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STUDY ON THE POSSIBILITY OF DEVELOPING OCEAN ENERGY RESOURCES OF EAST AFRICAN COASTAL MEMBER STATES

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INTRODUCTION

1. Today energy has become a critical element in the African economy for which there is a growing demand and an uncertain long-term supply. In Africa, it has now been recognized and accepted that long-term energy supply cannot be based on low-cost petroleum. Serious consideration of other possible sources of energy needs to begin, and in this consideration a wide range of possibilities exists. Among the most attractive are sources which are widespread, renewable and non-polluting. On this level, such new and renewable sources of energy as solar, wind, ocean and biomass are available and could make a valuable contribution to energy supply in the future, supplementing traditional sources and, in some cases, replacing them in specific uses. Questions to be dealt with before this becomes practical involve technology, economics and, to some extent, the inertia of the present system.

2. This study is based on critical review of all available publications on the possibility of developing ocean energy resources in Africa with particular reference to East African coastal member States, and one island country (Mauritius).

3. All the accessible forms of ocean energy resources could be classified according to their origin, lifespan and best use and table 1 lines up these forms of energy. In this paper, five forms of ocean energy are discussed but some researchers are inclined to include here wind energy and biomass produced in the ocean. In some other studies, offshore winds and marine biomass are included in a separate group embracing ocean currents, salinity gradients and ocean geothermal energy. All of these sources of energy are in the early stage of consideration and their development can not be expected in the near future.

Table 1: Ocean energy resources

Origin	Form/source	Lifespan	Realm	Best use
Earth/moon rotation	Tides	Quasi-renewable	Sea water	Kinetic, electrical
	Waves	Renewable	Sea water	Kinetic, electrical
	Temperature	Renewable	Sea water	Thermal, electrical
	Salinity	Renewable	Salt deposits Sea water	Chemical, electrical
Thermo-nuclear	Currents	Renewable	Sea water	Kinetic, electrical

Source: Harvesting ocean energy, The UNESCO Press, 1981, p. 19

I. TIDAL ENERGY

4. The utilization of tidal energy is a special case of hydroelectric energy development confined to locations having favourable configurations of coastal lines and large tidal variations. The power is obtained from the filling and emptying of an estuary or a bay which is closed by a dam. The enclosed estuary or bay is filled and emptied only during brief periods (at high and low tides) in order to develop as much power as possible.

5. Thus, a tidal plant works an average of 2,000 hours per year, against 5,700-6,000 hours which is the annual working time of a hydropower plant.

6. The efficiency of a tidal plant depends on three major factors:

(a) Large tidal amplitude (over 10 m);

(b) Interconnection with an electrical grid (as the plant gives discontinuous electric power);

(c) A location with suitable depth for building a dam in order to not diminish the tidal amplitude.

7. Tides, a phenomenon which can be observed on almost all the earth's coasts, are the regular and periodic movement of sea water by virtue of which the water level rises and falls every day in a given place. Tides are the result of the combined attraction of the sun and the moon which is felt most on the water-covered segments of the earth's crust (ocean tides).

8. In Africa, the phenomenon is best observed in Levrier Bay, near Nouadhibou in Mauritania. Among 34 potential world sites for tidal development, Porto Gole in Guinea-Bissau is considered promising with a mean tidal range here of about 5.5 m. Other African regions such as the Atlantic and Indian Ocean coasts may be promising. In Eastern Africa, it would be interesting to install tide measurement instruments at certain points to have a better understanding of the phenomenon and evaluate the most promising areas for exploiting tidal energy.

9. The most notable tidal development to date is the Rance Tidal Power Project in France. Leaving aside the technical details of a 2,240-MW installed capacity project, one thing should be emphasized, that tidal power is a renewable source of energy that could be easily exploited with technology existing today.

10. But one has to bear in mind the fact that although it is a technical success, it is still disappointing from the economic standpoint because of the very high cost of the electricity produced. Also, the work required to develop potential promising sites would require heavy investments. That may be the reason why little use has yet been made of tidal energy world wide.

II. WAVE ENERGY

11. As waves move towards the shore, they carry towards it the energy that they have acquired from the wind. The power reaching the coast per metre of shore is low (of the order of 10 kW for waves 1 m in height arriving at 10-second intervals). This power, which is proportional to the square of the wave height and directly proportional to the interval between waves, varies markedly with time. If an appreciable amount of power is to be collected, a considerable length of coast would have to be provided with extremely robust equipment which should be capable of withstanding the effects of storms.

