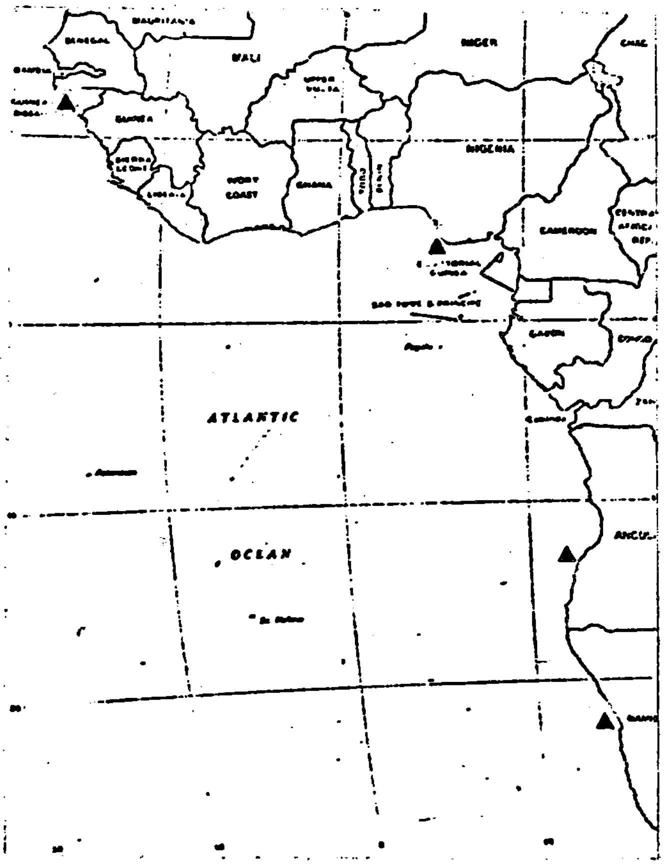

Figure 3-7

estuaries and gulfs in the West African Region. Thus, it would be valuable, at a minimum, to assess the extent of this resource so that evaluation could be made as to whether potential technological development of tidal energy has application to this region.

WAVE ENERGY

Wave energy is a concept that has captured the imagination of numerous inventors for centuries and a number of patents have been issued. There exists an equal variety of concepts that:

- Utilize onrushing water from breaking waves.

- Use pneumatic devices which employ the vertical motions of the sea surface to compress air for driving turbines.

- Use unidirectional valves to pump water from successive rising wave crests for operation of a turbogenerator.

- Use submerged devices to operate from the changing hydrostatic pressure of an overhead water column induced by passing waves.

- Convert the rise and fall of the sea surface slope to mechanical energy.

- Convert oncoming horizontal wave motion into a vortex for production of mechanical energy.

It is necessary to understand the sources of waves in order to understand why certain regions of the world have greater resources than others. Distant storms at sea result in wave trains directed towards coastlines and islands and these wave trains are often intensified by wind over the sea surface. Thus, those coastlines and islands in the path of frequent storms at sea are exposed to greater wave heights and frequency. The geographical regions of the world with the greatest wave exposure lie in the extreme northern or southern latitudes and between the longitudes of 30°W - 70°W and 120°W - 170°W. This again is a function of land mass in relation to the at-sea storms and winds, rather than any local characteristics or effects.

The wave climate in the West African Region is inadequate for serious consideration of waves as an alternative source of energy.

The studies that have been done show that the West African Region has an annual wave energy of 300 megawatt hours per meter of wave crest length, which ranks slightly above the poorest reading of 275 for the Mediterranean Sea and far below the highest reading of 535 for the North Atlantic Ocean. To the south, wave data analysis at several locations on the South African coastline determined that a favorable 10 kW/m of wavefront was available up to 1 km offshore and up to 50 kW/m of wavefront 30 km offshore.

Therefore, the future of wave energy in the West African Region is not encouraging, unless a process is developed that can favorably utilize relatively small and irregular wave formations. The United Kingdom is clearly the leading developer of this technology, with the U.S., Finland, Sweden, German Federal Republic and Japan also participating in ocean wave energy research and development.

OCEAN CURRENTS

Exploitation of the ocean's currents is the process by which one seeks to harness the passing flow of water in a manner very similar to a turbine in a river dam or an underwater "windmill". The ocean currents represent a steady and predictable stream of water but the flow is dispersed, thus making it more difficult to exploit than that of a river. Very few regions of the world possess sufficient ocean currents in close proximity to shore for technically and economically viable energy production.

