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PROCEEDINGS

OF THE

SYMPOSIUM ON SOLAR SCIENCE AND TECHNOLOGY

25 November - 4 December 1980

Bangkok, Thailand

VOLUME ONE

UNITED NATIONS

PROCEEDINGS
OF THE
SYMPOSIUM ON SOLAR SCIENCE AND TECHNOLOGY

25 November - 4 December 1980
Bangkok, Thailand

organized jointly by the

UNITED NATIONS ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

and the

REGIONAL CENTRE FOR TECHNOLOGY TRANSFER

With the financial assistance of the

UNITED NATIONS INTERIM FUND
FOR SCIENCE AND TECHNOLOGY FOR DEVELOPMENT

UNITED NATIONS
New York, 1981

The Symposium on Solar Science and Technology was sponsored by the:

- United Nations Economic and Social Commission for Asia and the Pacific
- Regional Centre for Technology Transfer
- United Nations Educational, Scientific and Cultural Organization
- United Nations Industrial Development Organization
- Food and Agriculture Organization of the United Nations
- World Intellectual Property Organization
- International Labour Organisation
- United Nations Environment Programme
- International Solar Energy Society
- Asian Institute of Technology

with the financial support of the

United Nations Interim Fund for Science and Technology for Development

and hosted by the

Ministry of Science, Technology and Energy, Royal Thai Government

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FOREWORD

In pursuit of the goal of acquiring new and renewable energy supplies for their development needs, many Asian and Pacific countries have initiated a series of policy measures leading to possible future self-sufficiency in energy. Since 1978, ESCAP in accordance with resolution 33/148 of the United Nations General Assembly, has undertaken several important programmes and projects for the development of alternative sources of energy in the region. New policies, plans and priorities have been set in motion towards achieving a well co-ordinated relationship between energy and development, including the management of their inherent and over-all impact on society.

As a major input to the field of solar energy for the United Nations Conference on New and Renewable Sources of Energy held in August 1981 at Nairobi, the Symposium on Solar Science and Technology was convened at ESCAP headquarters and at the Asian Institute of Technology, Bangkok, during November and December 1980 and attracted experts from various United Nations and other international and national organizations.

In the wake of this Symposium, and in order to emphasize its own commitment to the development of energy resources throughout Asia and the Pacific, ESCAP highlighted energy as the main theme at its thirty-seventh session which recommended, among other things, that ESCAP play an active role as the regional focal point for further work in the field of energy. In fulfilment of this role, and also to reinforce its already existing programmes concerned with energy, ESCAP has established a special unit on energy to cope with the increased demand for information and expertise on conventional as well as new and renewable sources of energy.

In particular, ESCAP will continue to place special emphasis on solar energy and to co-ordinate activities in member countries designed to meet immediate energy needs. Reflecting the priorities of the region, ESCAP will stress low-cost technologies applicable to small-scale farmers and rural communities so that its efforts in the field of energy will have the widest possible impact and will be of direct benefit to the peoples of Asia and the Pacific.

S.A.M.S. Kibria
Executive Secretary

PREFACE

The present Symposium on Solar Science and Technology was organized to serve as a major regional input in the field of solar energy to the United Nations Conference on New and Renewable Sources of Energy held in August 1981 at Nairobi. Recognizing the developments in highly sophisticated solar technology by many industrialized nations, the Symposium reminded the participating scientists, technologists and industrialists from Asia and the Pacific of the need to remain fully abreast of this rapid technological progress and vigorously to continue to work towards the greater use of solar energy in the region.

The primary objectives of the Symposium were to provide an exchange of scientific and technological knowledge concerning solar energy; to introduce programmes related to solar energy in university and college curricula; to promote the transfer of technology related to solar energy; and to encourage the incorporation of solar energy programmes into national energy policies and plans throughout the Asian and Pacific region. These primary objectives met with the unanimous support of the Symposium.

The Symposium had four components: (a) a general session for the presentation of keynote addresses; (b) a meeting of solar scientists; (c) a meeting of solar technologists and (d) a workshop to provide interaction between the two groups. After a comprehensive review of the status of solar science and technology in the region, the meeting of scientists broke up into four groups on photothermal conversion, photoelectric conversion, photosynthetic conversion and the storage of thermal energy. The meeting of technologists, divided into five groups, to study solar applications in drying, heating, cooling, pumping and cooking. Each group then returned to the plenary and presented sets of recommendations with regard to their respective disciplines. On the whole, the most notable recommendation emphasized by the Symposium was the need for the evolution of clear-cut national policies for the utilization of solar energy.

To substantiate the discussions at the Symposium, an exhibition of solar equipment (SOLEX'80) was displayed at the Asian Institute of Technology as part of the Symposium. This equipment has been retained at the existing site and maintained by AIT as its Energy Park.

The Symposium was supported by the United Nations and other international and national organizations. The United Nations Interim Fund for Science and Technology for Development provided financial support for the Symposium, while, UNCTAD, UNEP, UNIDO, FAO, UNESCO and WIPO actively participated and also lent their names in co-sponsoring it. This was in fact the first Symposium of its kind on energy, supported by the various United Nations bodies, the International Solar Energy Society and the Asian Institute of Technology.

The secretariat would like to express its sincere gratitude to those individuals who helped ESCAP and the Regional Centre for Technology Transfer in organizing this Symposium, particularly Dr. Prida Wibulswas (Dean, King Mongkut Institute of Technology), Dr. Robert Exell (Associate Professor, Associate Chairman, Division of Energy Technology, AIT) and Dr. G.Y. Saunier (Chairman, Division of Energy Technology, AIT).

I. STATEMENTS

STATEMENT BY HIS EXCELLENCY DR. THANAT KHOMAN, DEPUTY PRIME MINISTER, ROYAL THAI GOVERNMENT

Mr. Executive Secretary, Distinguished Participants, Ladies and Gentlemen,

It is for me a pleasure and a privilege to represent the government of Thailand at this inauguration of the Symposium on Solar Science and Technology. The reason is because the subject of solar energy is particularly close to my personal interest, concern and preoccupation. Indeed, many years back when oil prices had not yet skyrocketed, I was so concerned with the problems that I commissioned the Asian Institute of Technology, I am glad to say, to undertake studies and research on this important matter which yielded some satisfactory results.

At this time, when many countries, indeed the whole world, except those which have the good fortune to be endowed with oil resources, are facing the gravest energy crisis, this Symposium represents an attempt to tackle the problem in a courageous and rational way. It also signifies the determination of non-oil countries to survive, not to go down the drain swept by the spiralling of oil price increases.

While conservation measures are being adopted by most countries, except perhaps the notable exception of our own here, other renewable energy resources must be sought to obviate to the costly fossil fuel. Solar energy is one of them. There are many others but at least the one that all of us possess, in greater or lesser degree and independently of external control, namely solar energy, must be explored and if possible exploited and utilized by our fuel starving nations. If we succeed, even partially, we will be going a long way to help sustain the development efforts now being undertaken almost everywhere. Otherwise, millions of our impoverished people will be in dire predicament.

For these reasons, I applaud the timely initiative of the Regional Centre for Technology Transfer of ESCAP to organize this Symposium so that the question of this important renewable source of energy may be thoroughly examined and thus endeavour to keep this part of the world abreast with other regions which are already well ahead of us in terms of scientific knowledge as well as technological applications. Any advance which may be accomplished in the course of the ensuing meetings will be gratefully received and acknowledged by our teeming millions. The scientific progress which may be achieved will have ready repercussions in the economic field and contribute to the well-being of the multitude of our underprivileged population whose expectations are far from being fulfilled.

I, therefore, as representative of the Thai Government, extend to each and every one of you a hearty welcome and, above all, my sincere wishes for the success of your deliberations which hopefully may lead to practical and concrete realizations.

STATEMENT BY HIS EXCELLENCY DR. ANUWAT WATANAPONGSIRI, MINISTER FOR SCIENCE, TECHNOLOGY AND ENERGY, ROYAL THAI GOVERNMENT

Mr. Executive Secretary, distinguished participants, ladies and gentlemen,

I am extremely happy to be with you this afternoon at the closing of the Symposium on Solar Science and Technology. I have been associated with ESCAP in the planning stages of the Symposium and have also expressed my views suggesting the lines on which the Symposium could be organized. As the Executive Secretary has stated, I could not be with you earlier only because I was abroad on a mission. I am happy, however, to have gone through the record of your deliberations and to be able to share some thoughts with you this afternoon.

Being addressed to the problem of energy, the Symposium has discussed issues which are bound to be critical to our development in the coming decades. Our perspective cannot remain restricted to the conservation of energy. To eradicate poverty we have to aspire after much higher levels of production, which will inevitably involve larger infusion of enrgy. In these days of energy shortage our ability to find access to additional sources of energy will really determine our future welfare and destiny. It is not surprising, therefore, that the issues relating to energy have become the uppermost concern of the policy-makers in the developing countries. ESCAP, as the intergovernmental organization of this region, has rightly chosen energy as an issue of high priority in its work. The member countries are looking forward to the initiatives that could flow from this work and could reinforce the programmes being pursued at the national level.

This Symposium is an element of the programme of the ESCAP Regional Centre for Technology Transfer in relation to the new and renewable sources of energy. I would like to compliment the Centre for taking this most appropriate and timely initiative. I understand that the work of the Centre is not confined only to the direct utilization of sunshine but also includes its indirect use through the energy crops and their conversion into alcohol. These programmes of the Centre are of great relevance to this region, the bulk of which lies in the tropical zone and has abundant endowment of sunshine and vegetation. I firmly believe that these enormous sources can provide significant supplements to the supply of energy available for our use. If the Centre succeeds in generating some concrete and viable projects, it would have rendered a great service to the region. I believe that this Symposium has been a useful step in that direction.

I am glad that your Symposium has given attention to the entire innovation chain, starting from work in the laboratory and extending right up to the manufacture of solar equipment. You have among you some leading solar scientists of the region who have presented papers giving the results of their research. You also have among the participants experts engaged in the design, development and engineering of solar equipment and the organization of their production on a commercial scale. This set of experts are grappling with the pertinent questions relating to the viability of the newly innovated equipment. The discussions in this interdisciplinary group have disclosed policy options which will be of utmost value to our member countries for the optimum exploitation of solar energy for our development.

While discussing the issues relating to energy we have to contend with an extremely dynamic framework. It is unrealistic to take for granted any assumptions relating to supply, demand, pricing or technology. It is the extremely volatile nature of these factors which makes the discussion of energy issues so difficult and yet so fascinating. In such a situation it seems important to me that we should be clear in regard to the basic co-ordinates to which our discussions should be related. I firmly believe that rapid development must be our prime concern and that the other concerns must be subordinated to it. Keeping this prime concern in view it should be possible to evolve the basic ground rules for our energy planning. Even the energy mix appropriate to the different countries should partly be deduced from our prime concern for rapid development. I am happy to see this perspective runs through the entire deliberations of this Symposium.

The supplementary role of solar energy is now well recognized. There is a shelf of technologies available for the utilization of solar energy for a wide range of uses. What is important is to select the best of them keeping in view their viability and simplicity. It is in this area that regional initiatives at the level of RCTT can be extremely useful for the member countries. Carefully evaluated and selected solar technologies can be made the basis for well planned production and propagation programmes. In doing so, we shall have to give the utmost attention to the designing and engineering aspects and also to the marketing of the solar equipment so as to bring it within the reach of the people most in need of it.

The viability of the new solar equipment and devices is dependent on a whole range of pricing policies which affect the relative costs of different kinds of energy. I agree with the observation of the Symposium that the conventional sources of energy are still the recipients of sizeable subsidies. In many instances the subsidies are patent but in many others they are unseen. It is necessary to have a realistic idea of these subsidies and of the costs that are incurred by the society in sustaining a particular pattern of energy consumption. It is only by going deep into such economic questions that one could determine an appropriate pricing policy for the new sources such as solar energy. In doing so we shall necessarily have to take into account the finite availability of the fossil fuels and the uncertainties regarding their supply and price. We have to take deliberate steps to diversify our sources of energy and prepare our countries to shift our dependence to new and renewable sources. If for such preparation certain economic costs have to be incurred in the short run, we should be prepared for it. The specific ideas that the Symposium has proposed will be extremely useful in generating informed discussion in the member countries.

We have also to step up our effort to search out new technologies for exploitation of solar energy. We cannot simply remain dependent on the leads that may be expected from the researchers in the developed countries. If we do not ourselves take initiatives we shall be incurring a new kind of dependence, which will have an adverse impact on our future prospects. I am happy to note that pioneering work in the field of solar energy is being done by numerous scientists in our region. They must be provided with greater support. Mechanisms should also be built up whereby their activities may be harmonized so as to achieve more concrete results. In this RCTT can play an important role and function as a regional point of reference.

The Royal Government of Thailand in its energy policies is committed to devote priority attention to solar energy, both in its direct and indirect uses. Within the limits of our manpower and other resources we are already implementing several programmes. We are willing to co-operate with the other countries and participate in the regional programmes suggested by the Symposium. I am happy to mention that we have offered the assistance of our experts for the regional study on energy crops and their processing, which is due to begin shortly.

I would like to take this opportunity to express my support for the proposal to establish a regional solar energy association. I entirely agree with the distinguished Executive Secretary that such an association can serve as an important rallying point for the cause of solar energy. I do hope that steps for the establishment of the association will be taken earnestly.

I would, in conclusion, like to compliment the Executive Secretary and all who have been associated in the organization of this worth-while Symposium. I would, in particular, thank all the distinguished participants for having made commendable contributions towards the cause of solar energy. I cordially congratulate you all and wish you excellent health and successes in your research work.

I formally declare the Symposium closed.

Thank you.

STATEMENT BY MR. J.B.P. MARAMIS, EXECUTIVE SECRETARY, UNITED NATIONS ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

Excellency, distinguished participants, ladies and gentlemen,

I have great pleasure in welcoming you all to this Symposium on Solar Science and Technology. I feel particularly privileged in welcoming His Excellency Dr. Thanat Khoman, Deputy Prime Minister of the Royal Government of Thailand. He occupies not only a prominent political position in his country but also has an eminent role in promoting the cause of science and technology. His contribution as Chairman of the Asian Institute of Technology is well recognized. So is the momentum that he has been able to impart to the numerous development programmes in Thailand with a substantial science and technology content. We are fortunate that despite his pressing engagements he has found it possible to be with us this morning and to inaugurate the Symposium. We look forward to his valuable guidance in dealing with the important issues relevant to the harnessing of solar energy for development.

It is hardly necessary for me to dwell upon the criticality of adequate supply of energy at reasonable prices for the future development of the third world oil-importing countries. The levels of per capita consumption of energy in these countries are extremely low. If these countries have to industrialize and modernize their agriculture, a substantial increase in their aggregate energy consumption is inevitable. It is true to say that the economic and social development of a country is very largely a quantitative function of the total energy input. For the maximization of the availability of energy to them, the developing countries have to diversify their sources and choose a flexible mix which would respond to their changing and varied requirements. Our Commission has, therefore, been of the view that dynamic energy planning must be an integral part of the strategic planning for development. ESCAP has initiated a special project on energy under which a number of studies are now in progress. The results of the studies will be placed before the next session of our Commission in March 1981 with a view to assisting the member countries in the formulation of their national energy strategies and to evolving a regional approach to the major issues relating to energy. The Symposium and the other RCTT programmes relating to energy should be viewed as elements of the Commission's larger programme in this field.

I am happy that this Symposium has been co-sponsored by the International Solar Energy Society and almost all the United Nations bodies which are concerned with the various aspects of energy. The viewpoint that will emerge here will be representative of the entire spectrum of opinion which, I hope, will be a useful regional input for the U.N. conference to be held in Nairobi in August 1981. The technical panel on solar energy appointed for the U.N. conference on new and renewable sources of energy has submitted its report and had made a number of recommendations. The Symposium will have occasion to consider those recommendations and to express its reactions in the context of the needs and conditions of this vast Asian and Pacific region.

Keeping in view the representative character of this Symposium the financial support for it has been provided by the United Nations Interim Fund for Science and Technology for Development. I wish to take this opportunity to express my gratitude to the Administrator of the Fund, Mr. Bradford Morse, for his generous gesture. I also thank the Asian Institute of Technology for collaborating in the Symposium and the Royal Government of Thailand for extending generous host facilities.

Excellency, ladies and gentlemen, the sun is the biggest source of renewable energy. Over the ages it has been used in numerous forms. Though solar radiation varies according to location, time and climatic conditions, it is available everywhere and can be exploited from a limited surface. It is well recognized now that solar energy can provide a significant increment to our aggregate energy supply. In remote areas its contribution can be particularly important and for certain purposes it lends itself to exploitation through simple equipment and devices. If the current research succeeds in developing cost-competitive techniques, solar energy will also be amenable to high power applications. The objective of this Symposium is to take stock of the scientific work already accomplished and to assess the scope for the propagation of the equipment and devices already available. It will recommend the necessary measures to promote production of solar equipment on a commercial scale and its utilization on an extensive scale. The Symposium will also take into account the scientific work in progress and determine the most promising directions in which the inventive effort may be applied through regional co-operation. To pursue such a range of objectives we have invited to the Symposium not only some distinguished solar scientists but also experts engaged in the designing and production of equipment or engaged in the institutional, training and policy aspects of propagating solar equipment. I am confident that this interdisciplinary Symposium will succeed in charting out a pragmatic and balanced approach.

Solar Energy is right now cost-competitive in many decentralized types of applications and the available technologies are matured for commercial production. These applications include water pumping, desalting, drying, green houses, hot water supply, rural electric power, cooking and telecommunications. Some of the equipment and devices for such applications will be displayed in the exhibition SOLEX 80, which is being organized at the Asian Institute of Technology as part of the Symposium. These are not only cost-competitive as compared with the other sources of energy but also in terms of the pay-back period for the energy that goes into the production of the equipment. The factors which stand in the way of propagating these applications are not technological but relate to the institutional and physical infrastructure needed for their propagation and appropriate pricing.

While enterprises already exist for the production, procurement and supply of other sources of energy, steps have yet to be taken to establish institutions which could disseminate information regarding the available solar equipment and devices, or promote their production on an organized or decentralized basis. There is total lack of training facilities for the fabrication, designing and maintenance of solar equipment. Lacunae also exist in the regulations relating to construction etc. which could permit a fuller use of the sun. I trust that the Symposium will discuss these issues and suggest the lines on which the member Governments may proceed in order to provide an adequate institutional basis for an extensive use of the sun.

It is equally urgent to provide a reasonable pricing framework to permit adoption of the new devices for the use of solar energy. We have not only to avoid the continuance of wasteful subsidies for the conventional sources of energy but also to provide a margin for the deliberate promotion of solar energy. It is inevitable that in the years to come the pressures for inflation in the prices of the fossil fuels will only be accentuated. It is prudent for us to prepare for this well in time and provide the financial incentives that may be needed to encourage the adoption of solar devices.

As I have stated earlier, the high power applications of solar radiation are still at the stage of experimentation and research. Solar ponds, photovoltaics and satellite power systems have a sound scientific basis. They hold tremendous promise for harnessing solar radiation for the generation of power, which may be applied to industrial and other large-scale urban uses. However, it must be admitted that as yet the available technologies are not commercially viable and numerous environmental and technical problems remain to be tackled. Though the bulk of the research and development effort is being made in the developed countries, it is gratifying to note that a significant contribution is being made by numerous distinguished scientists from the developing countries. Many of them are assembled here and will be presenting their papers. I am confident that the interaction between them in this Symposium will assist in extending the frontiers of research. I also hope that they will be able to arrive at some workable arrangement for the co-ordination and harmonization of their future research activities.

Excellency, ladies and gentlemen, the development of promising solar energy applications has to proceed on a broad front so as to select applications with the greatest promise. It is such an approach that could assist in the inevitable transition to renewable energy sources which could well be underway by the middle of the next century. The challenge is to ensure that this transition takes place with the least adverse effect and in a harmonious relationship with conventional energy resources. The key to the successful development of solar energy will be inter-country co-operation and sharing of the knowledge gained. This Symposium is one modest step in that direction. I wish you all success.

Thank you.

STATEMENT BY DR. ROBERT BANKS, PRESIDENT, ASIAN INSTITUTE OF TECHNOLOGY

In the preface of the report on Renewable Sources of Energy and the Environment, organized by the United Nations Environment Programme in January 1980, Dr. Mustafa Tolba, Executive Director of UNEP, expressed the following view:

> "The general realization of the finite nature of fossil fuel resources has caused a re-examination of the possibility of using those energy resources which are of a non-depleting nature, and therefore, considered renewable. These energy sources, especially solar energy, are increasingly important both in developed and in developing countries. In the developed countries, strategies for the exploitation of such sources constitute a part of recent conservation policies which aim at reducing the dependence on fossil fuels to satisfy the growing needs for energy. In the developing countries, particularly those short of fossil fuel resources, the renewable sources of energy constitute a promise for meeting a part of the future energy needs, at a reasonable price, to accelerate the process of development, particularly in rural areas. The developing countries may enter the solar era before the industrial world does. Several features common to developing countries make such a prospect seem likely. Developing nations, by and large, tend to be more richly endowed than their industrial counterparts with sunlight. Their populations tend to be dispersed enough to facilitate the exploitation of decentralized energy resources: about half the people in Latin America, 70 per cent in South Asia, and 85 per cent in Africa still live in rural areas. The current high cost of conventional energy, especially electricity, has already made some renewable energy options economically competitive. A particularly important social advantage of such technologies is their potential for promoting development in previously ignored rural areas where it is most needed. Without strong rural development programmes based on decentralized energy sources, urban migration will become torrential, aggravating the already dire urban problems brought to attention at the United Nations Conference on Human Settlements in 1976. Similarly, the United Nations Conference on Desertification convened in 1977, emphasized the importance of using locally available renewable sources of energy to reduce excessive wood cutting in arid and semi-arid lands, which is one of the most serious causes of desertification. The importance of renewable sources of energy has been recently brought into focus by the decision of the General Assembly of the United Nations to convene a United Nations Conference on New and Renewable Sources of Energy in 1981".

The Asian Institute of Technology, like UNEP, has been strongly concerned with the energy problems that developing countries have faced since 1973. This is why it was decided, in 1977, to create a new Division of Energy Technology at AIT. In January 1980, this new Energy Technology Division enrolled its first group of 20 students; these students are presently studying for masters' degrees in Energy Technology. The next group of 25 students will be enrolled in January 1981 and 35 more every January beginning in 1982. Solar energy development is one of the main components of AIT's Energy Technology Division curriculum, in addition to energy conservation, and studies regarding energy demands, and energy planning and policy in Asian countries. Indeed, the objectives of this Division in the solar energy field, match very closely with at least three, of the four, immediate objectives of this Symposium on Solar Science and Technology. These are:

1. To exchange scientific and technological knowledge in research and development of solar energy,

2. To promote introduction of solar energy studies into curricula of universities and academic institutions within the region as established in developed countries, and

3. To provide directions for entrepreneurs to initiate immediate transfer of technology and encourage production and marketing of solar equipment.

Thus, it is logical that AIT is one of the co-sponsors of this Symposium. Further, it has been AIT's plan to construct an outdoor Energy Park to demonstrate for SOLEX '80, the solar exhibition planned by ESCAP to reinforce the technical and scientific sessions of the Symposium.

I am very pleased to report that the French Government, which has funded the construction of our Energy Park, made an additional contribution this year in order that the Park be completed in time for SOLEX '80.

It is noteworthy also that the French, German, and Italian Governments, as well as several Thai organizations and manufacturers, have responded favorably to ESCAP's call for exhibiting solar equipment.

The variety of equipment on display at SOLEX '80, range from well-known and long-time manufactured solar water heaters, to numerous various prototypes in their early stages of development. The latter includes locally designed and manufactured rice dryers and refrigerators, as wll as sophisticated solar tracking photovoltaic and thermal devices. All of these devices illustrate rather strikingly some of the following fundamental questions concerning the future development and utilization of solar energy:

- What are the current research and development trends?

- What equipment available on the markets of the more developed countries are suitable for technological adaptation to the Asian setting?

- What are the prospects for entirely local innovation?

I am delighted that the Asian Institute of Technology has the opportunity to participate in this Symposium on Solar Science and Technology. I wish to express our very sincere appreciation to ESCAP for organizing and presenting this Symposium.

Finally, on behalf of the entire community of the Asian Institute of Technology - its faculty, its staff, and most importantly its nearly 600 post-graduate students from 20 countries of Asia - May I extend our very best wishes for a highly successful Symposium.

II. REPORT OF THE SYMPOSIUM ON SOLAR SCIENCE AND TECHNOLOGY

I. ORGANIZATION OF THE SESSION

1. The Symposium on Solar Science and Technology was held at Bangkok from 25 November to 4 December 1980. It was organized by the ESCAP Regional Centre for Technology Transfer (RCTT), in co-operation with the Asian Institute of Technology (AIT), Bangkok, and with host facilities provided by the Ministry of Science, Technology and Energy of the Royal Thai Government. The Symposium was co-sponsored by the International Solar Energy Society (ISES) and several United Nations bodies, including the Food and Agriculture Organization of the United Nations (FAO), the International Labour Organization (ILO), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Industrial Development Organization (UNIDO), the United Nations Conference on Trade and Development (UNCTAD), the United Nations Environment Programme (UNEP) and the World Intellectual Property Organization (WIPO).

2. The financial support for the Symposium was provided by the United Nations Interim Fund for Science and Technology for Development (UNIFSTD).

3. The objectives of the Symposium were (a) to take stock of the progress of solar science and technology in the ESCAP region, (b) to provide interaction between leading scientists and technologists, (c) to identify directions of future effort to promote greater utilization of solar energy, (d) to arrive at concrete regional programmes for co-operation in this field and (e) to provide regional inputs for the United Nations Conference on New and Renewable Sources of Energy to be held at Nairobi in August 1981. The Symposium restricted its attention to the direct utilization of solar radiation.

Attendance

4. The Symposium was attended by 127 participants from 16 members and associate members of ESCAP, namely, Australia, China, France, Hong Kong, India, Indonesia, Japan, Malaysia, Nepal, Pakistan, Papua New Guinea, the Philippines, the Republic of Korea, Sri Lanka, Thailand and Viet Nam. The representatives of the following United Nations bodies attended: FAO, ILO, UNDP (United Nations Development Programme), UNESCO and ESCAP. AIT, ISES and VITA (Volunteers in Technical Assistance Inc.) were also represented.

Opening statements

5. The Executive Secretary of ESCAP welcomed His Excellency Dr. Thanat Khoman, Deputy Prime Minister of the Royal Thai Government to the opening session of the Symposium on 25 November 1980. In his statement he emphasized the serious consequences of an inadequate supply of energy at reasonable prices for the future development of the oil-importing third world countries. The levels of *per capita* con-

sumption of energy in those countries were extremely low and had to be substantially increased to enable those countries to industrialize and modernize their agriculture. In order to maximize the availability of energy to them, the developing countries had to diversify their sources and choose a flexible mix which would respond to their changing and varied requirements. ESCAP therefore held the view that dynamic energy planning must be an integral part of the strategic planning for development. It had initiated a special project on energy under which numerous studies were in progress and would assist the member countries in the formulation of their national energy strategies and in evolving a regional approach to the major issues relating to energy. The Executive Secretary observed that the Symposium and the other RCTT programmes relating to energy were the elements of ESCAP's larger programme in that field.

6. Having been co-sponsored by ISES and almost all the United Nations bodies concerned with the various aspects of energy, the Symposium would put across a viewpoint which would be representative of the entire spectrum of opinion and would be a useful regional input for the Conference.

7. He expressed his gratitude to the Administrator of UNIFSTD, Mr. Bradford Morse, for generously providing financial support for the Symposium. He thanked AIT and the Royal Thai Government for co-operating in its organization.

8. The Executive Secretary observed that it was well recognized that solar energy could provide a significant increment to the aggregate energy supply. In remote areas its contribution could be particularly important and for certain purposes it lent itself to exploitation through simple equipment and devices. If the current research succeeded in developing cost-competitive techniques, solar energy would also be amenable to high power applications. In that context, the Executive Secretary elaborated the objectives of the Symposium, which included taking stock of the scientific work already accomplished, assessing the scope for the propagation of the available equipment and devices, promoting their production on a commercial scale and identifying the many promising directions of the future inventive effort. To pursue such a range of objectives an interdisciplinary group of experts had been assembled.

9. The Executive Secretary pointed out that for many decentralized types of application, some of which had been depicted in the exhibition SOLEX '80 organized for the Symposium, the solar devices and equipment were already cost competitive. The factors which stood in the way of propagating those applications were not technological but related to the institutional and physical infrastructure needed for their propagation and appropriate pricing. There was a need to establish institutions which could disseminate information regarding the available solar equipment and devices, promote their production on an organized or decentralized basis and provide training facilities for the fabrication, designing and maintenance of solar equipment. It was equally urgent to provide a reasonable pricing framework to permit adoption of the new devices for the use of solar energy. Not only was the continuance of wasteful subsidies for the conventional sources of energy to be avoided but it was also desirable to provide a margin for the deliberate promotion of solar energy, through appropriate incentives.

10. In regard to the high power applications of solar radiation, which were mostly at the stage of experimentation and research, the Executive Secretary noted the significant contribution being made by numerous distinguished scientists from the developing countries of the ESCAP region. Many of them were assembled at the Symposium and would be presenting their papers. It was hoped that the interaction between them would assist in extending the frontiers of research and that they would be able to arrive at some workable arrangement for the co-ordination and harmonization of their future research activities.

11. In conclusion, the Executive Secretary emphasized the significance of inter-country co-operation for the maximum utilization of solar energy in the ESCAP region, a major part of which was situated in the tropical zone, with abundant sunshine and vegetation. He expressed confidence that the Symposium would mark the beginning of significant co-operative programmes.

12. Dr. Robert B. Banks, President of AIT referred to the increasing importance of energy resources of a non-depleting nature such as solar energy. In the developed countries, strategies for the exploitation of such sources constituted a part of the conservation policies which aimed at reducing their dependence on fossil fuels. In the developing countries, the renewable sources of energy constituted a part of the future energy needs, at a reasonable price, to accelerate the process of development. He felt that the developing countries might enter the solar era before the industrial world did. The developing nations were more richly endowed with sunrise than their industrial counterparts. Their populations were dispersed enough to facilitate the exploitation of decentralized energy resources such as solar energy. Its relevance to the future pattern of their development was particularly significant in the context of restricting migration to the urban areas, by assisting in a more rapid development of the rural areas. Dr. Banks recalled the recommendations for greater exploitation of solar energy which had been made by the various United Nations conferences relating to human settlements, desertification, etc.

13. He also explained the strong concern of AIT with energy problems and made mention of the creation of a new Division of Energy Technology in 1977. Twenty students had now been enrolled in the Division and were studying for Masters' degrees in energy technology. He indicated that the work of the Division would be greatly increased in the coming years. He also stated that solar energy development was one of the main components of the Division's curriculum in addition to energy conservation and studies regarding energy demand and energy planning and policies in the Asian countries. Indeed, the objectives of the Division in the field of solar energy matched very closely with those of the Symposium. It was logical therefore that AIT had collaborated in the organization of the Symposium. It particularly sought to reinforce the technical and scientific sessions of the Symposium through the organization of the solar exhibition SOLEX '80, the exhibits of which would be retained permanently at the outdoor site as Energy Park. He thanked the Governments of France, the Federal Republic of Germany and Italy as well as the several Thai organizations and manufacturers who had responded favourably to ESCAP's calls for exhibiting solar equipment at SOLEX '80. Dr. Banks observed that

devices exhibited at SOLEX '80 illustrated rather strikingly the current research and development trends, the range of equipment available in the more developed countries which was suitable for adaptation to the Asian setting and the prospects for entirely local innovation.

14. He expressed delight that AIT had been given the opportunity to collaborate in the Symposium and expressed the confidence that co-operation between AIT and RCTT would greatly increase in the future.

15. Inaugurating the Symposium, His Excellency Dr. Thanat Khoman, Deputy Prime Minister of the Royal Thai Government, observed that in the face of the impending energy crisis, the Symposium represented an attempt to tackle the problem in courageous and rational ways. It signified the determination of the non-oil countries to survive the onslaught of the spiralling oil prices and secure a reasonable level of well-being for their vast masses.

16. The Deputy Prime Minister stated that while conservation measures were being adopted by most of the countries, the renewable energy resources must be sought to obviate excessive dependence on costly fossil fuels. Solar energy was one such renewable energy resource. That resource, which all the countries possessed in greater or lesser degree and independently of external control, must be explored, exploited and utilized by the nations short of fuel. If they succeeded even partially, they would have gone a long way to help to sustain their development effort; otherwise, the millions of their impoverished peoples would continue to face a dire predicament.

17. The Deputy Prime Minister applauded the timely initiative of RCTT to organize the Symposium so that the questions relating to solar energy could be thoroughly examined and the scientific and technological experts in the region could keep abreast with the latest developments in other parts of the world. He observed that the scientific and technological progress in the field of solar energy would have ready repercussions in the economic field and would contribute to the well-being of the multitude of the underprivileged masses.

18. The Deputy Prime Minister extended a hearty welcome to the participants and expressed the confidence that their deliberations would lead to practical and concrete realization.

Election of officers

19. The Symposium elected Dr. Praprit Na Nagara (Thailand) Chairman, Dr. Koyoshi Takahashi (Japan) Vice-Chairman and Ir. Noel John Monerasinghe (Malaysia) Rapporteur. It also elected Dr. R.L. Datta (India) to preside over the technology and science sessions of the Symposium.

Adoption of the agenda

20. The Symposium adopted the following agenda:

1. Opening of the Symposium
2. Election of officers
3. Adoption of the agenda
4. Presentation of papers by representatives of United Nations bodies
5. Invited addresses
6. Technology sessions covering:
   - (a) Presentation of country papers
   - (b) Discussions on promotion of solar technology in the ESCAP region, technology transfer and development, manufacturing and marketing, pricing policy and linkage between research and development and manufacturing
   - (c) Possibilities of regional co-operation in the field of solar energy
7. Science sessions covering:
   - (a) Presentation and discussion of research papers
   - (b) A general discussion on the trends of scientific research relating to solar energy
   - (c) Institutional arrangements for the promotion of solar science
   - (d) Development of educational curricula to meet the needs of solar research
8. Any other business
9. Adoption of the report.

SOLEX '80

21. To reinforce the discussions at the Symposium, an exhibition of solar equipment, SOLEX '80, was organized at AIT as part of the Symposium. A variety of equipment was displayed, ranging from the technologically established solar heaters to the numerous prototypes of equipment in early stages of development. They included locally designed and manufactured rice dryers and refrigerators as well as sophisticated solar tracking, photovoltaic and thermal devices. A list of the devices and equipment displayed at SOLEX '80 is given in annex I. All the equipment will be permanently retained at the existing site as part of the Energy Park to be maintained by AIT.

22. The participants acknowledged the value of SOLEX '80 not only in facilitating their discussions but also for the numerous local visitors interested in solar devices. The Symposium placed on record its appreciation of RCTT, AIT and the other agencies which had assisted in its organization. It also recorded its appreciation of the Governments of France, the Federal Republic of Germany and Italy and the various firms which had contributed equipment for SOLEX '80.

23. The participants and 10 journalists from the ESCAP region, invited especially for the Symposium, were formally received at SOLEX '80 by the President of AIT on 2 December 1980.

Visits to places of interest

24. The Ministry of Science, Technology and Energy of the Royal Thai Government organized visits for the participants to places of interest in and around Bangkok. It also provided transport facilities for the participants on all the days of the Symposium. The participants placed on record their high appreciation of the generous and warm host facilities provided by the Ministry.

24A. The Symposium expressed its appreciation and grateful thanks to UNIFSTD for providing financial support for the Symposium.

II. PAPERS PRESENTED BY UNITED NATIONS BODIES

FAO

25. The detailed paper presented by the representative of FAO discussed solar energy technologies which were relevant to the energy needs of small farmers and rural communities in the developing countries of the ESCAP region. The technologies specifically considered related to agricultural drying, space heating, cooking, water pumping, refrigeration, small scale electric power, water heating, desalination and production of fuel from biomass. Particular attention was given to those solar devices, typically solar thermal, which had the greatest potential for indigenous manufacture, using locally available materials and labour. Both solar thermal and photovoltaic systems were considered for providing electric power for water pumping, refrigeration and other small scale electrical needs. Steam power was proposed as an appropriate energy system on which to build a mechanical and electrical power base. A hybrid steam system using concentrated solar energy and biomass waste was suggested as an attractive system for development in remote areas where those resources were readily available. It was concluded that the development of prototype hardware should be a co-operative effort between the technologist and the user.

ILO

26. The paper presented by the representative of ILO examined the socio-economic impact of energy policies on employment levels, income levels, income distribution,

working conditions and standard of living. It specifically considered the impact of constraint of energy availability on development *per se* and by sectors and regions. It also discussed the possible impact of the various energy conservation measures and dealt at length with the impact of choice of energy sources and technologies. Finally, the paper made reference to the most important of the ILO's continuing research programmes in the field of energy.

ESCAP

27. Two papers were presented on behalf of ESCAP, one entitled "Solar science and technology" which had been prepared by two consultants especially engaged for the purpose and the other entitled "Brief account of the main activities on solar energy in the ESCAP region" prepared by the Natural Resources Division of ESCAP.

28. The first paper outlined the important areas of science and technology in the field of solar energy. It concluded that, although there were a number of economically feasible solar technologies (such as those relating to water heating, drying, etc.), government actions such as incentives, demonstrations of efficient solar devices etc. were still required to help to accelerate the popularization of those technologies. Since the potential of solar energy was very high in many countries, concentrated national efforts should be applied to research and development of solar science and technology in order that more solar technologies would be made feasible in the near future.

29. The second paper provided a brief review of the activities relating to solar energy in the different countries of the region. In a separate section it also discussed the economics of solar energy, based on the economic data which were available in respect of the different solar devices in different countries.

UNESCO

30. The paper presented by the representative of UNESCO dealt with the issues of education and training for solar energy. It was observed that the subject was not widely pursued in the educational institutions of the ESCAP region. Although there were some good programmes of post-graduate training and research, most activities were the result of the interest and effort of isolated staff members. A survey undertaken by UNESCO had indicated the growing interest in non-conventional sources of energy, which was reflected in the emergence of several new programmes. There was undoubtedly a need for a great increase in the resources, both financial and intellectual, which were to be devoted to education and training not only of specialists and technicians but also of policy and decision-makers. Equally important was the need to provide information to the general public and the consumers of energy.

UNIDO

31. UNIDO contributed a detailed monograph on technology for solar energy utilization. It included an extensive survey of the industrial technologies relating to the

manufacture of solar equipment and devices. The monograph also contained a chapter recommending a programme for solar utilization in the developing countries. Another chapter provided a review of the activity in the various developing countries for the manufacture of solar devices.

WIPO

32. The paper received from WIPO was entitled "The international patent classification (IPC) as a means to identify basic technical information on solar energy and its applications". It introduced to the participants the basic features of IPC and explained how the relevant sub-groups of IPC concerned with solar energy and its applications could be found. The mechanism of retrieval of patent documents relating to solar energy and its applications was also explained. In particular, it was explained how the patent gazettes, abstract services, the international referral service and the state-of-the-art searches provided by WIPO could be used by those engaged in research and development and manufacture of solar devices.

III. INVITED ADDRESSES

33. Dr. R.L. Datta (India), a past President of ISES, delivered an address on "Strategies of solar energy development and uses in developing countries". In the framework of the aggregate energy scene, he discussed the particular relevance of utilizing solar energy for the satisfaction of the basic needs of the vast masses living in the rural areas of the developing countries. Keeping in view such relevance, he indicated the principal directions in which the utilization of solar energy could be attempted. He presented a plan of action which incorporated not only the institutional and policy aspects but also the harmonious development of technology and the manufacture of solar equipment. In relation to technology development, he emphasized the importance of credible data for solar radiation, efficient collection of solar energy, its storage and proper standardization and testing procedures.

34. Dr. J.C.V. Chinnappa (Australia) presented a review of developments in solar cooling. He discussed the aqueous lithium bromide systems, the aqua ammonia systems and also the rankine cycle systems. Separate sections in the paper were devoted to dehumidification by absorption and adsorption and to refrigeration. He concluded that solar cooling would be energetically less efficient than cooling with electricity. Still, the energy saving was significant and justified continued research and development in solar cooling. The technology had been demonstrated in most applications. There remained the problem of making solar cooling cost effective and that was the major challenge facing the researchers.

35. Dr. Richard J. Frankel, formerly a professor at AIT and currently engaged in business in Thailand for the propagation of solar heating equipment on a commercial scale, delivered an address on "Prospects and problems of the solar energy industry in Thai-

land". It surveyed the potential of solar energy utilization in Thailand, particularly for water heating. It discussed the extent of business interest in exploiting that potential and the problems that were being faced. The most critical was the public attitude towards solar heating, which appeared to be changing with installation of more units. The paper also went into details about the economics of solar water heaters and proposed the support measures which the Government should provide to encourage the early adoption of solar devices. These included modification of the building code, provision of low interest loans for potential users of solar water heating systems, import duty/tax relief for local manufacturers of solar energy equipment and reduction of tariffs on specialized solar equipment not manufactured locally.

