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REVIEW OF THE PRESENT STATE OF RESEARCH AND STUDIES ON RENEWABLE
SOURCES OF ENERGY IN THE MEDITERRANEAN REGION AND THEIR UTILIZATION

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I. INTRODUCTION

1. In the past few years, countries around the world have begun to assess their overall energy stocks, resources and potential. The dramatic increase in the price of petroleum and natural gas, and the realization that one day these resources might become seriously depleted have instigated an in-depth examination of all means of generating or tapping energy. In this process, all types of energy sources have been scrutinized with a view to determining the potential they could represent in meeting present and future indigenous energy needs. Conventional sources of energy - coal, petroleum, natural gas - obviously received priority as they are used daily in the commercial, industrial, transport and domestic sectors and because the distribution infrastructure is well adapted to them. Hydropower represents the main renewable source of energy currently utilized and efforts continue to expand facilities and to bring into production hydraulic resources hitherto unharnessed. Efforts to promote the use of nuclear energy have been undertaken in a number of countries. Furthermore geothermal energy has been tapped and utilized in many areas. The other major renewable sources of energy - sun, wind, biomass (wood, organic matter, wastes, etc.) - have also received increasing attention from many Governments.

2. It is difficult to place an exact figure on the funds currently allocated to research, development, demonstration and applications in the fields of renewable sources of energy but a rudimentary compilation recently undertaken has indicated that approximately 1,000 million dollars were spent all over the world in 1977. This represents a considerable expansion of the efforts made even five years earlier.

3. The countries of the Mediterranean region have paid great attention to various renewable sources of energy: most of them have programmes, are expanding their activities, and are integrating the prospects that renewable sources of energy represent into their own projected energy needs etc. The commercialization and industrialization of techniques related to the utilization of renewable sources of energy, while still in their infancy, have come to the forefront in recent years and the fact that renewable sources of energy could one day meet a significant fraction of the energy requirements of a country need not be viewed with suspicion.

4. It might be useful to list some of the more obvious potential, practical applications of renewable sources of energy which could one day contribute to meeting energy needs in the Mediterranean region. It should however be noted that these lists are by no means exhaustive, but are set out primarily for illustration purposes.

5. It should be stressed that many of the technologies currently employed for extracting, converting, transporting and using energy and the systems developed in recent times, have had, at their origin, the use of fossil (including nuclear) fuels. These technologies have influenced the design of renewable energy systems, which sometimes led to the erroneous

<u>Source of energy</u>	<u>Type of conversion</u>	<u>Quality of product</u>	<u>Examples of application</u>
Solar	-thermal	-low temperature levels	-water heating -space heating -greenhouse heating -dehydration and drying -pumping -desalination and distillation
		-medium temperature levels	-industrial heat -refrigeration -air-conditioning -cooking
		-high temperature levels	-industrial heat -electricity generation
	-thermal to mechanical	-mechanical energy	-pumping -electricity generation
	-photovoltaic	-electricity	-telecommunications -lighting -pumping
Wind	-shaft power	-mechanical energy	-pumping -operation of machinery (grinding etc.) -electricity generation
Biomass	-combustion	-low to medium temperature levels	-space heating -cooking -electricity generation
	-decomposition	-high calorie gas	-lighting -cooking -small-scale industries
	-pyrolysis	-high calorie gas or fuel	-lighting -industrial applications -electricity generation
	-fermentation	-liquid fuel	-internal combustion engines
Hydropower	-shaft power	-electricity	
Geothermal power	-none	-high to low temperature levels	-district heating -greenhouse heating
	-shaft power	-electricity	

conclusion that renewable sources of energy could be a direct substitute for conventional fuels. Hence it is necessary to devise renewable energy systems in a way that makes them appropriate to the specific nature of these forms of energy.

6. It seems that research and development efforts on new types of fission or fusion reactors, or in other areas, may one day provide a break-through for a centralized energy production. Therefore Governments will have to decide as to the type of energy system their countries should adopt: i.e. an increasingly centralized power system based, largely, on a single energy source with a large distribution network or a decentralized one making use of small and dispersed energy sources to provide a better utilization of energy resources (distribution and multiconversion losses) and ensure a smaller vulnerability of supply and exploitation. Governments will consider this question not only in terms of safety of individual supply but also of balance of payments, foreign policy and so on. There is no doubt the decisions reached will affect the future for decades to come.