The West African Region contains neither a strong ocean current adjacent to the coast nor narrow straits that would concentrate the current flow (see Figure 3-8). Thus ocean current energy cannot hold any great promise for the West African Region as an alternative resource, even if present theoretical studies materialize into commercial projects for the other sites in the world.

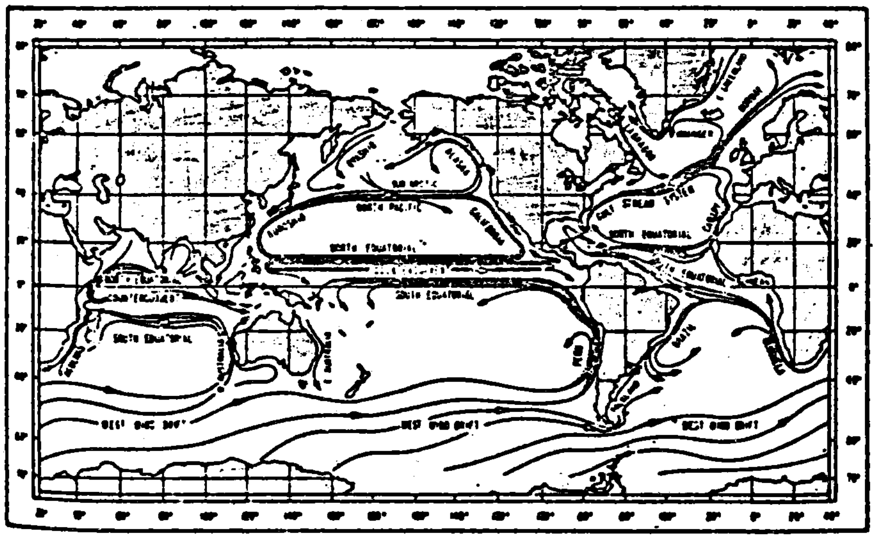

Figure 3-8. Average Surface Currents of the World's Oceans

SALINITY GRADIENT ENERGY CONVERSION

One of the more theoretical sources of energy energy is salinity gradient energy conversion. Salinity gradient energy conversion works on the well founded principle that two liquids of different salt content will, through a semi-permeable membrane, selectively allow fresh water only to flow from the less saline liquid to the more saline liquid. This process is called osmosis. Equilibrium is achieved when the salinity content is equal for both liquids, although the volume of one liquid increases at the expense of the other, thus creating a volumetric or pressure difference between the two liquids. This pressure difference represents mechanical energy that can be converted to electrical energy. Figure 3-9 illustrates the salinity gradient exchange both before and after osmosis.

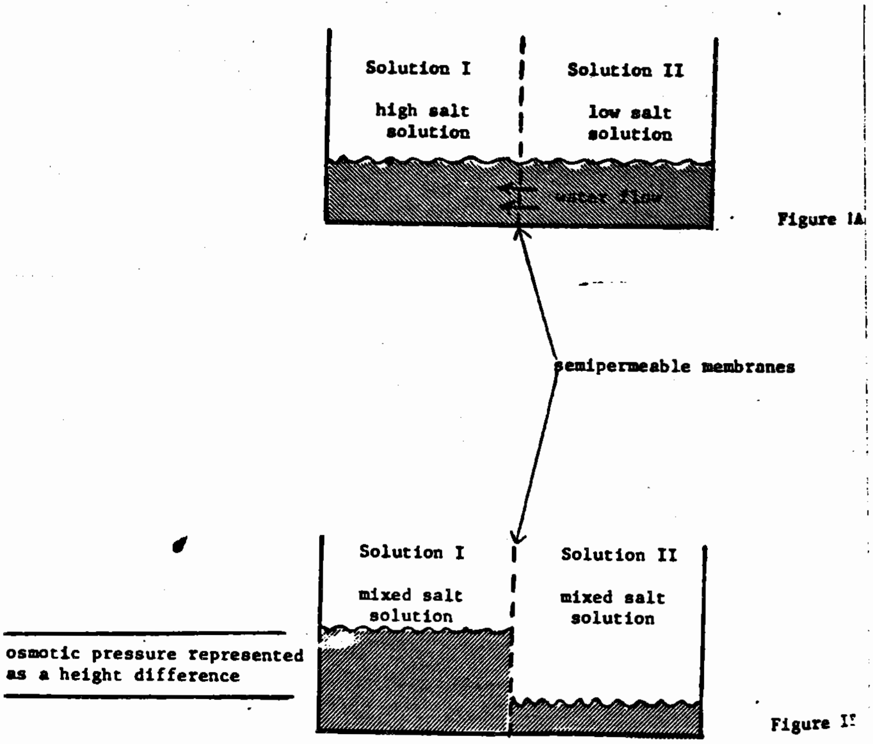

Figure 3-9

Theoretical application of the osmosis process to the oceans requires selecting points at which fresh water rivers meet the oceans as sites of the greatest salinity gradients. Researchers have suggested that if the salinity gradient could be exploited, significant sources of electrical power could be produced on a 24-hour-a-day basis, using the renewable sources of fresh and salt water.