36. The addresses were followed by lively discussion, the main conclusions of which are given below.

IV. CONSIDERATION OF ISSUES

37. Papers reviewing the solar energy situation in each of the participating countries were presented and were followed by discussions. The main points that emerged were as follows:

(a) The availability of solar radiation data in the countries of the ESCAP region for different geographical and climatic conditions was limited and in urgent need of improvement. However, the available data showed beyond doubt that the potential for the utilization of solar energy in the sun-swept region was immense; in the coming years it could serve as a significant increment to the aggregate energy consumption of those countries. The potential was particularly promising in the rural areas for the numerous dispersed types of applications. In view of the rising prices of fossil fuels, solar energy could be cost-competitive even for several urban uses, particularly those relating to domestic and industrial heating.

(b) It was observed, however, that only the developed countries had so far formulated concrete plans to so diversify their pattern of energy consumption as to derive a significant component from renewable sources such as solar radiation. The effort initiated in the developing countries was so far nominal and had yet to be consolidated by prescribing a specific ambition over a time frame, and by providing the necessary institutional and resource backing.

(c) The nucleus of institutions and personnel engaged in the promotion of solar energy had taken shape in most of the developing countries. However, substance had still to be infused into the newly created institutional forms. The critical mass of financial and personnel resources was still not available to enable those institutions to be able to make an impact.

(d) The production and propagation activities in the developing countries were so far restricted to heating devices and to a lesser extent to drying devices. In regard to the other uses of solar energy, the activity in the developing countries was at a very early stage of development and was restricted to following developments in the industrialized countries.

(e) The manufacturing sector had still not been drawn into the production of solar equipment and devices on any sizable scale. That was particularly due to the lack of awareness among the general public and among the various user sections of the community. It was also substantially due to the incomplete forging of the innovation chain - the results of the work done in the laboratory were not being upgraded into prototypes and commercial scale units; there was an utter lack of the institutional infrastructure needed for the production of solar equipment, its demonstration and propagation. In no countries had steps been taken to provide financial incentives for the early propagation of solar devices, while subsidies for conventional sources of energy continued in several forms.

(f) In some universities and technology institutes, courses had been provided for education and research in solar energy. They needed upgrading and expanding.

(g) The various research and development programmes in relation to solar energy initiated in the countries of the region showed wide areas of overlap. There clearly were possibilities of regional co-operation in research and development and in delivering the results for manufacturing. The flow of information in respect of solar technology was extremely inadequate and largely derived from the sources in the industrialized countries.

(h) There appeared to be a lack of a constituency to exercise pressure for the greater incorporation of solar energy in the aggregate consumption pattern of energy in the developing countries.

Need for clearly defined policies

38. The Symposium emphasized the need for the evolution of clear-cut national policies for the utilization of solar energy. It felt that those policies should fit into an integrated approach to energy and realistically identify the part to be played by solar energy. The policies should be addressed to the entire gamut of issues, including the institutional, legal, financial, educational, industrial and research aspects. The policies must be set in specific time frames and with adequate backing of resources. The Symposium held the view that a major effort of the United Conference on New and Renewable Sources of Energy to be held at Nairobi in August 1981 should be to persuade national Governments to evolve such policies.

Institutional framework

39. The provision of an adequate institutional framework at the national level would have to go hand in hand with the evolution of the national policies. The Symposium was

referring not only to the institutions which could serve as forums for thinking and policy making at the national level but also of institutions which would contribute to the implementation of such policies. It was noted that while institutions, production enterprises and supply organizations already existed in respect of the conventional sources of energy and were well entrenched, the tasks relating to solar energy remained unattended by sheer default.

40. The Symposium noted that the Beijing Institute of Solar Energy was already functioning in China and that considerable progress had been made in the establishment of a national institute in Pakistan. It urged that similar institutes be thought about and planned in the other developing countries. Such institutes could function as the national focal points for solar energy activities.

41. The Symposium pointed out that the utilization of solar devices could be expected to make substantial progress only if production enterprises could be stimulated by the national Governments. Entrepreneurs were understandably shy of entering the commercial production of newly innovated technology, the commercial viability of which was undergoing frequent changes in view of the extremely volatile energy scene. In such a situation it was essential for the Governments to show initiative and assist in the creation of enterprises for the production of solar equipment, either in the public sector or by suitably assisting the private sector.

42. The Symposium felt that an important element of the infrastructure for solar energy should be prototype development centres in the member countries. Such centres would play an extremely important role in transferring the technology developed in the laboratories to the users. They would function as an important link between research and development and the production sector. They would also assist in adapting the imported technologies to the local needs and conditions.

43. The prototype development centres should also act as testing centres for solar equipment as well as for the materials needed for their construction. The small countries which might not be in a position to sustain their own prototype development centres could seek the co-operation of the other countries of the region.

44. The Symposium felt that a major requirement for the propagation of solar devices was to arouse public awareness. It felt that such awareness could be imparted through suitably devised school-level educational programmes. At the same time, it would be desirable to organize mobile demonstration units for the rural areas. To create demonstration effect it would be worthwhile for the Government to establish solar devices at selected sites at its own cost. The mass media should be used for disseminating information about solar energy development.

45. The Symposium felt that at the regional level a regional solar energy association should be created to assist in generating consciousness about solar energy, to function as a regional activist group for solar energy and to act as a forum for interaction between

solar scientists and technologists of the member countries. It would also function as a link with the international mainstream of advance in solar science and technology.

46. The Symposium recorded its high appreciation of RCTT and AIT for having taken this timely initiative. It urged that those two institutions should maintain a continuing interest in the important subject. They should be instrumental in the creation of the proposed regional solar energy association and in promoting the various other regional activities proposed in the present report. RCTT should also consider the need for and feasibility of establishing a regional solar energy institute.

47. The Symposium noted the need for appropriate legal and regulatory frameworks which would assist in the promotion of solar energy. In particular, it called for an early review of the building codes.

Incentives for utilization of solar energy

48. The Symposium strongly held the view that in the initial period appropriate incentives would have to be provided for the adoption of solar devices. There were sizable subsidies for conventional sources of energy which continued to subsist in various forms. Offsetting the comparative disadvantage that new sources such as solar energy thereby suffered was a matter of great priority. Moreover, further inflation in the prices of conventional sources of energy was inevitable and it would be prudent on the part of the developing countries to anticipate that development and provide incentives for new sources so that their share in the aggregate energy consumption could be increased. For the remote and outlying areas for which solar devices had a particular relevance, it would be wise to provide incentives for the utilization of solar devices and thereby obviate the wasteful expenditure on transportation of the conventional energy materials. Moreover, the Symposium pointed out that any new field of technology would, in any case, require a certain amount of support which Governments must provide to ensure their successful introduction.

49. There was considerable discussion regarding the quantum of the incentives that might be extended for solar devices. It was pointed out that the commercial costs and prices of the solar equipment were hardly a proper index of their value. Those costs and prices emanated from the interplay of numerous supply and demand constraints and hid in them numerous subsidies and cross-subsidies. It was essential for the Governments so to influence those prices that they came to approximate the true relative value of the various types of energy to the country. In that context the Symposium held the view that energy accounting would be a good basis for the determination of appropriate energy prices. It was felt that the payback period of the energy used for the production of energy material and devices should serve as a basic index. If a particular solar device had a reasonable payback period for the energy input that went into it, the Government must so determine the size of the incentives and subsidies that the resultant commercial price of the device became competitive in the market.

50. The form of the subsidies and the points at which they should be administered (to the producers of the equipment or to the consumers or to the suppliers of material inputs, etc.) would have to be determined by the Government within the framework of its numerous considerations.

51. A point was raised whether subsidizing solar devices in their initial stages could have the effect of retarding developments in the technology of solar devices which could lead to the achievement of higher efficiency. It was felt that if in pursuing the aforesaid recommendation the reasonable payback period of energy was properly fixed, that apprehension could be guarded against.

Research and development

52. The Symposium noted that most solar equipment still needed a good deal of R and D effort to make it efficient and commercially viable. It urged intensification of the R and D effort for solar energy. The total financial allocation for R and D needed to be raised manyfold in the developing countries.

53. It was further observed that the limited hardware and personnel resources available in the developing countries could be put to optimum use if attention could be concentrated on a limited number of R and D projects. The Symposium suggested that the national authorities should make a critical review of the R and D programmes and try to fix proper priorities.

54. Another way to optimize the utilization of R and D resources would be to enter into joint R and D programmes between different institutions in the region. The Symposium expressed the hope that RCTT would be able to identify the possibilities of such joint efforts and bring about appropriate inter-institutional co-operative arrangements.

55. A major point emphasized by the Symposium was to relate the R and D activities with the production sector. It was felt that the prototype development centres proposed in an earlier paragraph of the present report would go a long way in providing such linkages. It would be equally necessary for the Governments to assist in the commercialization of the developed technologies. They should come forward to provide the funds needed to scale up the laboratory models into prototypes and commercial units. They should also provide risk capital to induce entrepreneurs to venture into the production of newly innovated models.

56. The Symposium noted that educational and training facilities for solar energy had now been incorporated in several institutions in the region. However, those facilities needed to be greatly expanded. It was felt that systematic efforts should be devoted to the development of curricula in solar energy studies, both at the undergraduate and at higher levels in engineering colleges and technological institutes. The Symposium suggested that UNESCO should take early initiatives in that matter.

57. The Symposium also emphasized the need for the training of technicians and maintenance personnel for solar equipment.

58. It was felt that subregional and regional workshops for solar experts should be organized at frequent intervals to enable them to exchange knowledge and experience and to be acquainted with the latest developments.

59. The Symposium felt that serious gaps existed in the development of instruments for research and development and testing of solar equipment. It urged that attention be devoted to that important aspect. While some progress was being made in the establishment of standards for solar equipment, it would be desirable to enforce quality control in the very initial stages of solar energy so that it could later develop on sound lines.

Technical information

60. Recognizing the value of flow of technological information in respect of solar devices, the Symposium recommended that appropriate arrangements should be instituted at the national level. That could be done through the issue of technological digests, newsletters, occasional monographs, etc. The institutions concerned at the national level must also make arrangements to answer the specific queries that might be received from the general public or from solar technologists.

61. It was also important to provide the linkage between the relevant institutions in different countries so as to stimulate a regional flow of information. It was recommended that RCTT should provide a regional focal point through which information relating to solar equipment could be channelled to the national institutions. The Symposium expressed the hope that a provision for that would be made in the regional technological information service which was to be established by RCTT.

62. The Symposium noted the usefulness of the publication of a roster of experts and institutions engaged in solar energy in the developing countries of the ESCAP region, which was being prepared by ESCAP/RCTT and was expected to be published within the next few weeks. It was hoped that that publication would assist in the inter-country exchange of expertise in the field of solar energy.

Recommendations in respect of specific solar equipment

63. The Symposium, after a comprehensive review of the solar energy scene in the ESCAP region, came to the conclusion that the uses of solar energy of maximum interest and application in the region related to drying, heating, cooling, pumping and cooking. It constituted separate groups to consider in detail the state of technology, the potential, the prospects of commercialization and the measures needed for each of those areas. The views and recommendations of the groups were considered by the Symposium and, as adopted by it, can be found in annex II.

V. CONSIDERATION OF ISSUES IN SOLAR SCIENCE

64. The Symposium received 57 research papers, 26 of which were presented and discussed. The papers received for the Symposium are listed in annex IV.

65. A general discussion on the progress of solar science research in the region disclosed that more work was being done in photothermal devices (mainly in solar heating and drying) than in photovoltaic and photosynthetic devices. Two of the papers described in detail the properties of salt-hydrate systems and lead batteries - materials used in energy storage. Certain aspects of radiation data were highlighted in some of the papers while selective coating was discussed in two of them.

66. The points made in those papers and the discussions following them indicated the need for a detailed consideration of the undermentioned topics:

(a) Intensity of radiation;

(b) Solar conversion;

(c) Energy storage;

(d) Materials of construction;

(e) Training and education;

(f) Establishment of a learned society in the field of solar energy;

(g) Regional programme and mechanism.

The main points that emerged from the consideration of the above topics were as follows.

Intensity of radiation

67. It was observed that data regarding intensity of radiation were indispensable for the effective utilization of available solar energy resources. Intensity of radiation had to be assessed in different countries and in different parts of the same countries with a view to ensuring proper planning. It would be difficult to develop a plan either of utilization programmes or for R and D activities without having mapped out the energy resources. There was a need to train scientists to make measurements, assess intensity of radiation and prepare maps of their countries indicating solar energy potential. Systematic compilation of radiation data would call for proper planning of activities and provision of adequate resources. This work should be in conformity with the standards specified by the World Meteorological Organization.

Solar conversion

68. Solar conversion was discussed under three separate headings: photothermal, photoelectric and photosynthetic. It was noted that more work was being done in the

photothermal area. A large number of institutions, scientists and technologists were involved in it. Many photothermal devices such as flat-plate collectors were already being fabricated, some of which were commercially available in India, Nepal, the Philippines and Thailand.

69. In the area of photoelectric conversion, some countries such as China and India had already produced photovoltaic cells. Other countries such as Thailand were attempting to begin their manufacture. In some countries of the region, photoelectric devices were being used for operating pumps for irrigation and drinking water supply in rural areas.

70. There was a growing interest in photosynthetic conversion processes. Attention in the region was being concentrated on the production of biomass for fuels through cultivation of suitable plants for energy farming. In future, more emphasis would have to be laid on encouraging the growth of plants with larger energy contents.

Energy storage

71. The importance of solar energy storage in any application was well recognized. A number of workshops and seminars had been organized to focus attention on various aspects of energy storage. It was felt that a reliable low-cost thermal storage system was needed in the low and medium range of temperatures. Efforts had so far been confined to thermal storage mainly utilizing water, oil and pebbles. In view of the importance of solar energy storage, it was necessary for institutions and scientists to give greater attention to that area.

Materials of construction

72. It was noted that materials were the media through which the systems operated. Growing importance was being attached to the use of indigenous materials. Special attention was being directed towards determining the properties and qualities of the materials used. The choice of good materials depended on their capacity to withstand high temperatures, their desirable radiative properties, inherent mechanical strength and proven resistance to corrosion. Development of new materials which would meet those qualities to a higher degree was considered necessary. The price of a finished product would be guided by the efficiency of the materials used, their local availability and versatility. The need for research and rigorous scientific and technological work in the area of materials was emphasized.

Training and education

73. The need for good training facilities for scientific and technological personnel and provision of well thought out educational programmes for schools and colleges was considered. Reference was also made to the UNESCO document which had specified those requirements. It was felt that the number of scientists and technologists engaged in the

field of solar energy was generally inadequate. Some countries such as India and Thailand had started technical training courses in the field of energy, and at the Indian Institute of Technology, New Delhi, a decision had been taken to establish a United Nations training centre for solar science. However, in many developing countries such courses and facilities were not available.

74. Students wishing to pursue careers in solar energy should have a broadly based education in science/engineering and should have exposure to a specially designed solar energy programme. The institutions that were already established to provide training in solar energy were in need of resources to become more effective. Those resources were in terms of people, finance and other facilities. Adequate personnel and financial backing needed to be provided by the country Governments. In respect of education it was emphasized that at both high school and university levels the curricula needed to be suitably developed. To encourage interest in the study of solar energy a suggestion was made to develop and provide suitable demonstration kits for the use of students. In the training of architects, building engineers and others, solar energy studies should be included. Emphasis was also laid on demonstrations and exhibitions in the universities, colleges, etc. It was suggested that ESCAP/RCTT, in collaboration with UNESCO and AIT, should develop suitable regional initiatives in that field.

Establishment of a regional body for solar energy

75. The work of ISES was highly commended. It was felt that that society, which had the status of non-governmental organization to the United Nations, had been doing important work. To strengthen its programme of work and to invoke its assistance in building up viable programmes in the field of solar energy, it was necessary that it should have an enlarged membership from the developing countries. There were certain countries in the ESCAP region which had national sections of ISES. It was suggested that the other countries might also consider establishing such national bodies. The smaller countries could, however, group together to set up joint sections. It was felt that the creation of a regional body affiliated to ISES would be to the advantage of the countries. It was suggested that ESCAP/RCTT should examine the feasibility of setting up such a regional body. Its financial and other implications would also have to be worked out.

76. Recognizing the important role which the Symposium had assigned to RCTT in the promotion and transfer of solar science and technology in the countries of the region, it was felt that the competence of RCTT in the field of solar energy should be adequately strengthened. It was suggested that a high-level panel of experts in solar science and technology should be immediately constituted and attached to RCTT so that it might advise and guide the Centre in building up an appropriate regional programme. Preparation of rosters and compilation of directories should also be carried out under the advice of the proposed panel. It was suggested that at least one full-time expert on solar energy should be engaged and his services made available to advise the countries in response to their requests. The expert should also be responsible for collection and dissemination of data and information on solar energy.

Regional programme and mechanisms

77. Keeping in view the constraint of resources and infrastructure, it was suggested that work in the field of solar science and technology should, in the beginning, be confined only to a few items of high priority. It was recommended that each country, in view of its specific country situation, should make a strategic choice of the items of work to be undertaken. Further, to maximize the use of scarce resources at the command of individual countries, they should, with the assistance of ESCAP/RCTT, make a deliberate effort to identify areas of common interest and develop and implement joint regional or subregional programmes in the field of solar energy.

78. Some of the activities identified for immediate action were: generation of higher temperatures to enable production of electricity; production of photovoltaic materials and equipment; selective coatings which increased the efficiency of absorption of solar energy; encouraging fundamental studies of photosynthesis and photochemistry; development of instruments; and study of effects of solar radiation on health.

79. The participants were highly appreciative of the value of symposia such as the present one. They held the view that it had served as a forum for mutual exchange of experiences and knowledge and had assisted them in building up contacts between them. It was felt that similar meetings should be organized periodically. The Symposium noted with appreciation the offer made by the participant from the Indian Institute of Science to host the next Symposium at Bangalore in December 1981.

Recommendations in respect of specific sectors of solar science

80. After a comprehensive review of the status of solar science in the ESCAP region, the Symposium was broken into four groups to consider in greater detail the following subjects:

(a) Photothermal conversion;

(b) Photoelectric conversion;

(c) Photosynthetic conversion;

(d) Energy storage.

81. The views and recommendations of the groups were considered by the Symposium and approved. Their reports are given in annex III.

IV. ADOPTION OF THE REPORT

82. The Symposium adopted the report at its closing session on 4 December 1980. The Symposium was concluded with a statement by His Excellency Mr. Anuwat Wattanapongsiri, Minister for Science, Technology and Energy of the Royal Thai Government.

Annex I

DEVICES AND EQUIPMENT DISPLAYED AT SOLEX '80

1. Clockwork solar tracking mechanism
2. Solar cookers (China)
3. Solar autoclave
4. Linear concentrator
5. Parabolic system
6. Photovoltaic concentrator system
7. Photovoltaic water pump
8. Thermal solar pumps - spylett steam pump
9. Thermal solar pumps - wonder freon pump
10. Flat-plate thermal solar collector
11. Biogas plants
12. Biogas plant (AIT model)
13. Solar-powered refrigerator
14. Cabinet dryers
15. Solar rice dryer
16. Solar stills
17. Wind mill
18. Wind mill (KMI model)
19. Wind generator
20. Solar instruments on top of the field laboratory
21. Solar television set

Annex II

RECOMMENDATIONS OF THE TECHNOLOGY GROUPS

A. Drying

Solar drying of agricultural products is an important area of application of solar energy in the ESCAP region. Drying not only improves the quality of agricultural products but also offers to the farmers economic benefits. The group identified the following crops for immediate attention in the region: (a) paddy, (b) corn, (c) tobacco, (d) onions, (e) vegetables and (f) spices. The group recommended that there should be close interaction among scientists and technologists working in this area in different countries of the ESCAP region. A mechanism should be established for promoting such interaction. The participants from Viet Nam, Malaysia, Indonesia, India, Thailand and Pakistan expressed interest in co-operating with each other in programmes of mutual interest. The group felt that there was a good possibility of implementing joint programmes of research and development among the countries of the ESCAP region. Information should be collected for this purpose and specific programmes of mutual interest should be evolved. Working arrangements should then be evolved for carrying out the programmes. ESCAP/RCTT could take the initiative. It was recommended that technology centres should be established as key institutions for the purpose of exchange of information, building of prototypes and evolving standards. There was a need for the involvement of manufacturers from the very initial stages of the R and D programmes. This would facilitate easier transfer of technology. Regional co-operation should be promoted for the exchange of scientists, the organization of workshops or symposia and the implementing of educational programmes.

B. Heating

The group had the feeling that the recommendations to be presented were not all new and therefore saw a challenge to the countries of the region and to the United Nations for urgent action on a number of recommendations already made in the earlier meetings on the subject.

The group discussed the subject under four topics: (a) testing for low and medium temperature heaters, (b) manufacturing and marketing, (c) information systems and (d) promotion and testing.

A number of test standards already existed. However, they needed to be harmonized and an agreed system developed.

There was a need for an actual thermal performance test procedure. The manufacturers of equipment could be requested to supply data to enable evaluation of the performance of systems they were manufacturing and selling. Out of all these a standard test procedure had to be developed which was related to the intrinsic collector parameter to prevailing conditions that would be experienced in actual practice. There was a need for a national or a regional organization to test manufactured equipment and certify the same.

Manufacturing standards were essential for quality control on a national basis. Initiatives at the national level must be taken to ensure quality products which could give tested performance. In the initial stages, restrictions by tariffs and otherwise on imports and exports of equipment would have to be judiciously determined. Time-bound targets for manufacturing efficiency should be set.

There was a need for "a handbook of best practice" for solar flat-plate collectors, giving designs, construction details, materials of construction, testing procedures, etc. ESCAP/RCTT was requested to take the initiative in this matter and to bring out a handbook at an early date.

This area needed continuous monitoring, and information obtained from time to time should be channelled by ESCAP/RCTT to the users in the region.

There was a need for carefully controlled limited commercialization activities before full-scale introduction of solar heaters in the market. Initiatives were required for popularizing the use of solar heating systems. This could be in terms of incentives based upon energy justification. There should be incentives for use of local materials. Energy produced by solar heaters should be considered as a contribution to energy conservation and an equitable incentive system evolved for assisting manufacturers and users of the equipment. It should be mandatory for government and public buildings to install solar heaters. The Government should encourage private housing development using solar heaters.

C. Cooling

Cooling equipment may be classified into two types: (a) those operating at temperatures above zero, e.g., air conditioning and (b) those operating at temperatures below zero, e.g., ice making. In the ESCAP region, the position with regard to the development of the cooling equipment can be summerized as follows:

A. Commercially available:

Above 0°C	Aqueous Li-Br: Yazaki, Sanyo, etc.
Below 0°C	Zeolite-water absorption refrigerator: Zeopower

B. Under commercial testing:

Above 0^oC	Rankine cycle-vapour compression, e.g., Barber Nichols; Dornier
	Open cycle, e.g., Solar-Mec (USA)
Below 0^oC	Dornier

C. Under laboratory testing:

Above 0^oC	Rankine cycle, e.g., BHP Labs, Melbourne University; NERD Centre, Sri Lanka; University of Technology, Kuala Lumpur
	Aqueous Li-Br cycle, e.g., Melbourne University; Indian Institute of Technology at Delhi; institutes in China
	R-22/DMF system (Japan)
	Open cycle, e.g., Commonwealth Scientific and Industrial Research Organization (Australia); University of Hong Kong
	Ammonia water systems, e.g., James Cook University; Indian Institute of Technology at Madras; BHEL, Bombay; Peshawar University, National Research Centre.
Below 0^oC	Ammonia water systems (Asian Institute of Technology, Bangkok; James Cook University; Papua New Guinea University of Technology)

The design of collectors both flat-plate and concentrating must be appropriate for solar-cooling applications, e.g., stagnation conditions cannot always be avoided.

The next stage in the promotion of the technology for solar cooling plant involves:

(a) The preliminary assessment of the cost of manufacture and operation, which should proceed concurrently with the assessment of the plant's performance in the laboratory;

(b) The development of a prototype demonstration model in consultation with production experts. This exercise could take place in industry development centres which exist in some of the countries in the region;

(c) Economic assessment of the performance of the demonstration model;

(d) A careful assessment of the performance of the demonstration model in relation to users' requirements, namely servicing and maintenance and case of operation.

The group did not feel competent to express any opinion with regard to the manufacturing and marketing of these devices, or the pricing policy. It was recognized that marketing of a product involved a very comprehensive investigation requiring answers to a number of questions, some of which are:

(a) Does the product meet the need?

(b) Is the product socially acceptable?

(c) Can the market afford it?

(d) In what form is the product marketable?

The group was of the opinion that with the exception of the aqueous Li-Br chiller none of the devices in solar cooling listed above has reached the stage where marketing needed to be considered. A considerable amount of work was still required in all the devices mentioned (except the aqueous Li-Br chiller) before a demonstration model could be built.

While this, in fact, was the case, the group was convinced that cooling was a need in the region and that, furthermore, the solar operation of cooling equipment would result in a saving of fossil fuel. There was therefore a real case for countries in the region to consider subsidizing solar plant. This would have a profound effect on the price of these devices and so influence market conditions.

The group felt that courses on solar cooling should be conducted once every two years in the region commencing perhaps with one at AIT, which already has the administrative structure for organizing such a course.

It is vital that information on the work in solar cooling in the region is available to workers in the region, and the Group recommends that RCTT, possibly using the facilities available in the Renewable Energy Resources Information Centre at AIT should provide information to scientists. Preferably, existing publications in countries in the region, for example, "Solar Progress" (published by ANZAC ISES Section, Australia) should be used.

The group also recommended that a panel of the workers in the region on solar cooling should be formed to disseminate information from ESCAP and RCTT to the workers in the various countries, and also to serve as a liaison between the workers.

D. Pumping

There are five main objectives that can be served by solar water pumps:

(a) Water for irrigation;

(b) Water for cattle;

(c) Water for domestic consumption;

(d) Water for remotely located industries;

(e) Lowering the water table to reduce waterlogging.

However, at present, there is an enormous potential for their immediate use in rural areas for agricultural operations and domestic consumption.

From the several installations of solar water pumps working on these principles around the world and the evaluation of their performance, it is seen that, at present, the cost of installation of water pumps in the low power range, e.g., 5 kW, is controlled by economic factors. Pumps are already working in the 25 kW and higher ranges, yielding 25,000 litres/day from a depth of 5 m. In fact, several others are working in the range of 50,000 to 60,000 litres/day capacity. The storage problem is quite simple for water-lifting pumps. Either the energy may be stored or the water may be lifted above the ground, depending on which suits the consumer.

Companies in several countries have put consumer products on the market and the technology is readily available for full-scale utilization. It is felt that the concerned Governments should play a positive patronizing role by heavily subsidizing and creating large markets to give encouragement to manufacturing and marketing concerns, by giving tax relief, heavy purchasing, etc.

It is also felt necessary that comprehensive market research should be conducted in each country for the benefit of all concerned, viz., the industrialists, agriculturalists, technologists and general consumers so that the economies of the product may be controlled to bring the prices to a reasonable level.

It is common knowledge that the research and development stage consists of the following steps: product development stage, demonstration projects, evaluation, actual field trials and manufacturing stage. However, the group identified a very serious missing link in this series. This is between the field trial stage and the manufacturing stage.

It is considered necessary that, after the success of the field trial, the technology of fabrication of each component and the whole unit from the point of view of actual mass production should be developed as a special part of this series, before it is set for an assembly line.

Generally, no expertise exists for this purpose in the developing countries and it is strongly recommended that such expertise should be generated on a crash programme basis.

It is important that water lifting pumps should be used with discretion so that the hydrological balance of the location is not disturbed adversely.

E. Cooking

A number of countries in the ESCAP region have developed solar cookers essentially for domestic purposes. A number of models exist. However, their acceptance by the users has not been encouraging. It is understood that there are only about 2,000 solar cookers in China and far fewer in other countries. Sufficient efforts to introduce cookers have not taken place. Therefore the promotion of the use of solar cookers in the ESCAP region requires a carefully thought out plan and implementation. The plan is as follows:

(a) Three regions should be selected which have different available fuels and climatic conditions;

(b) Three or four types of cooker designs should be selected which are suitable for such climatic conditions;

(c) A major joint effort should be undertaken in laboratory testing, field demonstration and operation of at least one cooker design in each of the selected countries. At least 50 to 100 of the selected designs should be demonstrated at each field site. The field demonstration must be preceded by an evaluation of local needs and available resources and followed by extensive user instruction and education;

(d) Evaluation of cooker performance must be continued in order to improve the design, economics, social acceptance and performance. The whole programme must be designed to respond quickly to feedback data.

In areas of technology transfer, local organizations such as agricultural and technological committees, women's affairs training centres and village-sponsored committees, youth groups and educational institutions should be used as the media for transferring technology to the users.

While many of the existing models do not require specialized manufacturing facilities, there are certain models that do. Financial support is required in the initial stages of production of a large number of selected cookers.

Consideration must be given to the over-all effect of the utilization of solar cookers on reducing wood cutting, deforestation and improving ecological conditions, and they must be sold at a suitable price. The Government should give incentive for promoting the sale of cookers by way of tax relief, avoidance of duties and payment of subsidies.

R and D must be more positively linked to manufacturing and information should be disseminated about presently available solar cooker technologies. Further R and D is necessary for the development and manufacture of new cookers incorporating heat storage, heat pumps and newer, larger materials.

Regional co-operation is indicated in the field of information, sharing of experiences, exchange of prototypes and organization of academic and manual training. Sharing of experience could be facilitated through roving seminars, exhibitions and publications.

Annex III

RECOMMENDATIONS OF THE SCIENCE GROUPS

I. PHOTOTHERMAL CONVERSION

Introduction

The members of the solar-thermal discussion group considered the papers that were presented and were of the opinion that the papers did not cover the entire spectrum of solar energy applications. The group decided to encompass all direct thermal applications in the discussion. The applications were listed and considered in turn. Attention was focused on their present state of development, problems and associated difficulties of implementation. Recommendations were then made to indicate the directions for appropriate future R and D efforts.

Applications

The following applications of interest were considered:

(a) Drying;

(b) Water heating;

(c) Cooling and refrigeration;

(d) Thermal power generation and pumping;

(e) Cooking;

(f) Distillation;

(g) Solar pond.

Low temperature applications (25° - 100°C)

(a) *Drying*

Solar drying is one of the oldest applications of solar energy and numerous designs are available. Presently, the use of solar dryers is being promoted and encouraged as a substitute for either direct sun drying or for drying using conventional fuel. Agricultural and marine product drying are the more common applications of the above technology.

Recommendations

1. Thermal performances of various solar air heaters should be studied, evaluated and compared.

2. Studies on drying characteristics of the various grains and other products with respect to drying temperatures and air flow rates should be made.

3. Field tests of prototype models and systems should be conducted and their performances evaluated.

4. Efficiency and durability tests for local materials used in the construction of solar dryers should be made.

(b) *Water heating*

Solar water heaters are commercially available in almost all countries. However, since various designs exist and component parts are made of different materials, their performances and durability characteristics differ.

Recommendations

1. National standards and testing procedures giving accurate data on collection and efficiency should be developed. This should not preclude the development of regional standards.

2. Because of the varying meteorological conditions to which collectors can be exposed and the subtle effects of test conditions, national testing centres for testing solar collectors should be established.

3. Continuing work on improving standards and testing procedures should be undertaken.

4. National efforts to develop inexpensive, efficient and durable material such as covers, absorber plates, insulation, housing, surface coating and associated systems hardware are required.

Medium temperature applications (100° - 350°C)

(c) *Cooling and refrigeration*

The solar cooling systems which are commercially available at present are very expensive compared with conventional systems. Considerable research is still required to determine appropriate and more efficient systems.

Recommendations

1. Basic research into cooling cycles and associated hardware and research to reduce the cost of these sytems should be conducted.

2. Further development should be undertaken, and intensified work should be carried out in the field of ice making, especially for rural application.

3. Research towards the development of collectors that can handle refrigerants like ammonia directly should be undertaken.

(d) *Thermal power generation and pumping*

Solar thermal power generation is another direct solar application which is currently an expensive technology.

Recommendations

1. Basic research into prime movers, cycles and hardware is required.

2. Efforts should be made towards developing more cost-effective collectors for thermal processes. This requires research work on both concentrating and flat-plate collectors. More specifically, it is recommended that special attention should be paid to research on medium temperature collectors (e.g., materials, design, performance, standards, etc.)

(e) *Cooking*

A variety of solar cookers are available in some countries for cooking food. However, the designs and sizes of solar cookers are not necessarily the most appropriate ones considering the socio-economic characteristics of the area.

Recommendations

1. Appropriate design and sizes should be developed according to specific requirements of individual families in order to minimize cost.

2. Standards for evaluating the performance of different solar cookers should be considered.

3. Research and development, leading to solar cooker designs using indigenous raw materials with a potential for village manufacture should be encouraged.

4. An intensive demonstration programme to assess the acceptability of particular solar cookers should be carried out in selected areas.

(f) *Distillation*

Solar distillation finds practical application in places where there is a shortage or lack of potable water. The tent-type or green-house type of solar still is the most common design. It is felt, however, that this design has been adequately researched.

Recommendations

1. Research should be carried out into other systems such as the flash distillation and freeze distillation, which will require the use of higher temperature and higher efficiency collectors such as those used for refrigeration and steam production.

(g) *Solar pond*

The solar pond is a potential energy source and means of storage for large-scale low-temperature applications.

Recommendation

More research and development into the suitability of solar ponds for rural application in this region, specifically in relation to control and operating conditions, should be undertaken.

General recommendations

1. In all of the above solar thermal applications, long-term performance and durability tests should be made.

2. In the case of solar water heaters, possible fouling, corrosion and water chemistry should be considered.

3. As current costs of most solar devices are prohibitive, serious efforts should be made to optimize cost-effectiveness.

4. Efforts should be made to develop medium temperature collectors paying special attention to heat transfer processes and problems.

5. Solar devices, like conventional devices, need to be properly maintained, and problems regarding maintenance should be discussed at regional conferences.

6. Since most solar devices (e.g., water heaters) are usually integrated with some other system, integrated performance tests should be carried out. The role of instrumentation, control devices and control systems in integrated performance is crucial and work in this area is important.

7. In order to maximize the efficiency of solar devices, the transient effects should be studied.

8. There is a need for research to develop more efficient, durable and cost-effective materials.

9. Meteorological data are necessary and required and should be presented in standard (SI) units (i.e., solar radiation data at hourly intervals, dry bulb and wet bulb temperatures, wind velocity, humidity and sunshine hours).

10. There is a need for solar energy availability and wind speed pattern models for different parts of the region.

In addition, the solar thermal discussion group recommends that:

(a) A directory identifying solar energy programmes and research personnel in the various institutions should be published;

(b) Appropriate institutions should be identified and funds granted to encourage and increase in-depth research;

(c) Steps should be undertaken

(i) To coordinate, promote and oversee demonstration programmes following the successful research in the above areas;

(ii) To organize courses to train academic personnel who, on their return to their respective countries, could conduct similar national courses to train their own personnel;

(iii) To organize technical and scientific seminars and workshops to enable researchers to meet and exchange experiences and results;

(iv) To establish national focal points (individual or institutional) in the various countries for regional contacts;

(v) To formulate appropriate standards for installation and testing of solar devices.

The group recommends the formation of a suitable agency or a unit in an organization which is already in existence (e.g., ESCAP, RCTT or UNESCO) to implement the above recommendations.

II. PHOTOELECTRIC CONVERSION

Solar photoelectric systems (SPS) offer an attractive alternative for meeting the basic needs for electricity in the vast rural areas in the ESCAP region where 70 to 80 per cent of the population live in villages and a large number of these villages are still to be electrified. In addition, in many remote areas, for applications such as navigational aids and communications, SPS are already economic compared with other alternatives. The price of solar cells has undergone a cost reduction by a factor of 10 in the last five years, raising hopes for the large-scale use of SPS. Almost all countries in the ESCAP region are consequently engaged in some photoelectric work.

The level of development of photoelectric technology, however, varies greatly from one country to the other in the region and the steps that will be taken in this field by a country are determined by the local conditions and needs. However, the following general recommendations can be made:

1. A number of demonstrations, field trials and evaluations should be arranged in order to obtain experience and test the suitability of these systems for particular places. International organizations such as UNDP might take the lead in this direction in collaboration with national Governments.

2. Particular emphasis should be placed on the development of balance-of-systems (BOS) components in each country, since they constitute an important fraction of the over-all cost of SPS.

3. A recent UNDP project report indicates that a major application of SPS in this region is small-scale water pumping for drinking water and irrigation. The efficiency of pump motors in this small-scale application is relatively low. Priority should be given to the local development of high efficiency pump motors, particularly those with d.c. units.

4. There are a number of low-power applications in remote areas such as in navigational aids, microwave repeaters and signals, where the use of SPS is already economic. Governmental programmes to install SPS for such applications would provide considerable experience in the design and development of SPS.

5. The single crystal silicon solar cell is the most developed and commercially available solar cell at present. An attempt to build up photovoltaic capability should therefore start with the production of single-crystal silicon solar cells and facilities for this are now available in Japan, China and India.

6. Active research on polycrystal and amorphous silicon as well as other solar cell materials is being carried out in Japan, China and India, among other places. A good mechanism for the exchange of scientific information, documentation and personnel should be developed to cater to the needs of interested scientists and technologists in all countries of the region. A regional documentation centre might be established. RCTT should take the lead in this matter.

7. An annual conference/workshop on photoelectric solar energy conversion dealing with all aspects of materials, devices, systems and demonstrations might be held in this region as is the case in the European Economic Community area in Europe. The conference should be hosted by different countries in rotation.

8. Co-operation with developed countries in some form or other may be necessary.

III. PHOTOSYNTHETIC CONVERSION

Photosynthetics represents an emerging and very important aspect of solar energy, since this resource can provide alternative fuels which can often be transported and stored.

The recommendations stressed that research and development are required in the production of photosynthetic fuels.

The growth of plants is based on photosynthesis, and life therefore is dependent on this process. The most common applications are those of direct agriculture. Of the many known modern applications the following can be mentioned:

(a) Gasohol production (cellulose materials, e.g., wood waste, sugarcane and maize);

(b) Fuel from energy plantations (fast growing trees, elephant grass);

(c) Pyrolysis (for example, as a safe means of fuel storage);

(d) Integrated farming systems (with greenhouses, atolla plantations, fishponds, pigdung for biogas, etc.);

(e) Producer gas (gasified wood);

(f) Biogas production.

Some other applications for the future are:

(a) Hydrogen production;

(b) Nitrogen fixation, hydrogen-artificial photosynthetics.

On the basis of the present applications, it can be said that photosynthetics will have a tremendous potential for energy production. A number of countries are working hard on fossil fuel replacement for their daily needs, whether for running motors, increased food production or food preparation (more efficient use of biomass, stoves for cooking, etc.).

The present known systems are of very low efficiency, but much greater efficiency should theoretically be possible. However, this energy of the future is relatively new, especially for rural areas, and too many factors are as yet unknown.

At present, the direct application of biogas produced by fermentation is one of the best known and widest uses, particularly in rural areas. Biogas production depends on several factors, e.g., catalytic influence of seeds, rate of dilution and especially on a good ambient temperature; in many cases, most of the developing countries in the region located in the solar belt are particularly well suited for the widespread establishment of biogas plants for the production of fuel for cooking.

Many successful installations exist in China (over 7,000,000), India (80,000) and also in smaller countries such as Nepal and Thailand. However, many of the results obtained are often based on trial and error, and for more work has to be done in the field, e.g., increasing gas production and reducing construction cost.

It is obvious from this that we are only at the beginning of the very promising work in solar coversion and that much research and development remain to be done. Combined and co-ordinated effort is required.

Practical solutions applicable to rural areas must be found to the problem of fuel supply, mainly for cooking, whether of charcoal, wood or biogas plants, in combination with improvement of soil fertility through organic recycling. Improved food production and storage facilities naturally play a vital part in the combined processes.

All these practical applications are in need of active government support for investigation and dissemination. The following recommendations are made for the promotion of photosynthetics:

(a) Investigation of available plant materials;

(b) Investigation of available information and applicable technologies;

(c) Investigation of materials for construction;

(d) Dissemination of relevant information;

(e) Improvement of efficiency and working conditions, e.g., of biogas production, including at lower temperatures;

(f) Pyrolysis, including the characteristics of the products and materials used;

(g) Rotating meetings on photosynthetics (for integrated systems, specifically biogas production) as a rapid solution applicable to rural areas in developing nations;

(h) Training workshops;

(i) Promotion policies for the use of photosynthetics, research and development and dissemination;

(j) Scientific research and development on improvement of efficiency in photosynthetic coversion (2 per cent maximum, known at present, but could theoretically reach 10 per cent);

(k) Scientific research and development on energy plantations.

IV. STORAGE OF THERMAL ENERGY

One of the major problems impeding the utilization of solar energy for heating and cooling of buildings for the generation of electricity and for many other applications is the lack of a low-cost, reliable, thermal storage system that does not require a large amount of space. Solar and most other recurrent energy sources have special requirements for energy storage, since the source is normally periodic and intermittent. At least three thermal storage methods have been identified: heat storage, latent heat storage and storage by chemical substances.

There is probably no "best" storage medium for all applications. The ideal storage medium is low-cost and is preferably locally available to reduce transportation costs. It should be non-toxic and safe under all conditions for personnel and equipment. It should be non-degradable and maintain constant properties throughout its entire life, with no decomposition products. It should be non-corrosive and, if designed to contact either a working or intermediate fluid, should have no effect on them. The ideal storage medium has a high heat capacity, or latent heat, or both, a high thermal diffusion, and does not require high-pressure storage. The ideal storage system has direct contact between the storage medium and charging fluid, and also the working fluid; this can avoid a costly heat exchanger.