7. If renewable energy technologies are to play a role from now till the turn of the century, it must be remembered that it will take several decades more to produce appropriate systems for meeting energy needs, with production, marketing, servicing and maintenance facilities fully operational. One cannot turn on renewable energy systems instantaneously and expect them to be competitive technically, economically or even socially, with well-established conventional systems. These have withstood the test of time and are, for better or worse, integrated into the patterns of industrialized economies. However the development of simple and cheap combined systems, integrating the interesting features of several renewable sources of energy, which would be specially adapted to various needs and connected to appropriate energy storage devices, seems to be one of the first attempts that will prove useful.

8. Nevertheless, it should be stressed that renewable sources of energy may represent for countries less developed from an economic point of view a more easily and more immediately viable alternative to centralized power systems than in industrialized countries. Indeed, industrialized countries often have a limited choice in their possible future energy systems mainly resulting from pre-established but not yet amortized equipment (such as high tension distribution networks), from indigenous and sometimes state-supported industrial and capital and labour intensive infrastructure, manufacturing equipment unusable in renewable energy systems (such as for example large-scale transformers) and from the fact that the living habits of their population rely entirely on centralized energy systems. Less developed countries from the economic point of view are initiating the process of establishing energy infrastructure and therefore have a larger freedom of manoeuvre than industrialized countries in choosing their energy systems, and may in particular have a wider choice in their capital investment policies in the energy sector.

9. In rediscovering the use of renewable sources of energy and in proposing and developing their innovative applications emphasis should be placed on the protection of the environment, as an integral part of the design process. Furthermore and obviously, the cost of renewable energy systems must, in the long term, be competitive with that of conventional sources of energy in order to play a significant role in the Mediterranean region. Now, however, it seems that most renewable energy technologies currently require higher capital investments but operate on lower costs than conventional energy systems. Consequently, life cycle costing should be applied, in order to allow an adequate comparison.

10. It is against this background, faced with growing populations, increasing energy demands, requirements for improved living standards and better quality of life and environment, which cannot be achieved without the protection and enhancement of the environment, that most Governments have opted to integrate their renewable energy programmes with parallel and complementary programmes of energy conservation although for the time being most energy conservation measures taken in industrialized countries seem more cost-effective than the use of renewable energy systems. This situation might not however last for very long as energy savings will require paralleled larger investments which should progressively make renewable energy systems more and more attractive from the economic point of view.

II PRESENT STATE OF RESEARCH AND STUDIES ON RENEWABLE SOURCES OF ENERGY IN THE MEDITERRANEAN REGION AND THEIR UTILIZATION

A. Organization of a fact-finding mission to most Mediterranean countries

11. Before initiating any significant effort aimed at organizing possible co-operation among Mediterranean coastal States in the field of renewable sources of energy, it was felt useful by UNEP and UNDP to organize a mission which briefly visited most of the Mediterranean countries. The purpose of this mission was by no means to cover comprehensively all possible interests nor all possible activities which could be undertaken in a co-operative manner in the region but (a) to explore the interest of Governments visited in a co-operative programme concerning the practical applications of renewable sources of energy in the Mediterranean area; (b) to have preliminary discussions with Governments on the relative importance they attached to renewable sources of energy in national energy strategies or options as well as on the potential role of these sources of energy in meeting domestic needs; (c) to explore the ways and means of implementing a co-operative programme on a regional basis and to assist Governments wishing to make specific proposals in this respect; (d) to collect information on scientific and technological work already carried out in order to provide the meeting of Government experts scheduled in Malta for 9 - 13 October 1978 with some basis on which collaboration efforts could be launched at the regional level; and finally (e) to prepare background documents for consideration at the meeting of Government experts in Malta.

12. During the first part of 1978, the mission paid very brief visits to all Mediterranean coastal States with the exception of Albania and Monaco. Consultations were also held with various international and intergovernmental organizations working in the Mediterranean region.