At the present time, only laboratory tests supporting this theory are available. The West African Region would stand to benefit from further development of this process, since a number of fresh water rivers flow into the gulf merging with sea water that has a higher-than-normal coastal salinity content, generally 35 parts per 100. The Congo River has been cited in the literature on this subject as having a very high flow rate of 5.7×10^4 m/sec, with a potential osmotic pressure head of 24 atmospheres, which is theoretically capable of producing 1,300 megawatts of power.

Thus it is valuable to track the development of this technology, but no immediate or midterm benefit should be expected.

SUMMARY

A number of ocean energy technologies that are being researched by the developed countries of the world have a direct and attractive application to the West African Region. The leading candidates would include oceanic bioconversion, ocean thermal energy conversion and tides. Those technologies lacking the available ocean energy resources would include waves, currents, winds and offshore geothermal. Finally, one technology, salinity gradients, has a potential to the West African Region, but it's future potential is sufficiently distant that it should not be depended upon.

Ocean thermal energy conversion holds particular promise since it has the predominent amount of world research and development effort and the West African Region is adjacent to some of the greatest ocean thermal gradient resources in the world. A successful venture in the Hawaiian Islands, plus other planned projects, makes the technology all the more real and available to the West African Region.

Oceanic bioconversion is expecially attractive to the West African Region since it requires the least amount of capital costs of all the ocean energy technologies and it requires the greatest amount of manpower for harvesting and processing. Furthermore, the product can be delivered in the form of methane, ethanol, fiber fertilizer or other industrial products. The resource in the West African Region is adequate for the growth of species like that of Macrocystis and Thalassia particularly near areas of natural upwelling.

Ocean tides represent another potential opportunity for energy development in selected areas of shallow estuaries and gulfs that have an average tidal range of 5.5 meters or greater. Four sites have been identified in the West African Region and more may exist but due to lack of data they cannot be pinpointed at this time. A number of plants have been installed on an experimental and commercial basis and development is continuing in this technology.

The next chapter discusses in a preliminary manner the actions and issues that are paramount to the West African Region utilizing these three particular ocean energy technologies.

CHAPTER IV: MAJOR ISSUES INFLUENCING THE UTILIZATION OF OCEAN ENERGY

The previous chapter briefly described the ocean energy resources common to the West African Region and the state-of-the-art of the technologies available to exploit these resources. There exists the need, on the basis of this preliminary assessment, to investigate further the size and characteristics of the prevalent resources in the West African Region.The true energy supply potential would then be known for the individual states, and the West African Region as a whole. The technological development is being conducted primarily by the developed countries but there exists ample opportunity to participate in the research, particularly in those technologies where the energy resource is abundant, such as OTEC and bioconversion. Concurrent with the resource assessment and technological development there exists the need to resolve economic, institutional and legal issues, as well as to plan for the necessary manpower training and the construction of the supporting infrastructure. The balance of this chapter discusses some of these major issues that need to be addressed prior to widespread practical application of these ocean energy technologies.

RESOURCE ASSESSMENT

The West African Region can be regarded as a singular body of water with fairly common ocean energy resource characteristics, except for tidal energy. As previously noted, attractive resources exist for ocean thermal energy conversion, oceanic bioconversion, tides and salinity gradient exchange, but rather poor characteristics exist for wave and current energy. The favorable resources are believed to exist but their size and characteristics are not confirmed because of limited site specific data. Since the characteristics are of the gulf, rather than exclusively contained within one boundary or another, a regional approach to resource assessment would be the most productive and economical. The methodology for resource assessment for each of the favorable resources is different, but has been performed in some parts of the world. Therefore, any interested party would merely need to acquire the established methodology and employ it in the region with either local scientific resources or those from other parts of the world. The methodology for this resource assessment is far too detailed for this chapter, but it has been refined and is available to any region wishing to pursue the subject further.