There are several important applications of solar energy in the temperature range of 40°C to 400°C ranging from house heating to power generation. Some of the applications and their temperature ranges are as follows:

(a) Hot water for domestic, agricultural and industrial applications (50°C to 90°C);

(b) Hot air for domestic, agricultural and industrial applications (50°C to 200°C);

(c) Refrigeration and airconditioning (100°C to 150°C);

(d) Solar cooking of food and power generation (150°C to 400°C).

Possible means of storing thermal energy are listed below:

(a) Sensible heat (hot water, pebble, oil, oil-pebble);

(b) Latent heat (phase change material);

(c) Chemical reactions.

Some of the characteristics of a heat storage medium are as follows:

(a) Maximum storage per unit volume;

(b) Low cost and preferably locally available;

(c) Non-toxic;

(d) Non-corrosive;

(e) Non-degradable;

(f) Maximum repeatability;

(g) High heat capacity or latent heat or both and high thermal diffusion.

The collecting devices and their temperature operations are as follows:

(a) Flat-plate collector and solar panel (50°C to 80°C);

(b) Flat-plate collector with booster (95°C);

(c) Non-tracking concentrators and evacuated tubular collectors (150°C);

(d) Tracking concentrators (200°C);

(e) Dish concentrator (300°C to 400°C).

Various concepts are listed below according to generic type and a descriptive name for such unit is given.

1. *Sensible heat systems*

(a) Storage in impressurized fluids: oil and salt, oil bath;

(b) Storage in pressurized fluids:

(i) Prestressed cast-iron vessels, steel tanks;

(ii) Underground lined cavern for water storage;

(iii) Thin-insulated steel shell under ocean containing pressurized water;

(c) Storage in stationary solid:

(i) With a passage through rocks or solid blocks;

(ii) Rock bed with liquid heat transport fluid;

(iii) Hollow steel ingots;

(iv) Heat storage in concrete or sand with tube;

(d) Storage in moving soild:

(i) Sand in a fluidized bed;

(ii) Sand powered over pipes.

2. *Phase change material (PCM) systems*

(a) Stationary bulk PCM medium surrounding high packing density tubes: thermal energy storage heat exchanger and steel ingots immersed in PCM bath.

(b) Stationary encapsulated PCM:

(i) PCM macro encapsulation;

(ii) Heat of fusion, energy storage, boiler tank;

(c) Moving PCM: moving scrapers to remove solid PCM from heat transfer pipes;

(d) Direct contact: direct contact between PCM and transport fluid.

The group help the view that very little effort was being made in designing thermal storage systems, particularly in developing countries. Some of the recommendations in this field are listed below:

1. The concept of thermal storage really forms a part of almost all solar thermal systems. Research and development efforts are therefore necessary to study their effective utility, particularly with regard to cost-effectiveness.

2. Research in the electrochemical aspects of the materials used for storage batteries and for thermal storage should be intensified.

3. Water is the best material for storing heat as well as the best heat transfer medium. Research and development efforts are required to make the system cost-effective.

4. For storing energy at temperatures above 250°C, a packed bed such as that used in an oil and pebble system can be used effectively. Considerable research and development are required to establish pebble size, compatibility of the pebble quality with the oil, optimization of the storage size and insulation and degradation of the oil; these appear to be some of the problem areas.

5. PCM storage has been found to be the most promising technique of storing thermal energy. Hydrated salts can be used for storing thermal energy for comfort heating. Suitable hydrated salts which can store heat within a temperature range of 40°C to 60°C should be selected, and detailed properties such as phase separation, supercooling nucleation, rate of crystallization and cycling should be studied.

6. PCM storage systems working at around 350°C are most suitable for solar thermal power generation applications.

7. The solar pond is a potential thermal energy collector-cum-storage system. Research and development work to make its performance efficient, maintain its stability and optimize its size must be undertaken.

8. Solar cookers have great potential, particularly for rural areas. These could become popular if a suitable storage system is developed. The properties of combinations of eutectic salts should be studied in depth for their application to solar cookers and also to power generation.

The thermal storage systems developed so far have mostly been in the nature of empirical experiments and an extensive development programme based on sound engineering principles must be undertaken before attempts are made to use them.

Thermal storage systems are still in the research and development stages. A well co-ordinated R and D programme on storage should be undertaken with international support. An internationally recognized organization should be identified and entrusted with the lead responsibility of studying the various storage systems.

The use of subsoil thermal energy storage is another potential technique, particularly for areas where long-term storage is required because of rather longer non-sunny conditions. R and D efforts are therefore necessary to study the periodic behaviour of energy storage and the utilization patterns.

For electrochemical storage of photovoltaic solar energy, lead acid battery storage appears to be most suitable at present and in the near future. However, some research or development should be carried out in developing low maintenance grid alleys and long-life low-cost batteries.

Nickel cadmium batteries are suitable for very low-power applications. However, they cost about three to five times more than the equivalent lead acid cells. Considerable research and development are necessary to bring down the cost.

Other advanced types of storage batteries such as sodium sulphur, zinc chlorine, lithium metal sulphide and redox systems are primarily being developed for load levelling and electrical vehicle applications. However, the performance of these high-energy-density batteries is yet to be optimized for solar power applications.

Annex IV

LIST OF PAPERS

1. "A solar power plant for remote rural consumers: design and evaluation of experimental plant", W. Brazier (Australia)*

2. "Planning of territorial energy systems in limited resource areas", F. Butera (Italy)

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4. "Solar photovoltaic systems for remote area power supply", Norman R. Sheridan (Australia)

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12. "Correlation of diffuse solar radiation distribution with climate characteristics in Indonesia", Parangtopo and A. Harsono (Indonesia)*

13. "Development and commercialization of solar water heaters", A. Bachmann and G.R. Shakya (Nepal)*

14. "Optimum collector slope for a sub-tropical country", C.T. Leung (Hong Kong)

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* These papers were presented and discussed at the Symposium.

15. "A computational model for solar radiation pattern in Iran", Reza Hashemian and Esfandiar Afshari (Iran)

16. "The Philippine experience on the dispersal of the solar drying technology using non-conventional sources of energy for countryside development specifically using solar energy in food processing", I.S. Pablo (Philippines)

17. "Design, construction and testing of a solar corn dryer", I.H. Shah and Ahmad Murtaza (Pakistan)*

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III. PAPERS PREPARED BY THE ESCAP SECRETARIAT

BRIEF ACCOUNT OF THE MAIN ACTIVITIES ON SOLAR ENERGY IN THE ESCAP REGION

Note by the ESCAP secretariat

CONTENTS

INTRODUCTION

Solar energy was used centuries ago mainly in drying, cooking, heating and to some extent in ventilation. It was, however, only at the end of the nineteenth century that serious harnessing of solar energy started. In Chile, in 1872, a solar still of a total area of about 5,000 m^2 was built to provide fresh water from salt water. This plant operated effectively for about 40 years producing up to 25 m^3 of fresh water per day [1, 2]. In France, in 1878, a solar concentrator operated a small steam engine which ran a printing press. Other applications of solar energy in driving steam engines which were mainly used in pumping water were reported in Egypt and the United States of America (South Pasadena, California, Philadelphia and New Mexico) at the beginning of the present century [1].

Historical references, such as those above, remind us that many of the solar applications and devices are simple enough to be developed and manufactured in developing countries. The devices mentioned above did not, however, survive the competition from cheap fossil fuels, with the exceptions of solar drying and, in some countries, solar water heating.

Still, it is encouraging to see that commercialization of solar systems has become a reality in some applications. Impressive progress has been made in the design, improvement and cost reduction of solar collectors that are manufactured. The houses that use solar water heaters are counted in the millions in the Middle East and in the tens of thousands in Australia and the USA. Solar drying is also being used on a commercial scale in a few developing countries such as Brazil and India, and greenhouses are used in almost all European countries. However, it is not encouraging to consider the total amounts of solar energy used in industry. Solar energy has a large potential for low-grade thermal energy used in the 60° C to 150° C range, but difficulties exist in terms of system design and economics.

Other solar applications such as thermal and photovoltaic power generation, space cooling, refrigeration and water pumping have made considerable progress but they still have a long way to go before they are economically viable in view of their high investment costs. However, the continuous escalation in fossil fuel costs on the one hand and the downward trend in the cost of solar systems on the other are improving the economy of conventional solar devices. Non-economic factors can also hinder the development and utilization of solar technology: problems of technology transfer, such as availability of appropriate raw materials, manpower and local skills; social factors such as the reluctance of both the public and the administration in using new sources and technologies and in adopting new habits in cooking, heating, etc.

It would therefore be wise to analyse these factors and tackle them one by one at the same time as the technical and scientific work on solar devices. But it would be a mistake to wait until solar devices become popular or commercialized in industrial nations before adopting them in developing countries. The climate of almost all developing countries is characterized by high solar fluxes. Accordingly, a device could enter the economic viability margin in developing countries before it does in industrialized countries, particularly if account is taken of the cheaper manpower cost in developing countries. Besides, the type of device that is of interest to industrialized countries may not be appropriate for the developing countries. In view of the well developed energy system of the industralized countries, they would be more interested in developing large-scale devices that might be a substitute for their conventional centralized plants rather than small-scale devices which might be more appropriate in the rural areas of developing countries in the ESCAP region.

I. SOLAR RADIATION

The amount of solar radiation received by the earth is enormous, but for various reasons it cannot be used directly as a substitute for other conventional energy sources. One of these reasons is the dilution of solar irradiance over the entire surface of the earth. Another reason is the seasonal, diurnal and sometimes hourly fluctuations in the availability of solar radiation.

For designing and operating solar devices certain solar radiation data are needed. For example, information about global (direct + diffuse) solar radiation is needed in detail for the design of devices operating at low temperature, like flat-plate collectors, driers, stills and greenhouses. The methods of measuring and estimating solar radiation from other available data are given in some detail in annex I.

Charts of global solar radiation in the ESCAP region are presently being compiled and will be published in the near future.

II. REGIONAL ACTIVITIES ON SOLAR TECHNOLOGY

A. Solar drying

A variety of activities are being carried out in research and development on solar drying in the ESCAP region as well as attempts to introduce solar drying devices to potential users. The current solar dryer which is being dried by means of solar heated air. Details of several driers are given in annex II.

The National Industrial Development Corporation (NIDC) of India has developed large-scale systems, up to 20 tons/day, for grain drying. These systems are reported to have performed satisfactorily for more than two years in the field.

A simple cabinet solar dryer for agriculture products has been tested in Indonesia. It was reported that the dryer enabled the drying time to be shortened by about 12 hours and the drying area decreased from 24 m^2 to 8 m^2 in comparison with traditional sun drying on concrete.

Solar rice dryers are also being tested in Malaysia. Preliminary tests have shown that one dryer has cut down the drying time significantly.

Quite a few types of solar dryer are being designed and tested in the Philippines. These are the tent, shoe-box dryer and dryer-storage systems. Performance tests carried out on the latter type gave satisfactory results.

In Thailand, a simple rice dryer with natural circulation has been developed in the Asian Institute of Technology (AIT).

B. Solar water pumping

Solar pumps can be operated with solar energy directly converted into electricity using photovoltaic cells, or by using thermal energy itself to heat a working fulid which is then used to produce mechanical energy.

The development of the first pump category is dependent on the progress made in photovoltaics and the success in reducing the cost of the cells. In spite of their relative high cost, at present they seem to have greater potential for small-scale application in the rural areas in view of their simple construction and case in maintenance. These pumps are being tested in several institutions in the region.

The development of the second category, the thermodynamic pump, is in fact very much related to efforts to develop a solar engine. In this case, a solar collector, usually a flat-plate collector, is used for heating the working fluid. The details of the SOFRETES pumps which are being tested in India and the Philippines are given in annex III. One of the features of the SOFRETES pump is that its components can be manufactured locally in the user country.

Another pump which may be mentioned in this respect is the BITS solar pump with its two versions: air- and water-cooled pumps. This pump was developed in Birla Institute of Technology and Science (BITS), India. The details of this pump are also given in annex III.

In Pakistan, a solar pump using an 8 m diameter paraboloid fitted with flat mirrors, a boiler and a steam engine has been designed. The complete system was made with locally available materials, and provided 1.5 kW to the water pump. In order to study smaller portable units 1.4 m diameter mosaic mirrors were constructed and connected to a steam engine and boiler.

C. Solar cooking

Generally, solar cookers are of two types. One is based on concentrating solar energy by a reflector onto a cooking vessel. The other is a solar oven which depends on some concentration of radiation, combined with the greenhouse effect for trapping heat within a small space in which the food is placed. Both approaches have been developed to a degree of satisfactory technical performance. Research and development is in progress in the ESCAP region on both types.

One of the problems that is acting as a deterrent in solar cooking is heat storage. The system should be capable of storing heat at a temperature high enough to permit effective cooking later. It is also desirable to be able to regulate the rate of heat available for cooking with such stored heat. A solution was suggested in one of the papers presented at the International Solar Energy Congress (ISEC), held at New Delhi in January 1978. A cooker, referred to as a "heat package", contains a chemical system capable of absorbing energy from the sun, storing it and releasing the heat on demand at a temperature near 300°C. A possible candidate for the chemical system is the ammoniated salts of magnesium chloride and calcium chloride. To charge this cooker, ammonia is driven from the high temperature salt bed ($Mg Cl_2$) to the ambient temperature salt bed ($Ca Cl_2$) where it combines with the salt. Heating this low temperature bed slightly will dissociate the ammonia; it then returns to the high temperature bed, reacts with the salt exothermally, freeing heat for use in cooking. The Central Salt and Marine Chemicals Research Institute at Bhavnagar in India is reported to be investigating this type of cooker. Another inexpensive solar cooker, made out of bamboo cane, paraboloid in shape and having aluminium sheeting as the reflecting surface, was designed and developed at the Solar Energy Laboratory, Indian Institute of Technology, Madras, India. It is claimed that the cooker can cook an Indian meal consisting of rice and hall in about 40 minutes at noon. The inside surface is smoothed by paper pulp before aluminium reflector sheets are glued onto it.

Although some designs are functionally satisfactory, there are not very many solar cookers in use. The main reasons for this are (a) social habits, (b) technical drawbacks and (c) inadequate promotional efforts. Families in rural areas can gather wood and cow dung for fuel for conventional cooking. Furthermore, solar cooking involves alteration in the household routine, since the housewife must prepare the evening meal during daylight, well before the traditional time, which incurs the additional problem of keeping the food hot. Also, the housewife must remain in the hot sun while cooking.

D. Solar water heating

Basically, a solar water-heater comprises a black, flat-plate collector (absorber) containing water channels, facing the general direction of the sun, together with an insulated storage. There can be one or more transparent covers for the collector at intervals of about 2 cm above the plate, and thermal insulation at the rear; the higher the number of covers, the higher the temperature reached in the collector, but the less the energy that reaches the plate, in view of the increase in heat loss.

Building and testing solar flat-plate collectors is a favourite student project in nearly all technological institutions in the region. Local industrialists are becoming interested in spite of low expectations of profits and small demand. In Australia, Hong Kong, India, Japan, Malaysia, Nepal, Pakistan, the Philippines, the Republic of Korea, Singapore and Thailand, solar collectors have already been commercialized to a varying extent and installed in government quarters, hospitals, sports club's, institutions and some private houses. However, the industry of water-heating collectors is not yet well established in the developing countries of the region.

Normally, the absorber is a sheet of copper or galvanized iron to which is soldered or brazed a continuous zigzag tube, the main direction of the tubing being slightly off the horizontal to prevent air locks at the bends. Water flows either by gravity or from a pump into the lower end of the tube, and back and forth across the surface of the sheet, issuing at the upper opening. The spacing between the bends of this tubing may vary and, in some designs, may be 15 mm. In some versions, the collector is in the form of a sandwich which consists of a corrugated galvanized iron sheet backed with a plain sheet of the same material, the two being secured by rivets: the edges along the length are hammered together with an overlap and sealed with soft solder. The openings along the width at the two ends are formed into pipes by folding the plane sheet over the corrugated sheet, then welding or soldering. In this manner, header pipes are formed at the two ends. The corrugated face is blackened and the whole assembly can be put in a wooden box containing insulating material. The upper face of the box is glazed with a sheet of window glass with an air gap of perhaps 5 cm. This currugated type of flat-plate collector has good heat-exchange efficiency, of about 50 per cent, and heats water to 50°C to 60°C.

In Afghanistan and Bangladesh, different types of flat-plate collectors have been constructed and tested. The Government of Fiji is installing solar water heaters in its government quarters and has plans for banning electric water heaters. Tax allowances have been provided since mid-1976. Promising heat pipe collectors are being developed at the Materials and Energy Research Center of Aryamehr University of Technology, Tehran, Iran. Long-term tests of flat-plate collectors are performed and one collector is designed to pasteurize milk for dairy purposes in remote villages. A large corporation in the Philippines has carried out comparative tests of commercial solar water heaters and is planning to install, backed by the Energy Development Board, a substantial area of collectors for processing heat in the near future. Glass tube collectors, made from obsolete fluorescent tubes, are being tested at King Mongkut's Institute of Technology, Thonburi, Thailand.

The performance of flat-plate collectors, the backbone of solar heaters and other solar appliances, could be improved by providing selective radiation surfaces on the absorber plate. The development of these surfaces is a fruitful area for co-operation among developing countries and with industrialized countries who have developed effective selective coatings (e.g., Australia and Japan). Other areas for development and co-operation in water heater manufacturing are the manufacturing process itself, the development of durable sealants, paints and other materials.

E. Solar distillation

A solar still, in its simplest form, is a tray with a backened bottom holding shallow saline water, covered with a slopping glass roof. The sun's rays pass through the glass roof and are absorbed by the blackened surface at the bottom. As the water becomes heated, its vapour pressure increases and the water vapour is condensed on the underside of the roof and runs down into the channels that conduct the distilled water to a tank. Solar stills can produce 3-5 litres of distilled water per square metre per day, depending on the amount of solar radiation. The cost of operation is low because no fuel and little labour are involved. The capital cost can be reduced by using cheaper materials. Plastic roofs are sometimes used instead of glass roofs, but they have a much shorter life.

In the Commonwealth Scientific, Industrial and Research Organization (CSIRO) in Australia, a project was undertaken between 1960 and 1972 for the development of a simple and reliable low-cost method of producing freshing water using solar energy. The information obtained may be requested from CSIRO.

In India, the Central Salt and Marine Chemicals Research Institute, Bhavnagar, has installed in a nearby village a solar distillation plant capable of producing 5,000 litres of fresh water per day.

At the Aryamehr University of Technology at Teheran, Iran, an interesting version of a solar still is being developed: it consists mainly of polystyrene foam and a glass plate. A moul for the polystyrene was manufactured to enable series production.

Studies on solar distillation are also being undertaken in the Institute of Technology of Bandung in Indonesia, at the University of Malaysia at Kuala Lumpur, Peshawar University in Pakistan, the Korea Institute of Energy Conservation in the Republic of Korea, the Ceylon Institute of Scientific and Industrial Research in Sri Lanka and by the National Energy Administration in Thailand.

F. Refrigeration and air-conditioning

There is great demand for refrigeration and air-conditioning in the countries in the region. A substantial quantity of foodstuffs need to be preserved, otherwise they get spoilt. The peak seasonal electricity demand occurs during the hottest period when energy consumed on air-conditioning is substantial. However, this peak load period corresponds to the period of high insolation, when solar energy is at its peak and comfort cooling is needed.

There are three main types of systems of space cooling: vapour compression, vapour absorption and dehumidification and cooling by evaporation. The first system, which is widely used in conventional refrigerators, requires a solar heat engine to drive the compressor. In the second, heat required to distil the refrigerant in the generator is supplied directly from solar energy. In the third, an absorbent is used to dry the air at constant enthalpy. As the temperature of the working fluid in the flat-plate collector is usually less than 100°C, the efficiency of transferring this energy into mechanical energy is less than the efficiency in using it directly as heat to distil the refrigerant. Consequently, an absorption process may seem more appropriate for cooling.

In Australia (Brisbane), a solar air-conditioned experimental house has been in operation for several years. The system uses a lithium bromide water absorption refrigerator supplied with water at temperatures up to 95°C from a flat-plate collector.

Research and development work on air-conditioning and refrigeration is being carried out on both vapour compression and absorption cycles in the National Physical Laboratory (NPL), Indian Institute of Technology, Central Arid Zone Research Institute and others in India. The details of the absorption system investigated by the NPL are given in annex IV. In Indonesia, the Institute of Technology, Bandung, has developed an intermittent refrigeration unit using the absorption cycle. In Japan, solar air-conditioning systems have already been commercialized by some companies; details of a vapour-compression system used there are given in annex IV. Studies are being carried out at the University of Malaysia on the dehumidification of air by using silica gel as the desiccant and solar regeneration of silica gel. In the Philippines, experimental work is in progress on an ice-making machine and absorption refrigeration system. An air-conditioning system of the ammonia-water system is being investigated in the University of Sri Lanka. In the Asian Institute of Technology in Thailand, and intermittent ammonia water absorption system with a collector area of 2 m^2 is being used as a prototype; the details of the system are given in annex IV.

G. Thermodynamic electricity generation

Thermodynamic electricity generation systems can be either high- or low-temperature systems. In the first approach, mirrors or heliostats concentrate the solar energy on a boiler or boilers. The high-temperature fluid generated in the boiler is readily used for the generation of electric power by conventional means. If one boiler is used, heat losses are minimized, but each reflector or heliostat should be steered to track the sun; this increases the cost substantially. It is also possible to use many boilers, each installed at the centre of a concentrator. These small boilers may be connected by ducts that feed the heated fluid to a central station. The drawback of this method is the cost of the ducts and the heat losses in the heat transport system.

In the low-temperature approach, flat-plate collectors replace the concentrators. This system is much simpler but its thermodynamic efficiency is low in view of the low temperature of the working fluid. An example is the system installed in the Indian Institute of Technology (Madras) in India. Here, hot water from flat-plate collectors at 95°C is used to vapourize freon 114 which drives a screw expander coupled to a generator. The plant installed under the Indo-German technical co-operation programme produces 10 kW peak load.

H. Photovoltaic electricity generation

In photovoltaic electricity generation, an electromotive force (voltage) is generated as a result of the absorption of ionizing radiation. Materials that have shown the best photovoltaic performance in sunlight are the semiconductors. When photons in the sunlight are absorbed in a semiconductor, free electrons are generated. A junction of materials, with different electric properties, could provide the electric field necessary for these electrons to flow out of the semiconductor.

The silicon solar cell has so far been the most developed and used cell. Cadmium sulfide/copper sulfide have also undergone considerable investigation and remarkable progress has been made in their development. Gallium arsenide cells have the potential for higher conversion efficiencies than silicon.

Numerous universities in the region are investigating photovoltaics. At present, solar cells are still rather expensive. A great deal of research and development work are being carried out in France, the Federal Republic of Germany, the USA and the USSR on photovoltaics to reduce the cost. One promising way to lower the cost per watt generated is to concentrate sunlight on the cells. Recent experiments have shown that silicon cells can be made to have the same efficiency at 100 suns as they have at one sun intensity, provided that their temperature is maintained constant. Thus, the cells must be cooled for such higher concentration ratios but this does not appear to be a limiting factor. If the heat released in cooling the cells could be used, i.e., in a thermodynamic cycle, the cost-effectiveness (cost-efficiency) of the system may improve drastically.

III. ECONOMICS OF SOLAR ENERGY

Studies on the cost-benefit of alternative renewable sources of energy as compared with conventional sources of energy are meagre. This is a fruitful field for increased exchange of knowledge and experience among developing countries regarding the methodology as well as the conclusions of such studies.

With respect to the conventional cost-benefit analysis, the economics of alternative sources of energy poses serious problems of concept and measurement. Conservation of non-renewable sources of energy, though an immediate problem, cannot be satisfactorily resolved without obtaining a long term perspective of the economy as a whole, national and global. Structural changes as implied in any energy alternative considered. Structural comparisons require analytical tools which have to go beyond the prevalent methods of cost-benefit analysis.

The use of conventional cost-benefit analysis, as a "second best", itself poses problems of measurement: for instance, social and economic costs in terms of spreading and evoking acceptance of non-conventional energy sources, valuation of the environmental benefits from such acceptance, quantification of advantages in conserving a depletable resource, etc., in addition to the well-known problems in measuring costs and benefits, direct and indirect, of inputs and outputs.

However, as a preliminary exercise, some comparative examples of limited validity are given below on the production of electricity and heat by solar energy.

A. Cost of thermal energy (Heat)

The current average cost of a flat-plate collector system for water varies between $US 80 and $US 150/m^2. Assuming an efficiency of 50 per cent for the collector, a life of 15 years, an investment interest of 10 per cent and neglecting the running cost, the cost of heat produced by this solar system will be 1.16-2.17 cents/kWh for ESCAP countries with an average global solar radiation of 1,800 kWh/m^2/year.

This cost can now be compared with the costs of producing heat by conventional methods. In urban areas, heat is usually produced either by electricity or liquefied petroleum gas (LPG). In rural areas, the situation is somewhat complicated. In domestic applications, the requirement of low-grade heat need not be considered as firewood and other non-conventional resources are used. Accordingly, the comparison here with fossil fuel may include electric heating, heating using LPG, oil and coal. The average cost of domestic electricity in rural areas of the ESCAP region may be assumed as 12 cents/kWh.

The cost of thermal energy from oil depends on the price of oil, which is rising. Assuming a cost of 40 cents per litre of oil, including transport and tax, a calorific value of 40 MJ/kg and a burner efficiency of 60 per cent, the cost of thermal energy from oil will be about 5-6 cents/kWh.

However, the prices of butane gas and coal differ considerably from place to place, which makes the comparison difficult. In some countries, butane gas costs 80 cents/kg; in others, it may cost only 30 cents/kg. Assuming a calorific value of 45 MJ/kg and a burner efficiency of 60 per cent, the cost of thermal energy will be 4.5-12 cents/kWh.

Table 1. Average costs of thermal energy from solar and conventional sources

Source	*Cost U$ cents/kWh*	*Source*	*Cost in US cents/kWh*
Solar collectors	1.2-3	Coal burner	2-3
Electricity from grid	10-15	LPG (butane)	4.5-12
Oil burner	5-6	Firewood	0-5

Coal in small quantities may cost $ 20-30/ton. Assuming a burner efficiency of 20 per cent, the cost of thermal energy from coal would be in the range 2-3 cents/kWh.

Firewood costs range from nothing to 3 cents/kg. The burning efficiency of firewood is usually not more than 10 per cent; accordingly, the cost of thermal energy from firewood would vary from 0 to 5 cents/kWh.

B. Cost of electricity

As mentioned before, electricity can be produced from solar energy through a thermodynamic cycle or through a photovoltaic cell.

In small-scale (1-10kW) thermodynamic systems, the collectors will form about 70 per cent of the total cost of the system; the rest will be the cost of the heat storage and the engine. The average cost of a system of 1kW capacity is about $ 20,000. For an interest rate of 10 per cent, the cost of electricity production will be about $ 8/kWh for a load factor of 50 per cent.

The cost of electricity from a photovoltaic cell, including a rechargeable battery, is about $ 8/kWh.

These costs can be compared with the costs of electricity production using conventional methods. The average cost of electricity from the grid in the rural areas is assumed to be 12 cents/kWh. The average cost of electricity from small-scale diesel generators can be 50-80 cents/kWh. A summary of these costs is given in table 2.

Table 2. Average cost of electricity generation

Method	*Cost in $US/kWh*
Solar thermodynamic systems	0.80
Solar photovoltaic system	8-12
Electricity from the grid	0.10-0.15
Small-scale diesel engine (1-10kW)	0.5-0.80

From the costs given in tables 1 and 2, a few general conclusions can be drawn:

(a) Solar heating is economically feasible;

(b) The cost of electricity production from thermodynamic systems cannot, in general, compete yet with the cost of electricity from the grid, but is competitive with the cost of electricity produced by small-scale engines;

(c) The cost of electricity production from the photovoltaic system is still much higher than the cost of electricity production by other conventional methods.

As was mentioned before, these comparisons are only indicative. In order to complete the comparisons, it should be assumed that the cost of fossil fuels will increase by a suitable rate. Moreover, environmental and social factors should be taken into account. Also, the dwindling nature of fossil fuels, particularly oil, and the possibility of a shortage in certain types of fossil fuels during the present and the next decades should be taken into account.

Annex I

SOLAR RADIATION

The energy received from the sun, per unit time, on a normal surface at the average sun-earth distance outside the earth's atmosphere is equal to 1,353 W/m^2. This is known as the solar constant. A part of this radiation, about 190 W/m^2, is abosrbed by the atmosphere. The rest is divided into direct and scatter radiation. About 383 W/m^2 of the direct radiation is reflected back, mainly by cloud, to space [1]. The rest, which is about 460 W/m^2, is absorbed by the earth. A part of the scatter radiation (about 80 W/m^2) is scattered back to space. The rest, about 230 W/m^2, known as diffuse radiation, is absorbed by the earth.

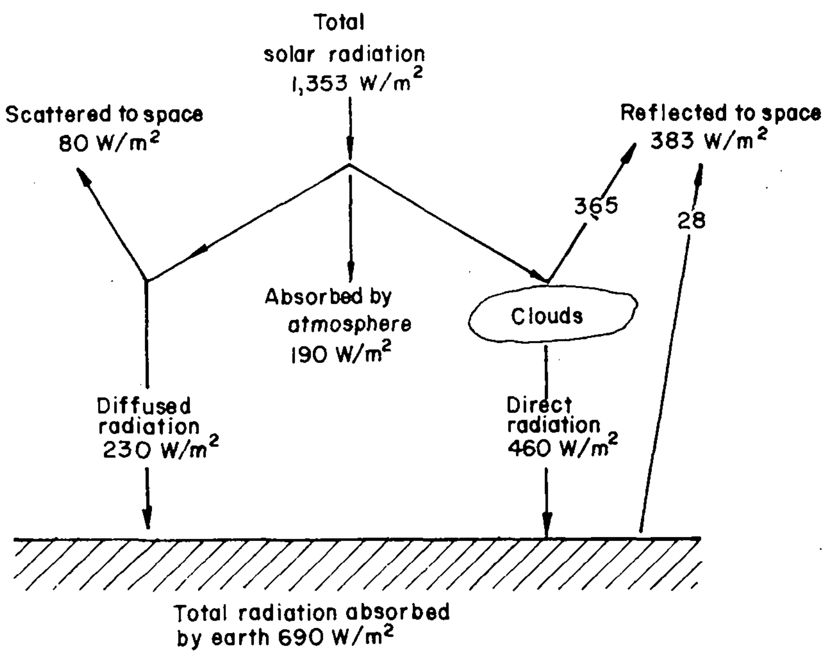

Figure 1. A simplified sketch for the paths of solar radiation

The amount of radiation (direct + diffuse) absorbed by the earth is about 690 W/m^2. This figure is an average value; it varies according to the site (latitute), season (time of the year), time of day (hour angle), and the climate, particularly the cloudiness. It may reach a value of 1,100 W/m^2 or more at noon on a clear day and may go down to 100 W/m^2 or less during heavy overcast conditions.

When designing solar devices operating at low temperatures like flat-plate collectors, driers, stills, greenhouses, etc., it is important to have detailed information about global (direct + diffuse) solar radiation. Solar concentrators and focusing collectors, however, focus the direct solar radiation received on a large area to a relatively small area; hence information on direct solar radiation is needed for the design and operations forecast for concentrators and collectors. For photovoltaic, photobiological and photochemical systems it is necessary to have data on the solar spectral irradiance.

In this section, the devices and methods for estimating the total, direct and diffused solar radiation and spectral irradiance are briefly reviewed.

A. MEASUREMENT AND ESTIMATION OF SOLAR RADIATION

1. *Global solar radiation*

The estimation of global solar radiation fluxes received by a horizontal surface is most important for the solution of numerous practical problems. Empirical relationships are available for calculating from these data, with enough accuracy, solar radiation on inclined surfaces, if required.

(a) *Direct measurement of total solar radiation*

Total solar radiation measurements are most often made by pyranometers. They have a view angle of 2π steradian and measure the global (direct + diffuse) radiations received on a surface. There are many models and types available. The most common pyranometers in use today are based on detection of the difference between the temperature of black and white bodies by thermopiles. The latter, which should be properly protected from wind and compensated for changes in ambient temperature, give millivolt signals that can be readily detected, recorded and integrated over time. Pyranometers can also be based on thermopiles having hot junctions exposed to solar radiation and cold junctions shaded from the radiation on the differential expansion of bimetal elements exposed to solar radiation or on photovoltaic detectors.

The pyranometer is a reliable and convenient device for measuring solar radiation. It can measure the global solar radiation on a horizontal surface or on an inclined one by tilting the pyranometer to the desired angle. Pyranometers are not available in all meteorological stations. If they are not available, solar radiation should be determined from other meteorological data.

(b) *Estimation of global solar radiation using meteorological data*

It is more common in meteorological stations to record sunshine hours, cloudiness, humidity, temperature, etc. than solar radiation. Empirical formulas have been developed to estimate the solar radiation from these data.

(i) Use of sunshine hours data

Most of the formulas used for this purpose are based on Ångstrome's formula for estimating the mean daily total radiation ϕ on horizontal surface for the period under consideration as follows:

$$\phi = \phi_o (a + b \, \tau/\tau m) \qquad \ldots\ldots\ldots\ldots \quad (1)$$

where ϕ_o is the mean daily global radiation on horizontal surface on a cloudless day for the period under consideration;

τ is the mean daily duration of sunshine measured with sunshine recorders;

τm is the maximum possible duration of sunshine during the period considered;

a and b are constants depending on the latitude and climate of the site.

The values of ϕ_o and τm can be determined from charts as in figures 2 and 3 respectively.

The values of the constants a and b have been calculated for several sites using the sunshine and radiation data recorded at the same time for the same stations. Some values of a and b for sites in the ESCAP region are given in table 3. It may be noticed that the values of a and b are comparable for sites at the same latitude and of similar climate.

(ii) Use of cloud cover data

The total solar radiation ϕ received on a horizontal plane can be determined as follows:

$$\phi = \phi_n (1 - 0.71 \, C^2) \qquad \ldots\ldots\ldots\ldots \quad (2)$$

where ϕ_n is the net shortwave radiation

and C is the cloud cover

C = o for cloudless sky and 1 for a total overcast.

The net shortwave radiation, ϕ_n, may be determined from the following equation [3]

$$\phi_n = 1218 \sin^2 \alpha/(\sin \alpha + 0.22) \, W/m^2 \qquad \ldots\ldots\ldots \quad (3)$$

applications without conversion to electricity. For example, solar heat and bio-gas may be used directly for heat using processes, or domestic requirements for cooking or lighting and therefore can be quite viable vis-a-vis other energy sources.

14. Non-commercialised energy sources can therefore be a fairly important contributing factor in reducing demand for commercial power and at the same time improve conditions of life and work, particularly in poorer regions and segments of economic activities - rural homes, agricultural inputs for water and fertiliser, small industries, agro-processing, etc. Attention to these technologies should not be at the expense of other more conventional ones where such potential exists. Rodberg, in the earlier mentioned study on USA, has estimated that conventional energy demand, in combination with energy conservation measures supplemented with non-conventional energy inputs can be lowered by 37 per cent by the year 2,000 A.D. The main question however, is how is this to be achieved, particularly the development and use of non-conventional energy at grass-roots level. The problem is that of institutional development. Inappropriate promotion policies and institutions can lead to the same skewed development as happens in respect of the commercial sector. The Indian government has reassessed its support to the bio-gas plant promotion scheme as the benefits mostly went to middle-class and richer rural families.

15. In some ILO studies it has been suggested that the decoupling of commercial energy demand from economic growth would help the attention being given to the non-commercial sector, such as through solar energy to that extent such energy technology can be viably used. At present however, it is premature to make any judgements on the contribution solar energy can make to the energy balance of all countries.

III. *Continuing Areas of ILO's Research Programmes*

16. ILO's studies, and particularly the one by Chris Baron show that the energy policy options faced by developing countries are pregnant with social implications. Subjects in the field of energy in which the ILO has completed, continuing or starting studies and advisory services relate to:

a. Effect of higher oil prices on technology and employment (an ILO-WEP study on several countries).

b. Energy in the manufacturing sector, Relevance of "energy analysis" of products and processes and compatibility of technological choices based on other factors and objectives.

c. Energy in Civil Construction and Transportation.

d. Urban Energy Conservation particularly of commercial energy.

e. The effects of small-scale non-conventional energy technologies, domestic machine fabrication industry, employment, and conditions of living particularly in rural areas, and institutional requirements.

minimisation of human physical energy inputs to work. Yet men require physical exercise for their health. Then again, it is also stated that men and animals are very inefficient conversions of physical energy. The same could possibly be stated of mental work with the coming in of micro-processors. There would possibly be certain levels and certain conditions to which and at which such work inputs are efficient and viable. The second choice is between the various conventional energy technologies. This choice is fairly straight-forward and depends on the availability of fossil fuels or hydro-power potential and based on economic considerations of exploitation and availability of capital and skills. This possibility cannot be minimised because oil and gas is now known to be more widely available than formerly known, and hydro-power has been developed to only about 10-15 per cent of existing potential. But in most of these cases of commercial energy development, *distribution* policies have a bearing on the socio-economic impact. Quite often such distribution is to points of concentrated consumption viz large industries, urban centres and the like, and agriculture, small industry and rural areas are not benefitted, or if it is reaches them at all, it is at a price. Skewed socio-economic development may be the result of poor power distribution and pricing policies which penalises the poorer segments of the population.

13. It is in this respect that soft-energy, or non-conventional or small-scale energy development has relevance. Their present state of technical development is not up to commercialisation levels. The capital costs and operating costs are often quite high depending on the technology used. For example, the mini and micro hydro electric generation plants are estimated to cost as little as US$1,500-2,000 per kilowatt, whereas a solar-cell unit costs around US$8,000-9,000 per kilowatt (to gradually go down to $5,000 per kilowatt).[6] In terms of costs to the consumer, a Tanzanian study indicates the following comparative costs per kilowatt-hour:[7]

		T.Sh.
Diesel engine generation	...	2.30
Windmill generation	...	1.50
Small hydro power	...	0.26-0.97
Bio-gas and generator	...	18.20
Photo-voltaic cell supply	...	11.00 (aimed to go down 0.83 by 1985)

However, because of these cost factors, the costly ones need not be condemned. If one were to bank on commercial energy only, the undeveloped sectors will always get neglected unless purposeful government policies, action and resource allocation is pursued to benefit them. Moreover, each of these technologies is likely to have direct energy

6 Andrew Mackillop: *How Soft Energy Gets the Hard Sell*, Asia Week, Sept. 26, 1980.

7 Tanzania National Scientific Resource Council: *Workshop on Solar Energy for Villages of Tanzania*, 1978.

because all power generation technologies on a commercial scale are capital intensive, more 80 than oil refining and oil or gas-based power plants. Therefore capital gets diverted from other very needy sectors such as agriculture, or roads and communication or education and health services and this in turn defers the achievement of projected development goals. The energy sector, excepting for coal mining, or hydro-electric infrastructure (during the construction stage, if carried out with labour-intensive technology) do not absorb much labour, and whatever manpower is required, is highly skilled. The net result is skewed development in the initial years till down-stream power utilisation activities develop. The World Bank estimates that the effect of all this is likely to increase the percentage of gross fixed capital formation in these countries rising from 7-8 per cent to 10-12 per cent in the power sector during the next decade. Thus allowing lower imports of energy to prevail without increased domestic supply *or* increasing domestic supply, have both serious socio-economic implications on developing economies.

10. Looking at the *socio-economic impact of conservation* measures, there are both positive and negative aspects. As stated earlier, conservation needs to be implemented on a selective basis, because in most developing countries, there are sectors, regions and activities which are so undeveloped that they can only develop through greater energy inputs. Any restriction on energy flows to such sectors and sections will result in stagnating in development. The availability of power itself can be an incentive to development. The availability of power itself can be an incentive to development, such as electrification in rural areas. But it has to be proved whether and in what conditions it leads to more production or to greater energy usage efficiencies, can have very positive effects because it has been estimated that these measures are less capital consuming compared to equivalent power generation facilities. Moreover, energy saving technologies already exist, and when applied can generate considerable employment as well. One estimate for USA[5] places additional employment prospects for 2.17 million jobs in such activities, in addition to 1.14 million jobs required for small-scale, supplemental energy devices.

11. Energy conservation can have other dimensions. Where it leads to lowering of working conditions such as continuing heavy physical work or poorer lighting conditions, or comfort (heating or cooling), diseconomies will arise elsewhere, through lower production or poor labour conditions, etc. Moreover, the selection of manufacturing technologies based on energy efficiency of the process or equipment, may favour high-level technologies, but based on employment creation goals may favour small-scale technologies. Such differences are known to exist in small-scale bread making, or brick making technological choice. In all such instances, conservation measures can be directed at developing more heat efficient bread baking ovens or brick kilns as used in small-scale plants.