12. The study of the possible use of wave energy was carried out at Casablanca, where the average wave height is large. This study showed that even under these very favourable conditions, the cost of the energy obtained in this way would be very high. The estimate made at the time was that it would cost about 10 times as much as energy from low-fall hydraulic installations, and would clearly be much higher if the system had to be installed on a coast without an already existing jetty. The energy available at the outlet to the plant, for this particular site, would be of the order of 12,000-17,000 kWh per year and per metre of coast. About 100 km of coast would therefore need to be fitted with the devices in order to obtain an output equivalent to that of a 250-MW (1.35 TWh per year on the average) thermal power station.

13. It is thus difficult to envisage the industrial use of wave energy because of its variability over time and the fact that it is dependent on chance, its low concentration and the cost of constructing the equipment needed to collect it; this equipment would have to be installed out at sea, and precisely at those places where the sea is roughest.

14. This would be justified only in very special cases, namely where the following conditions are simultaneously satisfied: the use of other energy sources is extremely difficult; requirements are very small; and the location is particularly suitable in that there is little variation in wave height and construction of the devices on the coast would not pose any problems.

15. Low-head reservoirs have been built at Pointe Peseade and Siddi Ferrach in Algeria. Their construction was followed by extensive laboratory tests undertaken at the Laboratoire danphinois d'hydraulique in France between 1944 and 1950 to develop designs for the converging channels that maximize the run-up of the waves.

16. Considerable funding and resources are being provided for the research and development of wave power as a major commercial source of power. The International Atomic Energy Agency (IAEA) Committee on Research and Development established a Working Group on Wave Power in 1976. The interest of many countries in wave power is also evident from a review of the technical literature.

17. Mauritius wave energy project. Historically, the work on the Mauritius wave energy project began over 25 years ago. It was first proposed by Mr. A.N. Bott, the then General Manager of the Central Electricity Board of Mauritius. In the 1960s considerable effort was made to investigate wave characteristics and to determine wave run-up rates along inclined walls. Wave run-up tests were carried out at the Hydraulic Research Station, Wallingford using a narrow wave tank and regular wave generator.

18. Based on these results a feasibility study report was prepared by Sir Alexander Gibb and Partners in 1966 which demonstrated the technical viability of the scheme. However, at that time the cost of generating electricity from a wave power scheme was at least four times more expensive than the cost of generating electricity from imported oil.

19. In the wave of oil price shock in the 1970s, interest in the Mauritius wave power scheme was revived and Alexander Gibb and Partners submitted a revised feasibility report in 1976 to the Government of Mauritius. In 1979, two wave riders were acquired and a two-year programme of wave recording was initiated. An analysis of these recordings has been carried out by the University of Mauritius and the results indicate that wave power potential off the Rimabel Coast stands at 20 kW/m length of the wave front.

20. The idea involved in Bott's project is rather simple although it calls for a great deal of challenging civil engineering. It would consist of building a long (about 5 km) wave wall of suitable crest height and suitable inclination (both would be determined from careful wave tank study) and two cross bunds at right angle to the outer wall, thus turning the shore into an enclosed power lagoon. The sea waves approaching the reef, instead of breaking and thus dissipating their energy, would roll up the inclined wall and fill up the lagoon behind the wall and thus raise the water level in the lagoon. Once the water level is raised to about 2.5 - 3.0 m above the mean sea level, this water head will drive a set of specially designed low-head turbines coupled in turn to electrical generators, thus converting the wave power into usable electric power.

21. Extensive studies have been undertaken and it has recently been concluded that the resulting wave power will be competitive with alternative power from diesel motors or hydroelectric schemes. Designs rated at 5,000 and 20,000 kW have been proposed.

22. Development of wave energy converters is still in the early stages. There are several technological schemes adopted in the United Kingdom, and Japan; however, at present it is not possible to decide which technology of using wave energy is more appropriate. Moreover the existing equipment is not yet economically viable.

23. To date no activities have been undertaken in Africa for the development of this source of energy. However, good possibilities for its utilization are known off the western coast and in the offshore areas of island countries in the east.

