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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
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Meeting of the Consultative Group on Solar Energy Research and Application (COSERA), Beijing (China) Dec. 11-15, 1989

# Solar Energy Research and Application : Status and Prospects for International Cooperation with Special Reference to OIC Countries

by

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## Abstract

This paper considers first the different applications of Solar energy and their present state of development. It discusses the environment of research and the present situation in Developing Countries with main attention to solar energy and renewable energy sources. The paper then investigates the difficulties facing international cooperation in solar energy and gives special reference to the experience of the 45 OIC states.

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# Solar Energy Research and Application: Status and Prospects for International Cooperation with Special Reference to OIC Countries

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## 1_ INTRODUCTION

While science is the seeking of knowledge in itself, in practical terms, unless this knowledge leads to some technological innovation, society would not support it for long. This is indeed the direct link between science and technology. Consequently, while Research and Development (R&D) in Solar Energy can only be a result of scientific advances, it is part of R&D in Energy in general. However, unless it helps in the socio-economic development of society, it would not be supported and thus becomes reduced to repetition of experiments or would die out altogether.

To bring results R&D needs a great degree of investment in human and financial resources, and even with such investment the results are not immediate. Consequently, it is difficult for societies with poor experience in R&D to accept to put such an investment. Thus, to diminish the risks of failure and to pool the energies and resources, as well as to exchange knowledge and know-how, international cooperation seems to be a necessity more than an exercise. However, for international cooperation to succeed many conditions have to be met. Most of these conditions are linked to the development process itself.

This paper tries to look at the difficulties and at the prospects, with emphasis on the specific case of the OIC member states.

## 2- SOLAR THERMAL ENERGY

One of the most widespread methods of using solar radiation is by converting it into heat. Solar heat devices can be divided into three categories as far as temperatures of utilization are concerned: a) high-temperature devices, for temperatures higher than 150 C; b) medium-temperature devices, for temperatures between 60 C and 150 C; and c) low temperature devices, for temperatures lower than 60 C.

For high-temperature devices, solar energy has to be concentrated. Thus, large reflectors covering large surface areas and using more or less sophisticated tracking mechanisms are required. Furthermore, expensive materials are necessary and work under severe operating conditions is the norm. Much of these devices are, consequently, still in the experimental stage and are not yet economically attractive.

In the lower range of the high-temperature devices are the solar thermodynamic pumps. For pump capacities lower than 50 kW, process heat of up to 200 C is needed. 50 kW pumps would need 300 C steam engines, and 500 kW pumps would need 400 C temperatures using concentrators, etc.. Solar water pumps are not yet economical and development work to make them competitive with other systems, including photovoltaic ones, is most probably going to be expensive.

Higher range high-temperature systems are even further remote from potential widespread economical utilization. These include the possibility of producing hydrogen from water or production of process heat for such industries as ammonia or cement.

One application of high-temperature systems which deserves attention is the production of cold and air-conditioning in dry warm climates such as is prevalent in northern and southern arid belts.

Medium and low-temperature devices do not require concentration or tracking. They are, therefore, economically attractive and technically simple. Applications include water heaters, cookers, and desalination systems. Space heating is considered only in temperate zones, mostly in developed countries. As no solar concentration is used, economies of scale are achieved in these devices at a level low enough to be attractive to a dilute energy utilization in rural and remote areas and compatible with the dilute nature of solar radiation. However, economies of scale should be sought after in the manufacture of these devices which depend on the design and engineering considered.

Thus, research in medium and low temperature devices should move out from making prototypes and testing them, to production technology and product design, if these units are to be accepted on a large scale. However, if storage of energy is to be avoided, such solar systems would be either oversized or under-utilized or be used with some other source of energy as energy boosters.

Solar water heaters are produced in many countries, such as Australia, Japan, Israel, Cyprus and Jordan. They are produced in small firms which, in developing countries, are often assemblers that buy components usually from abroad. Solar water heaters have a market in temperate or sub-tropical regions and in dry hilly areas where solar energy is available abundantly, but temperatures are low enough to make hot water desirable. Solar water heaters become economically competitive depending on the relative selling price of other energy sources, such as electricity, gas ,or fossil fuel. Nevertheless, solar water heaters are now based on a mature technology and do not need much research for further development.

There are many designs of solar cookers in the market. Others are being developed and tested. The basic problems with solar cooking are: 1) the need for cheaper designs; and 2) the difficulty of cooking while exposed to sunlight or after sunrise. Concentrating cookers are expensive and still inconvenient to operate. They do not have much chance to conquer a large market neither in developing nor in developed countries.

Flat-plate solar cookers are, on the other hand, more promising. They are cheap and could be made cheaper with good engineering and commercial production. They are also easy to operate. However, flat-plate solar cookers can handle limited cooking operations, such as boiling, baking or steaming. They are slow, their efficiency depends on season and climate, and they are not always effective when food is needed.

Also, solar cooking has certainly good potential for large applications operating in tandem with other devices using fossil fuels, such as LPG and kerosene, or charcoal. For solar cooking to be successful, research is nevertheless needed in market identification and development for large scale production.

There are inherent limitations in the economics of solar stills. Indeed, the simple flat-plate stills have no economies of scale, and requirements of fresh water are usually large. Thus, solar stills will not be large suppliers of fresh water for the foreseeable future. They might be promoted on a large scale as small units to produce drinking water in remote arid areas where most water is brackish or polluted.

Finally, solar drying is one of the most potentially important applications of solar energy. Such thermal process might, however, occur first by spreading the product to be dried in the sun, without incurring the extra cost of the dryer. However, even in this case, solar drying may be justified only when improvement in the quality of the dried product may be made, for instance by keeping out insects, birds, dust and contamination. Nevertheless, every one of these problems could be solved without recurring to the solar dryer as such.