12. *The socio-economic impact of various energy technologies* is very varied. The first question is to what extent can and should human labour for all mechanical energy requirements be replaced. It has been assumed that humanisation of work requires

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[5] Leonard Rodberg: *Employment Impact of Solar Transition*, U.S. Government Printing Office, Washington, DC 1979.

product choice in terms of its energy-intensiveness per capita of final benefit (e.g. individualised transport vs. public transport, burnt bricks instead of compressed soil bricks in rural one-storied houses, etc). In essence, all these measures are aimed at improving energy usage efficiency as a whole. Oil substitution possibilities become more pronounced as oil price increases occur, bringing into the substitution range those resources and technologies which had been considered high-costs, at their existing and projected levels of their respective states of the art. Inspite of the steep increase in oil prices, two major global studies viz. the Workshop on Alternative Energy Strategies (Energy, Global Prospects, 1985-2000), as well as the World Energy Conference (World Energy: Looking Ahead to 2020), both published during 1977-1978, did not accord any significant role to these non-conventional energy sources, particularly in respect of commercial energy supplies.

II. *The Socio-Economic Impact of Energy Policies*

7. Energy policy components fall basically into three categories, viz: (i) the target level of energy supplies to be aimed at and the manner in which this is to be achieved, (ii) the nature of conservation measures to be undertaken, and (iii) the sources of energy supplies and energy technologies to be chosen. Thus it would be in order to examine the socio-economic impact of energy policies on employment levels, income levels and income distribution, working conditions and standard of living under the following three heads:

a. Impact of constraints on energy availability on development perse, and by sectors and regions,

b. Impact of energy conservation measures, and

c. Impact of choice of energy sources and technologies.

8. Examing the *socio-economic impact arising from the constraints of energy availability*, it is seen that the ratio of the value of imports of energy to the value of all merchandise exports is about the same for most developing and industrialised countries, subject to the extent of their domestic resources of energy. Increase in this ratio arises from an upward pressure from oil prices, as also downward pressures from exports due to internal inflationary tendencies. This squeeze affects negatively growth of basic industries which are mostly energy intensive (steel, fertilisers, cement), both in respect of energy requirements for these industries as well as ability to buy capital goods from abroad. The World Bank has assessed that in developing countries as a whole (excluding OPEC countries), the growth rate of GDP declined from 6.2 per cent during 1965-74, to 4.9 per cent in 1974-77. The middle income countries in the process of rapid industrialisation were affected most. This has had its effects on employment and income levels as well.

9. Such a squeeze on imported energy supply, where it leads to increased activities for domestic energy exploitation because of estimated potential, two results are noticed. Such activities lead to increased pressures on capital allocation to the energy sector

among several candidate-energy sources in a country has a pattern which gives priority consideration to expanding domestic production of primary energy in the conventional categories which permit of easy commercialisation such as petroleum and gas, coal and hydro power. They are the ones which have proven technologies for commercialisation. Even in these categories, intensive exploitation is being aimed even with scattered and small-unit resources such as with mini and micro- hydro-electric plants for small communities. But all these can only benefit countries which have such potential in fossil fuels and hydro-electric generation. The next order of priority, seems to be taken by atomic power plants, the choice for which is not entirely confined to domestic availability of raw materials or to economic factors. For most developing countries it increases dependance on the developed countries for technology, skills, materials and sometimes capital and therefore has political implications. In some countries geo-thermal power is a definite possibility. Finally comes the group known by non-conventional or small-scale or soft-energy technologies derived from commonly available resources such as the sun, wind, tides and biogas. In this field the state of the art is that they are proved to be feasible scientifically and technologically but most of them are yet to be proved viable for large-scale commercialisation. They are therefore largely establishment-based exploitation facilities (home, office, and small factory or individual village level), and in some cases their viability arises from the fact that part of the capital inputs is provided by the user in the form of work. These are therefore sometimes grouped together as non-commercial energy sources, the first being direct solar energy, and wind, tides and bio-gas as indirect solar energy embodied in running water, tides, wind and plants after photosynthesis.

5. The first question which arises is whether to conserve energy use or to expand it. The rough averages of per-capita consumption of energy indicates that in 1976, low-income countries consumed 116 kgs of coal-equivalent, the middle income countries 916 kgs, and industrialised countries 7079 kgs.[4] This indicates that for the countries in the first group it is not a question of conservation of energy but expansion of energy consumption because such expansion is needed for economic development, for incomes improvement through increased productivity and for better standards of living. But in these countries, such overall policies will have to differentiate between the urban and rural sectors where consumption rates differ widely, as also between agriculture, industry and transport, etc.

6. In all countries, developed and developing, the oil price increases have two common policy implications, viz: (a) conserving *oil usage* and substitution with other viable primary energy resources for meeting the normal and desirable needs of economic growth, and (b) conserving measures with a view to avoiding or lowering energy wastage of *all* energy usage which takes place because of poor technologies or equipment for conversion of energy from one state to another (heat to light or to mechanical power, etc.), *or* poorly designed usage equipment whether for domestic, industrial or agricultural purposes (poor cooking stoves, industrial burners and agricultural pumps), *or* poor

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[4] ILO, World Employment Programme Studies, 1978.

ENERGY POLICIES AND SOCIAL IMPACT

ILO

I. *The Energy Dimension of Development Policies*

1. The impact of fast rising petroleum prices on non-oil producing countries has brought into sharp focus question relating to: (a) what is an appropriate mix between programmes for energy conservation and for continued expanded energy consumption using substitute energy sources, (b) prospection for new primary energy resources to improve domestic self sufficiency, (c) the effects of energy supply constraints and costs on economic growth, particularly in developing countries and socio-economic effects on living and working conditions.

2. Some of the most disturbing facts of this decade for planners are the uncertainties of oil supply and its price levels. Some studies of the ILO have implied that the rising price of oil arising out of producer country decisions is not by itself a dominating, disturbing and unsettling influence on the global energy scene, but is a symptom closely related to the limits of current and future supplies of fossil-based energy available at low cost.[1] As early as 1865 an economist, Stanley Jevons, had written that:

> "While other countries subsist upon the annual and ceaseless income of the harvest, we (in UK) are drawing more and more upon a capital (coal) which yields no annual interest, but once turned into light and heat and motive power, is gone for ever ... The cost of fuel must rise, perhaps within a lifetime, to a rate injurious to our commercial and manufacturing supremacy; and the conclusion is inevitable, that our present happy progressive condition is a thing of limited duration" ...[2]

3. The question of alternative resources has been the subject of examination and discussion for decades. As early as 1949, the US Atomic Energy Commission engaged a consultant to study the world demand for energy during a 50-100 years span. Surprisingly, this consultant, Palmer C. Putnam,[3] examined all alternatives and mentions of the uncertainties of Middle East oil, the upcoming coal crisis, solar heaters, windmills, biological energy, synthetic fuels, alcohol from farm wastes, potential effect of burning fuels on world climate, etc., all of which are subjects of intensive global discourse now.

4. The prospects of Solar energy harnessing and utilisation can only be examined within the context of the options available to developing countries in respect of all other viable energy technologies and resources. Choices for expansion of energy supply from

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[1] C. Baron: *Energy Policy and Social Progress in Developing Countries* International Labour Review Geneva, Sept.-Oct. 1980, pg. 533.

[2] V.S. Jevons: *The Coal Question*, Macmillan, London, 1865, p. 412.

[3] Chichiro Kikuchi: *Nuclear and Solar Energy, Problems and Prsopects*, APPROTECH, Michigan University USA, Sept. 1980, p. 16.

54. "Photowatt Setting Up Ivory Coast Unit, Receiving Photovoltaic R & D Funding from France," Solar Energy Intelligence Report, pp. 305, August 4, 1980.

55. R.W. Matlin, "Design Optimization and Performance Characteristics of a Photovoltaic Micro-Irrigation System for Use in Developing Countries," MIT Lincoln Laboratory, Lexington U.S.A., July 1979.

56. "Solar Heating and Cooling Experiment for a School in Atlanta - Construction Report," prepared for the U.S. Energy Research and Development Administration (ERDA), Contract No. EY-76-C-02-2628, Westinghouse Electric Corporation, Special Systems, Baltimore Md. 21203 USA, December 15, 1976.

57. S.F. Bruning and M.S. George, "Shennandoah Community Center; A Total Solar Design Concept," ASHRAE Journal, November 1976.

58. B.W. Tleimat, "Solar Distillation: State of the Art," Sea Water Conversion Laboratory, University of California, Berkeley, California, U.S.A., *TECHNOS*, pp. 55-69, October-December 1977.

59. T.A. Lawand, "A Solar Distillation System for a Haitian Village," Brace Research Institute, McGill University, Quebec, Canada, Presented at the UNU Seminar on Solar Technology in Rural Settings: Assessments of Field Experiences, Atlanta, Georgia, June 1-2, 1979.

60. B.A. Stout, et al., *Energy for World Agriculture*, Food and Agriculture Organization, Rome, Italy, FAO Agriculture Series No. 7, UNIPUB, New York, N.Y., 1979.

61. J.W. Tatom, A.R. Colcord, J.A. Knight, L.W. Elston and P.H. Har-Oz, "A Mobile Pyrolytic System Agricultural and Forestry Waste Into Clean Fuels," Georgia Institute of Technology, Atlanta, Georgia, *Proceedings of the 7th National Annual Conference on Agricultural Waste*, Syracuse, N.Y., April 16-18, 1975.

62. J.W. Tatom, A.R. Colcord, J.A. Knight, L.W. Elston and P.H. Har-Oz, "Clean Fuels from Agricultural and Forest Wastes - The Mobile Pyrolysis Concept," Georgia Institute of Technology, Atlanta, Georgia, presented at The Heat Transfer Division of the American Society of Mechanical Engineers, Houston, Texas, November 30 - Decmeber 4, 1975, ASTM Paper No. 75-WA/HT-47, 1975.

63. J.A. Knight, M.D. Bowen and K.R. Purdy, "Pyrolysis - A Method for Conversion of Forestry Wastes to Useful Fuels," Georgia Institute of Technology, presented at Conference, Energy and Wood Products Industry, Forest Products Research Society, Atlanta, Georgia, November 15-17, 1976.

43. S.H. Bomar, Jr., E.L. Meeks, T.B. Elfe and J.D. Walton, Jr., "Preliminary Design for a Solar Powered Irrigation System Using a Concentrating Collector Concept," Georgia Institute of Technology for Al Dir' Iyyah Institute of Geneva, Switzerland, October 1978.

44. A.L. Rawlings, *The Science of Clocks and Watches*, 2nd Edition (1948), published in U.S.A. by Caldwell Industries, Luling, Texas 78648 (1974) pp. 100-102.

45. G. Francia, "Pilot Plants of Solar Steam Generating Stations," *Solar Energy, 12,* No. 1, p. 51-64, September 1968.

46. J.D. Walton, Jr., "Report of Mission to Algiers to Advise on Post Graduate Research and Training Program in Solar Energy," UNDP (ALG/75/038), for UNESCO, 7, place de Fontenoy, 75700 Paris, France, 15 March 1980.

47. Two lithium bromide air conditioning systems using commercially available components have been designed and demonstrated by Georgia Tech.

One in 1976 at the Kuwait Institute of Science and Technology and one in 1978 at the University of Riyadh, Saudi Arabia.

48. D.I. Tchernev, "Solar Energy Applications of Natural Zeolites," *Natural Zeolites, Occurance, Properties Use*, Edited by L.B. Sand and F.A. Mumpton, Pergamon Press, London, 1978.

49. L. Rosenblum, W.J. Bifano, F.G. Hein and A.F. Ratajczak, "Photovoltaic Power Systems for Rural Areas of Developing Countries," US National Aeronautics and Space Administration (NASA) Lewis Research Center, Cleveland, Ohio, *Natural Resources Forum*, 1980.

50. W.J. Bifano, A.F. Ratajczak, D.M. Bahr and B.G. Garrett, "Social and Economic Impact of Solar Electricity at Schuchuli Village: A Status Report," NASA TM-79194, Presented at the UNU Seminar on Solar Technology in Rural Settings: Assessments of Field Experiences, Atlanta, Georgia, June 1-2, 1979.

51. W.J. Bifano, A.F. Ratajczak and J.E. Martz, "A Photovoltaic Power System in the Remote African Village of Tangaye, Upper Volta," NASA TM-79318, Prepared for the UNITAR Conference on Long-Term Energy Resources, Montreal, Canada, Nov. 26 - Dec. 7, 1979.

52. W.J. Bifano, "Review of Stand-Alone Photovoltaic Application Projects Sponsored by U.S. DOE and U.S.AID," NASA Lewis Research Center, Cleveland, Ohio, to be presented at the National Conference on Renewable Energy Technologies, Dec. 7-11, 1980, Honolulu, HI.

53. E. Jacobson, G. Fletcher and G. Hein, "Photovoltaic System Costs Using Local Labor and Materials in Developing Countries," Georgia Institute of Technology, Final Report for NASA Lewis Research Center, Cleveland, Ohio, May 20, 1980.

29. "Evaluation of Solar Cookers," Volunteers in Technical Assistance (VITA) Mt. Ranier, Maryland, USA, 1977.

30. J.A. Duffie, G.O.G. Lof and B. Beck, "Laboratory and Field Studies of Plastic Reflector Solar Cookers," University of Wisconsin, *Proceddings of the United Nations Conference on New Sources of Energy, Volume 5, Solar Energy II*, Solar Cooking, III. C.4, pp. 339-344, Rome, United Nations, New York, 1964.

31. Personal visit to Upper Volta, May 1978.

32. L. Crabtree, "Conceptualizing and Implementing Rural Development," *TECHNOS*, Vol. 8, No. 1-4, January-December 1979.

33. T.E. Bowman and J.H. Blatt, "Solar Cookers for Haiti - A Feasibility Study," Final Report for Contract AID/ta-c-1333, Florida Institute of Technology for the U.S. Agency for International Development, December 1977.

34. B.D. Vaughan, "A Simple Solar Cooker from India," MRA Centre, Asia Plateau, Panchgani, Maharashtra, India, *Appropriate Technology*, Vol. 6, No. 1, May 1979.

35. J.D. Walton, "Development of the Spiral Fresnel Concentrator," Georgia Institute of Technology, Presented at the International Symposium on Solar Thermal Power and Energy Systems, Marseille, France, 15-20 June, 1980.

36. F. Fiatte and M. Clemot, "Water Pumping - A Practical Application of Solar Energy," *Heliotechnique and Development*, Volume Two, Development Analysis Associates, Inc., Cambridge, MA 02139 (1976).

37. "Testing and Demonstration of Small-Scale Solar-Powered Pumping Systems," Sir William Halcrow and Partners, London, UNDP Project GLO/78/004, December 1979.

38. S. Steinhart, "Solar Thermal Pump Development Excites Third World Interest," *Solar Times*, Vol. 2, No. 8, August 1980.

39. Omnium-G, Heliodyne Tracking Concentrator, 1815 Orangethorpe Park, Complex B, Anaheim, California 92801, USA, 1978.

40. "Small Scale Solar Powered Pumping Systems," UNDP Project GLO/78/004, Dr. E.M. Mitwally, UNDP Project Manager, World Bank, Washington, D.C. 20433, U.S.A.

41. S.S. Shergill and R.P. Morgan, "Analysis of an Oscillating Engine for Power Generation Based on the "Drinking Bird" Principle," University of Missouri, Paper No. 699076, Intersociety Energy Conversion Engineering Conference, 1969.

42. H. Tabor, "Solar Cookers for Developing Countries," National Physics Laboratory of Israel, Jerusalem, *Solar Energy*, October 1966.

15. "Survey of Solar Agricultural Dryers," Technical Report T-99, Brace Research Institute, January 1976.

16. "Proceedings of the Solar Drying Workshop," Manila, Philippines, October 18-21, 1978, Ministry of Energy, Fort Bonifacio, Makati, Metro, Manila, January 1979.

17. J.M. Troeger and J.L. Butler, "Peanut Drying with Solar Energy," USDA, SEA-AR, Coastal Plain Experiment Station, Tifton, Georgia, Presented at the Conference on the Use of Solar Energy for Crop Drying, Atlanta, Georgia, April 1979.

18. J.H. Schlag, A.P. Sheppard and J.M. Wood, "Material Selection for Agricultural Solar Systems," Georgia Institute of Technology Presented at the Solar Crop Drying Conference, Raleigh, N.C., June 1977.

19. J.H. Schlag, A.P. Sheppard and J.M. Wood, "A Low Cost Solar Collector Suitable for Use in Peanut Drying Applications," Georgia Institute of Technology, Presented at the Solar Crop Drying Conference, Raleigh, N.C., June 1977.

20. J. Stoney, "How to Build a Low Cost Solar Agricultural Dryer," Georgia Institute of Technology, School of Electrical Engineering, Developed under USDA Contract, Project Manager, A.P. Sheppard, Principal Investigator, J.H. Schlag, Undated.

21. P.D. Blankenship and V. Chew, "Peanut Drying Energy Consumption," *Peanut Science* 6, 10-13, 1979.

22. G.R. Guinn and P.N. Fisher, "Soybean Drying Using Heat from Solar Energy," Teledyne Brown Engineering, 300 Sparkman Drive, Huntsville, Albama 35807, USA, *Solar World*, 1977.

23. E.J. Carnegie, P.W. Niles, J.A. Hoffmann, W.B. Stine and R.E. Boche, "Design of a Solar Heat Source for Industrial Hydration," California Polytechnic State University, San Louis Obispo, California 93407, USA, *Solar World*, 1977.

24. M. Lillywhite, Domestic Technology Institute, P.O. Box 2043, Evergreen, Colarado 80439, USA, Private Communication.

25. W.D. Holcombe and S.D. Robertson, "Georgia Broiler House Solar Study Shows Promise," *Broiler Industry*, January 1980.

26. L. Brown, *By Bread Alone*, Overseas Development Council, Washington, D.C., 1974.

27. A. Makhijani, *Energy and Agriculture in the Third World*, Ballinger Publishing Company, Cambridge, Mass., 1975.

28. T.E. Bowman and J.H. Blatt, "Solar Cookers," Report CREA-78-1, Florida Institute of Technology, Melbourne, Florida 32901, USA, March 1978.

REFERENCES

1. K.B. Bota, J. Weinstein and J.D. Walton, Jr., "Proceedings of the African Solar Energy Workshop," Volume 1, Summary Report, The Atlanta University and the Georgia Institute of Technology, October 1979.

2. J.D. Walton, Jr., A.H. Roy and S.H. Bomar, Jr., "A State of the Art Survey of Solar Powered Irrigation Pumps, Solar Cookers and Wood Burning Stoves for Use in Sub-Sahara Africa, "Georgia Institute of Technology, January 1978.

3. "Solar Energy. Study of the Difficulties Involved in Applying Solar Energy in Developing Countries," Research Laboratories of N.V. Philips, Eindhoven Netherlands, Undated.

4. National Academy of Sciences, *Energy for Rural Development*, Washington, D.C., 1976.

5. UN-ESCAP Proceedings of the Meeting of the Expert Working Group on the Use of Solar and Wind Energy. Energy Resources Development Series No. 16, New York, 1976.

6. D.W. Bakke, "Energy in Developing Countries," Fall 1978, unpublished.

7. T.B. Taylor, "A Preliminary Assessment of Prospects for Worldwide Use of Solar Energy," a report to the Rockefeller Foundation, February 1978.

8. N.L. Brown and J.W. Howe, "Solar Energy for Village Development," *Science*, Vol. 199, pp. 651-657, February 1978, J. Langerhorst, G. Prast and T. Thalhammer.

9. H.P. Gary, "The State of Solar Technology Research for Rural Development," *Bhogirath*, Vol. XXV. April 1978.

10. D. French, "Renewable Energy for Africa-Needs, Opportunities and Issues," prepared for AFR/DR/SDP, USAID, Contract AFR-147-46 (Item 001AC) July 1978.

11. C. Stambolis, "Solar Energy Utilization in the Third World," Heliotechnics Associates International, 37 Geatton Road, London, W. 14, 1979, Unpublished.

12. UNEP, "Solar 2000," Nairobi, March 1979.

13. *Postharvest Food Losses in Developing Countries*, National Academy of Sciences, Washington, D.C., 1978.

14. R.P. Morgan and L.J. Icerman, "Appropriate Technology for Renewable Resource Utilization," Final Report, AID Contract AID/DSAN-C-0061, Washington University, Saint Louis, Missouri 63130, USA, June 1979.

dialogue between technologists in developing and industrialized countries and between them and the consumer of energy or potential manufacturer of the appropriate device or system. Only after this interaction and the cooperative development, construction and evaluation of the technology *in the rural setting* should it be expected that the appropirate system or device would emerge.

A major purpose for preparing this paper has been to share these ideas with others concerned with the energy needs and problems of the Asia and Pacific Region. If this paper helps to stimulate dialogue and cooperation in the development of solar devices that some day will help to meet the energy needs of the small farmer and rural communities, it will have accomplished its purpose.

The design, construction and evaluation of several pilot plant pyrolsis units built by Georgia Tech has led to the successful development of two large commercial 50 dry tons per day field test pyrolsis plants. The present Georgia Tech pilot-plant will process one ton of waste per hour depending on the density of the feed material. The types of waste that have been successfully processed through these systems includes peanut hulls, wood chips, pine bark and sawdust, macademia nut hulls, cotton gin wastes, automobile wastes and municipal wastes.

Approximately 70 percent of the energy content of the input feed is contained in the char and oil. Heating values for char will vary from 11,000 to 13,500 Btu/lb and for the pyrolytic oil from 10,000 to 13,000 Btu/lb. This compares with a typical heating value for dry wood of 8,500 Btu/lb.

In addition to the development of these units for the pyrolysis of wastes in the United States, Georgia Tech has constructed experimental units in Gahana and the Philippines. Although these units have functioned satisfactorily, their construction, operation and maintenance have presented problems related to the rural environment and the availability of materials. Future projects involving the introduction of this process in developing countries should be carried out on a technology exchange basis involving local people in the development of the prototype design and incorporating as much as possible the use of indigenous or locally produced materials and involving local labour for its construction and operation. Also, the mode of operation of the unit should emphasize the production of char and attention given to developing local uses for the pyrolytic oil that is produced.

A pyrolytic unit, constructed from appropriate materials and designed for village operation should prove a valuable resource to rural communities that are engaged in agricultural activities that concentrate on agricultural wastes in the vicinity of the village.

IV. *Summary*

This paper has briefly reviewed the principal solar energy technologies which typically are considered as appropriate to meeting the energy needs of developing countries. Emphasis has been given to those technologies with the greatest potential for low-cost, in-country manufacture and which are applicable to small farmers and rural communities.

Solar cooking and water pumping were emphasized since these systems would impact two of the most serious problems facing most developing countries; the need for water for people, animals and agriculture and the need to reduce the problem of deforestation which results from the increasing use of fuel wood and charcoal for cooking.

Although this paper has attempted to suggest areas where existing technologies or devices might be suitable for rural applications, it must be emphasized that these should be taken *only* as ideas and suggestions. Hopefully they will serve to stimulate

I. *Production of Fuel from Biomass*

Basically, there are two ways to obtain biomass for use as an energy source: (a) to collect by-products of wastes, and (b) to grow a crop for that specific purpose.[60] For most areas of the world collecting residue is the more practical. Wastes are often concentrated in one place, like industrial by-products (bark, sawdust, crop residues, etc.), or are collected for environmental reasons (urban refuse, manure, etc.). In these cases the cost of collecting for energy conversion is low. However, the variability and periodic nature of the availability of these resources often limit their use.

As mentioned previously, wood, or charcoal made from wood is the primary source of fuel in the developing countries of the world. Also, it was pointed out that the increasing use of wood as fuel is causing serious ecological problems threatening the well being of man and the land upon which he depends for his livelihood. Thus, if a practical and economical means can be found to convert biomass waste into charcoal the resulting product could be substituted directly for a traditional fuel source for those areas currently using charcoal.

Processes and equipment have been developed to convert agricultural and forestry wastes into clean fuels by pyrolysis.[61, 62, 63] Pyrolysis is the utilization of heat to effect the decomposition of organic mateial. The products that can be obtained are char, pyrolytic oil, water containing soluble organic compounds and non-condensible combustible gases.

The steady-flow, low temperature pyrolysis process is one type and involves processing of the material in a porous, vertical bed. The process is illustrated in a flow diagram in Figure 11. Among the advantages of this process are its simplicity and its low temperature of operation. A further advantage of the system is its self-sustaining operation which requires a minimum of processing of the feed material prior to pyrolysis.

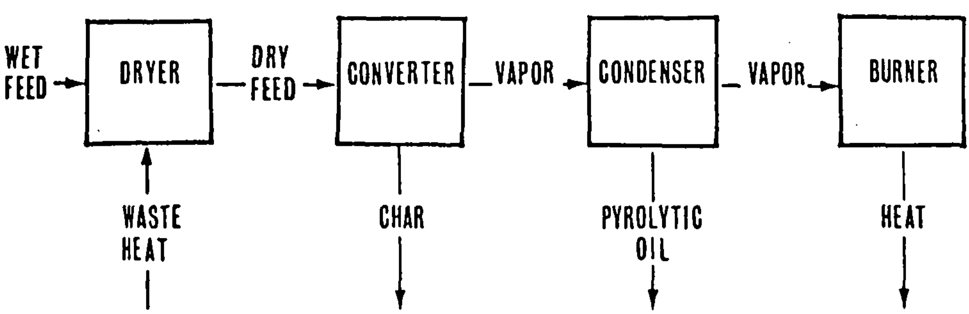

Figure 11. Flow Diagram of EES Pyrolysis System

remote areas where the addition of a small PV powered fan to assist air circulation might be considered economical, particularly where a cash crop or other food is to be dried.

G. *Water Heating*

Solar water heaters, employing natural convection (thermosyphon circulation) are common items in solar laboratories and universities throughout most of the developing countries. For urban areas, where hot water has been typically provided by electricity, a market for locally manufactured solar water heaters is developing as the price of electricity becomes more and more expensive. Also, in rural areas where the value of hot water is becoming recognized as important to cleanliness and health, interest in solar hot water heaters is growing. Therefore, during the past ten years solar hot water heating has become the subject of substantial in-country development, demonstration, evaluation and commercialization.

Clearly, for areas where freezing is not a problem, the thermosyphon solar heated hot water system provides the simplest and most economical means of producing hot water for both urban and rural areas of most developing countries. In cooler climates forced hot water circulation and freeze protection may make solar water heating feasible.[56, 57]

H. *Water Distillation*

Although the first solar desalination system was built more than 100 years ago in Chile, solar stills received little attention until the last three decades when sustained drought conditions in many parts of the world brought water supply problems to world attention.[58] Since that period most developing as well as industrial countries have carried out numerous programs to optimize solar still designs and materials of construction.

The most common and lowest cost solar still is the basin-type. It consists of a shallow pool of brine from which a slow evaporation of water takes place. The bottom of the basin is black to absorb the solar radiation and is covered with sloping sheets of transparent glass to form an airtight enclosure. The evaporating water condenses on the underside of the cooler glass cover and runs into troughs at the lower edges where it is collected to storage. Prototypes of small stills using aluminum and glass are demonstrated at national and regional laboratories and universities in most developing countries. These stills are easily adapted for small farmer use to provide 2 to 4 liters of distilled water per square meter of glass area per day. For rural communities proven designs are available using standard, durable construction materials such as glass, concrete and asphalt. A good example of applying appropriate technology in developing and constructing a solar distillation system to meet the water needs for a rural village was recently carried out by Brace Research Institute.[59]

with concentrating solar collectors. Therefore, if a given module is designed to be used with solar concentrators with a concentration ratio of 10 suns, it theoretically would require only one-tenth the number of solar cells as the equivalent module with no concentration. Of course the costs of the concentrators and some sort of cooling system for the cells must be added to the costs of the concentrating PV module. However, if these additional items could be provided by the developing country they would not add to the imported cost. Thus, for this hypothetical example, both the imported cost and the total cost of the system to the consumer should be significantly reduced. In addition, by building more of the system in the developing country, the economy also should be stimulated.

d. *Small-Scale Uses for Photovoltaics*. This section has considered small scale electric power primarily from the village standpoint. However, there are several single-function applications for which photovoltaic devices are being developed. Two of these will be mentioned here: water pumping and auxiliary power.

(1) *Water Pumping.*[37] During the past five years, as the prices of solar cells has been steadily decreasing, there has been growing interest in developing small scale PV water pumping units. Currently there are about 60 small water pumps in operation around the world, most of these installed since 1975.

As mentioned previously, water pumping is typically carried out under conditions which do not require energy storage. Therefore, in the simplest design, the output of the PV array is fed directly to a permanent magnet DC motor which is coupled to a positive displacement or centrifugal pump with no battery storage or regulation control. Although such a system will perform satisfactorily with a fixed PV array, an electronic tracker has been developed that optimizes the array output under all conditions for maximum electrical power. This is reported to improve daily output with varying insolation as well as to make the system less sensitive to changes in pumping head.[55] Many such modifications and innovations to PV system design are currently under development to improve the performance of these systems, but the resulting cost-benefit balance is yet to be determined. At the present time complete, turn-key PV water pump units are of the range of \$15 - \$20 per peak Watt in the 250 to 500 Watt size.

(2) *Auxiliary Power.* In addition to providing the power to serve some primary energy function such as water pumping, photovoltaics may be an economical way to provide auxiliary power for other systems. For example, the power required to drive the tracking mechanism for paraboloid dish concentrator in a solar thermal power system is very low because of the slow tracking speed of 15° per hour. Therefore, a small PV module may prove attractive for that purpose. Also, a PV source might also be considered for powering a small pump to circulate the heat transfer fluid through the receiver and boiler of such a solar thermal system.

Although many solar dryers can function satisfactorily with the natural circulation provided by a passive solar design, efficiency usually can be improved by the use of forced air circulation. Therefore, there should be a number of applications in

TABLE 3

INSTALLED PHOTOVOLTAIC SYSTEM COST PROJECTIONS
(1978 $/PEAK W)

Year	Module Cost	BOS Cost	Total First Cost	Averaged Annual Capital Cost	Averaged Annual Replacement and Maintenance	Energy Cost $/kWh
1978	13.00	15.00	28.00	3.29	0.44	2.33
1979	9.00	12.00	21.00	2.46	0.31	1.73
1980	5.00	10.00	15.00	1.76	0.23	1.24
1981	2.45	8.00	10.45	1.22	0.17	0.86
1986	.61	5.00	5.61	0.66	0.10	0.47

photovoltaics in a particular country. The acceptance of the technology depends primarily on the relative prices of alternative energy sources within a national economy. This would, of course, assume that other factors related to technical acceptability were equal.

A recent example of incorporating local labor and indigenous materials into the construction of photovoltaic systems in a developing country was reported in Alyan, Ivory Coast.[54] An international photovoltaic company set up a subsidiary in Abidyan to develop, manufacture and install photovoltaic modules, generators and systems for the growing energy demand for Ivory Coast and ultimately for the West Africa market.

c. *Reducing the Costs of Photovoltaics*. Even with the decreasing costs of solar cells and the increasing number of installations and demonstrations of photovoltaic systems in developing countries, it is not possible to estimate how long it will be before the small farmer or rural community can afford such systems without large subsidies from national or foreign governments or financial support from donor groups. An added constraint is the fact that the PV modules and most of the electrical components of the BOS must be imported from the industrialized countries. Thus, the importation of PV systems will add to a strained balance of payments situation which already threatens the economic stability of many developing countries. Therefore, for photovoltaics to become a serious energy alternative, every effort must be made to increase the energy alternative, every effort must be made to increase the energy potential from every photovoltaic item that must be imported. One way to do this is to increase the electrical power generated by every solar cell in the module. This can be done by designing the module to be used rate of the well. The mill was selected to provide about 320 kg per day of finely ground grain, enough to meet the daily requirements of about 640 families. The system load consists of a commercial 1 hp burr-mill and a 1/4 hp motor driven positive displacement water pump. The pump is capable of deliverying 1475 liters of water per hour at a total dynamic head of 28 meters. The mill has a manufacturers rated capacity of 45 to 136 kg per hour, depending on the material being ground.

The Tangaye solar project represents the first major PV technology effort in a US AID program. NASA reports that the experience gained in this project indicates that (1) PV systems are practical in remote areas of developing countries, (2) much of the installation can be accomplished by local labor, (3) local people can manage and operate the system, and (4) energy cost is competitive with that of diesel powered generators for the amount of electricity required at Tangaye.[51]

b. *Economics of Photovoltaics for Rural Applications.* Photovoltaic system costs are divided into the costs of the photovoltaic module and the costs of the balance of system (BOS). The module is basically the electrically connected assembly of solar cells, environmentally protected in a sealed package, it is the basic unit of the solar array. The BOS consists of the following:[49]

1. Array, structure and site preparation.
2. Electrical wiring, control circuits and instruments, voltage regulation, power conditoning, etc.
3. Storage batteries and associated supporting structures and enclosures.
4. Installation and checkout.
5. System sizing and design, module test and inspection, packaging and freight and maintenance equipment.

Table 3 presents projected module and BOS costs together with resulting energy costs for the period 1978 through 1986, assuming an annual energy output per peak watt of 1.6 kWh, annual interest rate of 10 percent and system life of 20 years.[49]

A cost analysis of energy from photovoltaic systems at remote sites indicates cost competitiveness relative to diesel generators at today's module prices for cases where the *delivered* price of diesel fuel is $3 per gallon ($.80/liter).[52] Recently a study to determine the costs of photovoltaic systems in countries that do not have high technology industrial capacity was completed.[53] The study attempted to determine the relative cost of integrating indigeneous labor (and manufacturing where available) into the BOS industries of seven countries: Egypt, Haiti, Ivory Coast, Kenya, Mexico, Nepal and the Philippines. Although it was determined that the cost of installing and maintaining comparable PV systems in developing countries was less than in the U.S., it was also apparent that relative prices among countries could not determine the feasibility of

TABLE 2

PHOTOVOLTAIC APPLICATIONS IN RURAL AREAS OF DEVELOPING COUNTRIES

Application Category	*Typical Uses*	*PV System Power Requirements*
Water pumping	Potable water	0.08 Wp/L/day[a]
	Irrigation	85 Wp/ha-mm/day[b]
Refrigeration	Food, drug and vaccine preservation	100 Wp/5 ft^3 refrig.
Lighting	Homes and work areas	16 Wp/20 W fl. lamp[c]
Communications	Educational TV	40 Wp/TV set[d]
Food preparation	Milling and decortication	3.5 Wp/kg flour/day
Cottage industry	Metal or wood forming	2.0 x Wp/1 hp motor[e]

[a]30 m total dynamic head.

[b]For 5 m head; 60 percent field efficiency.

[c]Average use 2 h/night.

[d]32 W TV; 4 h/day.

[e]8 h/day.

and are gradually changing their food-buying habits to use more refrigerated foodstuffs.[50]

(2) *Tangaye, Upper Volta.*[49] A photovoltaic system powering a grain mill and water pump was installed in Tangaye, Upper Volta, as part of a project sponsored by the U.S. Agency for International Development (AID) titled "Studies of Energy Needs in the Food System." The system consists of a 1.8 kW, 120 volt DC photovoltaic array, 540 amp-hour battery storage, regulator, controls, etc. The PV array, located in a fenced-in area, provides power by underground cable to a control system in the nearby mill and battery room.

The size of the system was based on available funds and certain site related details. The water pumping was established at 5000 liters per day based on the recovery

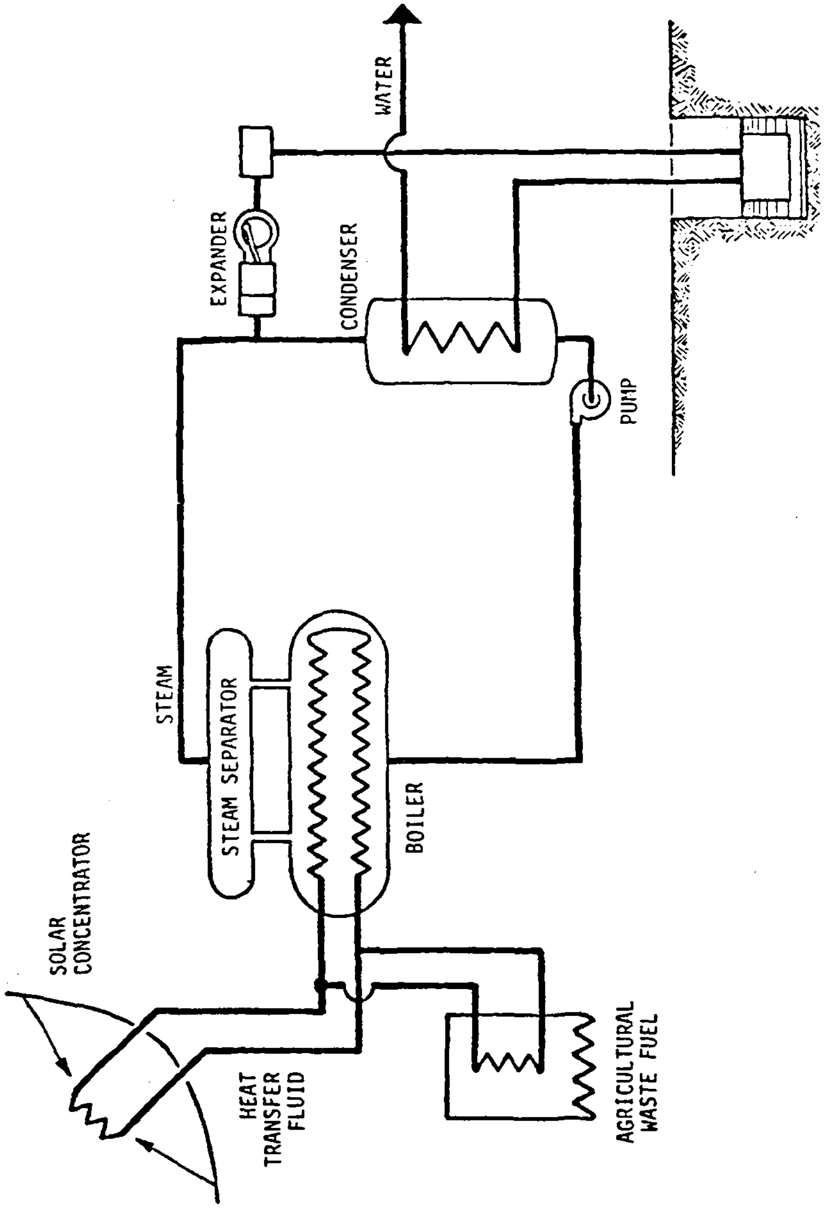

Figure 10. Possible Concept for a Hybrid Solar-Agricultural Waste Fired Stream Power System for Water Pumping

When the sun is not shining the compressed air is used to run the steam engine and produce electricity. Unfortunately, both of these storage systems add significantly to the cost and complexity of an already expensive system. Therefore, it is doubtful that in the near future stand-alone solar thermal systems can be produced at a cost low enough to be affordable by either the small farmer or rural communities. However, there is the possibility that affordable electric power might be produced from a hybrid solar-biomass thermal system of the type shown in prior Figure 10. In this case the steam engine would turn a generator rather than a water pump. Although this system probably would be beyong the reach of the small farmer, it might be adaptable to those rural communities which have access to an adequate supply of biomass.

2. *Photovoltaics*. During the past five years, photovoltaics, or solar cells, have become the object of a rapidly expanding research development and demonstration effort in a number of the major industrialized countries of the world. Although originally developed and commercialized for use in space satellite programs, current activities are directed almost entirely towards terrestrial application. Included among these are small scale applications in rural or remote areas and for developing countries. Table 2 lists several major applications and uses pertinent to rural areas of developing countries.[49]

a. *Rural Village Applications for Photovoltaics*. This section will describe two NASA projects involving village application for photovoltaics. One in Schchuli, Arizona, U.S.A. includes water pumping, lighting, refrigeration and housekeeping services.[50] The other, in Tangaye, Upper Volta, includes water pumping and grain grinding.[51]

(1) *Schchuli Village, Arizona, USA.*[49] The Schchuli Village photovoltaic power system consists of a 3.5 kW, 120 volt DC photovoltaic array, 2380 amp-hour of battery storage, controls, regulators and instrumentation and an overhead electrical distribution network. The system is all DC to avoid the losses associated with commercially available DC/AC inverters and to maximize system efficiency. The system was set at 120 V to permit the use of commercially available switches, motors, appliances, etc. A 2 hp motor powers a jack pump which delivers approximately 4165 liters per hour to the village water system including a 41,635 liter storage tank.

Forty-seven 20 watt fluorescent lights are used in the village. A total of fifteen 0.13 cubic meter refrigerators are installed in the domestic services building. A standard wringer-type washer was retrofitted with a 1/4 hp motor. The wringer type washer was selected for its overall simplicity and to reduce water consumption. A commercially available sewing machine with a 1/8 hp universal motor also was installed in the domestic services building.

The Schchuli system has been operating satisfactorily since December 16, 1978. Water pumping has been about one-half that planned because of the unusually cold and wet weather and because the women in the village are only gradually beginning to use the washing machine. The people enjoy the convenience of electric lights in their homes using either ammonia or lithium bromide have been the subject of most of the solar cooling activities. However, because of the relatively low temperature provided by the flat plate collector, these systems have typically operated at only about 50 percent of their rated cooling capacity. Georgia Tech has constructed and installed two commercial type solar powered air conditioner, absorption refrigeration systems for instructional and demonstration purposes in developing countries.[47]

Another possibility is the use of mechanical compressor systems using power provided by concentrating collectors such as the one proposed for water pumping. Again, if a suitable solar steam technology can be developed at the rural level, the resulting mechanical shaft power could be used to drive a compressor directly to provide refrigeration or to turn a generator to produce the electrical energy needed to run a conventional refrigerator or air conditioner unit.