B General findings of the mission

13. The general findings of the mission which might be of interest to the meeting of Government experts are the following:

- (a) in all the countries visited, research and development activities concerning the practical applications of renewable sources of energy have been undertaken;
- (b) all the Governments of the countries visited have expressed a keen interest in renewable sources of energy and seemed to give them variable but generally quite considerable importance in their very long-term energy perspectives;
- (c) at the time of the mission and in most of the countries visited some kind of national structure had been established or was about to be established with a view to co-ordinating and promoting research and planning efforts undertaken at the national level in the field of renewable sources of energy. In most cases however these national structures were at a relatively early stage of operation though subsequent development seemed to be very rapid;
- (d) all the Governments and practically all the scientific institutions visited declared that close international co-operation at the Mediterranean region level was desirable and could become a fruitful and useful instrument. The feeling was often expressed that this co-operation could cover not only the scientific and technical aspects of renewable sources of energy but should also address itself to the general question of integrating renewable sources of energy in national energy strategies;
- (e) in most of the countries visited a real interest was expressed at Government level in exchanging experiences with respect to the integration of renewable sources of energy in energy strategies as well as, more broadly, in energy policy making. Their interest seemed to result from some perplexity concerning national long-term energy planning: all countries were evidently aware of the often very large solar energy potential they possessed and expressed great interest in knowing, for example, the possibly most efficient incentives for promoting the applications of renewable sources of energy, the experience gained by other Mediterranean countries in this field, and whether it might be advisable to try to reverse an energy-centralizing trend which was often felt to be irreversible;

- (f) most Governments also stated that they visualized a possible co-operative programme on the practical applications of renewable sources of energy as an ideal area for reinforcing the Euro-Arab dialogue. Wishes were several times expressed that a most fruitful and successful co-operation be established in this field between the Arab world and the Mediterranean coastal States of Europe;
- (g) solar energy was undoubtedly the most praised renewable source of energy. It seemed to be the one that was most easily and readily applicable in the Mediterranean region. All countries visited are undertaking research and development work on its applications and there is no apparent shortage of scientists interested in solar energy utilization. There is however a certain lack of training, of adequate research facilities such as equipment, libraries, scientific publications etc. and sometimes of adequate data for the designing and testing of prototype equipment. Furthermore, it should be stressed that, in most Mediterranean countries, the price of a family-size solar collector for domestic water heating represents for an average citizen an investment corresponding to several months' salary;
- (h) according to very preliminary estimates, it was generally felt that wind power could probably play only a very limited role in the Mediterranean region as a whole although some potentially interesting areas existed in several countries. A precise evaluation of the wind power potential had often been regarded as useful, as well as research on means which could widen the spectrum of wind energy applications until now apparently fairly restricted for technical reasons;
- (i) only a few countries expressed interest in the use of biomass for energy production and national research and development efforts in that field were generally said to be very modest. The potential for biomass, although important in some countries, was often described as not practically and economically harnessable; furthermore it would sometimes give rise to profound changes in the socio-economic living habits of some populations (nomadism). Animal wastes seemed as a rule to be used on the spot as fertilizers and burnt for heating or cooking purposes only in exceptional cases. Countries having timber industries and large-scale farms or feedlots seemed to have the most easily usable biomass potentials;
- (j) geothermal power had high priority only in the countries that had significant geothermal reservoirs or had at least found encouraging signs of geothermal activity, generally during oil exploration works. Hot springs are not rare in the Mediterranean and several Governments have decided to support research in the practical applications of these low level energy resources;

- (k) the hydro-electric potential of several Mediterranean coastal States was said to be under reassessment particularly with a view to using micro-hydropower plants for meeting very localized needs. A limited number of projects aimed at utilizing naturally occurring depressions which would be linked with the Mediterranean Sea or the Atlantic Ocean were under examination for electricity generation;
- (l) so far, renewable sources of energy seemed to have penetrated the daily life of people in only two of the 16 Mediterranean coastal States where it has been estimated that solar energy now meets between one and two per cent of domestic energy needs. Most countries however have some kind of production facilities manufacturing devices for tapping renewable sources of energy, particularly solar collectors, but they were generally described as artisanal and often faced with licensing, taxation and other related problems which were said to prevent them from marketing competitive products;
- (m) in most countries, emphasis was given to the fact that the design and production of components and elements of components related to renewable sources of energy technology should be based primarily on the utilization of indigenous raw materials or at least on basic materials easily available on the local market.