On the other hand, flat-plate solar dryers low temperatures limit their output and the speed of drying. Thus, dryers using fossil fuels or electricity can be cheaper than solar dryers when drying on a large scale has to be done rapidly. Sometimes plain air-drying is not possible in cold or rainy weather or when a crop is to be harvested before it is dry.

From the above it seems clear that the market of solar dryers is not obvious and their economies are precarious. Here again hybrid dryers using both solar energy and fossil fuel may improve greatly their attractiveness.

## 3- SOLAR ELECTRICITY

Solar energy can be converted into electricity by two main methods: 1) through a heat stage; or 2) directly through the photovoltaic effect.

There are three methods of converting solar energy into electricity through a heat stage: 1) by using a solar distributed receiver system (STDS); 2) by using a solar thermal central receiver system (STRS); or 3) through solar ponds. In STDS, solar energy is collected by flat-plate collectors over a large area and heat is transmitted to a working fluid. In STRS, solar energy is concentrated on a receiver on top of a tower by a large number of heliostats. As for solar ponds, they use inversed temperature gradient in a special salt solution to trap collected solar heat.

One of the most advanced such heat systems is the STRS Solar One 10 MW power plant. It used 1818 heliostats of 39 m2 each, produced 71000 kWhr/day at 13% average efficiency at a cost of US$13/We. The location has an 950-990 W/m2 insolation and days with 10-11 hours average sunshine hours. The capital cost of solar heat power plants is still very high. The cost per peak kW could be reduced as the technology is improved along with the construction of new prototypes. Nevertheless, solar heat power plants are based on a submarginal technology, their future is questionable, and their markets, because of their large size, might be limited. Furthermore, the larger plants are incompatible with the dilute nature of solar energy. Therefore, it does not seem that further research in this area be justified at present, especially not when there are more interesting alternatives represented by solar photovoltaic (pV) cells.

Indeed, because pV systems lack economies of scale, they are most economical for stand-alone uses in remote areas. However, as the capital cost per installed kW is still too high, pV units are more practical for low voltage uses such as lighting, telecommunications, radio and television. However, all these usages necessitate energy storage, unless the power produced is fed to the grid. This solution is attractive when the overall diurnal energy demand matches the insolation curve.

Furthermore, pV systems necessitate power conditioning equipment the cost of which per installed kW decreases with the size of the unit.

However, pV systems have the advantage of using no moving parts, no fluids at high temperature and no tracking systems. Their overall efficiency is nevertheless lower than 20%.

The materials using the pV effect most attractive in pV systems are: 1) monocrystalline silicon; 2) polycrystalline silicon; 3) amorphous silicon; or 4) thin films using cadmium sulphide/cuprous sulphide or gallium arsenide.

The manufacture of photo-cells, based on monocrystalline and polycrystalline silicon, involve four stages, with the main objective of unit cost reduction. These are: 1) production of silicon; 2) sheet manufacture; 3) cell manufacture; and 4) panel manufacture. In the production of silicon, cost could be reduced by reducing purity, but this would lead to loss in efficiency. New technologies in sheet manufacture, such as monocrystal continuous sheet production and production of polycrystalline silicon wafers, reduce cost but also efficiency. The technology of cell manufacture has practically frozen because of the automation of operations. As for cell manufacture efforts are made to increase cell output by using concentrators, such as in the SOLARES power plant in Saudi Arabia. However, concentrators limit use of solar energy to direct energy and necessitate tracking which introduces economies of scale, making about 3 MW the minimum economically acceptable size of the plant.

All in all, the cost of pV modules has been falling from US$50/peak W in 1973 to $US6 in 1984. It did not fall much since then as the 1984 cost was a result of a price war between oil companies and other manufacturers of photocells. It does not seem that new major cost-reducing possibilities are left in the above-mentioned pV cell manufacture. New methods and technologies are being investigated for this purpose.

One of these is thin film technology using amorphous silicon cells or compound semiconductor cells. Both have at present low efficiencies and low stabilities under working conditions, but their prospects are good. Most encouraging are amorphous silicon cells which have better optical absorption and photo-conducting properties than both monocrystalline and polycrystalline silicon cells. They use less silicon and could be deposited on any non-crystalline substance such as polymer films, stainless steel substrates, and ceramic substrates, or even roofing tiles. Efficiencies are already in the 10 to 12% range.

Research in thin film technology is encouraging, but the technology did not reach yet the commercialization stage. It is widespread in the universities of developing countries.

For the use of pV modules to extend to the utility market, its cost should further fall to $2/W. This is not a far-fetched aim to reach in this last decade of this century. Thus, pV systems should receive the highest attention compared to other solar energy applications.

## 4- RESEARCH & ITS ENVIRONMENT

Development of solar energy research and applications is not independent from other activities in a country. Indeed, if solar energy is to be developed properly, it would have to be part of the energy policy of that country, and consequently included in its overall socio-economic development program. In other words, solar energy research and applications will be promoted if there is a need for them and this need is expressed properly within an effective functioning system.

Thus, research, in general, could be visualized within an electric circuit simulation, in which the load is the application used on a commercial basis and the source of power is the need, whereas the driving potential is the will to fulfil the need, and the charge carriers are the human workers in the entire system. Thus, research should be a response to a need generated by the user. Unless the circuit is closed, no indigenous development occurs neither in solar energy nor in other areas. Consequently, it is essential to review the proper research environment for development of solar energy and its applications, pointing out in particular, limitations predominant in developing countries.

Two characteristics must be attached to research: usefulness and quality. Indeed, research must respond to a practical need and respond to it properly. For this to happen, the users of research, such as policy makers and producers, must be knowledgeable in using research enough to translate it into practical decisions. Similarly, the director of research should be capable to translate a practical need into a research program. Thus, the degree of usefulness and quality of research shall depend on the effective interaction between "doers" and "users"of research.