The use of concentrating collectors such as parabolic troughs to increase the efficiency of absorption systems should be studied in the rural setting. Also solid absorption materials such as Zeolites[48] should be evaluated since these materials are much more suited to the rural setting than ammonia or lithium bromide.

At this time it is not clear that present solar refrigeration systems offer a practical solution to the refrigeration needs of rural communities except for very specialized applications such as those associated with health delivery systems.

F. *Small Scale Electric Power*

1. *Solar Thermal.* This section will consider solar electric power as provided by solar thermal consersion systems. Basically, the same systems as those previously described for providing shaft power for water pumping and compression refrigeration could be used for turning a generator to provide electric power. However, for the application of electric power production a major problem exists with respect to energy storage.

In the case of providing shaft power for water pumping, fluctuations in solar radiation (insolation) is not particularly critical since water is often pumped into an elevated reservoir from which it is supplied, by gravity to the crops as needed. Even in a low-lift situation, in which water is supplied directly to the field, minor fluctuations in water delivery rate is not a serious problem. Similarly, a type of energy "storage" can be easily provided for solar refrigeration systems either in the form of ice or by the use of adequate thermal insulation in the cold storage system.

For small scale solar electric power systems the problem of energy storage is much more complex than for the case of water pumping or refrigeration. For DC systems the electric energy can be stored chemically in batteries. Mechanical energy can be stored in compressed air as mentioned for the Omnium-G System.[39] In this system the collected solar thermal energy, in the form of steam, powers a steam engine that turns a generator and a compressor. The compressor supplies compressed air to a pressure tank for storage.

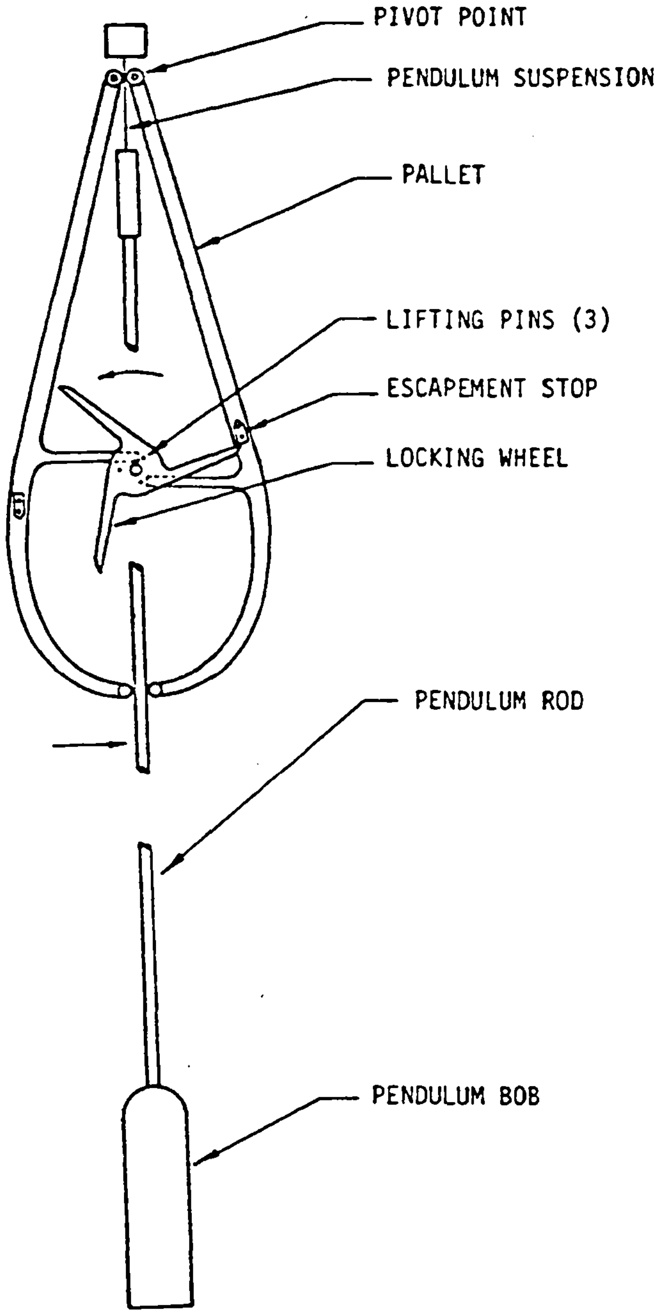

Figure 9. Drawing of Grimthorpe's Gravity Escapement Proposed for Use in Regulating Mechanical Tracking Speed

The automatic tracking system would consist of a weight attached to a cable which is wound around a drum on a shaft and coupled to a worm gear train by chain and sprockets. A clock escapement mechanism would be used to control the falling speed of the weight, thus supplying the hourly tracking motion. One escapement mechanism which appears especially suitable is the Grimthorpe Gravity Escapement[44] illustrated in Figure 9. The Grimthorpe mechanism has been used for more than 100 years in London's "Big Ben" and other large tower clocks, so that its design is well proven in timing applications. In a similar manner, Professor G. Francia used a tower clock escapement to provide the tracking motion for 271 mirrors to concentrate focused solar energy on a 100 kW central receiver steam power system.[45]

The author designed and supervised the construction of a mechanically operated equatorial tracking mechanism for a heliostat while on a mission to Algeria.[46] This demonstration illustrated that such a device can be constructed by local technicians using locally available materials.

Figure 10 shows a possible hybrid steam power system which would use concentrated solar energy to heat the heat transfer oil while the sun is shining and some other fuel such as waste biomass in the evening or at other times when the sun is not shining.

3. *The Potential of Solar-Steam Systems for Developing Countries.* Clearly there are many possible combinations of materials, designs and concepts for solar thermal power systems that can be developed using existing, basic concepts, including those suggested here. The examples put forth in this section have been for the purpose of illustrating that high temperature systems using simple but relatively precision, mechanical two-axis tracking and capable of generating steam are possible using local, in-country technologies, materials and people. Since steam power was the basic thermal-mechanical energy steam on which the industrialized nations developed, the steam engine would appear to be an appropriate mechanical energy device for developing countries; certainly early steam engines were simple and easy to build with relatively simple machines. Modern steam technology of course involves the use of heat engines constructed from advanced alloys and built with great precision and providing much higher efficiencies than their 19th century counterparts. Thus, steam technology provides a complete spectrum of thermal-mechanical energy systems suitable for the widest possible range of applications, not only for the farm and rural communities but for urban areas as well.

E. *Refrigeration*

In many areas of developing countries refrigeration is required for the preservation of meat, fish and other foods and for medicines and vaccines. A particularly serious problem exists in coastal village communities where fish often spoil before they can reach the market.

Typically solar cooling programs have concentrated on absorption type regrigeration systems using flat plate collectors as the heat source. Absorption cycles

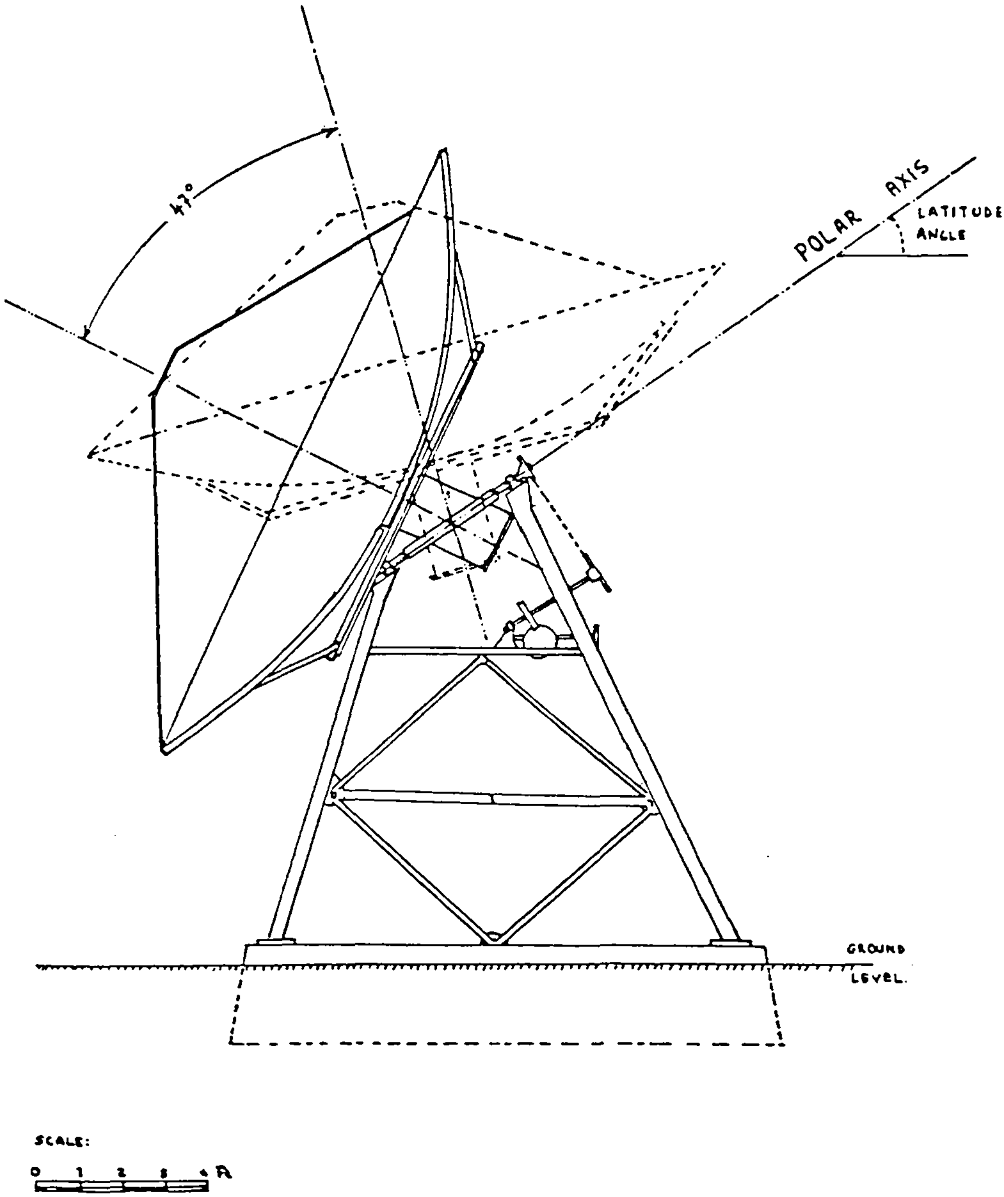

Figure 8. Sketch Showing Possible Design for an Equatorial Mount for Mechanically Tracking a Point Focusing Concentrator

the weight of the 18-spiral concentrator configuration should be only about one-half of that of the equivalent 5-meter dish. These combined factors of reduced wind loading and lower weight should permit the use of a much lighter mounting and tracking system, thus reducing still further the potential cost and complexity of the multiple spiral concentrator as compared to conventional paraboloid dish concentrators.

Assuming that the conditions shown in Table I can be realized, this system should provide more than 1000 watts of shaft power with a direct solar insolation value of 800 watts per square meter.

In order to provide as simple a system as possible at the lowest cost and with the greatest potential for in-country manufacture, it has been proposed that this system use an automatic, clock driven equatorial mount for sun tracking and that steam be used as the working fluid since steam technology is readily available and still practical in many developing countries. A cavity type receiver at the focus could be used to heat a suitable heat transfer oil which would then be transported to the ground where it would produce steam in a suitable heat exchanger. Figure 8 is a sketch showing how such a structure might be supported on an equatorial mount.[43]

TABLE 1

ASSUMED CONDITIONS FOR PROPOSED SOLAR THERMAL POWER SYSTEM USING MULTIPLE SPIRAL CONCENTRATORS

Area of single concentrator	1.2 m^2
Number of concentrators	18
Total area	20.2 m^2
Effective fraction of area	0.9
Reflectivity	0.85
Cavity receiver thermal efficiency	0.9
Thermal mechanical efficiency	0.1
Overall efficiency	6.9%

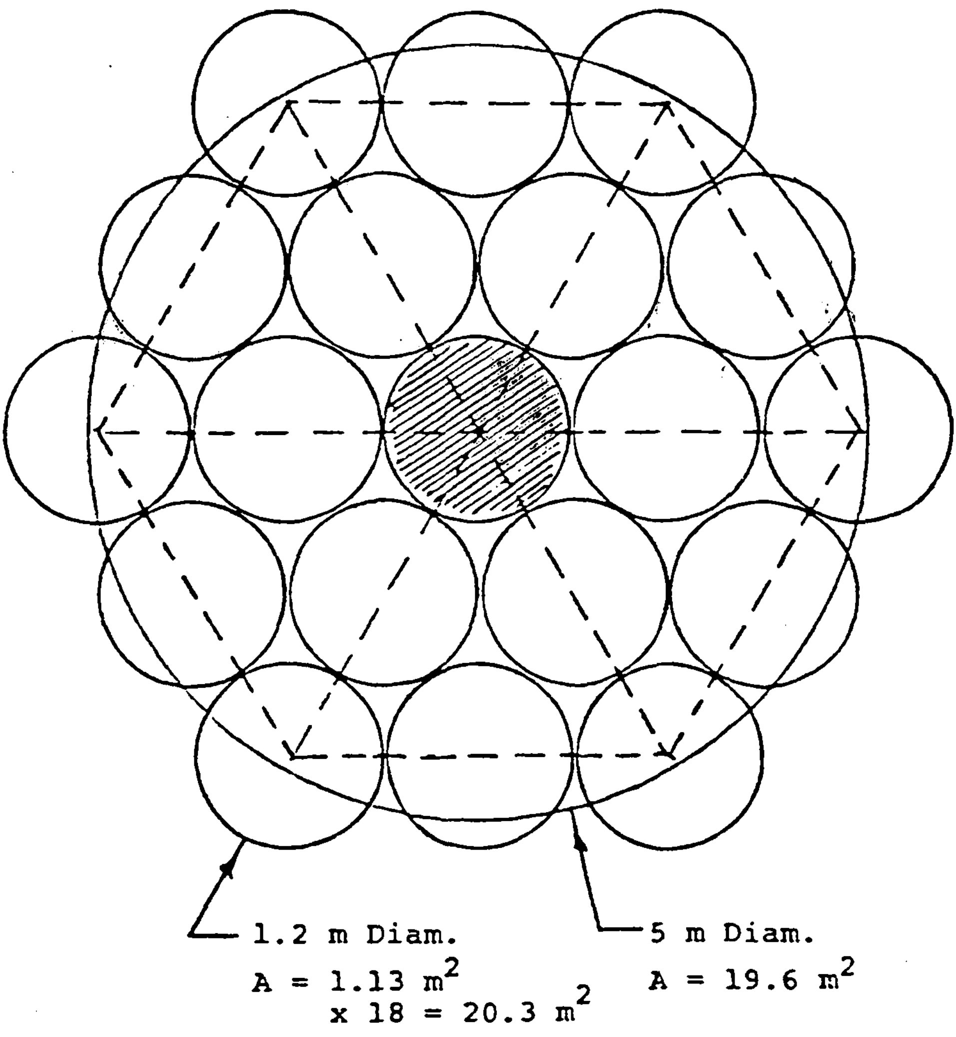

Figure 7. Conceptual Arrangement of Multiple Spiral Fresnel Concentrators to Form a Single Concentrator

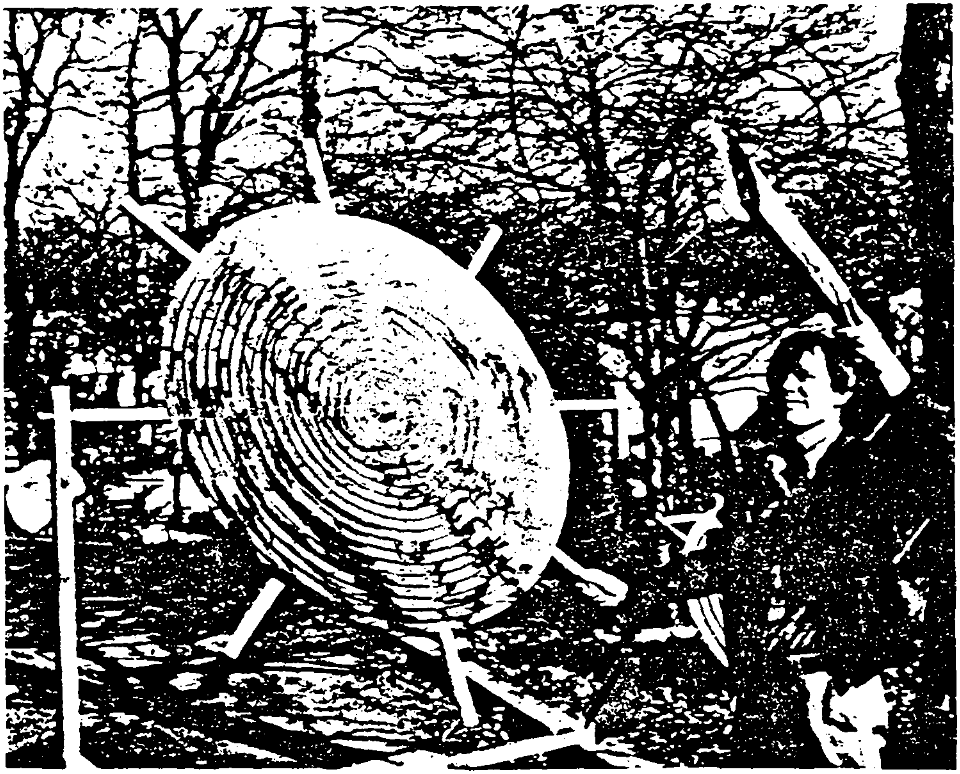

Figure 6. Prototype High Concentration Ratio Georgia Tech Spiral Concentration

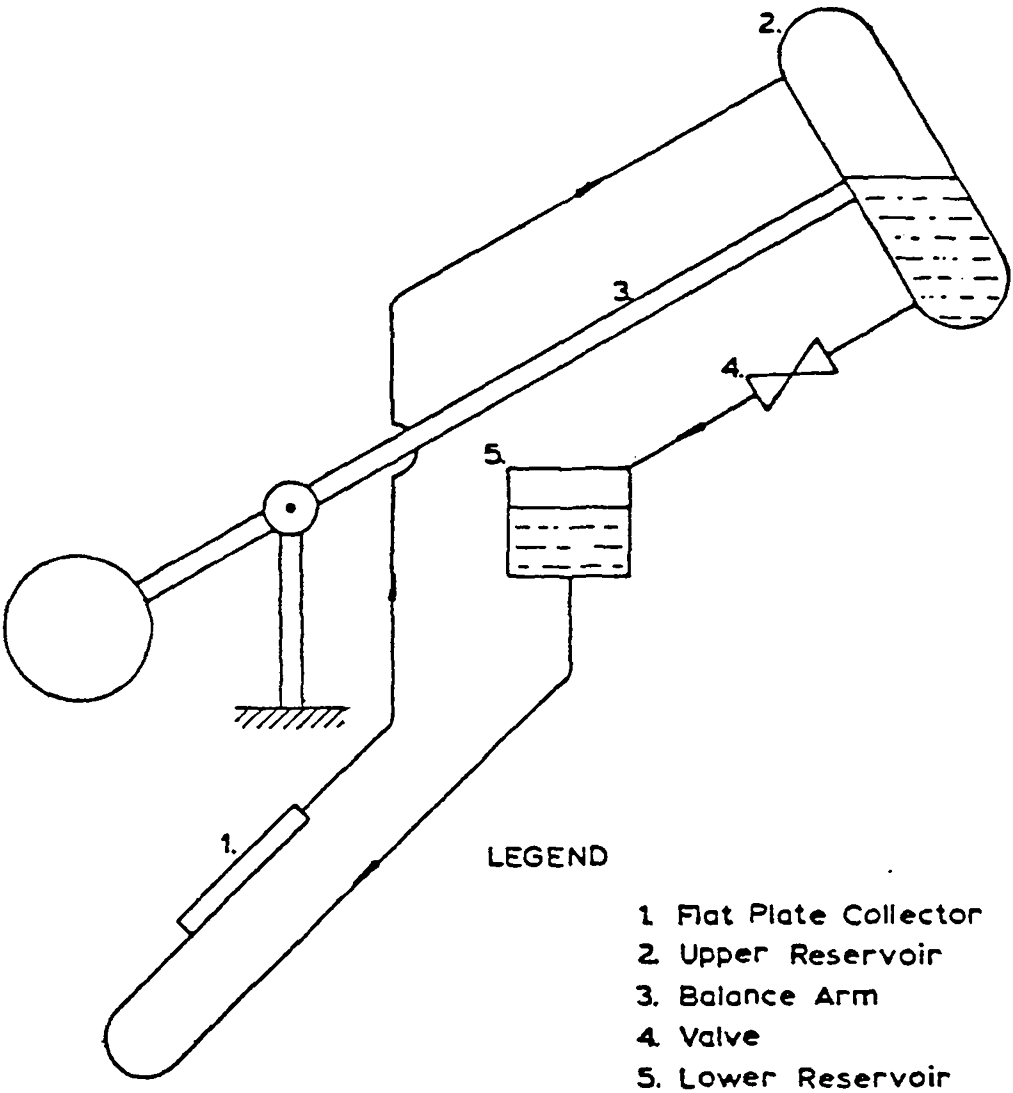

Figure 5. Schematic Showing Principle of Operation of the "Camel" Water Pump

a. *The "Camel" Pump.* Two solar thermal power systems currently could be considered. One would use the "camel" or "drinking bird"[41] principle. This system involves the heating of a low boiling point organic liquid such as Freon in a flat plate collector to produce a vapor which is condensed at a higher level. The weight of the collected condensate is then used to do work while it is returned to a lower level. A schematic drawing showing the principle of operation of the "camel" pump is presented in Figure 5.[37] The working fluid, Freon, is evaporated in the flat plate collector 1. The vapor travels up a flexible pipe to the reservoir 2, where it condenses. When sufficient condensate has collected it over-balances the arm 3, thereby delivering some water as the arm is connected to the positive displacement pump (not shown). A value, 4, then opens automatically and returns the condensate by gravity to a lower reservoir 5, and then back to the solar collector 1.

b. *Solar-Steam System Using the Georgia Tech Spiral Concentrator.* Another type of system would involve the use of the spiral concentrator described earlier.[35] This simple, easy to fabricate, potentially very low cost concentrator could provide much higher temperatures and thus higher efficiencies than flat plate collectors. This concentrator could be designed to provide concentration ratios from about 50 to 2000 suns. Figure 6 shows a spiral concentrator designed for high temperature applications. This concentrator was made from a sheet of electropolished aluminum and attached to a four member aluminum frame. The concentration ratio of this concentrator was approximately 500 suns and the temperature developed at the focal point quickly ignited a piece of wood as illustrated in Figure 6.

At the present time it appears that it should be possible to construct a spiral Fresnel concentrator up to any size that a conventional paraboloid dish type concentrator can be made. However, for concentrators made from a single sheet of electropolished aluminum the size of the reflector is limited by the available sizes of this material, which is between one and two meters. Of course larger concentrators are possible if such sheets can be satisfactorily joined together, for example by welding. For other types of sheet material to which a reflective surface is to be attached, the limit would be about four meters without joining sheets. An alternative to making one large spiral concentrator would be to use some number of smaller concentrators mounted on a suitable frame so that they have a common focal point. An example of a possible configuration for such a concept is shown in Figure 7. This system might be considered as a large scale version of the multi-mirror solar cooker developed by Tabor.[42] Figure 7 shows a possible arrangement of 18 spiral concentrators, each 1.2 meters in diameter (same size as shown in Figure 6) arranged on a hexagonal frame which is indicated by the dashed lines. Also shown in this figure is a circle defining the area covered by a 5-meter paraboloid dish concentrator which should provide about the same aperture as the 18 spiral concentrators. (The center concentrator in Figure 7 would not be used since it would be shadowed by the receiver.) It can be seen that the overall size of the multiple spiral concentrators is only slightly larger than the 5-meter circle. However, because of the open structure of the spiral concentrator and the open spaces between concentrators the wind loading on this structure should be much less than that for the equivalent paraboloid dish. Also, to heat an organic working fluid which drives a heat engine to power a mechanical pump.[36] Because of the low temperature of the working fluid, the overall efficiencies are of the order of one per cent. Because of this low efficiency and the resulting requirement for large areas of collectors and supporting structures, commercial systems are not yet economical for most applications.

The most active group in developing solar powered irrigation systems during the past 20 years has been the French Company SOFRETES. The basic SOFRETES system utilizes flat plate collectors to heat water which passes through a heat exchanger (evaporator) in which a low boiling point organic liquid such as butane or Freon is vaporized. The vaporized gas then operates a Rankine cycle reciprocating engine or turbine, The expelled gas passes through another heat exchanger (condenser) where it is condensed to the liquid phase by the cooling provided by the pumped water. The condensed organic liquid is then returned to the boiler (evaporator) by a pump driven by the engine or turbine.

Present development activities related to small scale water pumps for developing countries generally take one of two directions. The first is to simplify the low temperature, flat plate system so that inexpensive materials can be used and simple thermal mechanical mechanisms developed to replace the expensive, precision type organic vapor-powered heat engines. Typical of these are the Camel,[37] the Liquid Piston Rankine Cycle System[37] and a Rankine cycle direct acting piston-lever arm pump.[38] The second is to develop concentrating collector systems which increases the operating temperature and thereby the efficiency of the overall system operation. Work in this second area is drawing on the technology being developed in the large scale projects being carried out in the industrialized sector. The primary example of this type of system is the Omnium-G.[39] This system, referred to as a Heliodyne Tracking Concentrator, employs a paraboloid dish, point focusting concentrator, six meters in diameter with a focal length of four meters. The concentrator is mounted on servo motor controlled two axis tracking system directed by both sun seeking and open-loop data control. At the focus of the concentrated solar energy was a steam generator that powered a steam engine to drive a generator that produced a peak power of about five electric kW. A compressed air system was used to provide storage.

An excellent review of the use of small-scale solar powered pumping systems for crop irrigation in developing countries has been published by Sir William Halcrow and Partners in association with The Intermediate Technology Development Group.[37] This work is part of the World Bank program to develop small-scale solar pumping systems for water supply and irrigation applications in developing countries.[40]

2. *Rural Water Delivery.* Developing countries need a reliable supply of potable water. By combining appropriate water pump technology and small-scale industrial development with solar thermal power systems, it may be possible to develop a simple, direct operating, reciprocating type solar thermal power system to operate the pump.

Figure 4. Georgia Tech Spiral Concentrator Used for a Solar Cooker

to a planar surface (during construction of the concentrator), each spiral segment assumes the proper angle (twist) to make the reflector act as a point focusing concentrator.

When the computer drawn pattern in completed it is photographically enlarged to the size necessary to provide the desired thermal power level. The pattern is then attached to the surface of a sheet of the material from which the concentrator is to be made. By means of a band saw or other suitable tool, the spiral is cut from the selected sheet material by cutting along the lines of the pattern.

b. *Application for Solar Cooking.* Figure 4 shows a full scale Georgia Tech spiral concentrator constructed for a solar cooker application. This concentrator had a diameter of 1.1 meters and was made from a sheet of 3 millimeter thick fiber board (a pressed wood fiber material). The reflective surface was obtained by adhesively bonding aluminum foil to the surface of the spiral. The spiral was then attached to a cross member made from two pieces of wood. The cost of the materials for this concentrator was about $5. By combining this concentrator with the supporting structure designed in Upper Volta, a very inexpensive and versatile cooker could result. It was reported that the price of the frame for the upper Volta cooker was about $12 to $15 and the paraboloid dish about $25. Since the Georgia Tech spiral concentrator would be much lighter than the paraboloid dish, the support frame also could be lighter, possibly even made from wood. Assuming that the cost of the material for the frame would be less than $10, the total material cost for the entire cooker should be less than $15.

Finally, another potential advantage of the Georgia Tech spiral concentrator is in the optics of the spiral Fresnel system. The distribution of the focused energy should be much more uniform over the focal area than that provided by a paraboloid dish concentrator. Also, it has been predicted that, for the spiral concentrator, the focused energy should be less dispersed (less aberration) when the incoming radiation is not normal to the axis of the concentrator, than for the paraboloid dish. Thus, this type of concentrator would appear to be particularly well adapted to the Danchurchaid system where the food is moved to follow the reflected image of the sun rather than rotating the concentrator to maintain the sun's radiation normal to the axis of the concentrator.

D. *Water Pumping*

Water pumping requirements for developing countries generally are for raising water from depths of less than 10 meters. An ever increasing number of solar powered pumping systems have been developed and currently are in operation in various parts of the world. Both photovoltaic and thermal powered water pumps have been and are being developed. However, this section will deal only with the solar thermal systems.

1. *Solar Thermal Systems.* Solar thermal pumping systems have been developed and demonstrated using both flat plate and concentrating collectors. Typically, the large scale demonstration projects, 25 to 150 kW, use concentrating collectors (parabolic trough) while small units 1 to 25 kW more often employ flat plate collectors and are used primarily in developing countries. In these small systems flat plate collectors are used

situation.) (2) The vertical support members extend beyond the focal length of the paraboloid dish to a height that permits the food to be hung from a cross member connecting the top of the two support members. By suspending the food, further safety is provided for the food so that if the cooker is accidently shaken the food is mechanically isolated so that it merely swings on the hanging members, and (3) by hanging the food and orienting the cooker so that it faces south (adjusting only for the sun's altitude) the food itself is moved on the top cross member to follow the reflected image as it moves west-east. Thus the principle of operation of this new cooker is that the food is moved to follow the moving reflection of the sun instead of having to turn the entire paraboloid dish to follow the motion of the sun. This project provides an excellent example of what can be accomplished through technology exchange between industrialized and developing countries working in the village situation. Thus, this project supports the importance of local involvement so necessary in any attempt to introduce technology into village life.[32]

Many innovations are possible in adapting solar cookers to the needs and customs of the villages of developing countries. For example, it should be remembered that eating habits with respect to the time of day for the main meal is not a universal constant, but is a matter of local custom. Even on the small island of Haiti the time for the principal meal varies from one group to another.[33] The point focusing concentrator has the ability to cook over a wider range of conditions than the non-concentrating ovens being able to fry meat, brown vegetables, cook stews, etc. On the other hand, non-concentrating ovens typically are used to cook food over a longer period of time at a lower temperature, and if properly insulated can keep food hot until long after sundown. Thus, for late evening meals each cooker could be used during the day for their respective application and the whole meal kept hot in the non-concentrating oven until time for the evening meal.[34]

2. *Spiral Fresnel Concentrator.* This new type of concentrator known as Georgia Tech spiral concentrator* was invented by Mr. Richard Steenblik while a student at Georgia Tech.[35] Very simply, this concentrator uses a flat sheet of a suitable material cut into the form of a spiral; by attaching the spiral to a planar surface and slightly coiling it, like a spring, the surface of each spiral segment would assume a natural twist and each point on the surface would reflect light, directed along the axis of the spiral, through the focal point.

a. *Method of Construction.* The first step in developing a given spiral concentrator is to select the desired concentration ratio and focal length for the particular application. This information is then used in a computer program developed by Mr. Steenblik to generate a spiral pattern and to locate sets of mounting points. These mounting points are located so that when they are aligned in a straight line and attached

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* The Georgia Tech Research Institute GTRI has applied for a patent on the Spiral Fresnel concentrator concept. All rights to the development demonstration and dissemination of this technology are reserved by GTRI.

Figure 3. Photograph of Solar Cooker Developed by Danchurchaid Being Used to Broil a Chicken in Upper Volta

Typically, the reasons given for the lack of acceptance of solar cookers are: (1) too expensive, (2) too complicated, (3) not traditional, (4) danger of getting burned, (5) cooking must be done in direct sun, (6) cooking can only be done during the middle of the day, (7) must be imported, (8) cannot cook traditional dishes, etc. Certainly most of these reasons may apply in some area of the world and one or more in most areas of the world. However, it is suggested that their lack of use runs deeper than these reasons alone. For example, in many areas of the world the principal meal is prepared in the middle of the day and cooking is typically done out of doors. Also, even paraboloid dish type, point focusing concentrators do not need constant adjustment so it would not be necessary for the person doing the cooking to continuously stand in the sun. One cannot argue with the fact that solar cookers are not traditional but neither are transistor radios or satellite communication systems, both of which have found significant use in many developing countries. The problem is to create the proper environment for the acceptance of a workable, affordable solar cooker.

During the survey of the state of the art of solar cookers[2] it was found that the reasons given above for the lack of acceptance were based more on the opinion of the solar technologist than on the results of extensive efforts to introduce solar cookers into the actual village situation. In fact, only two programs involving long term efforts to diffuse this technology into rural villages were found; one in Mexico[30] and one in Upper Volta.[31] The social anthropologist involved in the first project (a four year effort (1958-1961) to introduce cookers into three villages in Mexico) reported that, with village participation in cooker development, fabrication and operation, there should be a good probability of acceptance in those areas of Mexico where wood is scarce. The Upper Volta project, although still in progress, has provided important information concerning the role of the user (women) in solar cooker prototype design and development for village use. Typically the paraboloid dish used in point focusing type solar cookers is supported on a "U" frame which pivots on a vertical shift at the bottom of the "U" frame to allow the reflector to rotate to follow the east-west motion of the sun. The food is typically supported on a platform suspended across the top of the "U" frame at the focal point of the paraboloid.[30] In the Upper Volta case, Danchurchaid (a Danish AID organization) supplied only the paraboloid dish, the remainder of the system was designed and developed by a technologist from Danchurchaid in collaboration with the local people. The solar cooker that resulted was a new design of major significance for two important reasons. First, it provided a novel solar cooker system which promises to make cooking with a point focusing concentrator much easier, safer, and more versatile. Second, it dramatically illustrated the importance of involving the user in the design and development of an "appropriate" solar device and emphasizes the innovative and creative potential of rural people.

The solar cooker developed in Upper Volta is shown in Figure 3. The novel features are: (1) The support frame for the paraboloid dish. This frame consists of two vertical members resting directly on the ground and connected by a cross member and forming a "T" section for added stability. There is no rotation east-west to follow the sun. (The pivoting of the usual solar cooker on a single shaft provides for a very unstable inadequate for the heating work required. This resulted from the poor heat conduction from the rocks on the surface of the bed (where the solar heat was collected) to the rocks in the interior of the bed where the thermal energy was to be stored. Large rocks improved conduction but provided a relatively low surface area for transfer to the air. Smaller rocks provided the necessary surface area but restricted the heat to the surface of the bed. This was the same problem encountered in the design of the dryer previously described and which led to the use of the auxiliary black-film air heater with forced convection in order to provide sufficient heat transfer to the rock storage. One of the problems with this system has been the durability of the materials. The low initial cost materials used to build the growout house resulted in high maintenance requirements. This experience has emphasized the need for demonstration projects in actual farm situations in order to properly assess the true economics and applicability of new technologies for the rural situation.

C. *Cooking*

During recent years there has been growing concern over the fact that most of the less developed countries of the world depend upon wood as their major source of fuel. In rural areas of the third world where wood is readily available, nearly 95 per cent of households use it as a primary source of energy. The use of wood as fuel is causing problems which in many areas are already severe and will become so in other areas if better management of wood resources is not instituted. In the Sahel region in Northern Africa it contributes to the inexorable southward advance of the Sahara and in the Indian Subcontinent to flooding in the Gangetic and Indian plains.[26]

Wood fuel for cooking is an extremely important part of the energy budget in the Third World, generally representing about 50 per cent of the fuel used.[27] Clearly, developing solar cookers that could find widespread acceptance would solve one of the most serious ecological and energy problems facing many of the developing countries of the world.

Most developing countries have some type of solar cooker demonstration or development activity, usually at national laboratories or universities. Typically solar cookers are of two basic types; (1) solar ovens using the direct absorption of solar heat with little or no concentration, and (2) those which use concentrated solar energy, focused by a paraboloid type reflector or reflectors either directly on the food to be cooked or on a vessel containing the food. Numerous examples of both types of solar cookers have been described and their method of fabrication, use and performance discussed in various stage of the art reports.[2,28,29]

1. *The Non-Acceptance of Solar Cookers.* Although solar cookers have been the subject of countless research, development and evaluation activities for more than 100 years both in industrialized as well as developing countries, they remain probably the least used of current solar technologies.

low cost, readily available materials. Figures 1 and 2 are sketches of an integrated rock system using forced air circulation over a black-film hot air collector. This collector, designed to dry three tons of peanuts in 20 hours had a 720 square foot (60 x 12 feet) hot air collector connected in series with a 480 square foot (60 x 8 feet) integrated rock storage and collection system. The rock bed was 12 inches deep with a thermal storage capacity of 10^6 Btu at a ΔT of 100° F. A report describing the construction of this peanut dryer was prepared as part of this project.[20] The materials cost of this unit was about $2 per square foot for the black-film air collector and $1 per square foot for the integrated rock-storage and collection system. This system was designed to be attached directly to commercial peanut drying trailers using propane gas-fired heaters. The typical energy consumption for the commercial unit per ton of peanuts dried was 20.45 kW.hr for the blower and 46.14 liters of propane for heating at an energy cost of $5.44 per ton of peanuts dried in 18 hours.[21]

Because of the industrial nature of the agricultural drying projects in most developed countries, the solar systems thus developed typically are incorporated into conventional system designs using forced hot-air circulation and auxiliary fossil fuel heat sources. Although such devices are operated basically as fuel displacement systems, these designs incorporate many features which are applicable for the Asia and Pacific region, particularly for industrial or large scale, rural community applications. Two that are typical of these systems are solar dryers for soybean drying[22] and raisin drying.[23]

B. *Space Heating*

Space heating is not a serious energy need for a large portion of the Asia and Pacific region. However, it is included here because space heating devices are often similar to those used for solar dryers and simple modifications of these designs can be adopted to provide heat for dwellings and for animal shelters in those high altitude regions where space heating may be required. Several examples of such systems for use in Botswana were described at the African Solar Energy Workshop.[1] These included a solar reliant greenhouse and a vertical passive solar heater either attached to or integrated into the design of the typical family dwelling.[24]

Two solar space heating systems for animal shelters have been designed by Georgia Technical University. Both of these systems utilized the direct solar heating of rock-bed storage-collector systems to provide heat for growout houses used to raise chickens from the age of few days to maturity.[25] The rock-bed solar-collector was built on a south facing hillside, graded to a 30 degree slope, just below the growout house. The slope was selected to maximize the collection of solar energy (for the latitude of chicken farms in Georgia) and to effect natural convection (passive operation) to carry the heated air into the growout house. The purpose of the system was to reduce the amount of propane gas used. In order to be economical and practical it was constructed from low cost, easily obtained materials and designed so that the majority of the construction could be carried out by the farmer himself. Although the system did function as a passive air heating system, the use of the rock-bed storage system as the solar collector was found to be

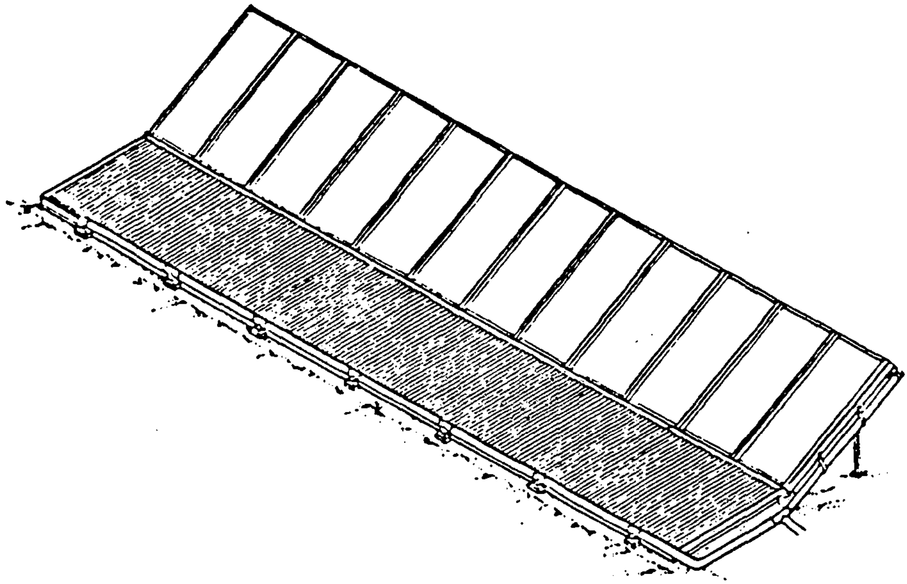

Figure 1. Sketch of the Georgia Tech Solar Dryer for Drying Peanuts

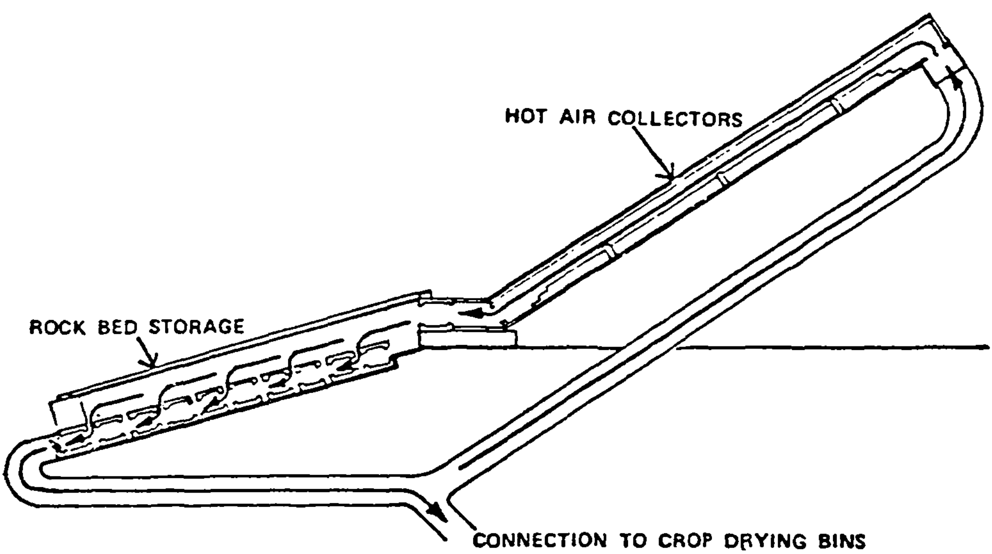

Figure 2. Schematic Showing Air Flow Path Through Paunut Dryer

4. Water pumping
5. Refrigeration
6. Small scale electric power
7. Water heating
8. Desalination
9. Production of fuel from biomass

A. *Agricultural Drying*

Food and crop drying is perhaps one of the most important and immediately practical applications of solar energy for the farmer. Solar energy has been used for the open air drying of agricultural crops and meat since before recorded time. However, this method exposes the food to contamination by dirt and insects, exposure to birds and rodents and in areas or seasons of high humidity to mold and fermentation. Improper and inadequate drying is one of the contributors to the problem of food losses in developing countries.[13]

On a worldwide basis, probably no single application for solar energy is receiving more attention than drying. About 100 organizations have been identified as participating in this activity, with more than 30 located in the United States.[14]

The classification of solar dryers is generally based on the manner in which the solar energy is applied to the product to be dried. Usually these are considered to be either the direct or indirect exposure to the solar radiation, and with or without forced air circulation.[15] An excellent overview of the types and applications of solar dryers for the region of Asia and Pacific was presented at the 1978 Solar Drying Workshop in Manila.[16]

Agricultural applications for solar energy in developed countries primarily are directed toward large scale demonstration projects. The typical areas covered by these projects include food processing, grain drying, lumber drying, crop drying, (peanuts, forage, tobacco), heating of livestock shelters and heating and cooling of greenhouses.[17,18,19] Since the temperatures required for agricultural applications frequently are relatively low, the emphasis has been in the use of individually designed, very low-cost systems using readily available materials, which can be constructed by farmers with technical assistance from the extension service.