C Technical findings of the mission related to the practical applications of solar, wind, biomass, geothermal and hydroelectric energy.

(a) *Solar energy*

14. As mentioned earlier, research and development in solar energy was under way in all the Mediterranean countries visited. The areas of research that were most frequently described and those in which the greatest interest were found appeared to be:

(i) Solar radiation monitoring

15. The knowledge of solar radiation and other pertinent meteorological data for solar energy utilization is a prerequisite to the development and the comparative testing of any kind of solar-powered equipment. These data also appear to be essential for standardization as well as for an appropriate intercalibration of measuring equipment. Most countries had several solar-radiation monitoring stations in general connected with national meteorological services. Few countries had established full-scale networks monitoring direct and diffused radiation and few long-term measurements were available for vertical or tilted surfaces.

16. Most institutions felt that it was not possible to make a proper determination of availability or suitability of data and were therefore facing serious difficulties in obtaining appropriate measurements for the development and design of solar devices. These difficulties were said to result mainly from obsolete equipment and very often from an acute shortage of monitoring apparatus particularly for continuous recording.

(ii) Flat-plate collectors for water and space heating

17. Numerous institutions in all the Mediterranean countries visited had embarked on research into and development of flat-plate collectors. The most frequently mentioned activities were the development of equipment using raw materials indigenously produced or currently available on the local markets, the examination and study of designs best suitable for local conditions, the technical and economic comparison of several types of collectors and the search for cheap and appropriate selective surfaces.

18. Most countries had small-scale production units marketing flat-plate collectors. These were said to be of greatly varying quality and performance particularly in durability tests. In most countries the production of flat-plate collectors was a side-product of a workshop or an industry primarily involved in another type of activity (car industry, metal box factory, etc.). Large-scale production units were found only in Cyprus and Israel (where a quarter of a million collector units were operated) and even in those cases no standardization of norms or performances existed.

(iii) Solar cooling and air-conditioning

19. In most of the countries visited, emphasis was put on solar cooling and air-conditioning as a means, on the one hand, to save electricity and, on the other, to improve working and sometimes living conditions of people in places where such installations - if powered with electricity - would not have been built. In the southern and the eastern parts of the Mediterranean basin, solar refrigeration of agricultural products and food was also frequently mentioned as a possible means to preserve the quality of food products as well as, incidentally, to limit losses caused by rodents.

20. Research and development activities were being carried out in several countries but technological constraints seemed to preclude small-scale applications in the short to medium term. A few large-scale solar refrigeration and air-conditioning installations have been installed in hotels, department stores, schools and a telephone exchange in one of the Mediterranean coastal States and several more are being planned in other countries. Most activities in this field were mainly directed towards the collection of technical information, the improvement of small prototypes as well as the economic and technical assessment of performances.

(iv) Solar desalination and distillation

21. This type of application of solar energy was often mentioned in most countries visited. Particular importance was given to it for the development and improvement of living conditions in arid and semi-arid zones. Various types of solar desalination equipment have been developed in several institutions and some are in operation. It should be noted that institutions having experience in this field often pointed out that solar desalination was technically much more delicate than it might appear at first glance, that it was a rather expensive technology and that careful and continuous maintenance was required if the desalinated water was intended for human consumption particularly because of microbial contamination.

22. Solar distillation of water or of other products was of interest to a limited number of countries and frequently intended for industrial applications.

(v) Solar drying

23. A strong interest was expressed in solar drying of fruits, vegetables or even wood and sand by institutions in many Mediterranean countries. The general trend was to find ways of accelerating and controlling the dehydration process in order better to preserve the quality of products, rather than simply drying them in the sun.