Essentially, governments are institutions that resolve conflicts. Practically, governments use a great deal of research to define policy. Whatever the nature of a government, all governments in developing countries and elsewhere have been forced to take action on energy problems, due to the scale of energy investments and the import costs or export earnings of energy. Such action would influence, in one way or another, solar energy research and applications.

The establishment of an energy policy for a country is an area that gives large room for interaction between government and researchers. Energy policy analysis, planning and management must ensure greatest effectiveness in reaching the desired goals. Thus, an important aim of energy research is to upgrade the quality of energy policy at all three levels.

Solar energy planning must be an integral part of energy planning, which, in turn, must be an integral part of national economic planning. Such planning should seek the best use of available resources to improve the overall socioeconomic development of the country and the citizens.

Energy policy planning has to consider several possible futures, and choose among them the most desired one, then select the policy instruments for achieving such a future. Research should be able to help at all these levels. However, for research to be able to improve policy effectively it should be carried out in professional institutions capable of giving independent views and which have the financial means to carry out their programs. Furthermore, the government should be an informed buyer of research and avoid the temptation to own it.

However, in practical terms, such independence is not easy to achieve. In general, the larger a country is, the more independent it can be in its decisions concerning energy policy. Furthermore, research would not be effective below a critical mass, which is rarely reached in most developing countries.

Producers of goods and services are the practitioners of production technology. They are also its major repository. But not all such producers are necessarily producers of new or improved technology. Since technological investigations tend to be located in teaching institutions, technological innovation tends to be in industries where the same process can lead to a wide range of products. In developing countries such industries, when present, are small in size and are therefore unable to contribute much in innovations. However, there are three areas of possible action: research and development; technological capacity; and technological infrastructure.

Research and development (R&D) is made up of two components: 1) using processes in a small scale, prototypes are produced singly or in batches to minimize cost; and 2) embodying the results of research into a practical production system. In developing countries, there is often too much of applied research but not enough development. The reason is that public funds, when available, are more readily given to state-owned research institutions not attached to producers. The situation in developed countries is different as public funds are generously allocated to R&D in private institutions linked with production. Thus, government's assistance should be tailored to build the capacity of private firms to observe their environment with a technologically sophisticated mind, and to create competitive market structures that encourage firms to seek innovation. Government's assistance should not be directed towards R&D as such nor to generate specific innovations. Thus, the technological capacity of the nation could be increased and the technological infrastructure developed.

In developing countries, special attention must be given to small firms, as they are the most widespread and the most handicapped in their capacity to innovate. Indeed, research for small producers is risky, and its outcome is uncertain. If research is then done for small producers, they should be in a position to use its results. This depends on several conditions: 1) product innovations usually require process change as well as bringing in changes in other processes. In large companies, coordination between ideas generating departments and those embodying them in production occurs within the company, whereas in small companies the two functions are per necessity separated: ideas come from outside, and the small company implements. Thus, means of coordination in such cases should be devised; 2) in large companies the internalization of the entire chain of innovation ensures benefits, whereas in small companies the chain is broken: the initiator of ideas pays the cost and the producer reaps the benefits. Thus, R&D for small companies should be subsidized; 3) introduction of innovations imply risks that small companies cannot afford. Thus, risk-sharing mechanisms should be developed; and 4) introduction of innovations requires skills not always readily available to small producers. Thus, this problem should be tackled as well.

Nevertheless, some international energy markets are so much controlled by a small group of producers that they will remain for a long time off limits to small countries. The markets of power equipment are now an example (70% of the exports come from five countries: USA; UK; France; West Germany; and Japan). Another example is the market of nuclear power plants (about 70% of plants are produced in four countries: USA; France; Canada; and the Soviet Union). In the future, as solar energy markets extend, some solar equipment, such as photocell-based ones, may fall into this category.

Research and training institutions must be the repositories of accumulated knowledge and skills. Thus, they must be capable of accumulating experience, diffusing intellectual skills and ensuring efficient use of intellectual assets. They must also be capable of bringing together diverse disciplines of science to tackle specific problems.

The biggest danger to research & training institutions is the utilitarian approach in their funding. Project funding often directs researchers towards a number of unrelated short-term projects, thus preventing them from developing real depth in any one discipline. Institutions that are too narrowly specialized run the risk of becoming obsolete when the subject of their specialization is not any more of major interest. Thus, program funding to research institutions must be, instead, directed towards building intellectual assets in specific fields of research. The financed projects should be able to use these assets fully.

Directors of research institutions have an important role in their success. Their role is crucial in relating researchers to problems, and programs to projects. Thus, directors would need both technical and managerial skills.

In developing countries, much importance is given to international funding in solar energy research. However, international funding agencies play a neutral, if not negative role, in building research capacity in these countries. Small-scale research, as is often the case in solar energy, which is generally unrelated to production and commercialization, is funded by small funding agencies. They are certainly not responsible for the lack of coordination between policy, production and use, on the one hand, and research on the other hand. This disconnection arises from lack of national policies and weakness of domestic producers. Due to international funding research is not supported by an inner need; therefore, such funding tends to reinforce the above-mentioned disconnection and makes a bad situation worse.

It is now of interest to look at the situation where research responds to demand and is therefore financed by those who need it.

## 5- DEMAND ANALYSIS & MANAGEMENT

Energy is a vital input that can encourage development when available, or constrain it when absent. The most basic unit for energy consumption is the household. In this respect, households can be classified into collectors, producers and buyers of energy. Households in developed countries are mostly buyers of energy, and demand theory fits them best. In developing countries a great number of households are energy collectors or subsistence producers.