One type of experimental dryer design incorporating rock storage systems using either the direct solar heating of the rock storage or the combination of air heating by a black-film type solar collector together with the direct solar heating of the rock storage has been developed by Georgia Technical University. In this effort a major objective has been to develop simple designs which can readily be constructed on the farm using greatest energy need; for example, in arid regions where water pumping is needed for irrigation and thermal energy is needed to conserve fuel wood and thus reduce or possibly reverse the process of deforestation.

This conference promises to be particularly important because it concentrates on the needs of rural areas in the Asia and Pacific region as a whole and involves the participation of solar scientists, technologists and government representatives throughout this region. Also, it considers not only research and development in specific technologies but industrial and training aspects of solar energy utilization as well.

II. *Background*

This paper considers solar technologies which were for the most part developed in an industrialized country. However, it emphasizes low-cost solar technologies applicable to small farmers and rural communities. Other significant solar energy developments which are relevant to the subject also are included, such as those described at the African Solar Energy Workshop[1] and observed during personal visits by the author to a number of African countries during the past three years.[2] Finally, information from other sources are included which may help to round out the state of development or help suggest the potential of the selected technology in meeting the energy needs of small farmers and rural communities in the Asia and Pacific region. Since such needs are typically small and widely dispersed, the solar hardware generally will be small scale. Also, since the cost of these technologies must be as low as possible in order to be financially accessible they will, where possible, make use of indigenous materials and local manufacturing capabilities.

It should be stressed at the outset that since most of the devices and technologies described and discussed in this paper were the result of efforts in a developed country, they should not be expected to be directly applicable to the needs of small farmers and rural communities without major modifications. In fact, it is the strong opinion of the author that the initial development of prototype hardware for use in a developing country should be the joint effort of the technologist and the potential user. In fact, the process of developing such solar technologies probably will be successful in the long run only when it involves technology exchange between these parties rather than simply technology transfer.

III. *Solar Technologies*

Following recent surveys of solar technologies for developing countries[3-12], the following have been identified as the ones most applicable to the needs of small farmers and rural communities.

1. Agricultural drying
2. Space heating
3. Cooking

SOLAR ENERGY FOR RURAL DEVELOPMENT IN THE ASIA AND PACIFIC REGION*

FAO

ABSTRACT

Solar energy technologies for developing countries are discussed as related to the energy needs of small farmers and rural communities in the Asia and Pacific Region. The solar technologies considered are those developed for (1) agricultural drying, (2) space heating, (3) cooking, (4) water pumping, (5) refrigeration, (6) small scale electric power, (7) water heating, (8) desalination and (9) production of fuel from biomass. Particular attention is given to those solar devices, typically solar thermal, which have the greatest potential for in-country manufacture using locally available materials and labor. Both solar thermal and photovoltaic systems are considered for providing electric power for water pumping, refrigeration and other small scale electrical needs. Steam power is proposed as an appropriate energy system on which to build a mechanical and electrical power base. A hybrid steam system using concentrated solar energy and biomass waste is suggested as an attractive system for development in remote areas where these resources are readily available. It is concluded that the development of prototype hardware should be a cooperative effort between the technologist and the user.

I. *Introduction*

The subject of solar energy for developing countries has become a topic of increasing interest to scientists, engineers and technologists not only in developing countries but in the industrialized nations of the world as well. At least four interdependent relationships appear to be responsible for the growing interest in this subject. *First is energy and development*. Energy is essential to development and the increasing cost and availability of commercial energy threatens to halt or even reverse this process in many less developed countries with the resulting adverse effects on the quality of life and economic well-being. *Second is people and resources*. The increasing use of conventional fuel such as wood and dung to provide the energy needed for a growing population and for development, is leading to massive deforestation and to the destruction of the resources base on which man depends for his survival. *Third is the type of energy need*. In most developing countries the population is widely dispersed and the local needs of energy are small. Commercial energy sources and associated delivery systems typically are large and their development and distribution will require very large expenditures of time and money; on the other hand solar energy is naturally dispersed and many solar technologies basically are simple, readily available and have the potential of being produced in-country at a low cost. *Fourth is the location of the energy need*. Most developing countries are geographically located in areas of high solar radiation (insolation) and the solar energy is typically at the highest levels in those regions where it can supply the

* Prepared for FAO by J.D. Walton.

IV. PAPERS SUBMITTED BY ORGANIZATIONS IN THE UNITED NATIONS SYSTEM

tries, concentrated international efforts should be carried out on the research and development of solar science and technology in order that more solar technologies will be made feasible as soon as possible and thus help to lessen the oil crisis.

cases, solar cells supply electrical power of a few tens of watts for communication equipment in remote locations. Installations having generating capacities in the kilowatt range exist; their economic remain to be demonstrated. Deterioration of cell encapsulation and performance has been observed in hot and humid environments.

Even with crystalline silicon cells an increased role for solar cells in supplying some electricity for rural areas in developing countries for water lifting and lighting is envisaged. It is deemed possible to reduce the cell cost by a fraction of two to three by importing silicon waters from industrialized countries, and carrying out the cell fabrication, assembly and power conditioners construction within developing countries. This is receiving attention in some countries because of the potentially large market and the availability of appropriate labour at lower cost. Introduction of polycrystalline silicon cells and rectangular crystalline silicon cells should bring down cell cost and stimulate more applications in the very near future.

To achieve the projected reduction in the cost of solar cell-generated electricity about one order and two orders of magnitude within ten and twenty years respectively, it is recognized that solar cell technologies embracing materials and fabrication processes independent of electronic devices-oriented technology must be developed. The ongoing research activities are in the areas of high efficiency cells for concentrated illumination, low cost thin film cells, novel cell structures and thermophotovoltaic cells. The performances of high efficiency crystalline silicon and gallium arsenide cells appraoch their theoritical limits. Experimental thin film cells employing ribbon, polycrystalline and amorphous silicon, binary and ternary compound semiconductors yield promising results. Cost minimization methodologies are being devised for large-scale fabrication of such thin film cells.

As solar cells are likely to supply significant amounts of energy on a global scale in the next century, studies on raw material resources, possible environmental impacts relating to worldwide-scale cell fabrication and utilization have been made; they indicate that all foreseeable problems are surmountable.

The rapid evolvement of solar cells technology must be carefully followed by energy planners. Some psychological barriers must be overcome to include the solar cell contribution to the national energy picture and to promote some solar cell related technologies and enterprises appropriate to each country. Such endeavour ensures due benefits in terms of the novel energy conversion means and helps to strengthen the much needed technological infrastructure in the countries of this region.

CONCLUSION

Although there are now a number of economically feasible solar technologies, for example, water heating, drying, etc., government actions such as incentives, demonstrations of efficient solar devices, etc., are still required to help to accelerate the popularization of these technologies. Since the potential of solar energy is very high in many counto produce electricity for remote areas or to drive pumps directly; thus the development will parallel the development of some solar thermal electric power generation systems. Up to the present there exist only a few experiences with the pumping systems.

Reciprocating piston pumps operating in stirring cycles using gas as working fluid have the advantage of versatility and have been studied both in developed and developing countries. At present, a high temperature is required to operate such an engine.

The low temperature application utilizing flat-plate collectors has a very low overall efficiency normally in the order of a few per cent. The system is particularly suitable for developing countries to produce small power in the range of 10-30 kW for irrigation purposes. The system is more favourable for implementation in areas where the ratio of diffuse to direct solar radiation is high since a flat-plate collector is used. Small vapour turbines (organic fluid) driven by flat-plate solar heaters have been developed and are now in use in some arid areas. The flat-plate collectors can be produced within the developing countries. The pumps, especially those which utilized liquid pistons, have been studied in many developing countries. The main drawback for low temperature application lies in its low efficiency, thus large collector areas are required.

For low temperature applications a pumping system making use of the difference of the specific volumes of a material upon changing phase is under study. There are two classifications, namely air cooled and water cooled pumps, in which a secondary working fluid is caused to undergo a cyclic phase change and the amount of water which can be pumped is equal to the difference in the volume between the phases. The main drawback is the large amount of energy which must be dissipated in the condensate. Various diaphram pumps have also been studied.

Solar, thermal pumping, particularly the low temperature application with special pumps, has high potential for many agricultural countries in this region. However, the technical and economic viability need to be demonstrated. Regional programmes to develop locally manufactured solar thermal pumps and to demonstrate their viability is recommended.

8. Solar cells

A few hundred million dollars are now spent each year by the public and private sectors in industrialized countries in solar cell research and development. Such an undertaking demonstrates the well recognized potential of solar cells for the future energy supply.

At present, commercial solar cells, which are available in significant quantities are exclusively crystalline silicon cells using technologies specifically developed for the electronic components and integrated circuits industries. This results in very high cell cost. Cell fabrications are carried out in countries with silicon technology expertise. Owing to cost limitations, terrestrial applications of solar cells are restricted. In most holds. Current technology can be used to build such a unit, the design can be simple and no advanced technology is required. However, skilled technicians are required for the fabrication and most current systems are very expensive and massive. More research and development are required to improve its efficiency and reduce the requirement of skilled technicians. The best combination of absorbent:refrigerant combination is still to be found; both liquid and solid absorbents have been used e.g. NH_3-H_2O, NH_3-N_aSCN, NH_3-$LiNo_3$, NH_3-$CaCl_2$, NH-$SrCl_2$. Refrigerants other than NH_3 which may be interesting are alcohol and methylamine.

For air-conditioning in the cities, solar heated continuous absorption systems are available commercially. They are being tested for reliability and economic feasibility in many countries. The continuous system requires high grade energy to drive a pump unless a very high generation temperature is used. For cooling systems only NH_3-H_2O and LiBr-H_2O have shown promising results for a closed cycle system. An open cycle system equivialent to evaporative cooling combined with dehumidifying and rehumidifying the air may prove successful even for wet climates. Dehumidification in moist hot climates is almost as important as cooling. Removal of moisture from the air is much easier to achieve than cooling the air. Active silica gel and LiCl systems have been used for the purpose, fellowed by regeneration. Cooling of houses can be achieved in hot, clear climates by radiation to the sky during the night, using a black cloth radiator. Since large amounts of electricity are now used for running air-conditioning units in the cities of this region, research and development on a pilot project in the area of solar air-conditioning technology is recommended especially in view of the fact that no high technologies are required.

7. Solar thermal pumping

Unlike most energy uses water pumping for irrigation purposes does not require continuity of energy supply. Currently, it is generally agreed that among all solar application technologies, photovoltaic water pumping below 10 kW_0 capacity seem to be more economically competitive than a thermodynamic system, whereas, for larger capacity the opposite is true owing to the economy of scale factor. Solar thermal pumping can be calssified according to the range of temperatures used, namely low, medium and high temperature application, or by the mode of pump cycles such as Stirling, Rankine and Brayton cycles, or by the working substances, e.g., solids liquid (vapours) and gases.

The high temperature application utilizing a paraboloidal disk concentrator uses steam or air as working fluid in Rankine or Brayton cycles. The system provides an efficiency up to 20 per cent. However, the main drawback results from the high technology required to produce the parabolic reflector and tracking system. The medium temperature application utilizing linear focusing collectors with concentration factors ranging from 5 to 100 can provide over-all efficiency varying from 6 to 10 per cent. The usual working temperature of the working fluid (usually water) is around 300°C. Both the high and medium temperature systems use conventional cycles which can also be used the coating on the receiver will deteriorate. Solar heat may be stored in high-pressure saturated steam in a steam accumulator or in high-temperature heat transfer oil.

The distributed collector system has many attractions for developing countries. First, its range of optimum sizes is suitable for rural electrification. Secondly, the technology is not too high and a number of its components may be developed locally in developing countries. Thirdly, the power output of the system can be increased without much difficulty at a later stage when the power demand goes up. Although various designs of the distributed collector system can be commercially obtained from a few industrialized countries, their prices are still too high and more development is still needed to reduce the first cost of the system.

In the central tower system, a vast field of heliostats is used for reflecting the direct radiation to the receiver which is placed on top of a high tower. As the tracking of the heliostats requires a very high accuracy, they are usually controlled by microprocessors. The maximum temperature of the system which is over 500°C can cause a number of problems to the receiver and storage materials. Since the optimum power output is over 100 MW, the system is more suitable for the electricity grid. The technology of the central tower system is still at the development or demonstration stage. No plant is commercially available even in industrialized countries.

6. Solar refrigeration and air-conditioning

The most widely used methods of refrigeration are the compression system, consisting of a compressor requiring high-grade energy such as mechanical or in most cases electrical, and the absorption system, in which the compressor is replaced by an absorber, a generator and in most cases a pump. Both methods require a condenser, expansion valve or system, and an evaporator. Since we can convert solar energy more efficiently to heat than to mechanical or electrical energy, the use of an absorption system seems to be the best solution at this time. Only two technologies seem to be promising at present for rural areas, namely evaporative cooling and the intermittent absorption refrigeration process.

The evaporative cooler, in principle, consists of a container surrounded by a suitably shaped piece of cloth, the lower part of which is submerged in a tray containing water. The water is absorbed by the cloth, and if the climate is dry and the cooler kept in a breezy spot in a shade, the food will be cooled, as the water evaporates, to a temperature that lies considerably below ambient. Evaporative cooling is suitable only for small domestic coolers. The main drawback lies in its effectiveness which is often very low unless the climate is extremely dry, since the wet bulb temperature is the limitation.

Intermittent absorption refrigeration equipment is somewhat more complicated and more expensive, the communal unit may be more attractive. A communal solar refrigeration plant could be either a cold storage building in which each family is allocated a storage space or a plant producing block ice for ice boxes in individual house-

So far, solar water distillation has achieved only moderate success in providing drinking water to remote areas and distilled water for special applications such as in lead-acid batteries, laboratories, etc. More research and development should be carried out not only to improve the distillation efficiency but also to make use of locally available materials and construction techniques as much as possible. The success of large-scale applications of solar water distillation will help to develop vast arid areas for human settlement.

4. Solar cooking

Existing solar cookers may be classified into three main types, namely the steam cooker, the solar oven and the spherical or parabolic cooker. The first type uses a flat-plate collector to produce steam; it can therefore only boil but cooking can be done inside or outside without attendance since no tracking is required. The solar oven may have a low concentration ratio by means of plane mirrors, it can boil and bake with little attendance since only occasional tracking is required. The point focusing cooker whose reflecting surface is usually made of glass, polished stainless steel or aluminium can provide a high temperature over 300°C. As a result, it can perform all kinds of cooking such as boiling, baking, frying, roasting, etc. However, since it requires continuous tracking and yields intense heat, attendance is required and cooking has to be done in the sun.

Besides the above shortcomings, solar cooking in the early morning and late evening with the existing types of cookers will not be possible since the radiation will then be too low. Popularization of solar cookers will still be difficult unless economical thermal storage and auxiliary heating are developed to extend the cooking time and make indoor cooking possible.

5. Solar thermal electric power generation

There are two main types of solar thermal electric power systems, namely, the distributed collector system and the central tower system. A recent comparative study of solar electric power systems indicates that for a power output from 10 kW to 10MW, the distributed collector system seems to be more economical than the photovoltaic conversion system and the central tower system; however, for a power output over 100 MW, the latter appears to be the most economical.

The distributed colleotor system has a few variations in collector setups such as line-focusing parabolic troughs, point-focusing parabolic dishes, plane-parabolic mirrors, etc. Glass, polished stainless steel or polished aluminium can be used as the reflecting surface. A very high reflectance can be obtained from the glass - mirror, but high technology is also required to produce parabolic glass. Curved steel and aluminium can be fabricated without difficulty, but their reflectances are relatively low. The maximum temperature at the receiver of the system must at present be less than 350°C, otherwise locally in a number of developing countries. The first two types require low capital expenditure but they are less efficient. The last type is more efficient and has a larger capacity, but its first cost is also high.

Solar drying of tobacco leaves deserves special attention. The tobacco curing barn requires precise temperature and humidity controls. Forced circulation and ausiliary heating have to be employed. Tobacco drying by solar energy still requires more research and development before it becomes practical.

Two applications of grain drying have been identified, namely small-scale drying for village or household uses and large-scale industrial use. Small-scale grain dryers using free or forced convection have been locally developed in a number of developing countries. A few countries have claimed successful designs for large-scale grain drying but very little information on technical and economic assessment of the dryers is available. It therefore seems that more research and development are still needed.

Very few countries have had experience in lumber drying by solar energy. Available data on construction, operation and economic viability of the lumber dryer are very limited. There is still a need for further development and refinement of the techniques.

Solar drying has high potential for many agricultural countries in this region. Although the technology of solar drying is now available for a number of applications such as marine products drying, cash crop drying etc., the technology has not been widely accepted in the region. National and regional programmes to popularize solar drying are therefore needed.

3. Solar water distillation

Basin-type solar stills have been developed for nearly one hundred years. The largest one in operation has an area of over 9,000 sq. m. There are many variations in the designs and materials used. The optimal design of the still depends upon its economics, efficiency and durability. For example, the best cover seems to be a thin sheet of glass which is, however, easily broken; some types of plastic sheet are quite tough but their transmittances are poor and they yield drop-wise condensation which reduces the rate of distillation. Black butyl rubber sheet provides a very efficient absorbing surface but its price is fairly high. Cheaper asphalt may be used but it gives an undesirable smell to distilled water. Mortar mixed with black iron oxide can also be used for making the absorbing surface though its absorptance is relatively low.

Efficiencies of various basin-type or single-effect solar stills are limited by the fact that the heat of condensation is wasted through the cover. This shortcoming has led to the development of multiple-effect solar stills such as the diffusion still, the chimney-type still, the regenerative still, etc., where the heat of condensation is transferred to the incoming raw water. At the present stage of development, multiple-effect stills are more complicated than single-effect stills and their costs are thus higher.

1. Solar water heating

Among various solar technologies, solar water heating is best established. Solar water heating systems are at present installed mainly in private houses, hotels and hospitals where hot water is required at a temperature below the boiling point.

In a number of developing countries, solar water heaters having conventional flat-plate collectors are now manufactured locally. The absorbing plates of the manufactured collectors normally consist of copper or alluminium fins attached to copper tubes. Selective coatings having medium absorptance/emittance ratios such as copper oxide, anodized alluminium are sometimes used. Manufactured collectors are mostly single-glazed and the transparent covers are usually made of low-iron glass. Since industrial standards for solar collectors have not been implemented in most developing countries, the quality and reliability of the manufactured collector greatly vary. This seems to be one main barrier of the popularization of solar water heaters.

Flat-plate collectors manufactured in developed countries usually have high efficiency and durability. Good selective coatings such as black chrome are often employed on the absorbing plates. Some manufacturers produce absorbing plates made of extruded black plastic which has high absorptivity and high resistance to corrosion. Tempered and white glasses may be easily obtained as the covers. Transparent plastics which are claimed by the manufacturers to have high light transmittance and high resistance to deterioration are also available commercially. For high temperature applications, double-glazed covers are used on the collectors.

Collectors for solar water heating in many industrialized countries are produced according to the industrial standards set up by Governments or professional bodies. Manufacturers usually guarantee the performances of their solar water heaters for periods of at least one year for domestic systems and up to five years for larger systems.

As well as the conventional flat-plate collectors, more advanced collectors such as evacuated tube collectors and compound parabolic collectors are commercially available in some industrialized countries.

When the cost of solar water heating is further reduced by research and development to such a level that it is acceptable for industrial process heat, the use of solar water heating will then be greatly increased.

2. Solar drying

Solar dryers may be classified according to the modes of air circulation, which are free convection and forced convection, or according to their applications to marine products and cash crop drying, grain drying and lumber drying.

For marine products and cash crop drying, three types of free-convection dryers, box-types, tent type and cabinet type having a separate air heater, have been developed

8. Photosynthesis

Photosynthesis is the means by which green plants absorb solar energy to produce biomass from carbon dioxide and water. The elucidation of the complex photosynthetic mechanism is an active field of scientific research.

The process requires a light absorber, chlorophyll, and two linked photosystems because solar radiation is not absorbed directly by the initial reactants and the single solar quanta have too low an energy for the chemical transformation. The first photosystem (photosystem II) leads to the oxidation of water to molecular oxygen and the phosphorylation of adenosine diphosphate (ADP) to adenosine triphosphate (ATP). The second photosystem (photosystem I) causes the reduction of nicotinamide adenine dinucleotide phosphate (NADP+) to its reduced form NADPH. ATP is a source of stored chemical energy and NADPH is a source of reducing power.

In most photosynthetic processes in higher plants the end products are glucose and other carbohydrates which can be used to produce fuel. Research is being undertaken into the farming of energy crops for firewood and charcoal, alcohol, and hydrocarbons that can be cracked to obtain hydrocarbons similar to those found in gasoline. It has been found that certain plants with the C_4 photosynthetic pathway, such as sugar cane, have a higher photosynthetic conversion efficiency than non-C_4 plants.

Another photosynthetic process which may lead to useful applications is the production of hydrogen from water with the help of the photosynthetically produced ferredoxin and the enzime hydrogenase found in certain algae and bacteria. Yet another process is the photosynthetic fixation of nitrogen.

In each of the photosynthetic systems light quanta are used to drive a redox process uphill at a cell membrane. Membranes which prevent back reactions by separating the charges are essential in photosynthesis.

As scientific reserach continues to increase our understanding of photosynthesis, it is expected that artificial photosynthetic processes will be developed that will provide new alternatives for the useful harnessing of solar energy by man.

II. SOLAR TECHNOLOGY

In the last few years, solar technology has been rapidly developed. In industrialized countries, advanced materials technology has helped to increase the efficiency and lower the cost of solar devices. With additional research and development efforts, developing countries have been adapting new solar technology to suit the technical, economic and social conditions of the countries. The status of solar energy technology in the region may be summarized as follows.

Thus, one objective of scientific research is the discovery of semi-conductors where band gap energies best match the solar radiation spectrum. Although GaAs CdTe and AlSb have high theoretical efficiencies, success in making efficient and durable cells with these materials has not been achieved. Only silicon and calcium sulphide cells look promising.

To prevent the trapping and recombination of electron-hole pairs by impurities and defects in silicon solar cells the crystals used must be ultra-pure and very carefully grown, which makes the cells very expensive. Much current research is therefore concerned with reducing costs by using polycrystalline on amorphous silicon in thin films.

In the polycrystalline cells the performance depends markedly on the grain structure of the material. This depends on the method by which the polycrystalline layer was formed. Amorphous silicon cells require only very thin layers of material deposited by glow discharge, spattering, or evaporation onto a glass or steel substrate. Research is concerned with the physics of the amorphous material. The use of amorphous silicon-hydrogen and amorphous silicon-fluorine-hydrogen alloys can produce an electronic structure with properties closer to those of pure silicon crystals than pure amorphous silicon. Consequently, the outlook for amorphous silicon solar cells looks promising.

Another material that has been used for making solar photovoltaic cells is a thin polycrystalline film of cadmium sulphide covered with a thin layer of cuprous sulphide. Since CdS is n-type material and Cu_2S is p-type, a n-p junction is formed very close to the front surface of the cell where the electron-hole pairs are separated. The good light-absorbing properties of the Cu_2S ensure that almost all of the electron-hole pairs are formed very near the junction and the material does not have to be chemically very pure or crystallographically perfect.

7. Electrical energy storage

Electricity produced for large-scale solar thermal generators or from small-scale photovoltaic systems needs to be stored in batteries for most applications. Therefore research into the development of electric batteries has an important impact on the development of solar energy.

Current research is focused on the new advanced types of batteries with lower initial cost and longer service life than the traditional lead-acid accumulator. Their projected uses include electricity storage for utilities and for powering transportation vehicles.

The sodium-sulphur cell is one promising new design. It operates at a temperature between 300°C and 350°C where the negative electrode of sodium and the positive electrode of sulphur are liquid. The electrolyte is solid beta alumina, which at 300°C has a high conductivity. Another promising type is the zinc-chlorine battery operating at temperatures in the range 30°C to 50°C.

mediate compounds in a sequence of four separate reactions. Combinations of thermal decomposition and electrolytic processes can also be used.

The simple photolysis of water by the adsorption of solar radiation is not a practical process because only ultraviolet quanta can be used and the adsorption mechanisms are very weak. To overcome this difficulty, research is directed to the quest for suitable photosensitizers for the photoreduction of water to hydrogen by lower energy quanta. In one reported scheme, methylviologen, reduced by a photoexcited ruthenium complex, generates up to 12 litres of hydrogen per day per litre of solution in the presence of a high activity platinum catalyst. The oxydized ruthenium complex is recycled through reduction by EDTA as electron donor in an irreversible oxydation that prevents the immediate back-transfer of the electron in the photo-redox process.

Another active line of research seeking to employ biological systems for using solar energy to produce hydrogen from water will be mentioned in the section on photosynthesis.

Much experience has now been gained with the storing and transporting of hydrogen as a gas or in liquified form and the technology is available. In this connexion, another line of current research is into the properties of metal hydrides for the storage of hydrogen in solid form. In these substances, hydrogen is packed at higher atomic densities than in liquid hydrogen. The charging, or adsorption, process is exothermic. Conversely, the discharging, or desorption, process is endothermic and heat must be supplied to liberate the hydrogen. To speed up the reactions by using a large surface area the hydriding substance is in powdered form. Because of a hysteresis effect, the charging pressures at a given temperature are higher than the discharging pressures. Using different metals and alloys hydriding substances with a wide variety of different properties can be chosen for different applications. One of the objects of research is to determine how well they retain their properties after a large number of changing and discharging cycles.

6. Photo-electric conversion

Although a variety of mechanisms exist for converting solar photons directly into electricity, semi-conductor photovoltaic cells are the only devices at present in widespread use. The commonest type is the single crystal silicon cell containing an n-p junction where electron-hole pairs created by the absorption of solar photons are separated by the internal electric field before recombination so that an electric current can be produced in an external circuit.

The efficiency of a solar cell is limited by the fact that photons with energies less than the energy required to create an electron-hole pair (the so-called band gap energy) are ineffective and serve only to heat up the cell, while photons with greater energies use only a part of their energy to create the electron-hole pairs, the excess energy again appearing as heat. Recombination of the electric-hole pairs before they have been used in the electric is another process limiting the cell efficiency.

component or by distilling a vapour and storing the condensed liquid under pressure. The latter method is best since there is a large latent heat involved which increase the amount of energy stored.

Closed cycle chemical heat pumps, or absorption refrigerators, provide the necessary system. Examples include the ammonia-water system in which water is a liquid absorber, and the ammonia-calcium chloride system in which calcium chloride is a solid absorber with the advantage that it is non-volatile and hence will not contaminate the thermally separated ammonia.

Research work is concerned with studying the properties of known chemical combinations and seeking new ones. One important combination that has been receiving attention recently uses the chemical potential changes associated with the drying of solid adsorbents. For example, zeolite molecular sieves adsorb moisture when heated. They have high heats of adsorption, and a large maximum adsorption capacity. To store energy a zeolite bed is dried with hot air. The temperature needed for maximum storage capacity is about 250°C. The dryness of the bed is a measure of the energy stored. To release heat from the bed, moist air is driven through it to produce a stream of dry air that has been heated by the readsorption of moisture by zeolite.

5. Hydrogen

Concern about the eventual exhaustion of our easily transportable fossil fuels has led to research into the methods of using hydrogen as an alternative energy carrier. The hydrogen fuel cycle involves (a) the use of a primary source of energy to split water into hydrogen and oxygen, (b) the storage and transportation of hydrogen for use at a desired time and place and (c) the recovery of the energy by combustion of the hydrogen. If the oxygen evolved in the initial splitting of water is released to the atmosphere and atmospheric oxygen is used in the combustion process, then the return of the water produced by the combustion to the environment completes the cycle, which is non-polluting and only days or weeks in length.

Solar scientific research work in this field is concerned mainly with methods of using solar energy to split water. The storage of hydrogen is another closely related field.

There are many ways of using solar energy to split water. In the electrolysis of water the problem is reduced to that of converting solar radiation to electricity and need not be considered further at this point. However, the thermal decomposition of water using solar heat merits closer examination. In the direct single step thermal dissociation of water temperatures exceeding 2000 K are needed which would be obtainable only in a solar furnace. To reduce the temperatures and amounts of work required numerous cyclic multi-step thermochemical processes for splitting water have been studied. They each involve a cyclic sequence of reactions proceeding at moderate temperatures and using gas-solid phase separations. For example, the calcium bromide process requires temperatures from 200°C to 730°C with calcium bromide and mercury forming a number of inter-enough to absorb the short wave radiation but not thick enough to spoil the polished metal surface for radiation at the longer wavelengths. Typical examples are electroplated nickel-zinc-sulphide on galvanized iron, and copper oxide on copper. Recent research has been investigating multiple layers of semiconductors obtained by chemical vapour deposition as selective surfaces for high temperature applications. Other work on selective surfaces includes experiments with selective paints have very small particles to absorb solar radiation but a large void retio in a binder transparent to the long wavelengths. The use of surfaces with a topological structure consisting of particles or holes with dimensions of the order one micrometre has also been investigated.

In most cases, the black receiver converting solar radiation into heat must be protected by a cover transparent to solar radiation and opaque to thermal radiation at temperatures of the order of 100°C. Accordingly, the radiative properties of different glasses and plastics have been the subject of research since the difference between the efficiency of collectors having covers with good and bad properties can be significant.

3. Thermal energy storage

The intermittency of solar radiation makes energy storage a necessity in most applications of solar energy. If solar radiation is converted into heat, this heat can be stored directly as sensible heat or latent heat.

The simplest sensible heat storage media for moderate temperatures are water and pebble beds. Water has a greater heat capacity and better heat transfer properties, but pebble beds can be used if necessary for temperatures above the boiling point of water. For higher temperatures other systems, such as hot oil or packed beds of iron spheres with liquid sodium as heat transfer cluid are being considered.

For practical reasons, latent heat storage is always in solid-liquid transitions at a fixed temperature. In cooling applications ice is an obvious choice, but most applications are for heating. Many substances are available for latent heat storage over a wide range of temperatures, for example, paraffins from 20°C to 70°c, $CaCl_2.6H_2O$ at 30°C, $Na_2S_2O_3.5H_2O$ at 48°C, $FeCl_3$ at 306°C, NaCl at 803°C, etc. The problems that occur with latent heat storage include slow heat transfer in solids, non-reversibility of the phase change due to dissociation or supercooling, etc. Thus, although latent heat storage seems promising and convenient, more research is needed before widespread application is possible.

4. Thermo-chemical energy storage

Heat leakage is a problem for the long-term storage of thermal energy and for short-term storage at a high temperature. This problem can be overcome by thermochemical methods in which the products of an endothermic reaction are separated for the purpose of storage. The heat is recovered when needed by recombining the products in the reverse(exothermic) reaction. The separation may be effected by precipitating one for studying the distribution of solar radiation over the surface of the earth. A more recent development has been the introduction of systems for the automatic recording of large quantities of data.

The principle agents reducing solar radiation at the earth's surface are atmospheric gases (ozone, air, water vapour), turbidity (dust and smoke) and cloud. In particular, turbidity and cloud are important but variable and unpredictable, and the study of their effects is a branch of climatology. Research is concerned with determining the statistics of the diurnal, seasonal and geographical variations of global and diffuse solar radiation, and with representing the results in the form of simulation models. A knowledge of global solar radiation is important in that it is the total amount of solar radiation available, but loss of directionality, indicated by the relative intensities of global and diffuse solar radiation, represents an increase in entropy per unit of energy reducing the amount of work that can be obtained from the radiation by thermal conversion technologies.

Another field that has received less attention, probably because the instruments required are more complex, is the study of climatic variations in the spectral quality of sunlight. Crude results can be obtained with pyranometers and colour filters, but monochromators are needed for more detailed work. The results are important for such applications as photoelectric cells and photosynthesis where the energies of the individual light quanta are significant.

2. Photo-thermal conversion

The conversion of solar radiation into heat is the most widely used of the solar energy technologies today because of its simplicity since all one requires is a black surface with a high absorptivity at visible and near infra-red wavelengths. Temperatures up to 100°C are attainable with flat-plate collectors in bright sunlight with efficiency of about 30 per cent. To improve these figures scientific research revolves around the study of optical concentrating systems and the properties of selective surfaces. The heat, once it is obtained, is used for a wide variety of applications ranging from domestic water heating through the operation of thermodynamic engines to the study of the high temperature properties of materials in a solar furnace.

Among the optical studies may be mentioned the development of non-imaging concentrators and cusp collectors that collect both direct and diffuse radiation over a small arc, such as the Winston compound parabolic system. The other main line of research is into the optics of large imaging mirrors and heliostats for high temperature central receiver systems.

Selective surfaces for solar collectors must have a high absorptivity in the optical and near infra-red (short wave) region of the electromagnetic spectrum, and a low emissivity in the far infra-red (long wave) region in order to reduce thermal losses. They must also be chemically stable. These properties are difficult to obtain, particularly since the cost of manufacture is important. Most of the selective surfaces produced employ a polished metal base that reflects long wave radiation and a black coating that is thick

INTRODUCTION

Science, technology and engineering form a continuum of human activities that cannot be separated sharply into categories. Engineering, whose aim is the economic utilization of the resources of nature for the benefit of man, needs technology to accomplish its aims, while the development of technology depends on the acquisition of scientific knowledge.

In recent years, the demands of solar engineering for the harnessing of solar power have stimulated scientific research and technological development to such an extent that the task of reviewing these activities in a short article is a forbidding one. We can do no more than select for mention a number of topics that appear to be important, other significant topics remaining overlooked. We hope that discussions in the Symposium will bring to light any important omissions so that they can be included in a revised manuscript for publication in the Symposium proceedings. We shall assume that solar science, to meet the demands of technology and engineering, concerns itself with (a) the characteristics and availability of solar radiation, (b) the conversion of solar radiation into other forms of energy through photo-thermal, photo-electric and photochemical processes and (c) the storage of the converted energy in appropriate forms. The study of the uses to which the solar energy harvest is put, and the methods used, belong to the fields of engineering and technology.

I. SOLAR SCIENCE

1. Solar radiation

There are three properties of solar radiation that are important in solar energy applications, namely its intensity, directionality and spectral distribution. Outside the atmosphere, solar radiation has the flux intensity of 1.35 watts per square metre on a surface perpendicular to the beam varying in a way determined by variations in the distance of the sun from the earth throughout the year. Its direction is confined to the solid angle of diameter $½^0$ subtended at the sun's disc, and its spectral distribution is close to that of a black body at a temperature of 5900 K. Since these properties are known and practically constant, and since solar energy collectors for terrestial use are on the surface of the earth, research for solar energy applications is concerned with the manner in which solar radiation is affected by the atmosphere.

The first requirement for this work is reliable instrumentation. The development of accurate pyrheliometers and pyranometers and the establishment of reliable standards for calibrating them has been a major task. Large number of these instruments are needed

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Note by the ESCAP secretariat

15. M.P. Thekaekara, "Solar irradiance, total and spectral" in A.A.M. Sayigh, ed., *Solar Energy Engineering* (New York, Academic Press, 1977).

16. L. Elterman, "Visible and IR alteration for altitudes to 50 km", AFCRL-68-0153, Office of Aerospace Research, US Air Force.

References

1. F. Daniels, *Direct Use of the Sun's Energy* (New Haven and London, Yale University Press, 1974).

2. R.C. Jordan and W.E. Ibele, *Proceeding of World Symposium on Applied Solar Energy, Phoenix, Arizona, 1955* (Stanford Research Institute, 1956).

3. Y.S. Elmahgary, "Thermal diffusion of the warm water of power plants into a sea basin", International Association for Hydraulic Research (IAHR), Paris, 1971.

4. Y.S. Elmahgary, *Thermal pollution, Estimation, Control and Conversion into Thermal Enrichment* (Helsinki, Finland, Inratram Voina 07, 1971).

5. J.W. Bugler, "The determination of hourly insolation on an inclined plane", *Solar Energy*, vol. 19: 477-491, 1977.

6. J.F. Orgill and K.G.T. Hollands, "Correlation equation for hourly diffuse radiation as a horizontal surface", *Solar Energy*, vol 19: 357-359, 1977.

7. B.Y. Liu and R.C. Jordan, "The interrelationship and characteristic distribution of direct, diffuse and total solar radiation", *Solar Energy*, vol 4: 1-19, 1960.

8. A.J. Biga and R. Rosa, "Contribution to the study of the solar radiation climate of Lisbon", *Solar Energy*, vol. 23: 61-67, 1979.

9. M. Iqbal, "Correlation of average diffuse and beam radiation with hours of bright sunshine", *Solar Energy*, vol. 23: 169-173, 1979.

10. T.N. Goh and K.J. Tan, "Solar radiation model building with data of non-uniform reliability and completeness", *Proceedings of UNESCO/WMO Symposium on Solar Energy*, Geneva, 30 August-3 September 1976.

11. N. Weyss, "Direct radiation data from global radiation and other given measurements using a computer aided method", *Proceedings of UNESCO/WMO Symposium on Solar Energy*, Geneva, 30 August-3 September 1976.