TECHNOLOGY

The technology development is occurring presently by the developed countries primarily for the eventual benefit of those countries. This can be construed as an advantage since the West African Region will get the benefits of research without having to necessarily pay for it. There does exist the need and opportunity to participate in the research and development to insure the use of the results of the research and development efforts are applied to the West African Region. A classic example of interest conflict currently exists in OTEC. The researchers are torn between maximizing the size of OTEC's up to 350 MWs for heavy industrial use, to get the capital costs lower due to economies of scale, and conversely, optimizing the unit size to less than 100 MWs for Developing Countries due to relatively limited electrical power grids. The presence of a West African Region research interest and potential market would obviously require these researchers to assess the decision much more closely.

The ocean energy technologies are presently on the verge of an impressive schedule and expenditure program for demonstration projects around the world. There remains a number of known technical challenges that have not yet been resolved and these demonstration projects will undoubtedly expose a few new ones, for the marine environment is notorious for its harsh treatment of operating machinery, particularly moving parts in the tidal area of the coastal zone. If the West African Region has an interest in utilizing ocean energy resources in the future, then the available scientific and management manpower needs to be participating in the on-going research and development.

RESOURCE MANAGEMENT

The performance and efficiency of each of these viable energy technologies will be a function of the adequacy and stability of the resource. Some of the technologies are quite sensitive to changes such as nutrient or temperature in oceanic bioconversion or the fact that a 1°C change in the ocean thermal gradient effects the plant efficiency by 5%. Thus the resource needs to be managed even though it is renewable. Use conflicts may arise as well with ocean energy technologies and therefore a means to resolve these conflicts within the ocean space would be needed.

ECONOMICS

One of the major issues associated with ocean energy systems is the high initial capital costs required for operation. The free fuel aspects certainly aid the economics of the project during the life of the project, but the ability to borrow or raise the initial investment is restrictive. Therefore, the economics of an ocean energy technology need to be seperated in terms of intial capital costs and operating costs.

The initial capital costs can be from two to four times more expensive as either a coal or oil fired electrical generating system. This represents a severe limitation to those developing countries and regions that have either reached or exceeded their ability to borrow long-term debt in the world capital market. Additionally, well defined electrical markets for the purchase and use of the power is necessary to justify such large volumes of capital.

The following will present an idea of the sums of capital involved. Assuming that an 80 megawatt plant, or energy equivalent, would be an appropriate sized unit to initially place within the electrical grid system, then Table 4-I represents the approximate amount of capital necessary for an 80 MWe system.

	1979 U.S. DOLLARS ($\$ \times 10^6$)
OCEAN THERMAL	184 - 256
OCEANIC BIOCONVERSION	144 - 216
TIDES	216 - 280
WAVES	300 - 400
CURRENTS	300 - 400
SALINITY GRADIENTS	Unable to Estimate

Table 4-I. Range of Ocean Energy Capital Costs for a 80-MWe Facility

At the present time these high capital costs make ocean energy technologies non-competitive with fossil fuel plants, even on a life-cycle cost basis. What is important to remember is that these capital costs will be decreasing substantially during the 1980's when the effect of innovation, standardization and mass production are taken into account. Concurrently, one may be led to believe that the price of fossil fuel will continue to climb at least equal to the rate of world inflation.

The final offset to the high capital costs is not only the free fuel aspects, but more importantly, the energy resource is renewable and cannot be deprived or excluded from the user; thus giving ocean energy systems a hedge against future increases in fossil fuel prices and availability.

MANPOWER TRAINING

It will be necessary to have skilled manpower in both the construction and operation of these ocean energy plants. Depending upon the technology chosen, most of the ocean energy systems require a minimal amount of roads, ports and facilities in order to install and operate. Most of the technologies will be manufactured in shipyards or graving docks elsewhere and towed or shipped to the operating site, thus leaving only final assembly and installation to the local labor force.

The operation of these systems are primarily concerned with maintenance due to the corrosive and hostile marine environment in which this equipment is operated. Therefore, a skilled maintenance staff and operations management would be needed for each labor shift of operations in which the technologies are producing energy. One ocean energy technology, oceanic bioconversion, has the least capital costs and highest labor involvement due to the harvesting and processing of the kelp. This low technology system is ideal for labor surplus areas.

There does exist need in the future for the training of manpower in all aspects of any system under consideration; from research and development to construction, maintenance and operation.

SUMMARY

This chapter has presented a sampling of the issues that need to be addressed prior to application of these ocean energy technologies to the West African Region.It is not enough to merely depend upon the developed countries to perfect this technology, for the resource assessment and manpower training all need to be performed concurrently with the technical development. Much of this work will be common to the data gathering and resource management necessary to acquiring a competency to manage and exploit a 200-mile Exclusive Economic Zone, if such an EEZ is enacted.