Therefore, it is necessary to develop concepts for study of households in remote areas and to see how solar energy could be introduced to alleviate their situation. In other words, in developing countries, more attention should be given to the study of the market and to the identification of the needs to which solar energy applications could respond.

For instance, collectors and subsistence producers of energy would respond to allocation of human labor to alternative uses. Furthermore, the study of system boundaries should include the dealings of both collectors and producers with neighbouring regions, and variations across regions and social classes.

Research on energy collection should be linked to the need for the protection of the environment, to which a value must be given whenever a solar energy solution is to be assessed economically.

As an example, assuming that a cheap solar cooker has been developed, or needs to be developed, for a given region, the fuel it replaces should be studied. If such a fuel is collected fuelwood, then, in comparing the economics, all items should be taken into account: human labor; impact on the environment, such as desertification and deforestation; quality and composition of the cooked food, etc... Only then attempt at influencing the behaviour of the household could be made, so need for solar cookers rather than fuelwood may be felt.

In general, development implies growth in output of goods and services, which in turn requires increases in energy consumption. As people develop, their need for lighting and household appliances increases. The first appliances to be acquired are electric fans, radios, and television sets. In remote areas, solar energy could have an impact even at its present stage of development, especially where the electric grid is not present and would not be economical to expand it there because of small loads and large distances.

As the economic level of the household rises, need for such items as readily available fresh water and hot water would increase. Solar energy could help in this area even now, in both villages and cities.

The need to make agriculture produce more food, implies more need for water, fertilizers, water pumps, produce dryers and other machines. All this implies more use of energy per person.

As the country raises its income, its energy demand structure and production pattern shift toward industry, thus leading to more energy consumption and more opportunities for solar energy applications. The rise in the living standards also leads to more consumption of goods and greater movement of products from one region to another, thus more energy to be used in transport.

Consequently, research in solar energy cannot be carried out in ignorance of production of goods using such energy. On the other hand, such production cannot be carried out with the rising of demand. Hence, it is necessary to study the factors that determine demand, especially in developing countries, where the need for such demand should be investigated and encouraged.

However, the problem in most developing countries arises from the fact that energy statistics in them are sparse and poorly organized. Only imprecise analysis of energy needs could therefore be made. Thus, efforts should be made to improve the data base for estimating more reliable relationships using more detailed data.

The income elasticity of energy consumption and translog functions between energy and other inputs do not help in identifying the factors affecting consumption. Input-output models describe in great detail the relationship between production and energy use. They allow the study of a large number of hypothetical situations, but they have their limitations. However, in general, there is no perfect way of studying aggregate energy demand as the behaviour of both producers and consumers cannot be accurately predicted through physical means.

Energy demand models can be used to study total energy intensity and manipulate it through policy measures such as taxes and subsidies. Taxes and subsidies could be used to encourage or discourage a given energy source such as solar energy. Their design, as social justice and other factors such as protection of the environment should not be ignored, is a real challenge for research. Research is also needed into better price regulation that is tailored to stimulate technological change for the better.

If an agricultural surplus is essential to sustain population outside agriculture, solar energy should be able to help in generating surplus, directly or indirectly. Thus, applications of solar energy which might not be considered now could be identified, researched and developed. This can only occur if communication is open continuously between the potential user in agriculture and the researcher in the research & training institution.

Finally, there are many applications in the household, agriculture and industry, where solar energy could have an impact on energy conservation. Identifying such applications would help create the need for them, and this in itself must be an important field of research.

## 6- NEED FOR INTERNATIONAL COOPERATION

In analyzing the need for international cooperation in the field of solar energy one has to consider separately the two categories of countries: developing and industrialized countries. Independently of the level of insolation in those countries, their different levels of development make the need for international cooperation vary in nature.

Cooperation between two entities, whereas countries or laboratories, can be fruitful and lasting only if both parties feel a need for it and draw continuous benefit from it. This implies a certain level of parity between the two cooperating parties in whose cooperation each one is a giver and a taker for the benefit of both. Cooperation between industrialized countries in the field of solar energy, as well as in other fields, responds to this criterion and is therefore comparatively successful.

While in each industrialized country research in solar energy is usually financed domestically and fits in an overall plan of development within the energy sector, the need to know what the others are doing in the same or similar areas is perceived as obvious. Indeed, exchange of information, mutual training of experts, and exchange of views help greatly in saving human and financial resources to reach the aim planned, or to redraw the plans to fit more realistic scenarios. Thus, North-North cooperation occurs not only in laboratories and research institutions but also in conferences, workshops, and symposia, as well as in research journals and professional societies. Infrastructures in developed countries support such cooperation, value it, and usually find the means to finance it within the overall program of each country.

The situation between developing countries is different, as no much South-South cooperation is to be observed neither in solar energy nor elsewhere. The difficulties facing such cooperation are numerous and would be considered in more detail in the next section. However, here we can already notice that, while there is to a certain degree parity among developing countries in their underdevelopment, such countries do not see the benefits they can draw by cooperating with each other, as they do not value much each other's efforts.

North-South cooperation between an industrialized country and a developing one seems at first sight viable, and it is widespread. However, with the possible exception of the three large developing countries (China, India, and Brasil), such cooperation does not seem to be between comparable partners. Also, while it seems that both such cooperatin partners benefit from it, they do not seem to benefit in the same manner. On the one hand, the industrialized partner in the cooperation program knows what to draw from the cooperation, and use it, under the cover of aid, for demonstration and development of markets. On the other hand, the developing country in the partnership usually does not have a program of its own, has practically no local funds for research and does not have a clear idea of what to draw from such a cooperation. Often, the decision to cooperate is taken by administrators and political decision-makers, and it is executed by a university professor starving for research funds and international peer recognition. The professor does benefit from such a cooperation, but not necessarily the country.