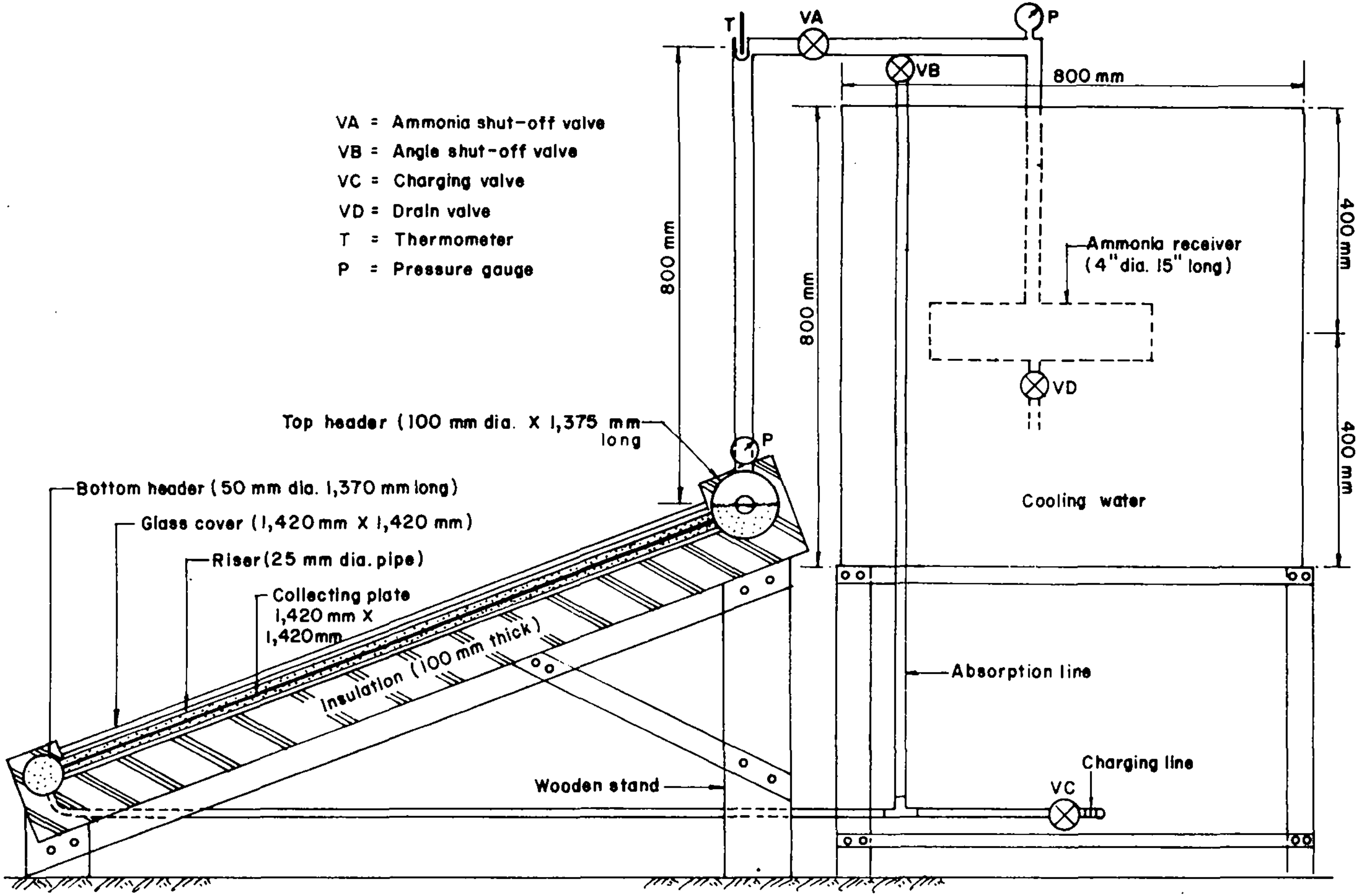
12. R.H.B. Exell, "A mathematical model for solar radiation in south-east Asia (Thailand)", submitted for publication to *Solar Energy*.

13. T.P. Thekaekara, "Solar radiation measurement: technique and instrumentation" *Solar Energy*, vol. 18: 909-325, 1976.

14. WMO, *Guide to Meteorological Instrument and Observing Practice*, 3rd edition, WMO-8, T.P.3 (Geneva, WMO, 1969), chapter 9.

refrigeration is started the tank of cooling water is removed and valve B is opened. The condenser now functions as the evaporator. Ammonia vapourizes due to the pressure difference between the generator and evaporator. The vapourization of ammonia absorbs heat from the surroundings of the evaporator, thus producing the refrigeration effect.

Ammonia vapour from the evaporator passes through the pipe taken to the bottom header of the generator so that the incoming vapour bubbles through the aqua-ammonia solution thus facilitating absorption in it. The glass covers are removed from the collector so that the heat of absorption can be dissipated to the sky from the generator risers. Refrigeration continues until all the liquid ammonia in the evaporator has vapourized. A full cycle is thus completed.



Scale 1:10

Figure 20. Small solar powered refrigerator (AIT, Thailand)

2. *Air conditioning and cooling system (Japan)*

A heating-cooling system has been investigated by Takenaka Komuten Company, Japan. In winter, the water heated in the collectors directly heats the building. In summer, the hot water enters the vapour generator of the Rankine Cycle engine to exchange its heat with the working fluid freon 11 and to generate high-pressure vapour. The vapour is used in a generator to drive a compressor of a vapour-compressive refrigerater (figure 19).

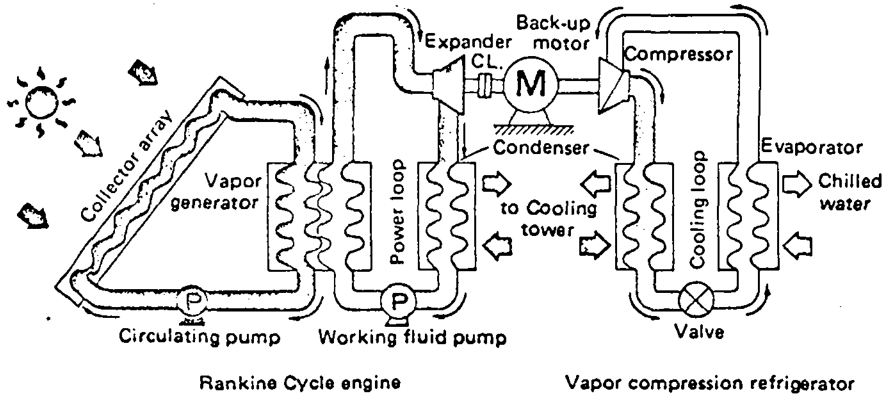


Figure 19. Schematic diagram of the vapour compressor system (Takenaka Komuten Co., Japan)

3. *Cooling system (Thailand)*

The Asian Institute of Technology, Thailand, has carried out experiments on a simplified absorption refrigerating system (figure 20).

The condenser in the system functions also as evaporator and the generator as absorber. During regeneration, i.e., the heating of the refrigerate absorbent fluid (ammonia-water solution), valve A is open and valve B is closed and the strong solution in the generator heated by the flat-plate collector produces vapour a high pressure.

The weak solution returns from the top header to the bottom header by the insulated return pipes. The vapour in the top header is mainly ammonia because water has a much lower volatility than ammonia. The ammonia vapour passes into the condenser which is immersed in a tank of cold water to keep it cool. The pressure is uniform throughout the system.

When heating stops, value A is closed; the vapour pressure in the generator drops. The concentration in the generator is now less than it was before regeneration. Before

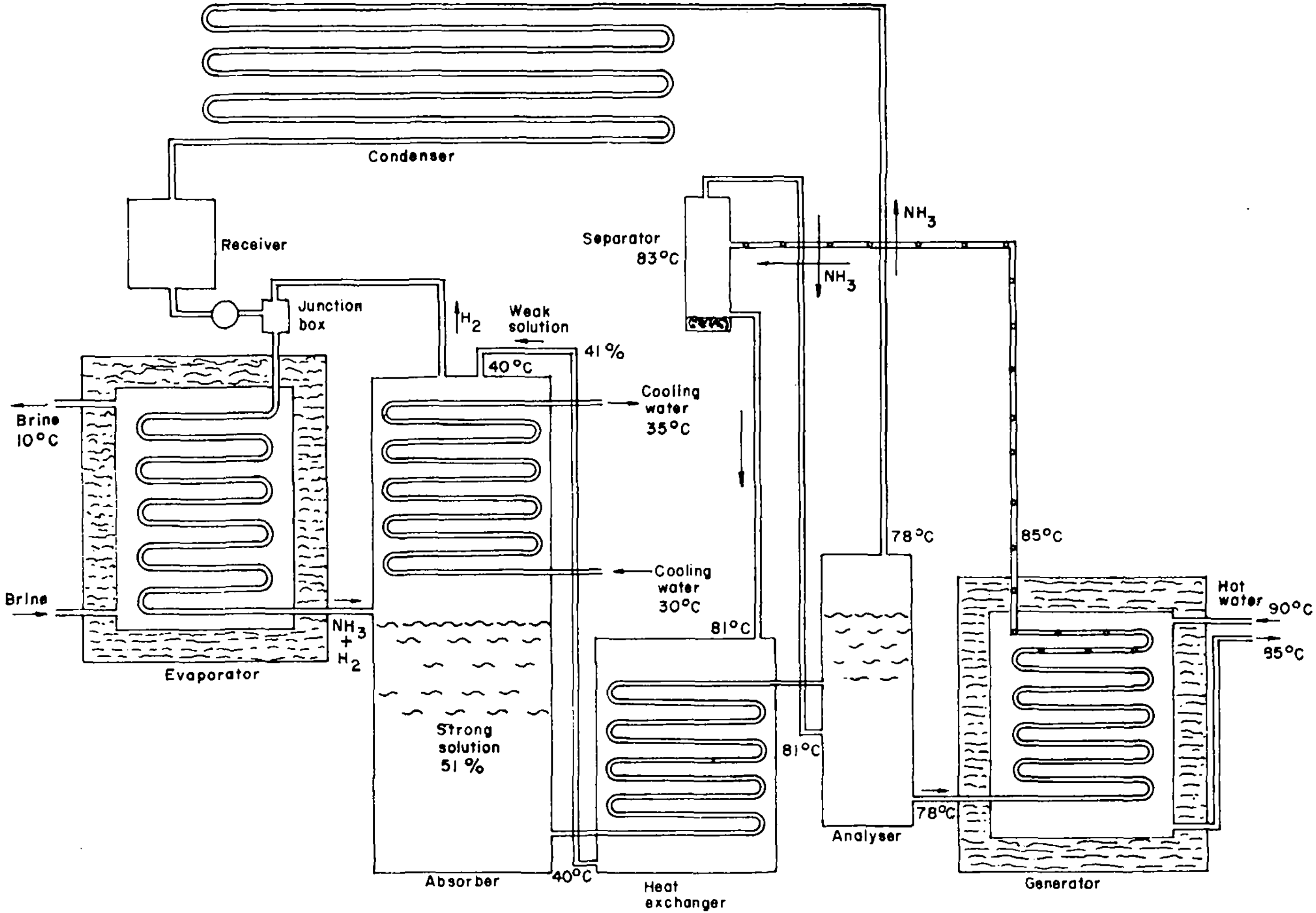


Figure 18. Air-conditioning system of the absorption type (NPL, India)

Annex IV

REFRIGERATION AND AIR-CONDITIONING

1. *Air-conditioning system (India)*

In the National Physical Laboratory, New Delhi, India, an absorption cooling system is being investigated (figure 18). Water heated by solar collectors in this system is stored in an insulated tank at a temperature of 92°C. This hot water is supplied to the generator. The hot water enters at the top and leaves at the lower exit at 85°C. The rate of flow is maintained at 5 litres per minute. The coil in the generator contains a strong ammonia-water mixture. The rate of flow of ammonia-water mixture is 2 litres per minute. The mixture contains 51 per cent ammonia. In the generator, 0.2 litres of ammonia gas are liberated; this gas and 1.8 litres of the solution, containing 41 per cent ammonia (0.82 litres of ammonia) at 85°C, enter the separator.

The weak ammonia solution drained from the bottom of the separator enters the heat exchanger, and 0.2 litres of ammonia gas from the separator enter at the middle level of the analyser containing the strong solution of ammonia liquid. In this analyser any trace of water vapour in the ammonia gas is filtered out.

The dehydrated ammonia vapour, roughly 0.2 litres/min, leaves the analyser at 78°C and enters the condenser. The condenser is cooled by cold water at 30°C. Ammonia gas condenses in the condensor about 35°C. During the process of condensation 240 MJ/min of heat is removed by the condensing cold water.

The absorber is cooled with water. The incoming ammonia mixes with the solution and the concentrated solution (51 per cent ammonia) collects at the bottom of the absorber. This strong enters the heat exchanger where it exchanges heat with the weaker solution from the separator at 81°C. As a result of this heat exchange, the strong solution gets heated to 75°C and enters the analyser and an equal amount of solution is transferred from the analyser to the generator to repeat the cycle.

The entire system is pressurized to 25 kN/m^2. Hydrogen acts as a carrier gas and helps the movement of ammonia vapour from the evaporator to the absorber and also to reduce the partial pressure of ammonia to 77 kN/m^2. In view of this reduction in partial pressure, the boiling point of ammonia in the evaporator coil is about 5°C.

The amount of hot water required to be passed through the generator is 5 litres/min at 90°C. This determines the collector area requirement.

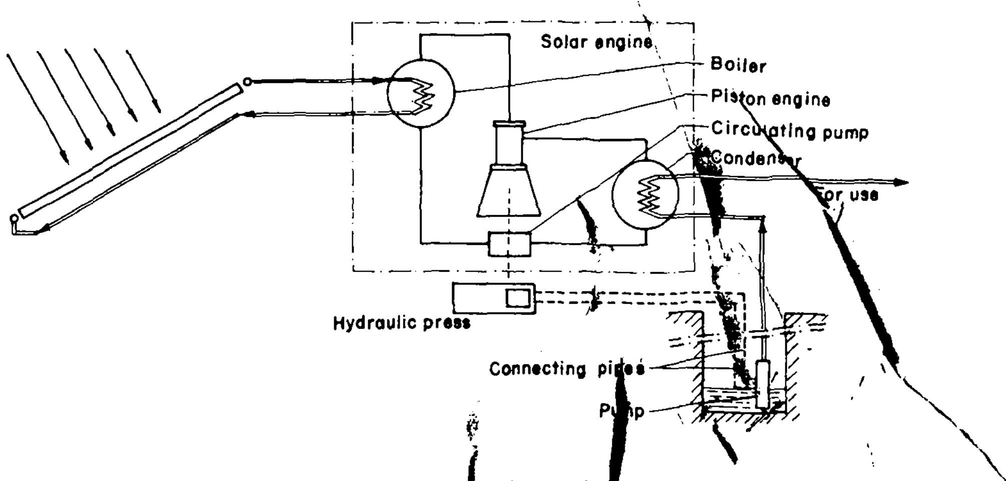


Figure 16. SOFRETES solar pump (France)

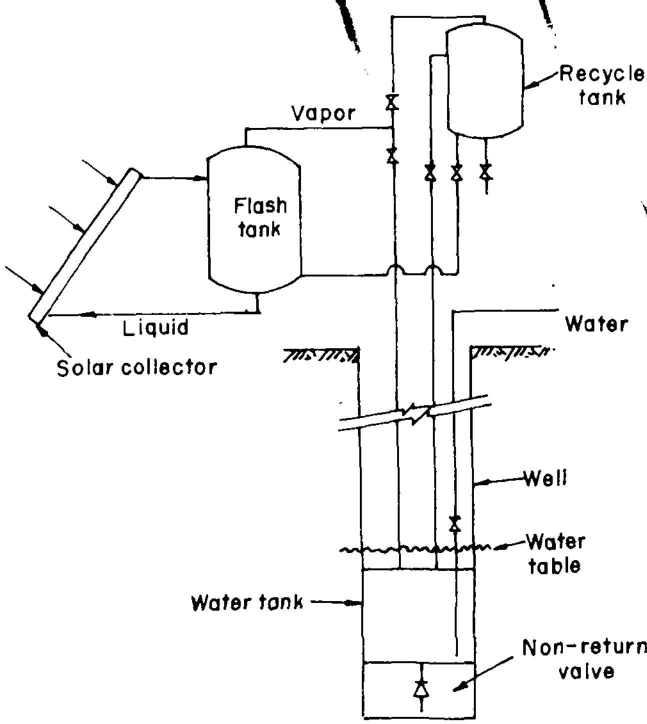


Figure 17. Sketch of air-cooled pump (India)

Annex III

SOLAR PUMPING

1. *SOFRETES Pump (France)*

The French SOFRETES pump is being tested in India and the Philippines. In this system (figure 16) water heated in the solar collector passes through heat exchangers where heat is given to a volatile liquid, e.g., methyl chloride. The colder water then returns to the collector, whereas the working fluid leaves the heat exchanger in gaseous form at high pressure, expands in a reciprocating engine and passes into a condenser. The gaseous fluid is liquified by pumped water and returned to the heat exchanger. In the final phase, the engine drives a hydraulic press which operates a pump inserted in the water in the well.

2. *The BITS solar pump (India)*

This pump was developed in Birla Institute of Technology and Science (BITS), Pilani, India. It uses solar energy to heat and vaporize a volatile fluid, e.g., pentane. The pressure so developed is then used to force water to a higher level from a water tank usually located inside the well (figure 17). In the air-cooled version, the collector acts at night as a condenser for the working fluid rejecting heat back to the atmosphere. This version gives only one cycle per day; thus, for lifting a meaningful amount of water the volume of the water tank may be too large to be economical. Efforts are being made to overcome this limitation by introducing a second version known as a water-cooled pump.

6. *Simple rice dryer (Thailand)*

A simple rice dryer with natural circulation has been developed at the Asian Institute of Technology. In this system, air is heated when flowing over burnt rice-husk, then it rises by natural convention through the rice paddy (figure 15). Tests have shown that the moisture content of 10 cm deep rice paddy was reduced from 24 to 14 per cent on one or two sunny days. For this paddy's depth, the ratio of the area of the collector to that of the paddy bed is 3:1.

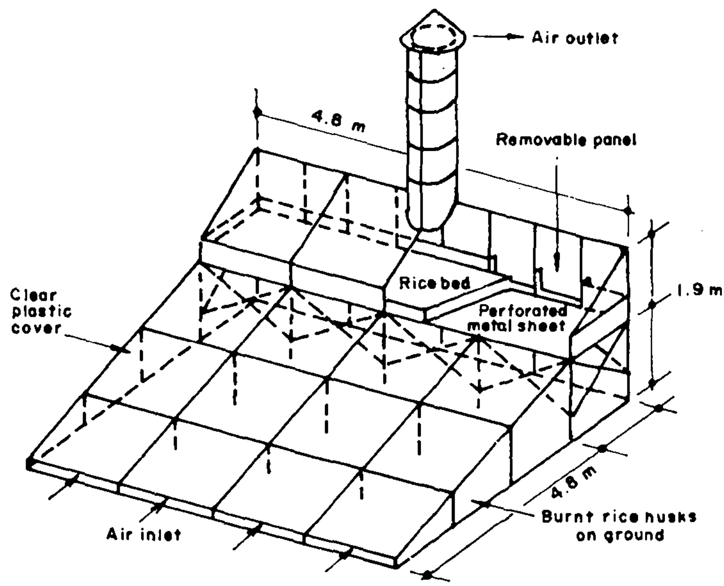


Figure 15. Low-cost solar rice dryer (Thailand)

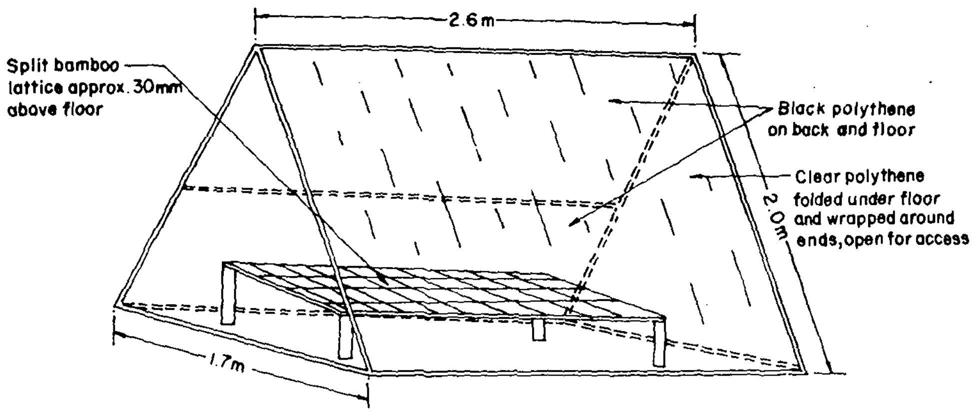


Figure 13. View of solar tent dryer (Philippines)

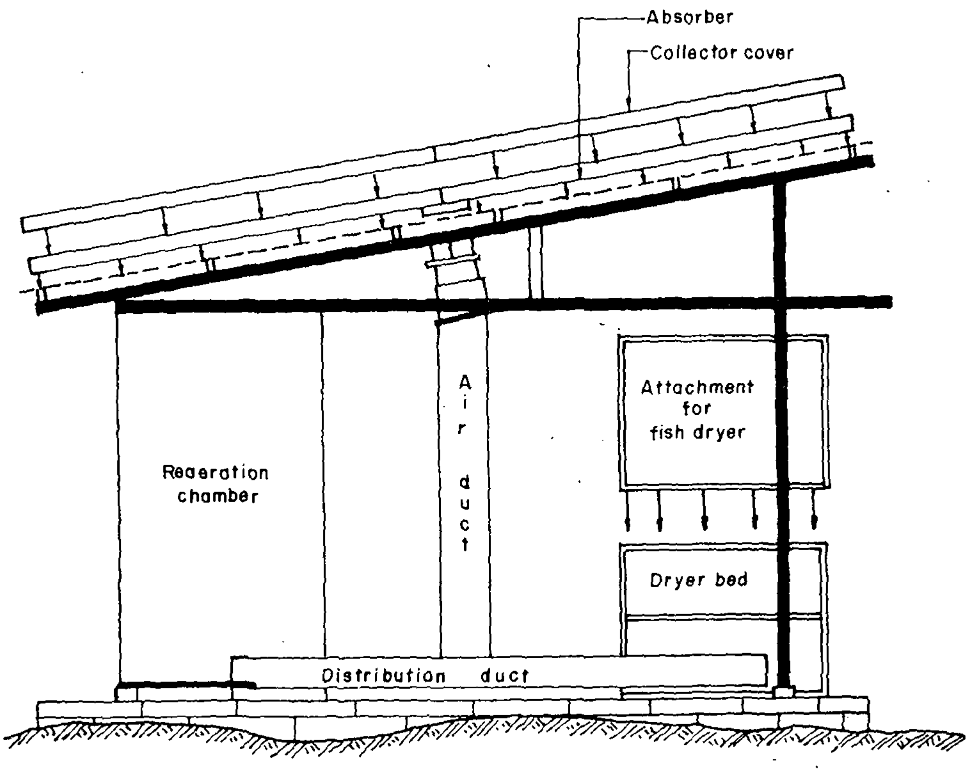


Figure 14. Solar dryer/reaeration system (Philippines)

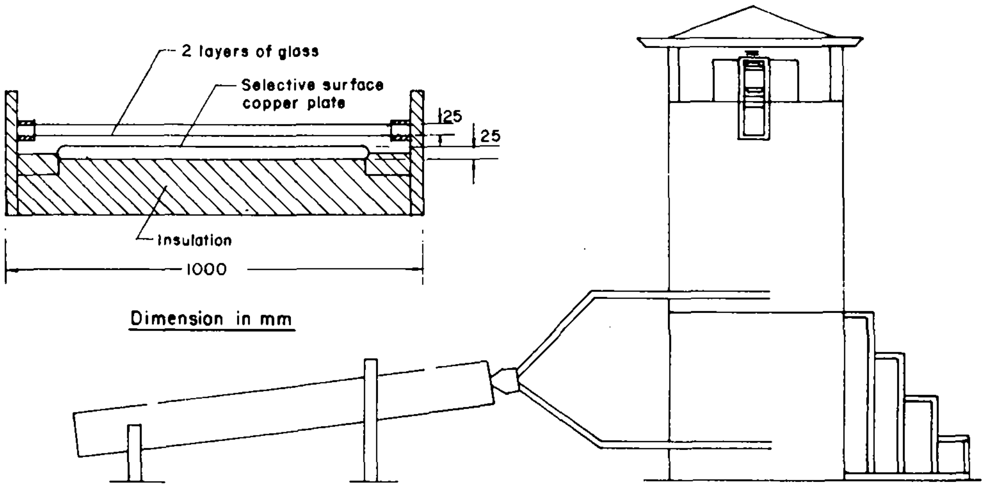


Figure 11. Schematic drawing of solar dryer (Indonesia)

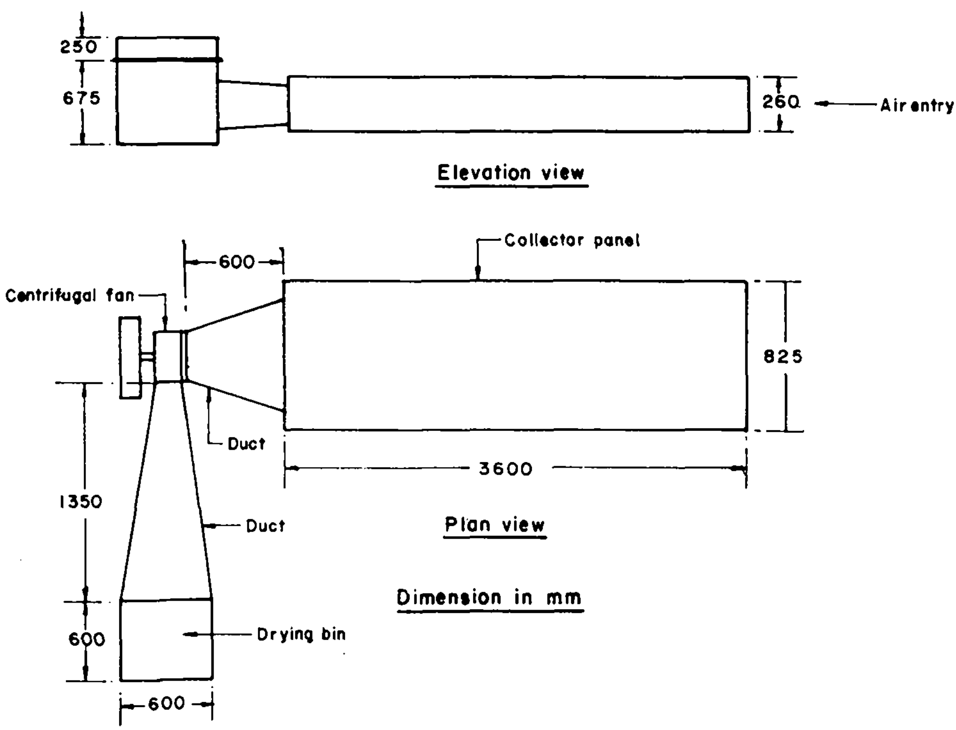


Figure 12. Laboratory size solar rice dryer (Malaysia)

The operation of these dryers over long periods indicates: (a) that maximum drying capacity is obtained if the materials are loaded in the evening and the blower is kept running during the night and (b) that drying of materials is very uniform.

2. *A simple cabinet solar dryer for agricultural products (Indonesia)*

(a) *Collector (absorber)*

This is made of a 0.3 mm thick copper sheet provided with copper-oxide selective surface coating. The cross-sectional area of the air passage is 0.025 X lm ^{2} and its total length is 3 m (figure 11). The collector thus has an area of 3 m^2 and is provided with double glass 3 mm thick. A layer of fibre 15 cm thick is used to insulate the bottom.

(b) *Drying cabinet*

The drying cabinet has a total volume of 1 x 1 x 1.5 m^3 and contains eight trays each with an area of 1 x 1 m^2.

(c) *Circulation fan*

A fan, driven by an 0.3 hp electric motor, is installed at the top of the dryer to improve air flow in the dryer.

3. *Solar rice dryer (Malaysia)*

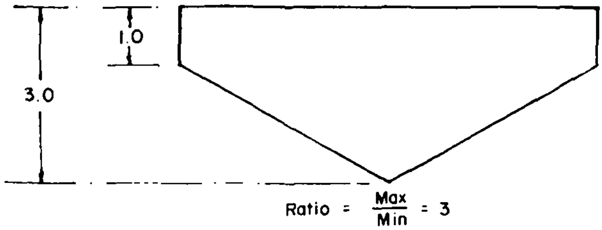
The schematic layout of the system is shown in figure 12. It consists of a flat-plate collector through which air is sucked by a centrifugal fan through the collector and forced into the drying bin.

4. *Tent and shoe box dryers (Philippines)*

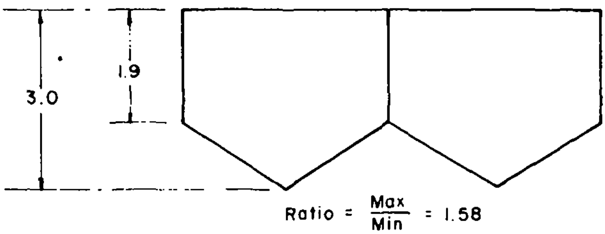
The solar tent dryer was adopted from a Bangladesh design (figure 13). This design is cheap and easy to manufacture, but its disadvantage lies in its inadequacy in removing the moisture. For this reason the shoe box dryers were designed and are being currently tested.

5. *Dryer/storage system (Philippines)*

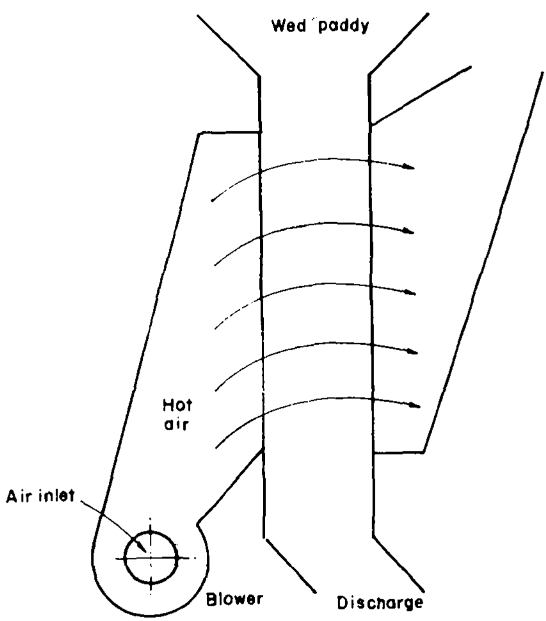
This design, which is intended for "home-made" fabrication by farmers, consists mainly of flat-plate collector, air distribution system, a drying bin and a storage bin (aeration compartment) (figure 14). Performance tests carried out on this dryer have given satisfactory results.



(a) Single cone type

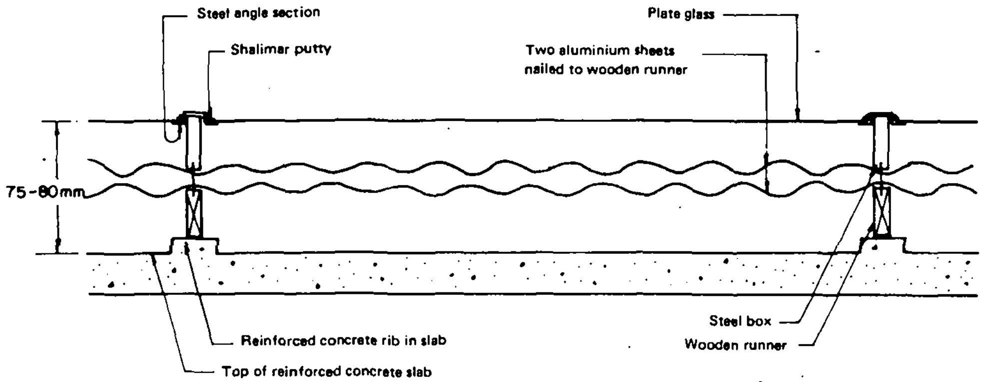


(b) Double cone type

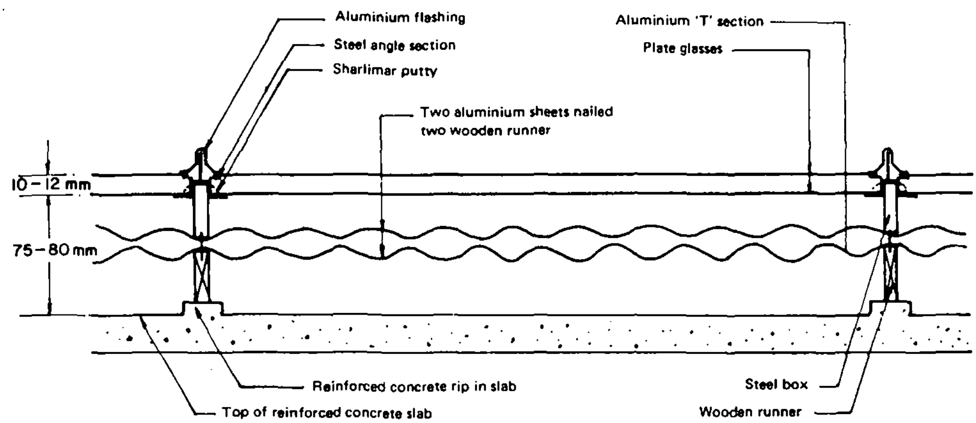


(c) Columnar type

Figure 10. Different types of bin (India)



(a) Singe glass cover



(b) Double glass cover

Figure 9. Different types of absorbers (India)

Annex II

SOLAR DRYING

Dryers developed by NIDC (India)

These dryers consist mainly of:

(a) *Collector (absorber)*

This is made of two bonded corrugated aluminium sheets painted with epoxy mat black paint and covered with a single or double glass according to the drying temperature desired (figure 9). The single glass is used for drying temperatures below 45°C and the double glass for drying temperatures above 45°C.

(b) *Collector housing*

The recommended materials for the housing are wood for small dryers up to a capacity of 1 tonne/day and reinforced cement concrete for larger dryers.

(c) *Drying pins*

For grains having easy flow characteristics like raw paddy, shelled corn wheat, shelled millet, pulses, oil seeds, conical bins (figure 10) are found to be advantageous. The multiple bin system (figure 10b) provides more uniform drying than the single core type system (figure 10a).

(d) *Air circulation system*

This consists of blower, air ducts and dust-filler. From 85 to 90 per cent of air is recirculated in all types of dryers, except those for marine products in view of excessive corrosion caused by salt.

(e) *Supplementary heat source*

In order to provide 100 per cent reliability, some installations are provided with a very simple agricultural waste furnace. A chimney of suitable height is used for providing the necessary draught to facilitate burning.

(f) *Material handling system*

For large dryers a mechanical material handling system is essential. Either bucket elevators or belt conveyors are used. Tobacco and marine products are manually loaded and unloaded.

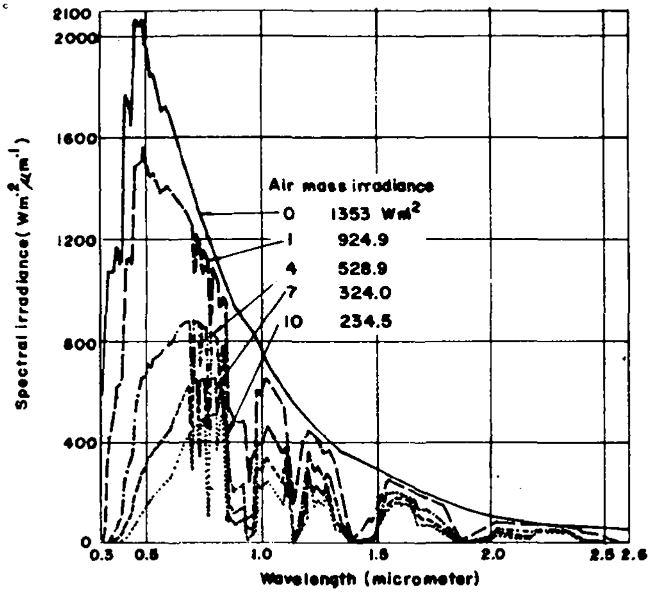


Figure 7. Solar spectral irradiance for different air mass values, assuming a standard atmosphere of 20mm of precipitable water vapor, 3.4 mm of ozone, very clear air (α = 1.3, β = 0.02).

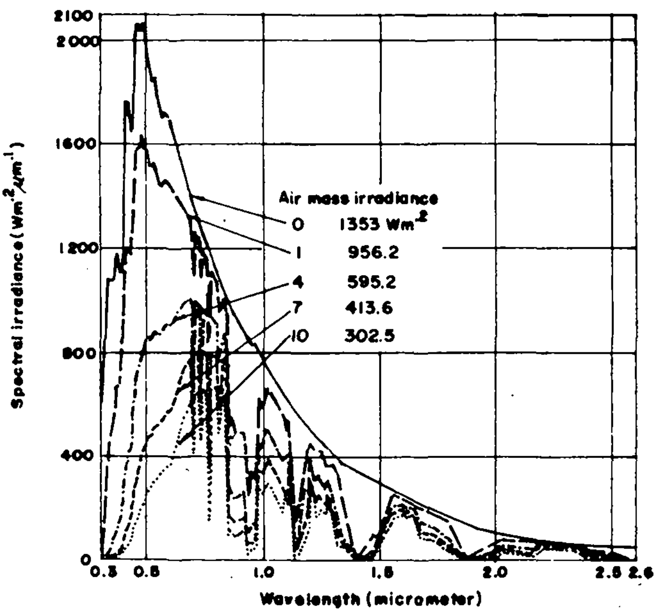


Figure 8. Solar spectral irradiance for different air mass values, assuming a standard atmosphere of 20 mm of precipitable water vapor, 3.4 mm of ozone, relatively clear air (α = 1.3, β = 0.04).

integrating sphere and dispersed by a monochrometer. The wavelength range is usually from 0.3 to 3 μm Quartz prism and grating instruments are both suitable for this range. Each one has its advantages and drawbacks.

(b) *Estimation of solar spectrum*

The solar spectrum depends mainly on the thickness and composition of the earth atmosphere, the air mass (or the solar altitude) and the sun-earth distance (the time of the year). Variation due to sun-spot activities has a negligible integral effect.

By measuring certain meteorological data and using suitable empirical or semi-empirical formulas the solar spectrum can be estimated. Empirical equations have been developed for that purpose.

They are however, rather complicated and each equation is applicable only to a certain range of wavelengths and sometimes for a single wavelength. No single empirical equation valid for the whole spectrum range of interest in solar radiation application (0.3 ... 3 μm) has yet been developed. Accordingly, it seems more convenient and reliable for the time being to estimate the spectral irradiance from diagrams and tables as a function of certain meteorological data. These are Ångstrome turbidity factors α and β, the weight of precipitable water vapour in a vertical air column of unit cross section,[a] the thickness of the ozone layer in the same column at nature temperature and pressure and the air mass. Two diagrams [15] are given in figures 7 and 8. As may be noticed they are all given for 20 mm of precipitable water vapour and 3.4 mm of ozone which were found to be the annual average values in many countries. For estimating spectral irradiance for other values of precipitable water vapour and ozone reference [16] may be consulted.

[a] Detailed information on these instruments are found in reference (13) and (14).

For running the model, the input data are the hourly average solar radiation in each month and the output consists of a set of hourly data for each day of the year.

The model is more useful in tropical regions, where the climate does not have seasonal variations but is subject to short-term changes, which affect the statistical usefulness of individual data values.

(ii) A model for formulating direct radiation data from global solar radiation measurements

In this model [11], the computer is first fed with available measured hourly data of total and diffused solar radiation at one station. The computer uses these data to calculate the constants (indicators) of the hyperbolas relating global to diffuse solar radiation sites of similar climate which were found to have repetitive similarity in values of the hyperbolic indicator throughout the year. Thus, for another adjacent station with similar climate the detailed hourly data of direct of diffused solar radiaton may be obtained after fixing the value of the indicator from hyperbolic straight line relationships between the relative global radiation (ϕ_t/ϕ_e) and the relative sunshine hours ($\tau/\tau m$). Large distances between the evaluated site and the reference station are permissible, if only monthly sums of diffuse or direct radiation are desired, as long as there is a comparable climatic relationship between the stations.

(iii) A model for calculating hourly and daily global and direct solar radiation for south-east Asia

This is a compact first order random model [12] for simulating daily totals of solar radiation and hourly solar radiation fluxes by computer. It is based on detailed studies of solar radiation data for Thailand and is expected to be applicable over the entire south-east Asian peninsula. Empirical formulas (biannual distributions) were formed to give satisfactory approximations to the probability distributions needed. Consequently, the model can be operated with only a modest amount of input information related to the statistics of the daily totals of solar radiation throughout the year. Provision is made for estimating the separation of the solar radiation fluxes into their direct and diffuse components.

3. *Solar spectrum irradiance*

(a) *Measurement of solar spectrum*

As was mentioned before, the spectral distribution of sunlight is important for a number of applications, particularly in photovoltaics.

The instrumentation used for the measurement of energy distribution received from the sun as a function of the wavelength is far more complex and of much greater variety than for total radiation. The solar energy is received on a diffusing surface or an

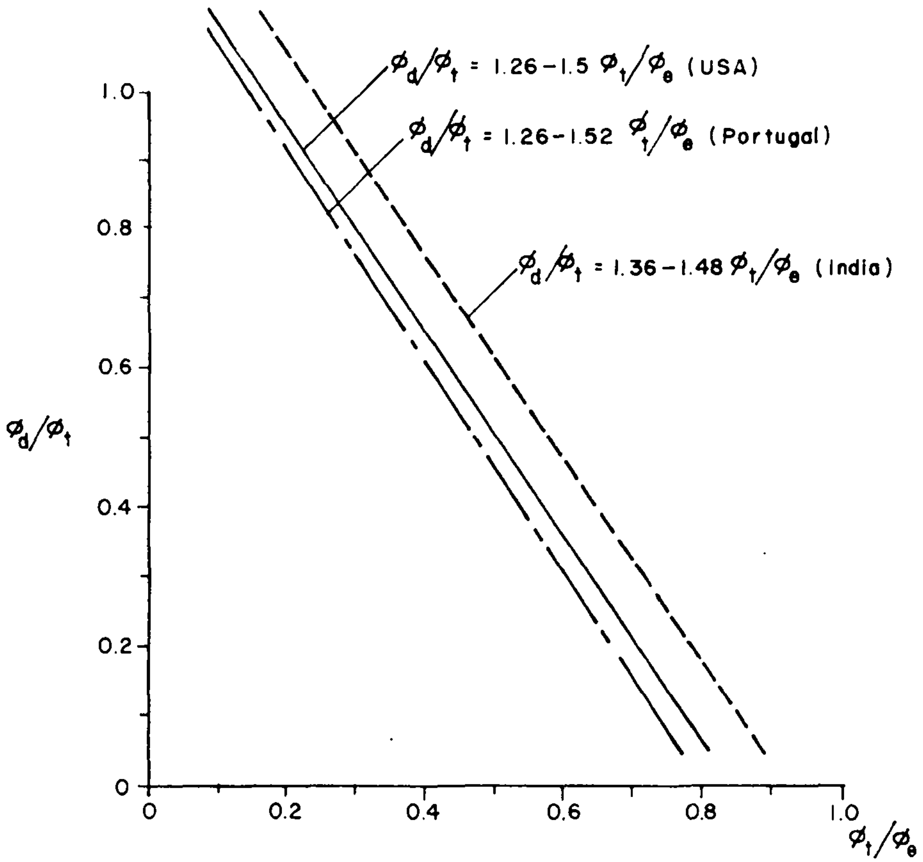


Figure 6. Correlations between daily diffuse and total radiations[g h]

even full-scale experimental investigation. These models are usually designed to provide more complete and comprehensive information using one correlation or the other. A few models of this type, using different approaches, are described below.