(vi) Photovoltaic cells

24. Photovoltaic cells are studied and developed in many Mediterranean countries. Several institutions were producing their own cells, testing them and frequently examining possibilities of producing large quantities of them on the basis of cheap and domestically easily available raw materials. Several institutions were also working on concentrating as well as on tracking devices. The activities carried out were all aimed at decreasing the investment costs per watt produced as well as making solar electricity a more reliable source of energy. Several institutions were investigating various types of application of photocells particularly in telecommunications and lighting, as well as for some low-power mechanical work such as solar pumping.

25. A few institutions were also involved in the related subject of photo-electrolysis as well as in the fundamental question of storing the energy harnessed during the daytime for night consumption.

(vii) Thermal power generation

26. The use of solar energy for the production of electricity through thermodynamical processes was under consideration in a number of countries and ranged from small-scale applications up to solar power plants of the

magnitude of the MWe output. All facilities were still purely experimental and were not intended for immediate competition with conventional means of producing electricity. Most of the work was oriented towards technological improvements of the design, technological and economic assessments of facilities as well as towards the comparison of various types of designs. There appeared to be limited work being carried out on storage facilities.

(viii) Passive solar heating and cooling of buildings

27. Most countries of the Mediterranean region have undertaken research work on this very important question. It was often felt that proper building design and an appropriate choice of raw materials could lead to very substantial energy savings. The conditions however vary very considerably from place to place and are often closely related to traditional patterns of building and living.

(ix) Others

28. Several other fields of research related to very specific applications or to somewhat unusual aspects of solar energy were under way in many Mediterranean countries. The following examples could be cited to illustrate the variety of research work undertaken: conception and construction of a "solar trailer" to improve living conditions of highway workers, development of a solar furnace for drying bricks, solar sterilization of sewage waters, drying cardboard in a paper-mill, accelerated production of sea-salt, and so on.

(b) *Wind energy*

(i) Wind speed and direction monitoring

29. The knowledge of wind speed and direction and other pertinent data for wind energy utilization is a prerequisite for the development and the comparative testing of any kind of wind-powered equipment. These monitoring activities were said to be carried out in only some areas of the region and were most often undertaken by national institutions not directly involved in the practical application of wind energy (national meteorological services). Only a few countries were having a general wind survey of their territory and information in this respect was mostly based on indirect estimates such as the existence of areas where for a long time there had been windmills or reputedly windy areas.

30. Most of the countries visited felt that a general assessment of their wind energy potential would be useful.

(ii) Water pumping

31. Water pumping with the help of traditional windmills was often cited as an example of an old technology which might deserve rehabilitation particularly in view of new achievements in construction materials resulting from the aircraft industry.

32. However it seemed that research and development activities in wind pumping were only conducted in a very limited number of countries. Most countries on the contrary felt that wind pumping could help in the development of specific isolated areas.

(iii) Electricity generation

33. Most countries seemed to have given very low priority to this particular application of wind energy. Therefore only limited research and development activities were under way in the countries visited.

(iv) Other applications

34. Various other types of applications of wind energy were mentioned and a few of them were under examination. Among them one could cite: grinding of cereals and similar produce, desalination and fertilizer production. It might be worth noting that none of the institutions visited were carrying out research on one of the oldest practical applications of wind power - i.e. sailing - either as a direct means of transport or as an auxiliary power aid.

(c) *Biomass energy*

(i) Assessment of the biomass potential

35. It appeared that practically no country had made a general assessment of its biomass potential usable for energy purposes. Few countries furthermore considered biomass as an important, readily available source of energy or as a national process for storing energy. It was however considered that in some specific cases such as collective farms this source of energy could play a significant role.

(ii) Biogas production

36. Some interest was being taken in biogas production in several of the countries visited and a certain amount of research work was being done. In most cases these activities were of a purely academic nature and were receiving low priority. A few small-scale installations intended for demonstration purposes were said to be operational.

(iii) Other applications

37. Several particular applications of biomass were mentioned in the institutions visited but it appeared that only a few of them were real research topics.