Therefore, let us look at the ideal situation for a cooperation fruitful to all concerned. In this respect, we shall consider three levels of cooperation: 1) cooperation of institutions within the same country; 2) cooperation between developing countries at the regional level (South-South cooperation); and 3) North-South cooperation. Finally, the ideal role of international agencies shall be analysed briefly.

First, no international cooperation is useful to a given country unless there is cooperation between the different sectors within it. For solar energy, a country shall be ready for international cooperation if it has a certain development plan which includes development in the field of energy which in turn has a solar component including research, training, demonstration and development, and where all the groups working on solar energy within the same country cooperate in such a manner as to form components within the same overall team.

No single developing country would be in a position to carry all research work needed in all areas of solar energy. Therefore, a given country shall choose its priorities in such a manner as to be able to bring in tangible results with its limited human and financial capabilities. Regional cooperation between countries of the same region, having similar levels of development, and often sharing the same language and the same culture, would seen attractive, if each one of such countries has developed its own program, coordinated its own teams, and defined its area of speciality. Therefore, the groups working on solar energy in the entire region would form an ensemble tackling the widest range of solar applications of usefulness to the region. However, such cooperation would succeed only if its cost is integrated within the budget of solar energy of each country. The ideal situation shall be reached when the solar energy program becomes basically a regional program shared by the different countries of the region.

Thus, such South-South cooperation at the regional level would prepare the region for more fruitful cooperation with an industrialized country. Such North-South partnership would not be only a relationship between a giver and a receiver of aid but on the country between two partners: the industrialized country on the one hand; and the developing region on the other, knowing both what they want from such a cooperation and what they are willing to give. Only such negotiated cooperation, financed by both parties could lead to real development for both in the applications and utilization of solar energy.

International agencies, such as UNIDO, could play an important role in encouraging South-South cooperation, by helping countries develop their own programs and by seeking necessary finance to start such cooperation. Also, through their programs, they should encourage North-South cooperation on a more equitable level for both North and South. International agencies could play an important role in bringing together not only workers in the field of solar energy from different parts of the world, but also the different actors at different levels of solar energy: the producers and the users; the researchers and the policy makers; the teachers and the industrialists; etc...

In the following section, we shall consider briefly the pathology of research & development in developing countries which make the above scenario difficult to achieve. Indeed, unless the effectiveness of developing countries research institutions is greatly improved and integrated into the productive and policy-making processes, such countries would not benefit from international cooperation.

## 7- DIFFICULTIES IN INTERNATIONAL COOPERATION

The problems faced by international cooperation in the field of solar energy in developing countries, as in other fields, emanate from several local and regional problems leading often to regional conflicts, rather than cooperation. First, even at local and national levels, research is poorly financed. As governments are the major users and financiers of research, their interest in financing research to solve long-term problems diminishes as they face more urgent short-term ones which receive all their attention. Indeed, as oil prices increased in 1973/74, many governments adopted a variety of corrective policies, such as import regulation and substitution, export promotion, and international borrowing. This strategy was successful for a while, and when the price of oil rose again in 1979/80, it was repeated but with a damaging effect this time. As the price of oil eased, developing country's governments discovered that they faced instead an insurmountable foreign debt serving problem eating at increasingly larger proportions of their GNP. Consequently, research became the first victim of such a situation as governments started cutting down their expenditures to service their debts.

Second, most developing countries are under a considerable degree of central direction, and most government funding is channelled primarily into captive research institutions. Such countries often lack independent professional research institutions that can act as repositories of knowledge and know-how and initiate the need for regional cooperation.

Third, most developing countries are too small and poor, even for supporting a research group with the minimal critical mass to enable it to contribute in a meaningful regional cooperation. So much so that even the small local capabilities are divided into non-cooperating and often contradicting small groups managed by different ministries with no mutual understanding or program.

Fourth, often governments in developing countries are not informed users of research. They tend to rely on consultants to make their decisions. The result is dependence on imported technology, rather than support to local efforts, which are rarely appreciated as immediate results are expected.

Fifth, often in developing countries, the circuit research-development is open in such a manner that results from applied research do not lead to commercialization. Therefore, producers are linked to research done in industrialized countries and do not see any benefit in financing research at home. Public funds for research, whenever available, usually go to state-owned research institutes not attached to producers. All this makes the need for regional cooperation unappreciated or inexistent.

Sixth, outside the public sector, producers in developing countries are often too small even to think about research. They rely on obsolete technology, and under the best circumstances they are able to use results of imported research. The latter is often too expensive and renders accumulation of knowledge and know-how at home impossible. Furthermore, local research appears unnecessary and remains unsupported. Consequently, the fruitfulness of regional cooperation does not appear obvious to the producers.

Seventh, researchers in developing countries have poor access to comprehensive libraries and experienced colleagues. especially in other developing countries. The poor state of communications prevalent between developing countries, makes cooperation difficult, if not impossible. The communication between a developing country is usually much better with its former colonizing power, which remains in the field of research, in solar energy as in other areas, the only point of access to experience and knowledge for the researcher.

Eighth, most research in developing countries is funded by outside donors, or by agencies financing one energy program or another. Therefore, such research is not fully under the control of the country considered. It would not necessarily lead to regional cooperation.

Ninth, cooperation in solar energy at the regional level cannot be taken outside regional cooperation in general. If regional conflicts are the norm in many regions of the developing world, communications suffer, and movement of goods and people, let alone ideas and views, becomes impossible, and therefore no cooperation could be carried out. Thus, regional cooperation in the field of solar energy is part of regional cooperation in general, and can occur only in a climate of regional integration or at least peace and understanding.