III. OCEAN THERMAL ENERGY

24. Ocean thermal energy conversion (OTEC) exploits the differences in temperature between warm surface water and cold deep water in the tropical and subtropical oceans of the world. The thermal energy is transformed into electricity by a thermal engine. A minimum temperature difference of 20° C is required.

25. The OTEC concept takes advantage of the role of the ocean as an enormous solar collector and energy storage medium. A working fluid such as ammonia is used to transfer heat from the warmer ocean surface water (up to 27.5° C) vaporizing in the process and driving a turbine. Cold water (near 4.5° C) which must be brought to the surface from a depth of about 1 km, condenses the working fluid to a liquid form in which it returns to the evaporator, thus completing the cycle.

26. In Africa the first experiment carried out in the waters off Abidjan for the production of electricity was not successful. In the first stage the equipment was to include a 3,500-kW unit. Industrial implementation studies showed that the process was applicable in principle; however, the test was abandoned in 1956.

27. The waters off Abidjan are among the most favourable points for the success of such an experiment in Africa. On the one hand, the existence of the "bottomless pit" is an undoubted advantage. On the other hand, thermal energy from the ocean is in fact limited to an area between the isotherms of 25° at the surface which roughly follow the lines of the Tropics. The process requires warm surface water throughout the year and depends on the shape of the coast allowing water to be transported from the deep through a pipe of a reasonable length. At Abidjan the region is very shallow, and it is the submarine trench known as the "Bottomless Pit" which makes it possible to reach a depth of 430 m by means of a pipe only 5 km long.

Table 2: East African coastal member States with adequate ocean thermal resources

Country	Latitude	Longitude	Delta T(°C) between 0-1,000 m	Distance from resource to shore (km)
Kenya	2°S -	34°E - 41°E	20-21	25
Madagascar	10°S - 25°S	45°E - 50°E	18-21	65
Mozambique x/	10°S - 25°S	35°E - 40°E	18-21	25
Somalia	10°N - 2°S	41°E - 50°E	18-20	25
United Republic of Tanzania x/	5°S - 10°S	35°E - 40°E	20-22	25

Source: Report of the Technical Panel on Ocean Energy on its second session, A/CONF.100/PC/25, 1981.

x/ Countries selected for this study.

28. On the globe, the only area which has ocean surface waters of a nearly constant temperature of 25-28° C is the one located between the Tropics. It also has deep cold water (between 5-8° C) at an acceptable depth (between 500 and 800 m), a condition required by a thermal ocean plant to be economically competitive. These figures are to be found at latitudes close to the Equator, mainly on the occidental coasts of the continents, i.e., close to the upwelling zones.

29. Some main disadvantages of an ocean thermal plant are:

(a) Limited geographical location;

(b) Difficulties in maintaining cold water pipelines;

(c) Low efficiency (the efficiency of an ocean thermal plant is estimated to be only one-tenth that of modern steam plants) because of auxiliary consumption;

(d) High cost of installed ocean thermal kW (some experts believe that the price of an installed ocean thermal kW may reach US$500-800, their estimates for an installed nuclear kW are of minimum $400. Other estimates consider the cost of an installed ocean thermal kW between $300-700 against $300-1,000 for an installed nuclear kW. It must be stated that the usual cost for an installed gas thermal plant kW ranges between $300-400);

(e) For floating power stations difficulty in transporting electrical power.

30. Some advantages of an ocean thermal plant are:

(a) The amount of heat is enormous and continuous, being replenished each year (since the heat comes from the sun, ocean thermal power may be considered as a form of solar energy);

(b) The water can be utilized for mineral extraction and for increasing fish populations (cold water brought and released at the surface is very nutrient-rich), or for production of aquatic plants for breeding horned cattle, etc.;

(c) Desalination and supply of large areas with fresh water;

(d) Air conditioning;

(e) The construction uses conventional technology and the servicing is easier because of the knowledge gained from off-shore petroleum technology;

(f) The constant availability of this energy source as opposed to solar radiation, etc.;

(g) Production of drinkable water through distillation of sea water.

(h) Because of high fuel costs, an ocean thermal plant may become today economically competitive. (It is to be mentioned that the cost of an installed ocean thermal kW is subject to considerable changes as technology advances and the prices may be significantly lowered).