Therefore, the preparatory work on the part of the utilizing country or region is significant. As mentioned in this chapter, most of the work to be performed can best be done in a coordinated fashion for the entire region, rather than just segmented parts.

Chapter V will deal with possible regional actions for the future utilization of ocean energy.

CHAPTER V. PROPOSALS FOR INCLUSION IN THE DRAFT ACTION PLAN

The development of ocean energy resources in West Africa requires a basic knowledge of ocean energy resource endowments as well as the means of financing such developments if this decision is made within the national or regional energy development strategy. An opportunity is present for cooperative efforts to investigate the feasibility of various systems and the means of employing them in the region.

Regional cooperation can first be enlisted in preparing maps of ocean thermal energy, wave energy, tidal energy and ocean biomass which would provide a first approximation giving the best location for the resources. The criteria for evaluating sites should be carefully defined and stated. Guidelines to assist governments in the assessment of their resources should be an essential component of this preparatory and general review of ocean energy resource potential.

Although the atlas can be begun using archival data, it is desirable that a study team visit the countries of the region to discuss their particular needs and investigate specific sites which may be more attractive. Study missions undertaken by other entities including the U.S. Department of Energy and the French Centre National pour Exploitation des Oceans (CNEXO) should be contacted in order to take advantage of their investigations.

An important feature of ocean energy systems is the possibility of having multiple uses developed which include mariculture and coastal protection. Because OTEC brings the nutrient-rich deeper ocean waters to the surface, it is possible to use these waters after energy generation for mariculture. The economics of OTEC system application is aided by a mariculture program which could produce protein-rich shellfish for local consumption or export. Shrimp, in particular, is an attractive species for mariculture and revenue production.

Ocean wave systems absorb the incoming wave energy and consequently reduce the intensity felt on the shore. By careful spacing and deployment, wave energy devices can provide a measure of shoreline protection, create safe swiming areas or interrupt the sediment transport pattern to assist in erosion control or shoreline accretion projects.

It is proposed that a number of case studies be prepared which would carefully examine the application of ocean energy systems and their multiple use capabilities. For OTEC, both open and closed systems should be considered together with large and small size shelf, floating or shore-based installations and mariculture, electricity and fresh water options. For wave energy, coastal protection, erosion control and harbor construction should be considered. For tidal energy, small-scale possibilities should be investigated for particular cases applicable to West Africa.

A Workshop could be organized on the potential of ocean energy systems in West Africa and the means of evaluating the local potential of different systems and options. The Workshop would also address the important question of financing and would invite various funding sources to participate.

CHAPTER VI. PROPOSALS FOR PROJECT ACTIVITIES WITHIN THE WEST AFRICA ACTION PLAN (WAAP)

ENVIRONMENTAL ASSESSMENT

1. Preparation of Resource Maps of Ocean Energy

Objective: To provide an overview and first approximation giving the location of ocean energy resources in order to identify potential sites and quantities of recoverable energy.

Work Plan: Using archival data, supplemented by studies undertaken by the U.S. Department of Energy, CNEXO, EUROCEAN, etc., the maps would be prepared by consultants who would circulate drafts of the maps for comments, additions and corrections.

2. Survey of Obstacles to Ocean Energy Development

Objective: To identify the key factors which limit or restrict the initiation of ocean energy resources and to make recommendations for overviewing these including administrative, financial and public awareness issues.

Work Plan: A survey will be conducted of the ways in which each country meets its energy needs and this will be improved with the potential contribution of ocean energy resources. Through discussions and meetings, a consultant or consulting team will identify the issues and make recommendations.

Financial issues will be discussed with major funding institutions including the Import Export Bank and the World Bank.

3. Regional Cooperative Efforts

Objectives: To encourage multi-country programs to investigate and develop ocean resources.

Work Plan: A survey of prime sites for multi-country ocean energy projects will be conducted including the usage of electric power output and compatible technologies such as mariculture, fuel cell production, industrial application and coastal protection.

ENVIRONMENTAL MANAGEMENT

1. Multiple Use Applications

Objective: To assess the multiple use applications of OTEC, wave and tidal energy for West African situations.

Work Plan: To develop specific OTEC case studies, varying closed and open systems, large and small size plants, shelf, floating or shore-based installations, mariculture, industrial, water electrolysis and electrical production. To develop case studies for ocean wave energy including coastal protection and erosion control. To develop case studies for small-scale tidal projects including local applications of energy protection.

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