Tenth, energy research and regional cooperation are part of overall socio-economic research. Researchers can be independent only if they are free to criticize policies and propose alternatives without fearing for their carriers and their research funds. Therefore, real research cannot occur, not even in such a simple field as solar energy, in societies that lack mechanisms for peaceful changes in policies and policy makers. Unfortunately, such societies are the norm in developing countries rather than the exception. With no meaningful research present, regional and international cooperations become pointless, if not impossible.

Under the above circumstances, let us look at the situation of a group of developing countries members of the Organization of the Islamic Conference (OIC) and their efforts to coordinate solar energy research between them, in spite of the difficulties mentioned above.

## 8- SOLAR ENERGY IN THE OIC MEMBER STATES

The OIC, established in 1969, groups 46 member states. Its aim is to promote cooperation between its members in all fields of endeavour. The OIC states had in 1989 a total population of about 950 million people, and a total area of about 27 million km2. These states could be divided into three groups: the Arab group (Egypt, Morocco, Algeria, Sudan, Iraq, Saudi Arabia, Syria, Tunisia, North Yemen, Somalia, Jordan, Libya, Lebanon, South Yemen, Mauritania, Kuwait, Oman, the United Arab Emirates, Djibouti, Bahrain, Qatar and Palestine); the African group (Nigeria, Uganda, Cameroon, Mali, Burkina Faso, Senegal, Niger, Guinea, Chad, Sierra Leone, Benin, Gambia, Guinea Bissau, Gabon, Comoros); and the Asian group (Indonesia, Bangladesh, Pakistan, Turkey, Afghanistan, Malaysia, Brunei-Darul-Salam, and Maldives).

The OIC member countries, while they are all part of the developing world, vary greatly in all their characteristics. The largest member state in area (Sudan : 2,500,000 km2) is 8.400 times larger than the smallest (Maldives : 300 km2). The largest member state in population (Indonesia : 190 millions) has more than one thousand times more people than the smallest (Maldives : 200,000).

If the GNP of the OIC member states is considered, their diversity becomes even more striking. For a total GNP of about US$800 Billion, eight countries contribute less than US$1 billion, whereas Saudi Arabia alone contributes about 20% of the total.

Estimates of renewable energy consumption in OIC states are above 30% of total energy consumption, mostly in the form of biomass. This percentage is much lower for oil-exporting countries such as Saudi Arabia, rises to about 50% for Pakistan and Bangladesh, and is above 80% in most African countries. Therefore, it is essential that renewable energy resources be exploited optimally. More interest is now shown in most OIC states to development of biomass and solar energy.

As solar energy technologies pass through different degrees of development some are already commercialized, others are technically viable, but not yet economical, yet others are still in a stage of research & development. At present, there is increasing interest in solar energy applications in OIC countries. However, the field is supported with limited resources which led to the establishment of the necessary infrastructure for further development. Such support is also characterized by dispersion of efforts, repetition and inefficiency in the utilization of the limited financial and human resources available. In the following pages we shall summarize the solar energy activity present in the OIC member states, treating each group of countries (Arab, African and Asian) separately :

A) The Arab Group:

Algeria: in R&D, Algeria has, since the French era, one heliodyne of 8,4 m diameter at Bouzareah. This is a solar furnace that could reach a temperature of 300 C at the boiler, and produce steam for a 30 kWe thermal turbine. Furthermore, experiments on pumps and photovoltaic modules and heliothermal collectors are carried out. Also, there are plans to build 100 kW solar thermal stations. Algeria uses solar water heating and photovoltaic units to power Hertzian relays, as well as pumping stations and desalination units.

Egypt: most R&D in Egypt is carried out at the Solar Energy Laboratory, National Research Center (Dokki). Most work was carried on solar thermal power, including power generation, desalination and drying. Photovoltaic research is carried out by several groups in Egyptian universities. Demonstrations and applications are limited to three villages using photovoltaic generation to produce electricity and three photovoltaic pumps. Solar water heaters were introduced in the market but did not succeed.

The United Arab Emirates: there is no much research in the UAE on Solar energy but photovoltaics are used for public lighting.

Iraq: solar energy research in Iraq is carried out at the Solar Energy Laboratory of the Scientific Research Council (Baghdad). Work is carried out on refrigeration and water treatment as well as a demonstration of a 300 kW photovoltaic generator. The main applications in Iraq are production of solar water heaters and photovoltaic cells under licence from SOLAREX.

Jordan: most solar R&D in Jordan is carried out by the Royal Scientific Society (Amman). They developed experimental water heaters, including a pilot unit of 42 m2. They also developed one photovoltaic pilot station of 1 kW capacity with measuring equipment. The main solar applications in Jordan are a desalting station by solar distillation having an area of 150 m2 and a flash evaporator with an area of 375 m2. Furthermore, Jordan is probably the largest OIC state producer and maker of solar water heaters.

Kuwait: research on solar energy in Kuwait is carried out at the Kuwait Institute of Scientific Research and to a lesser extent at the University of Kuwait. Most research was done on thermal application. The main demonstration unit is a 100 kW photovoltaic pilot station.

Mauritania: the main demonstrations are two photovoltaic pumping stations, distillers and gypsum dehydrators. The only application is the availability in the market of solar water heaters for homes.

Morocco: the work on solar energy in Morocco is carried out at the Solar Energy Research Center in Marrakech. R&D includes a systematic study of the solar potential, flat plate solar collectors and an experimental solar furnace. Demonstrations include one pV pump, two pV refrigerators and photovoltaic powered television.

Sudan: most R&D in the Sudan is carried out at the Solar Energy Laboratory of the National Council of Research in Khartoum. It includes solar dryers (75 C); four desalting units; and four experimental water heaters (75 C). Demonstrations include one photovoltaic pump and one photovoltaic refrigerator.