31. As far as ocean thermal power use in Africa is concerned, two large experimental power plants of 3.5 MW each, were built off the coast of the Ivory Coast in 1956. Difficulties of transporting the cold water from the deep by pipelines prevent the plant from operating at full capacity. The project was finally abandoned also because of the prevailing low cost of fuel in 1956, although it was planned for execution that very year. Despite this setback and taking into consideration the above-mentioned advantages there is ample scope for the development of this form of energy in Africa in the light of recent technological developments.

32. Before the experiment in the waters off Abidjan, George Claude had tried several times, between 1928 and 1935, to demonstrate the possibility of using this process suggested by d'Arsonval around 1900. After operating a 60-kW turbine in Belgium, with a heat difference of 20° C, on his third attempt in 1930 he succeeded in operating a small coastal power station producing about 20 kW with a 14° C heat difference. His attempt to operate a floating power station in 1934 failed for mechanical reasons.

33. The one-MW OTEC pilot plant is under construction in Jamaica; this is a suitable size for a pilot plant but too small for a commercial plant. Revenues are consequently estimated to bear no more than 50 per cent of the costs of the project. The OTEC plant will be connected to the Jamaican 24 KV power grid. Recently, the World Energy Conference undertook a study on the prospects and potential for ocean thermal energy conversion. It is intended that the study report will be presented on the occasion of the thirteenth World Energy Conference Congress in Cannes in 1986.

34. Japan has been making significant efforts in researching and developing prototypes in order to be able to exploit heat energy from the sea on large-scale models at the University of Tokyo. The Japanese are now at the stage of building an experimental power station with 1-MW capacity. If the tests underway are satisfactory, a 100-MW commercial floating power station will be built by 1985 at the latest, which will be the first of its kind in the world.

IV. SALINITY ENERGY

35. A large source of energy exists at the interface between fresh and salt water. So far, few serious attempts have been made to explore the possible potential of the salinity-gradient power which occurs where rivers flow into the ocean. For example, potential power due to salinity gradient of the Congo river (Congo/Angola) was estimated at 1.3×10^{11} watts.

36. This power is represented by the osmotic pressure difference between two solutions of different salt concentration separated by a membrane that allows passage of water, but not salt (a semi-permeable membrane). The water will flow from the less concentrated side (fresh water) to the more concentrated side (salt water). The surface level of the concentrated solution will be raised by this flow until the pressure due to its elevation is equal to the osmotic pressure difference. Then the flow will cease. The elevated salt water can then be discharged through a turbine to separate power. Salinity power is attractive because it is large and untapped. Its use could have little environmental impact. It is renewable due to sea evaporation and subsequent precipitation over land.

37. Experiments indicate that the equivalent pressure head between sea water and fresh water is approximatively 24 cm or 24 atmospheres for the Columbia river, one of the most highly developed rivers in the world. The dams along its length are a comparable height. Thus an amount of energy equal to the total amount of energy extracted from the river is being lost by the uncontrolled mixing of its fresh water with sea water at the river mouth.

38. Today, the technologies to harness salinity energy potential are known, but many technical problems must be overcome, including civil-engineering problems of construction, desilting of the river water, prevention or accommodation of biological fouling and minimization of concentration polarization. Also to be considered are the effects on aquatic life and other ecological and aesthetic factors. For these reasons, it is unlikely that there will be dams at the ends of Africa's rivers in the near future.

39. <u>Solar salt-gradient pond energy</u>: The solar salt-gradient pond is a still body of water that collects solar radiation and stores it in the water as thermal energy. When high salinity is maintained in the bottom layers of the pond and low salinity is maintained in the upper layers - with a radiation absorbing surface located in the lower more concentrated layers - solar radiation will heat the high-salinity water near the bottom. Temperature of the order of 60-80^{0} C can be obtained in this fashion.

40. The solar-heated water can be used to supply industrial process heat, or to operate heat engines using low-boiling-point fluids which flow into turbines to generate electrical power. Despite the low efficiencies of solar-pond systems, although higher than OTEC energy, and because of the low temperatures involved, these systems have the advantage of being able to operate year-round, on cloudy or sunny day, and even at night. They also are relatively inexpensive to construct. Naturally occluding salt-water bodies can be used to create salt solar ponds, or a solar pond may be artificially heated.