(d) *Geothermal energy*

(1) Heating

38. In several of the countries visited, low or medium level heat reservoirs have been discovered, generally during oil exploration or sometimes during specific drilling in areas where hot springs exist. The most common utilizations conceived for these sometimes vast amounts of available heat are district heating when a reservoir happens to be found near a town, or greenhouse heating when the supply is in a rural area. Most of the research and development activities carried out in this field are devoted to the usual problems encountered in geothermal power utilization, i.e. of transmission losses by pipes, incrustations, corrosion of equipment and reinjection of water. A few towns located in the Mediterranean coastal States are being heated by geothermal energy and it appeared that others might at least partially rely on geothermal energy in the future. A similar situation existed as regards greenhouse heating.

(ii) Electricity generation

39. Three countries around the Mediterranean have discovered sufficiently high quality geothermal reservoirs producing high temperature steam to allow the generation of electricity. In addition to large-scale industrial plants located in one of the coastal States, several small-scale pilot installations were in operation or were planned to be operational in the other two countries.

(iii) Other applications

40. A few other applications of geothermal energy were mentioned, especially the extraction of certain rare elements sometimes contained in geothermal exhausts.

(e) *Hydro electricity*

(i) Conventional

41. Most of those countries visited which had a hydro-electric potential were in the process of re-assessing it in the light of increased prices for oil and gas imports and their effects on their balance of payments. Very large hydro-power schemes have been built in some of the Mediterranean countries in order to provide additional electricity and, even more important, to increase dramatically the area of irrigated lands in semi-desertic areas. Small-scale schemes ("micro-hydro") were under investigation in many countries with a particular view to meeting local needs in areas situated outside the major distribution networks.

(ii) Hydro-helio power plants

42. Three of the coastal States have plans to connect depressions situated in coastal zones to sea-water and to use the difference in elevation for generating electricity, the system being kept running by

solar evaporation. Two of these projects were at an advanced stage of design.

(f) *Other forms of renewable sources of energy*

43. Very few other forms of renewable sources of energy concerning the Mediterranean region were under examination in the institutions visited. There is practically no tide in the Mediterranean Sea as well as no sea current comparable to those whose utilization is under examination in other parts of the world. However mention was made of a strong alternating coastal current in a singular part of the Mediterranean and its tapping was under consideration by a scientific institution. With respect to the use of ocean temperature gradients for generating electricity, there seems to be no appropriate site in the Mediterranean Sea for a technically and economically feasible installation. Little research work was being carried out on wave energy and this was confined to very specific applications such as providing power to buoys. It has become apparent that the average wave height in the Mediterranean would not allow a general utilization of wave energy in the region unless a technological break-through occurred.

III SUMMARY

44. The following general ideas could be considered as summarizing the state of affairs at the time the mission visited various Mediterranean coastal States. They could furthermore be visualized as broad elements which might be considered useful for establishing a co-operative programme on the practical applications of renewable sources of energy in the Mediterranean region. Some of these possible elements are explored in document UNEP/WG.20/4.

- (a) All the countries visited stressed the importance of renewable sources of energy and their practical applications. Their interest seemed mainly to result from economic and political considerations;
- (b) there was general agreement on the desirability of co-operating at the regional level on this topic;
- (c) the initiation of a co-operative programme on selected aspects of the practical applications of renewable sources of energy seemed feasible using the scientific expertise and national facilities that already existed in the Mediterranean region;
- (d) as all Governments expressed a strong interest in both the integration of renewable sources of energy into energy policies and in scientific and technical aspects related to practical applications, these two broad fields of activity should constitute the general framework for establishing a co-operative programme;

- (e) a selection of appropriate topics should be made among the numerous scientific and technical aspects of the practical applications of renewable sources of energy. Various utilizations of solar energy seemed to be an area of technical and scientific investigation likely to provide grounds for co-operation among all Mediterranean coastal States. Additional collaborative activities could also be established among interested countries in geothermal, biomass and perhaps wind energy applications;
- (f) there is no shortage of interested scientists and specialists in renewable sources of energy. There are however serious limitations in equipment and supporting facilities and a co-operative programme should include a comprehensive training component and provide additional equipment to participating institutions;
- (g) { the practical implementation of such a programme should make full use of, and be carried out in close co-operation with national, regional and international organizations already active in the Mediterranean region.