Syria: R&D in Syria is limited at the university to experiments on solar applications. But an effort has been put in encouraging solar water heaters as Syria is now producing 2,000 water heaters per year for the local market.

Tunisia: R&D in Tunisia is carried out at the "Ecole Nationale d'Ingenieurs de Tunis" (ENIT) and the "Institut de Researches Scientifiques et Techniques" (IRST). It includes some work on photovoltaics as well as a demonstration of two pilot photovoltaic stations, one of 2.9 kW and the other of 3.9 kW capacity, and one thermodynamic power plant. Experimentation is also carried out with medical refrigeration. On the other hand, Tunisia produces 4,000 flat plate collectors per year.

Saudi Arabia: solar energy R&D in Saudi Arabia is coordinated by King Abdul-Aziz City for Science and Technology (KACST), and carried out at the universities. Main work on R&D includes measurement of solar characteristics, solar cooling, and solar desalination. Demonstration includes a photovoltaic station in Al-Unaynah (near Riyadh) for rural electrification, and a desalination station in Yanbu' on the Red Sea. Saudi Arabia also produces pV cells and uses pV relays on highways.

Other Arab countries: the other Arab countries (Bahrain, Qatar, Oman, North and South Yemen, Djibouti, Somalia, Lebanon and Libya) all have some activities as well as some demonstrations in solar energy, but none is on a large scale. Most experiments are done on water heating and most demonstrations are on photovoltaics.

B) The African Group:

Burkina Faso: there is a series of demonstrations including 50 water heaters, 10 water pumps, 20 light stations, and 20 pV control relays.

Comoros: experiments are done on solar drying and there is a demonstration of one pV 165 W generator.

Mali: experiments are carried out at the Solar Energy Laboratory in Bamako on thermal solar applications.

Niger: most R&D in Niger is carried out at the Solar Energy Laboratory in Niamey. It includes: local study and development of a solar dryer, a generator, a furnace, a distiller, and the study of an experimental flat plate collector. Solar water heaters are also produced in the country.

Senegal: R&D is carried out mostly at the University. It includes pumping experimentation with thermodynamic motors; one 10 kW thermodynamic station for rural electrification; two 10 kW each pV power stations. There are also centers for heliometric measurements, members of the OMM Network. As applications, there are hundreds of installed solar water heaters and telecommunication pV relays. Senegal produces about 500 solar water heaters per year, but the market is not sure.

Other African countries: there is no much activity on solar energy in the other African OIC countries: Nigeria; Uganda; Cameroon; Guinea; Chad; Sierra Leone; Benin; Gambia; Guinea-Bissau; and Gabon.

C) The Asian Group:

Malaysia: most R&D is done at the universities or is managed by the Ministry of Energy & Environment. It includes two pV pilot stations for rural electrification (100 to 200 W/horse); distillers; refrigerators; and small power dryers.

Pakistan: there are seven pV pilot pumping stations, and efforts at encouraging solar rural electrification. Pakistan also produces pV modules at the National Institute of Silicon Technology in Islamabad.

Turkey: R&D in solar energy is carried out at the universities or at TUBITAK, the Turkish National Council for Research. It includes passive cooling; an experimental station for thermal collectors; a solar energy measuring station; production of electricity and water heating. Solar distillation is also used to produce fresh water as well as MgSO and N SO .

Other OIC Asian countries: there are also similar applications in some of the other OIC Asian countries, such as Indonesia and Bangladesh. In others, such as Iran; Afghanistan; Brunei-Darul-Salam; and Maldives, there are no much activities in solar energy. In general, no much research is carried out in those countries in solar energy, and the different applications are used as intermittent demonstrations from one foreign producer or another.

## 9- OIC SOLAR NETWORK

In 1981, OIC established two institutions under its umbrella: a) the OIC Standing Committee for Scientific and Technological Cooperation (COMSTECH) where the 46 member states are represented by their ministers dealing with science & technology. The Chairman of COMSTECH is the President of Pakistan; and b) the Islamic Foundation for Science Technology & Development (IFSTAD) as the executive arm for their cooperation. The another of this article was its first Director General, and the program described hereafter was executed and managed by him.

COMSTECH developed a Plan of Action for inter-Islamic cooperation, including the establishment of a series of networks in specific scientific applications. One of these networks deals with renewable energy sources.

Indeed, as seen above, few OIC states possess the human and material resources to establish the full range of activities for R&D, training, information, and production in solar energy, but collectively they could attain an acceptable level of capability. Similarly, expertise and information need to identify problems for correct choice of R&D priorities, and necessitate a collaborative, collective, and committed program for the scientists and technologists of the region to pool their resources to achieve real development in this area. Thus, a need was felt for OIC states to combine their activity to contribute to and benefit from cooperation in renewable energy sources and other fields.

COMSTECH proposed the establishment of cooperative institution networks between different member states working in specified disciplines, with the ultimate aim of establishing centers of excellence. IFSTAD then developed the mechanisms for starting such networks.

The rationale of establishing networks is based on the fact that correct choice of R&D priorities by OIC states necessitates collective and committed actions within a network encompassing as many OIC states as possible, allowing them to pool their various resources to reach their aims. The networks would also help save limited human and financial resources, stimulate growth of expertise, enhance self-reliance, and contribute to the economic-industrial development of the participating countries.

In order to prepare the establishment of the Renewable Energy Resources Network (RERNET) an expert group from OIC states was invited to a meeting held at the National Institute of Silicon Technology (Islamabad, Pakistan) on July 29. 1986. The working paper presented at the meeting was prepared by Senegal.