41. In 1979 one solar pond, covering 0.73 ha was developed in Israel to produce 150 kW. Now a project of 5 MW is underway covering 25 ha of the Dead Sea.

42. The Israelis have been working on low-temperature heat engines for the last quarter of a century. A clear theoretical analysis of the problem, completed in the late 1950s, was followed by experimental work and by the industrial production of turbo-generators. The basic principle is that the two-temperature turbine power system is similar to a conventional power plant in that it comprises the same elements: evaporator (or boiler) where heat is supplied to vaporize the motive fluid; turbine where the vapour expends and produces the useful mechanical power; a condenser where the vapour is condensed by rejecting heat to the cooling media; and a feedpump which returns the condensate to the evaporator.

43. The difference between the systems is the motive fluid, which in our case is not steam but an organic fluid selected so as to optimize the efficiency and other practical features at the low heat-input temperature. In low-temperature vapour turbine technology, the fluid is a free design parameter which is changed according to the power and temperature levels.

44. In Saudi Arabia there have been plans since 1980 for use of ponds by utilization of natural site within the Arabian Gulf area known as "Sabkhas" which may be a favourable site for solar pond establishment: level surface, availability of salts and/or saline water, limited subsurface permeability, and limited alternative uses for the site.

45. In India since February 1980, a 100-m2 experimental solar pond has been in operation. This pond has a depth of 2m. The experiments have demonstrated that a solar pond can be operated and maintained to collect and store solar energy effectively and cheaply even in hot, humid climates. The future of solar pond for application in remote or rural areas looks very promising because of the availability of skills for construction and maintenance, the use of low-energy natural materials, the low costs, and the benefits of heat storage.

V. OCEAN CURRENT ENERGY

46. It is well known that the oceans are disturbed by currents, particularly the Atlantic Ocean with a major ocean current such as the Gulf Stream off eastern North America, the Kuroshio off eastern Japan or the Agulhas Current off southern Africa.

47. The technological problem of harnessing this energy source can undoubtedly be solved. Because the resource is extremely limited geographically, there are relatively few areas where the investigation of ocean currents as a possible new energy source should even be considered.

48. The four main currents of interest in Africa as possible sources of energy are:

(a) The Canary North Equatorial, off Morocco, up to Senegal;

(b) The Benguela South Equatorial, off Angola, Zaire, the Congo, Gabon, Sao Tome and Principe, Equatorial Guinea, Cameroon, Nigeria, Benin, Togo, Ghana, the Ivory Coast, Liberia, Sierra Leone, Guinea, up to Guinea-Bissau;

(c) The South Equatorial Angulhas, Comoros, off Mozambique, Madagascar;

(d) The North Equatorial, off the United Republic of Tanzania, Kenya, Somalia.

49. The Somali-Agulhas current system off eastern Africa is the Indian Ocean counterpart of the North Atlantic's Gulf Stream, but with a major difference. The northern half of the system, the Somali Current, responds to the changing monsoon wind conditions and changes direction twice each year. In response to the November-to-April north-east monsoon, the North Equatorial Current flows towards the African coast and turns south as the Somali Current. In April, the north-east monsoon is replaced by the south-west monsoon, and the winds along the Somali coast are the first to change direction. The ocean quickly follows suit, and the Somali Current switches from a south- to a north-flowing current.

50. Any device to capture the energy from the Somali Current would therefore have to have the added capability of changing its orientation twice a year. In all probability, this would rule out the northern portion of the Indian Ocean's western boundary current. However, the same situation does not hold for the southern part of this current system - the Agulhas Current. South of the Equator, the situation is somewhat more conventional. The Trade Winds and the Prevailing Westerlies drive a counter-clockwise gyre (circular current), and its northern limit, the South Equatorial Current, carries large volumes of water towards the African coast where the part of it not involved in the monsoon system turns south past Madagascar and becomes part of the south-flowing Agulhas Current that runs some 300 km off the African coast. This is the strongest western boundary current in the southern hemisphere and reaches speeds of nearly 200 km/day. However, the strong flow is at the edge of a broad continental shelf 300 km from the shore where any generated power or products could be utilized.