The Islamabad meeting felt that renewable energy sources are of great importance to OIC states. Indeed, a great percentage of energy consumed in these states is non-commercial, mainly biomass. The inefficient way by which this energy is used leads to environmental degradation and desertification. It was also felt that interest in solar energy has not been translated, after two decades, in much tangible results. The Meeting felt that individual efforts of each OIC state alone would not bring the desired results and that there is a need for coordinating efforts in this area.

The Meeting also felt the need for RERNET, and proposed the following provisions for its establishment:

a) RERNET shall be implemented on a priority basis under the overall umbrella of IFSTAD, the science & technology arm of OIC.

b) All OIC states shall be invited to join RERNET and those states opting to do so, shall be the founding members of this network. They shall also nominate their representative institution in RERNET, implying the establishment of an internal national network on renewable energy sources, their representative institution being the focal point for RERNET and for the national network.

c) RERNET shall be managed by a board of directors comprising representatives of member states in RERNET, who shall be the heads of the institutions declared as focal points in RERNET by the member states. IFSTAD Director General shall be an ex-officio member of the Board of Directors.

d) RERNET states shall share the capital cost as well as the recurring expenditure of RERNET. In turn, they shall have exclusive rights to the benefits of RERNET.

e) Other OIC states may join RERNET after contributing towards the capital cost incurred, and share in the recurring expenditure.

f) The central data bank of RERNET would also gain access to suitable international data banks specializing in renewable energy, so as to provide enhanced level of data and information to the RERNET users. Efforts shall be made to earn extra revenue by making available the services of RERNET to OIC states not participating in it, as well as to non-OIC states at the discretion of the Board of Directors.

g) RERNET shall do its utmost to provide maximum information on its capabilities to the data bank so as to make the service more useful. This information shall cover all aspects of renewable energy sources such as scientific, technical, economical, legal, socio-political, cooperative, educational, training, industrial development, etc...

h) RERNET shall develop within its own member states the infrastructure for information, collection, and dissemination, necessary for the functioning of the national centers declared as focal points in the RERNET Network.

i) The information fed to the data bank shall be controlled for validity and authenticity both at the focal points' level and at the central data bank level.

j) The relevance of the information obtained through RERNET for the national development process shall be established, and efforts shall be made to measure the cost benefits of the services obtained from RERNET.

k) RERNET may also have fax facilities for quick exchange of messages within RERNET.

l) RERNET members shall exchange among themselves technical and scientific reports on their experience, work and facilities, on regular bases, and provide copies of such exchange to IFSTAD'S secretariat.

m) RERNET shall also cooperate in practical manpower training and encourage the movement of products resulting from their common efforts across their borders.

The Islamabad Meeting felt that the establishment of RERNET would go a long way in increasing the effectiveness of member states in the field of renewable energy. It would help them greatly save their financial and human capabilities to produce more effective and tangible results. RERNET would also help its member states benefit better from international cooperation, especially between REKNET as a whole and other countries. It was also believed that a cooperative effort through RERNET would lead to better usage of R&D in renewable energy for socio-economic development.

The work of the Islamabad Meeting on the feasibility, working mechanisms and charter of RERNET was put for consideration to the ministers of all OIC states at Third COMSTECH Meeting held in Islamabad (Pakistan) on November 1986. COMSTECH approved the Report and presented it for approval, alongwith their decisions on other networks, to the Fifth Islamic Summit (January 1987, Kuwait). Consequently, IFSTAD invited all OIC states to join RERNET and nominate their representative institutions.

The following countries responded in affirmative, and expressed their desire to join RERNET as founding members: Morocco; Algeria; Tunisia; Egypt; Syria; Iraq; Jordan; Qatar; Saudi Arabia; Niger; Senegal; Indonesia; Pakistan; and Turkey; i.e. a total of 14 states, or most of the countries that have a program in the field of solar energy and renewable energy sources.

The founding meeting of RERNET was then held in Islamabad, Pakistan, on Sept. 27_29, 1987, where representatives of the above 14 states were present. The Meeting approved the RERNET institutional framework, charter, program, and budget. Pakistan was elected as chairman of RERNET and the site of RERNET's secretariat was located at the National Institute of Silicon Technology (NIST) in Islamabad, Pakistan.

RERNET is now two years old. It is still functioning and its members meet regularly. Thus, the purpose of exchanging information and pooling efforts in training, for which it has been established, has been fulfilled to a certain extent. However, the aim of forming national networks on solar energy for each RERNET state as well as reaching some kind of overall program in which each country would specialize in a given area, has not been reached. However, the most serious shortcoming of RERNET is the fact that it is not yet financially autonomous. Its different member institutions are not sharing in its cost, and are unable to include such cost in their yearly budgets. It seems that most such institutions expect to receive from RERNET more than they contribute to it. Therefore, up to now the financing of RERNET comes from outside the Network. It does appear obvious that RERNET would not survive now if such funds are cut. Would it survive if they are cut after some years? This is the real challenge facing RERNET,

## 10- CONCLUSION

It would be of interest to follow the progress of RERNET and similar networks around the world. However, the same problems that lead to inefficiency of solar energy programs & applications in a developing country lead to the inefficiency or failure of a network between several developing countries. Thus, the problem of cooperation is linked to the problem of underdevelopment: the more a country is underdeveloped, the more it is unwilling to cooperate with others, as it does not see the benefits of such cooperation, or is unable to benefit from it, as it does not have the national human infrastructure to interface usefully with others.

One of the most important contributions that could be made by COCERA to the solar energy community is to pinpoint areas of success and failure in solar energy cooperation around the world. It is only when more light is shed on such efforts that they may be more appreciated and have better chances of success.

The smaller, poorer, and less-developed countries of the world can contribute to the advancement of knowledge and know-how in solar energy only through meaningful South-South and North-South cooperation. They should be helped in doing so and be given a chance.

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