51. In theory, the energy from ocean currents could be captured in the same way as wind in windmills. Hence experience gained from wind power could contribute to an assessment of the process involved. Conditions however differ greatly in the two instances. The power which a blade can capture in a current is proportional to the density of the fluid and the cube of the discharge speed. Water is around 750 times as dense as air but ocean currents flow much more slowly than winds. On the other hand, the speed of currents fluctuates much less in general than wind speeds. However, to exploit this energy would entail:

(a) Finding sites where the current is strong and regular and sheltered from waves;

(b) Designing equipment that can run properly in the sea at an acceptable cost price (the revolution speed will be low) and that are exceptionally resilient.

52. At the present stage, it is practically impossible to evaluate the cost price per kWh installed, but it would probably be higher than that of wind power, primarily because of the cost of the equipment and its installation and it would also depend on quality of the site (speed and regularity of the current, topography, etc.).

53. In practice, only a few sites would be suitable for individually designed applications and even then, a tremendous effort, probably out of all proportion to the results expected, would be required to develop the equipment and identify the sites.

VI. ENERGY FROM BARS

54. The energy available from the bars along many parts of the African coast and around the islands which are noted for the regularity and frequency of their waves could profitably be exploited because of the amount of movement involved.

55. A bar is an area formed by breakers unfurling on certain coasts. A shoal may be formed at the mouth of an estuary when the current from the river comes into contact with the waves from the sea.

56. Generally speaking, a bar is a sandy strip which is formed along certain flat coasts and which can emerge as an offshore bank. The shoals present problems for shipping. The Senegalese bar leaves hardly 2 m of water at high tide and a few cm at low tide, whilst the estuary reaches depth of 10 to 15 m.

57. Bars are built up by the offshore drift at times when the discharge of the river is insufficient to carry away the material it bears into the sea. They may emerge completely when the sand is porous enough that it absorbs the water at low tide, as is the case on the shore of the western part of the Ivory Coast.

58. Bars usually arise on coasts that are fairly smooth, sandy and subject to rough seas, for these are the conditions which are propicious for off-shore drifts. This is why the bars are particularly well defined on the coasts of Mauritania, Senegal, the Ivory Coast, Togo and Benin in West Africa.

59. This form of energy has not yet been exploited industrially and has been studied only in a rather cursory way. It would obviously be interesting to make more detailed studies and tests on the potential of this form of energy in terms of helping to satisfy Africa's future energy needs.

VII. CONCLUSION

60. Unfortunately, none of the renewable ocean energy sources look strictly competitive as yet (table 3). But throughout this paper, the emphasis was placed on two things. One is that the cost of conventional sources of energy is rising rapidly, and looks as though it will continue to do so. The second is that in an energy-hungry world, cost is not the only consideration in the future. The important criterion may be energy balance - how long does it take to pay off the energy invested in a new power plant? In this regard, ocean energy systems look more promising.

Table 3 : Economic projections

Source		Capital cost (US$ per kW)	Home-delivered cost[a] (cents per kWh)
Utility plant, existing			
oil fired	1,000 MW	500	4
nuclear	1,100 MW	1,000	5
Current			
CORIOLIS	80 MW	1,300	7
Temperature			
OTEC	250 MW	2,400[b]	7
Tide			
Rance	240 MW	1,000[c]	5
Maine	500 MW	3,500	9
Salinity			
100 MW range		4,000[d]	10[d]
Wave			
100 MW array		13,000[d]	15[d]

Source: Harvesting ocean energy. The UNESCO Press, 1981.

a/ Generally 2 cents per kWh over at-plant costs

b/ Includes plant-factor limitation

c/ 1968 cost, adjusted for inflation

d/ Denotes very uncertain estimates or averages.

BIBLIOGRAPHY

1. Harvesting Ocean Energy, The UNESCO Press, 1981.

2. Marine Science and Technology in Africa: present state and future development. Synthesis of UNESCO/ECA survey missions to African coastal States. Project RAF/78/024 UNESCO reports in marine science, No. 14, UNESCO, 1981.

3. David Ross, Energy from the Waves, Pergamon Press, 1979.

4. T. Berndt and T. Hogbom, The one MW OTEC Pilot Plant in Jamaica, Swedish Energy, 1983.

5. UNECA, Energy from the sea, document ROS/AIGUNCLOS/7, Addis Ababa, 1984.