(i) A model for the estimation of hourly and daily global solar radiation

A complete set of hourly data for every day of the entire year is first fed to the computer in this model [10]. The pattern of occurrence and the amount of radiation on rainy, cloudy and sunny days are analysed and indicators are computed.

A stochastic discrete time-series approach, based on Bax-Jenkins time-series model, is used for the treatment of short-term effects. The final model consists of deterministic, stochastic and meteorological forecasting components each having, respectively, particular significance for long, short and intermediate lengths of forecast lead time.

It is convenient to divide these correlations into three groups; viz, hourly, daily and monthly relationships, between diffused and total radiation.

(i) Correlations for hourly radiation

The correlations shown in full lines in figure 5 are based on measurements carried out in Australia [5]. For a cloudy sky, i.e., up to $\phi_t/\phi_c = 0.35$, the correlation suggested is $\phi_d = 0.94\ \phi_e$. For ϕ_t/ϕ_c 0.35, it was found that the correlation is dependent on the solar altitude.

However, measurements carried out in Canada [6] were correlated by three different equations as shown by the dotted line in figure 5.

(ii) Correlations for daily radiation

It has been shown [7,8] that a fairly smooth relationship exists between daily diffuse radiation and total radiation on horizontal plane in each month of the year. Some of these relations are shown in figure 6.

The differences that exist between the various correlations are apparently due to differences in the mean atmospheric conditions.

(iii) Correlation of monthly radiation

Empirical equations based on measured data in Canada have been developed [9] to correlate the monthly average daily diffuse radiation with the ratio of sunshine hours. Depending on whether or not the total radiation on a horizontal surface is known, the correlations for the diffuse radiation are:

$$\frac{\phi_d}{\phi_t} = 0.791 - 0.635\ (\tau/\tau m)$$

$$\frac{\phi_d}{\phi_e} = 0.163 + 0.478\left(\frac{\tau}{\tau m}\right) - 0.655\left(\frac{\tau}{\tau m}\right)^2$$

where ϕ_d, ϕ_t and ϕ_e are the monthly average diffuse, total and extracterrestial radiation on a horizontal surface respectively;

τ, τm are the monthly average number of sunshine hours per day and the monthly average day length respectively (figure 3).

(c) *Mathematical models for the estimation of solar radiation data*

Quite a number of mathematical models have been developed for the description, prediction and estimation of solar radiation data. The use of such computer models can considerably reduce the time and cost involved in lengthy measurements, calculations or

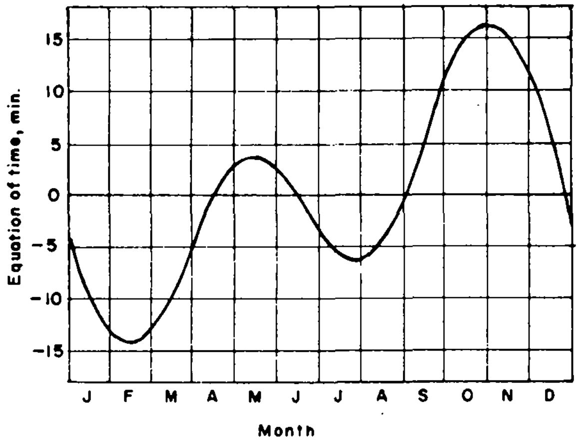


Figure 4. The equation of time, E, in minutes, as a function of time of year

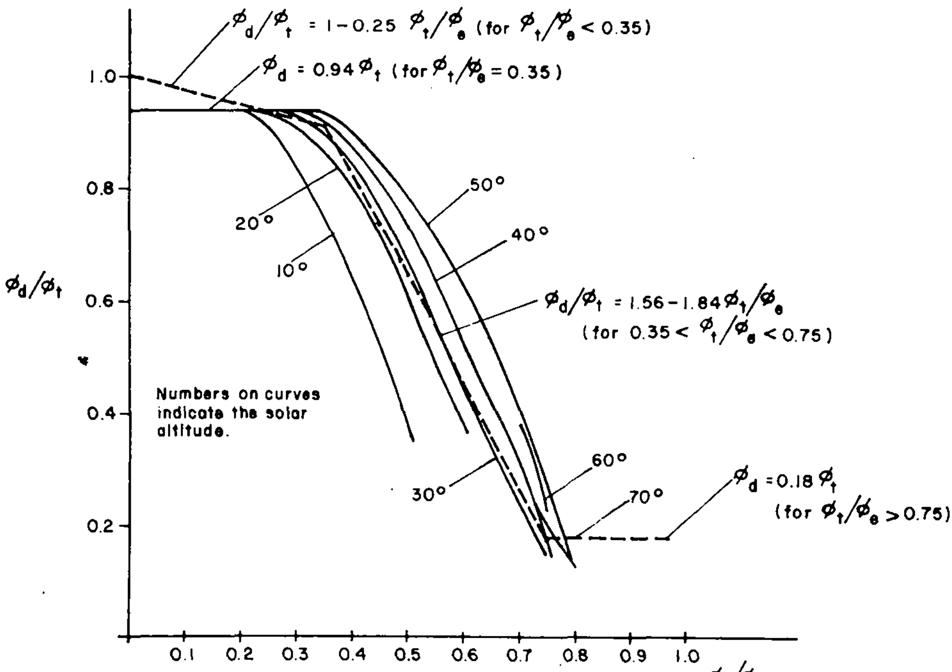


Figure 5. Correlations of measurements of hourly diffused and total radiation in Australia and Canada[e f]

solar time which does not generally coincide with the local standard time. The relation between the two is:

$$\text{Solar time} = \text{standard time} + E + 4(L_{st} - L_{loc}) \quad \ldots\ldots \quad (6)$$

where E is the equation of time (in minutes) and may be determined from figure 4

L_{st} is the standard meridian for the local time zone and

L_{loc} is the longitude of the site in question (in degrees)

Equation (2) gives the total solar radiation at any time of the day and day time of the year for the site in question. For estimating the average total radiation over a certain period, it should be integrated over that period.

Equation (3) was compared [4] with measurements and was found to give a maximum error of 3 per cent. However, the accuracy of the method of using cloud cover data is expected to be less than that of using sunshine hours data in view of the difficulty of estimating accurately the cloud cover.

2. *Direct and Diffuse solar radiation*

Like total solar radiation, direct and diffuse radiation can be either measured directly or estimated, usually from data on global radiation.

(a) *Measurements of direct and diffuse radiation*

The pyranometer described above can, after slight modification, directly measure diffuse radiation. However, for measuring direct solar radiation, an instrument known as the normal incident pyrheliometer, or simply pyrheliometer, is used. The sensor in this instrument is a thermopile at the base of a cylindrical tube which limits the view angle to the sun to about 5° of circumsolar sky. The instrument is mounted on a motor-driven heliostat. The axis of the heliostat should be readjusted two or three times a week to account for the change in sun declination.

(b) *Estimation of direct and diffuse radiation*

Several authors have established correlations between diffuse radiation and total radiation. These are usually in the form:

$$\phi_d/\phi_c = e\text{-}f\,\phi_t/\phi_e$$

where ϕ_d/ϕ_t is in the ratio of diffused to total solar radiation on a horizontal surface

and ϕ_t/ϕ_c is the ratio of the total solar radiation to the extra terrestial radiation on horizontal surface at the same site and during the same hour;

e and f are constants that generally depend on the site climate.

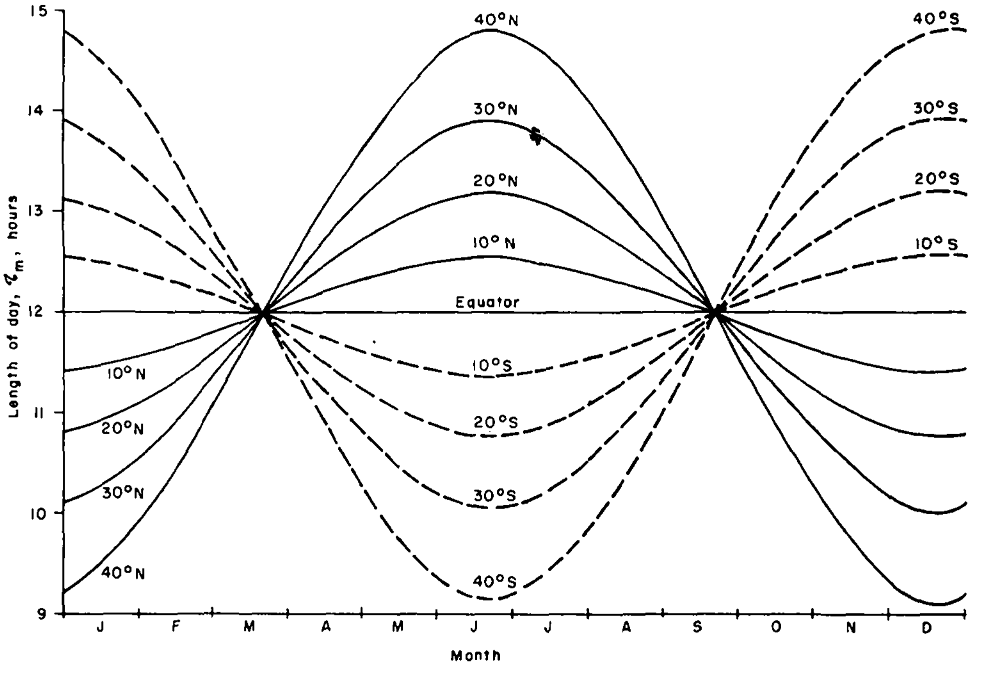


Figure 3. Length of the day as function of latitude and time of the year

where α is the solar altitude, the angle between the sun beam and the horizontal; α can be determined from the known equation first derived by Al Butani;

$$\sin \alpha = \sin \varphi \sin \delta + \cos \gamma \cos \omega \qquad \ldots\ldots\ldots\ldots \quad (4)$$

where φ is the site latitude

δ is the sun declination

and ω is the hour angle

Sun declination and hour angles may be found directly from the nautical almanac or from formulas. The solar declination, e.g., could be determined from the equation:

$$\delta = 23.45 \sin \left(\frac{360d}{365.25}\right) \qquad \ldots\ldots\ldots\ldots \quad (5)$$

where d represents the number of days passed after vernal equinox (21 March)

The hour angle, ω, at the solar noon is zero and each hour equals 15° of longtitude with mornings positive and afternoons negative. Thus ω = +30 for 1000 hours and = -22.5 for 1330 hours. It should be noticed that the solar noon is fixed according to the

Table 3. Values of a and b in equation (1)

Location	*Climate*	*Latitude*	*a*	*b*	*Reference*
Puna, India	Am	18° 31'N	0.3	0.51	3
Delhi, India	Caw	28° 35'N	0.38	0.57	3
Calcutta, India	Aw	22° 32'N	0.33	0.48	3
Madras, India	Aw	13° 04'N	0.37	0.49	3
Chiang Mai, Thailand	Aw	18° 30'N	0.32	0.56	4
Bangkok, Thailand	Aw	13° 40'N	0.31	0.52	4

Am = Tropical wet

Aw = Tropical wet and dry (savanna)

Caw = Humid subtropical (warm summer)

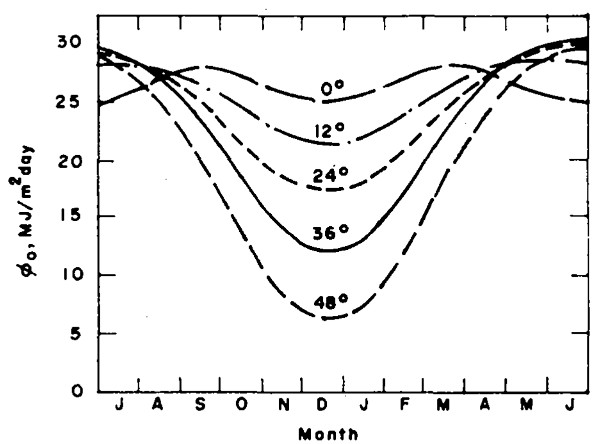


Figure 2. Clear day solar radiation on a horizontal plane, ϕ_o, for various latitudes

f. *Rural Energy Requirements*. This has many dimensions. The first is a series of studies on the socio-economic effects of rural electrification, positive and negative. It is also proposed to carry out rural energy-need inventories by types of energy sources. This would enable a proper matching to be made between the energy technologies and user needs, with minimum need for convention from one energy category to another.

TRANSFER OF SOLAR ENERGY TECHNOLOGY: ISSUES FOR DEVELOPING COUNTRIES

UNCTAD

Introduction

1. The purpose of the present note is to highlight some of the main issues for developing countries in the transfer of solar energy technology.[1] The relevance of solar energy technology to developing countries has been amply demonstrated in the existing literature on this subject, and has been the topic for debate in numerous international fora. This relevance may be summarized as follows:

(a) The world energy scene is in transition - out of oil-based to non-oil based energy supply. While the exact shape of the coming energy mix is yet unclear, the solar energy technology is considered to hold an important key in this transition;

(b) Developing countries, by and large, are well endowed with solar energy resources,

(c) Solar energy technology may be well suited to meet the widespread need for small decentralized sources of energy in rural areas, where a large part of developing countries' populations live.

2. Solar energy technology, however, is still in the embryonic state of its development, and the individual technologies are still mostly at the stage of research and development or of pilot or demonstration projects.[2] While a number of developing countries are taking active interest in the development of solar energy technology,[3] the greater proportion of the developmental work is being carried out in developed countries. For developing countries which are endowed with less financial and human resources for such work, transfer of the results of such developmental work is obviously

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1 The note reflects the ongoing work of UNCTAD on the transfer and development of technology in the energy sector. For a comprehensive account of this work, see UNCTAD. "Energy supplies for developing countries: Issues in transfer and development of technology" (TD/B/C.6/31/Rev.1), and UNCTAD, Major technology issues in the energy sector of developing countries (TD/B/C.6/65). The UNCTAD secretariat is also preparing an in-depth study on the development and diffusion of renewable energy technology.

2 The discussions in this paper relate generally to solar thermal technology (e.g. solar collectors, solar thermal power generation) and photo-voltaic energy conversion technology.

3 See chapter X of TD/B/C.6/31/Rev.1, cited above.

a question of utmost importance.[4] In the following paragraphs, an attempt is made to outline in a preliminary manner the main technology questions for developing countries in terms of the characteristics of the international market for solar energy technology, alternative channels of transfer, and the requirements for domestic technological capacity for successful transfer.

The inernational market for solar energy technology

3. Solar energy technology is still relatively new and its frontiers are constantly shifting as a result of increasing research and development activity in this area.[5] While many of the indididual solar technologies are still at the experimental and demonstration stage and are yet to be market tested, the global trend towards increasing energy prices has worked to hasten the process of development and commercialization of these technologies and stimulate international exchanges of the relevant information and equipment. One can thus conceive of an international market for solar energy technology, in which those firms and organizations which possess the technology act as suppliers and to which developing countries will have to gain access for its acquisition.

4. Since each solar technology embraces a wide range of technologies, from the very simple to the highly complex, as well as a wide variety in the scale of operation, the solar technology market is characterized by the operation side by side of both large and small enterprises. A particularly interesting aspect of the market composition is the increasing participation of major oil companies. Five of the 12 largest oil companies (Exxon, Shell, Mobil, Social and Companie francaise des pétroles) are actively involved in research on solar technology. The usual approach seems to be entry into promising markets through the purchase, either total or partial, of smaller enterprises with a high degree of technical expertise, taking full advantage of a well endowed capital position.

5. The role of these and other large companies is most prominent in the technologically more sophisticated areas. And it should be noted that normally the greater proportion of the financing of research and development contributed by the Governments of developed countries also goes into those very areas. A survey conducted by the National Science Foundation (United States of America) showed increasing concern on the part of small manufacturers about the opportunities of large companies to take the lion's share of the market "whenever the solar energy field looks lucrative".[6] In fact, the allo-

[4] The question of transfer cannot of course be separated from the application or diffusion phase which follows. The three phases of solar technology supply – that is development, transfer and diffusion — need to be assessed in the light of the general developmental framework and the energy situation prevailing in each country.

[5] The government R, D & D (research, development and demonstration) about for solar energy in the member countries of the International Energy Agency, which include 20 of 24 members of OECD, expanded from less than $ 10 million in 1974 to nearly $ 500 million in 1979. IEA, *Energy research, development and demonstration in the IEA countries, 1979 Review of national programmes*, Paris 1980, pp. 20-22.

[6] United States of America, Senate, Hearings before the Select Committee on Small Business, First Session on Energy Research and Development and Small Business, Ninety-fourth Congress (Washington, D.C., U.S. Government Printing Office, 1975), Part I, p. 473.

cation of federal funds favours large companies at the expense of small ones. According to the data provided by the survey, 25 large companies (those with more than 500 employees) received almost 90 per cent ($8.7 million) of the solar energy contracts sponsored by the National Science Fundation, while five small companies and five companies of unknown size shared just over 10 per cent ($1.1 million).

6. A related question is that of patent rights associated with the results of government-funded research and development. This is an important question because a large part of research and development expenditures on solar technology (with the partial exception of solar heating and cooling) is financed by government funds. This is true in most countries, including the United States of America. In the United States, patent rights on technical data and inventions or innovations developed under federal contracts belong in principle to the Government. The main reasoning for this is that in this way the Government can ensure the widest dissemination and extensive commercialization of the technologies involved, which is the ultimate objective of research and development subsidies.[7] The Austrian Government's policy of providing free access by developing countries to its solar technology know-how may be regarded as an international extension of the national arrangement, and merits special consideration in this context.

Alternative channels of transfer

7. Transfer of solar technology to developing countries on a commercial basis is still quite limited, reflecting the present fluid state of the international technology market on one hand and the lack of familiarity of developing countries in general with the more modern methods of solar resource utilization. The only solar technique that has reached the marketing stage in some countries is residential solar heating, but interest in it in developing countries is not very high, for obvious reasons. Nevertheless, solar water heaters have found certain specific uses in some of these countries and the industry for the manufacture of this equipment is flourishing in Israel, Cyprus, and Niger. These countries, however, have acted more in the role of pioneers in the solar technology sector than as beneficiaries of technology transfer.

8. Although trade in solar equipment as such is not very significant as a channel of solar technology transfer, some technical information and knwledge is flowing to a limited number of developing countries through experimental/demonstration projects involving different solar technologies and equipment. The organizers of these projects are in some cases solar equipment manufacturers in developed countries interested in exploring the market potential of developing countries. Developing countries should

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[7] How to reconcile this basic policy objective with the need to compensate for the time and effort expended by private contractors so as to provide sufficient incentive for their undertaking is a difficult question. The Federal Non-nuclear Energy Research and Development Act of the United States has a Patent Policy section which provides a framework for evolving practical solutions to this problem by allowing discretion to the Government in claiming or waiving public ownership of the technology concerned; see United States of America, Energy Research and Development Administration, National Solar Energy Research, Development and Demonstration Programme, Definition Report (ERDA 49) (Washington, D.C., U.S. Government Printing Office), JUne 1975, pp. v-6 and v-7.

make sure that these projects will not result solely in market penetration by these firms but in actual transfer of technology.

9. Experimental/demonstration solar technology projects are also conducted through aid projects on both a bilateral and a multilateral basis. In view of the considerable amount of R & D work which is undertaken by public and semi-public institutions in developed countries and by international organizations, this channel of transfer should provide a useful alternative to more commercially oriented ones.

10. A significant amount of solar technology transfer is also taking place in the form of information flow through seminars, workshops and publications. For example, participants from more than 50 countries discussed more than 400 papers on solar technology at an International Solar Energy Congress held in New Delhi in January 1978. Various organizations in the United Nations system are sponsoring a wide range of seminars and training programmes in this area.[8] The volume of literature on solar technology is expanding at an almost phenomenal rate. There are said to be some 140 research institutes in more than 40 countries engaged in various aspects of research on solar technology.[9]

The building up of domestic technological capacity

11. Access to technology is a necessary but not a sufficient condition for a successful transfer. A successful transfer of technology also requires existence of a certain technological capacity on the part of recipients. In fact, whether or not solar energy technology can have a significant impact on the energy situation in developing countries in the longer term will depend to a considerable extent on strengthening of the domestic technological capacity in the energy sector of these countries.

12. In the case of the transfer of solar energy technology, the domestic technological requirements may be even more demanding for developing countries than for conventional technologies owing to its newness and still evolving character. Thus, developing countries would have to develop, first of all, a capacity to monitor and assess international technology development as well as to devise an appropriate policy in this area. Such efforts should be made within the framework of over-all energy planning in these countries.

13. Second, they would also have to develop their own capacity to undertake R & D. The requirement for this stems primarily from the need to adapt the technology to specific local conditions and requirements. It is encouraging to note that a considerable

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[8] For a brief summary of ongoing solar energy programmes in the United Nations system, see B. Chatel, "Sorlar energy programs in the United Nations system", paper presented to the International Solar Energy Congress, New Delhi, 16-21 January 1978, a summary of which appears in International Solar Energy Congress: Extended Abstracts (New Delhi, 1978), vol. I, abstract No. 1208.

[9] See Overseas Development Council and J.W. Howe, "Energy for the village of Africa: recommendations for African Governments and outside donors" (Washington, D.C.), 25 February 1977 (mimeographed).

number of developing countries have actually initiated R & D programmes relating to solar technology over the last few years.

14. Third, the capacity to manufacture equipment and/or provide services relating to solar technology is another requirement for the technology transfer to succeed, although the scope of such activities may vary from country to country depending on the level of industrial development achieved and the size of the domestic market. It is important to note in this connexion that the technological complexity involved in the manufacture of some solar equipment (e.g. simple solar collectors, equipment for solar heating and crop drying) is not beyond the industrial capacity of most developing countries. Equipment for solar thermal power generation on small-scale has also been manufactured in some of the more industrially advanced developing countries such as Brazil and India.

Main technology issues for developing countries

15. Because of the potentials offered by, and the still relatively fluid state of, solar technology, and the fact that market obstacles to entry at the lower end of the technology spectrum are small, developing countries have great scope for exploiting this technology through their own developmental efforts. Such efforts are also needed if they are to overcome the technological dependence which is prevalent in the energy sector of most developing countries.[10] It should be emphasized, therefore, that early participation in developmental work on solar energy technology by developing countries is imperative. Such participation may be conceived of in a number of alternative ways. As already mentioned, monitoring of general technological developments in the area of solar energy is a primary step in this direction. In those countries which are endowed with financial and human resources for undertaking developmental work, indigenous developmental efforts should be made.[11] In order to allocate scarce resources in an effective way, developing countries might consider undertaking a co-ordinated efforts in research and development in this area, starting with an exchange of information and research results, and moving towards a joint creation of solar technologies which are appropriate to their common needs. Regional centres for transfer of technology already in existence in Asia, Africa and Latin America could provide a useful machinery for carrying out such projects.

16. Another issue which needs further consideration is the identification and assessment of alternative channels for the transfer of solar technologies. UNCTAD's ongoing work on this question indicates that there is a trend towards greater concentration in the supply of sophisticated solar technologies on the one hand, and on the other

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[10] The documents cited in footnote 1 above contain a detailed analysis of the state of this technological dependence, in particular in relation to the conventional energy technologies (e.g. technology for oil and gas exploration, coal mining and power generation).

[11] For illustration, see Tata Energy Research Institute, *Renewable Energy research in India*, Bombay, 1980.

towards increasing efforts by solar equipment manufacturers to create purely market outlets for their products in developing countries, rather than to enable those countries to import the relevant technology. The strengthening of the negotiating capacity of developing countries with respect to the acquisition of solar technology is of great importance, and the establishment of an appropriate juridical framework would greatly help such efforts. As a matter of general policy, it will be in the interest of developing countries to widen the choice of alternative channels of transfer. One alternative channel, which has hitherto received less attention than it deserves, is the possibility of the participation of scientists from developing countries in joint research efforts in developed countries for the purpose of acquiring scientific and technological know-how and the relevant technical skills in the field of solar energy. Such a channel could perhaps be expanded to give a more prominent role to the public and semi-public research and development institutes in developed countries in the transfer of solar energy technology to developing countries.

17. Another important issue relating to transfer of solar energy technology concerns the need to prevent the monopolization of the results of research carried out in developed countries. The governments of developed countries should take particular care that technical innovations and improvements funded by public finance are not appropriated by the private sector and that they are made freely available to developing countries. If complemented by their joint developmental work, such improvements in the international environment for the transfer of solar energy technology would go a long way towards bringing about successful transfer of solar technology to developing countries.

18. These and other issues will need to be discussed thoroughly in the preparatory process for, and at the United Nations Conference on New and Renewable Sources of Energy, to be held in Nairobi in August 1981. Based on its work in the area of transfer and development of technology in the energy sector, the UNCTAD secretariat is actively contributing in this process.

EDUCATION AND TRAINING IN SOLAR ENERGY: NEEDS AND FACILITIES IN ASIA

UNESCO

One of the major constraints in the widespread application of solar energy is the lack of adequate training programmes and facilities and it will be most difficult to realize the true potential of this enormous and ubiquitous source of renewable energy until steps have been taken to improve this situation. When we talk of education and training, we normally think of students in the classroom or of university laboratories where experiments and research are carried out, but in the case of solar energy (and non-conventional sources of energy in general), the problem goes somewhat deeper. In addition to increasing the work at the universities, programmes must be undertaken which will improve the understanding and acceptance of this new source of energy by the general public, introduce concepts of solar energy into the primary and secondary schools and train technicians to deal with the special needs and problems in solar technology. Beyond this there is need for a series of upgrading and familiarization programmes which will make it possible for engineers who have already been working in related fiels to obtain specialized training, and - and area which is much neglected - for policy and decision makers on various levels, including government officials, to be briefed on the techniques, the potential, the applications and the limitation of this new source of energy which may already play an important role in their countries (perhaps in the form of firewood and charcoal) and seems destined to play a more important role in the future. It will be seen then that the question of education and training is a critical one in any review of the future role of solar energy.

These conclusions were strongly reinforced by a recent survey which UNESCO carried out on Education and Training in New and Renewable Sources of Energy as part of its contribution to the preparation of the UN Conference on this topic which will be held in Nairobi in August 1981. This survey covered all of the world, and dealt with other non-conventional energy sources such as geothermal, ocean and small-scale hydro. Its results indicate that in spite of the fact that great interest has been expressed in these non-conventional sources of energy, there has been no systematic approach to the development of the necessary training programmes to promote them, and that little has been done in most countries on the development of courses or curricula, preparation of training materials, training of teachers, or even on the level of identification of needs and facilities in the field of education and training. As in many parts of the world, very much of what is being done in Asia is being done by individuals who, for one reason or another, have developed a personal interest in solar energy and have oriented their programmes (mainly research but spilling over into teaching) in this direction.

Solar energy as generally conceived, and as considered in this review, is not a compact and easily defined subject. It includes not only the various direct and indirect uses of the sun to produce heat or electricity but also takes in such sources as wind energy and biomass, including fuelwood and charcoal. Thus a training programme covering the full field of solar energy would have elements of most branches of engineering, of many branches of science and of a number of other fields such as architecture and forestry. This has been borne out in the UNESCO survey in which replies to the questionnaire which was widely circulated throughout the world came from schools of science, engineering and agriculture, and within these schools from a wide range of departments and divisions.

Clearly, at the moment there is no one point-of-focus for education and training in solar energy. At any particular institution it may be in the department of mechanical engineering or chemical engineering, or physics, etc. Considering the diversity within the subject, it seems likely that this situation should and will prevail, at least until certain specific applications of solar energy (e.g. photovoltaics) become sufficiently dominant and develop a sufficiently specialized technology and clientele to warrant the establishment of full training programmes devoted to them. Unfortunately, this diversity carries with it a corollary that, since there is no point-of-focus for education in solar energy, there is also no unit within the educational system which is actively promoting training in solar energy on all levels and in all applications, and thus the field does not have a body to serve as its promoter or spokesman. This is not completely true, since for example, UNESCO has taken steps to establish and support a number of regional networks and societies which espouse the cause of solar energy, but it highlights once more the need for a systematic approach towards training in alternative sources of energy.*

The UNESCO survey was designed as one early step in this direction. The general results, which include responses from some 78 institutions in 16 countries of Asia and the Pacific, confirm that there is a real need in all countries for manpower specialized in solar and other new energies, and an equally great need for programmes to improve public understanding in this field. This last would best be carried out within a broadly based programme of public information which would be somewhat outside of the normal education system, but which should be developed by extension services and adult and non-formal education groups, in close consultation with specialists in the field.

The formal education programmes were seen as being most critically needed on three levels:

1. Post-graduate specialization training, including training of teachers and research workers;
2. Technician training;
3. Training of policy and decision makers.

* In considering long-range energy supply, sight should not be lost of the fact that conventional sources will remain the major suppliers of energy for many years to come. However much greater attention should be given to new energy sources to prepare for the changes which will take place in the energy mix, and this should be done in a structured and systematic way.

At this stage the major training effort in solar energy should be dealt with on those three levels. So far as under-graduate or degree training is concerned, the consensus appears to be that it is not appropriate to introduce specialized courses at the under-graduate level, but that material on various aspects of solar energy, its technology and applications, should be introduced into existing courses in the normal curriculum. In addition, optional courses on solar energy that are open to both advanced under-graduate and post-graduate students might be made available. This recognizes that a specialist in the technical aspects of solar energy will require a firm background in fields such as thermodynamics, kinetics, fluid mechanics and heat transfer and that courses on these subjects should include applications to all sources of energy including solar, while, similarly, someone working on solar building will require the fundemental courses in civil engineering and architecture. Special programmes on solar energy would then be mainly on the post-graduate level.

This is, in fact, the same debate which took place over nuclear energy some twenty years ago and the answer is much the same. Over the intervening period, concepts of nuclear science and engineering have been introduced in a wide range of courses in science and engineering programmes. Although a number of specialized under-graduate programmes have been developed in nuclear engineering, nuclear physics, etc., most of the specialists working in nuclear energy do not come from these courses, while a large number of the graduates of these courses are working outside nuclear energy. Indeed, many of them are now working in the field of solar energy, which would bear out the need both for good training in fundamental subjects and for a degree of inter-disciplinarity. Beyong this, although we are dealing mainly with the technical aspects of solar energy it should be recognized that we are thinking in terms of a major change in the energy mix which will have impact on social organization, particularly on the village level, on architecture, on space allocation and on many aspects of life which require an even broader inter-disciplinary appraoch in dealing with solar energy, and thus in training specialists and policy makers.

In comformity with this appraoch, current programmes in solar energy in Asia are almost entirely on the post-graduate level, and many universities in the region indicate that they are giving courses in this field. The possibility of writing a thesis for a master's or doctor's degree on some aspect of solar technology exists in universities in most countries of the region, although it is difficult to evaluate the level or value of the work. Clearly, strong interest exists, and there are staff members who are carrying out research in solar science and technology. Australia has been one of the leading countries in solar energy since long before this became a field of general interest, and Japan with its well-known Sunshine Project is a world leader in the field. Also the results of research work in India which were displayed at the 1978 Congress of the International Solar Energy Society in New Delhi could not fail to impress the scientists from all over the world who attended that Congress. Even a small country like Nepal has carried out interesting research on the use of solar energy in buildings. However, in most countries the programmes are limited in scope, with limited links to one another and to the international arena and are often dependent on the efforts of a few dedicated specialists.

There are a number of international post-graduate programmes in solar energy in which Asian graduates participate, and these have been attended by many of the specialists who are now teaching about solar energy in their own countries. However, most post-graduate programmes are arranged on a case-by-casesbasis and are not specifically designed to meet the needs of participants from developing countries. One example of an international course in solar energy is that organized by the University of Perpignan, in cooperation with UNESCO, which for more than five years has been holding special post-graduate degree programmes for specialists from developing countries.

A number of such programmes are under active preparation in the Asian region, three of which will be mentioned here. The Indian Institute of Technology in New Delhi has a two-year programme of Master of Technology in Energy Studies which has Solar Energy Utilization as one of its areas of specialization. Fellowships are available to candidates from outside of India for this programme. The University of Melbourne in Australia is developing an M. Eng. Sc. programme in development Technologies which will have solar energy as one of its options. Fellowships for this programme are available through the Australian Government. The Asian Institute of Technology in Bangkok, in cooperation with UNESCO, has recently established a programme in Energy Technology with the possibility to do a research programme in thermal solar processes, photovoltaic applications, solar and wind energy potential, biofuels or windmills and wind generated applications. In each of these programmes, candidates will be given a broad review of energy technology but will have the option to specialize in some aspect of solar technology.

It is likely that programmes and facilities for advanced training and research in solar energy (and other alternative sources of energy) will increase in Asia and in other developing regions in anticipation of changes which will take place in the energy mix over the next decades, during which solar and other non-conventional sources of energy will become more important. If one considers that a student who enters graduate school today is preparing himself to do his most effective work between the years 1990 and 2010 when the energy mix will be very different from that of today, there is much logic to this shift in emphasis towards solar energy.

There is good possibility that these new programmes will receive stimulus and assistance from international programmes such as UNDP and the World Bank and, indeed, the World Bank has talked of the possibility of a major programme in energy, both conventional and non-conventional, which would have a training component, and would have the capacity to provide external assistance in the developing and strengthening of educational facilities and programmes in solar energy. UNESCO is currently implementing several programmes involving training in solar energy with support from UNDP and other sources and these are expected to increase.

So far as the other priority areas are concerned, programmes for training of policy and decision makers are very limited, and what training does exist is mostly within the framework of international or regional programmes. International courses on energy planning and economies have been organized for a number of years, for example by State University at New York, at Stony Brook, New York, and by the Institut National des Sciences et Techniques Nucleaires at Saclay near Paris in France.

There is a recognition that such programmes can usefully be carried out on the regional level and there are some efforts to promote this. For example, the East-West Center in Honolulu organized a meeting in 1979 of policy makers from the countries of Asia and the Pacific to discuss energy policy and planning, which recommended the establishment of a consortium to develop regional programmes in these fields. ESCAP has also convened regional meetings dealing with energy policy and planning. A major step is being taken to organize special programmes on energy policy related topics by the United Nations Development Programme, which is currently reviewing the possibility to assist in setting up a network of cooperative institutions in developing countries to provide training on energy policy and planning based on common standards and curricula. This type of activity is also a part of the World Bank plan.

There is a clear need for a number of such courses and workshops in the world, since the UNESCO survey indicates that there are 300-500 high-level officials (3-5 per country) who could usefully participate in training programmes of up to three months, and more than double this number of intermediate level specialists who would benefit from a six-month training programme. UNESCO, with its strong interest in education and training, and with its long history in solar energy, is playing an active role in the developing of these programmes.

The technician category includes specialists trained to install and maintain solar energy systems. These can be craftsmen familiar with the conventional techniques such as welding, plumbing and electrical installation. As solar applications become more popular, more widely used and probably more complex, the need for technicians with specialized training will increase. Most of such training will be carried out in local institutions so the major need will be for the training of teachers and the development of teaching programmes and materials. This is an area which does not receive as much attention as it should, and which must be built into any systematic programme for training in solar energy. External assistance may also be available for this.

The final area which should be touched upon is the question of continuing education or retraining of scientists and engineers who have already joined the work force, but who now wish to know more about solar energy. International short courses sponsored by many organizations have been carried out on a wide variety of topics and this may continue to be the pattern in highly specialized fields. For example, UNESCO has cooperated with the International Centre for Theoretical Physics in Trieste in sponsoring a series of short courses to upgrade teachers and researchers in solar energy, and UNEP organized a course in China for specialists from developing countries on the subject of biogas. The United Nations University has also organized a number of programmes which introduce new concepts of solar energy to specialists, with some emphasis on the village and rural levels. Most retraining programmes will be expected to be carried out on the national and sub-regional levels and will be organized by the national groups interested in solar energy, including the universities which have solar energy programmes.

Here, mention should be made of the role of the professional groups which promote the application of solar energy. Australia-New Zealand, Japan and India all have national bodies which are associated with the International Solar Energy Society and which play an active role in the promoting of solar energy through exchange of information, advisory services and promotion of public understanding. Such groups can play, and are playing, an important role in education and training for solar energy. On this level, some programmes in solar energy are carried out by the UNESCO sponsored Regional Centre for Energy, Heat and Mass Transfer in Bangalore, and steps have been taken to establish an Asian Network for Solar Energy.

In summary, one might say that so far as education and training in solar energy are concerned, the present situation in Asia is not too different from that in most of the world. The subject is not widely known or understood, and although these are some good programmes of postgraduate training and research, most activities are the result of the interest and efforts of one or two individual staff members. At the same time, concepts of solar energy are being introduced into existing courses and programmes at the undergraduate level and the UNESCO Survey indicates that a great many training institutions have plans to develop courses on solar energy in their programmes. With the growing interest in non-conventional sources of energy it is likely that increasing amounts of external assistance support will be available for this through UNESCO, UNDP, World Bank and bilateral sources.

That being the present situation, what of the future? The energy needs of a developing Asia, with its high man/land ratio, are out of all proportion to present consumption, and the sources of fuel which supply much of the population (in many cases, firewood and charcoal or animal dung), cannot be counted upon to supply more than a fraction of this need under present production conditions. The potential for energy from solar, wind and biomass sources in Asia (including improved firewood production) is great, and can make a significant contribution to the future demand, but the development of these existing renewable resources will require much effort and much understanding. This in turn will require a great increase in the resources, both financial and intellectual, which are devoted to education and training, not only of specialists and technicians, who are readily recognized as an essential part of the system, but also of policy and decision makers, who must be able to recognize the need for, and the potential of, energy from the sun, and, last but by no means least, the general public who are the consumers of energy, and who, given understandable options, will decide on the future applications of solar energy.

THE INTERNATIONAL PATENT CLASSIFICATION (IPC) AS A MEANS TO IDENTIFY BASIC TECHNICAL INFORMATION ON SOLAR ENERGY AND ITS APPLICATIONS

WIPO

INTRODUCTION

1. Today, in many fields of technology, scientific and technological development is advancing at a very fast pace. The role of scientific and technological information is assuming increasing importance which makes it a vital national resource in the development of national economy. The information has become a major factor in the formulation of policy decisions by national governments. A major obstacle is, however, that, of the vast information available, information of particular relevance to a certain technological problem is often not readily accessible at the right moment.

2. One of those fields, where a rapid innovation process is taking place, relates to solar energy, which is also constantly finding new applications. A recent study on information flows in the field of new and renewable sources of energy, undertaken by UNESCO, identifies a whole series of obstacles in information transfer, including the lack of systematic information collections and the existence of many documents that give biased, unevaluated or unreliable information. It is the main aim of this paper to present a source of technological information for which these obstacles are not of much relevance.

PATENT DOCUMENTS AS AN IMPORTANT SOURCE OF TECHNOLOGICAL INFORMATION

3. Patent Information, an integral part of technological information, has a number of specific features (i.e., combination of technological, legal and economic elements in patent documents, reliability of the information contained in those documents, the fact that the technological information is revealed in patent documents in a much more complete form and earlier than in other information sources, etc.) which makes it essential not only for current industrial activities and research and development but also for forecasting further technological progress.

4. In this document, the expression "*patent documents*" is used to include several different types of documents on industrial property rights related to inventions. The expression "patent information" is used not (as in some other contexts) to indicate information about patents and patent applications but to mean the *technological information content of patent documents*.

Characteristics of Patent Documents

5. Patent documents, due to legal requirements, generally *have a fairly uniform structure*: so-called claims give the essence of what is alleged to be new; a description is

required to explain the background to the invention (what was known before the invention i.e., the "prior art") and to state clearly the difference between the pre-existent technology and what the invention contributes as a new matter, as a step forward, in technology. This means, as distinct from scientific or technological articles, that the reader of patent documents does not first have to familiarize himself with, and adjust to, the mental processes--different for every author--of the author of a scientific article; in other words, this fairly uniform structure of patent documents makes their reading, once one gets accustomed to it, generally easier.

6. Patent documents generally disclose *technological information* by describing the inventions in accordance with the requirements of the applicable patent law and by indicating the claimed novelty and inventiveness by reference to the existing state of the art. They are thus sources of information not only on what is new (the invention) but also on what is already known (the state of the art), and in many cases furnish a history, in summary form, of the technological progress in the field to which they relate.

7. Patent documents generally *cover most of what is new and most of what is worthwhile knowing* about technological progress; this is shown not only by the great number of patents but also by the fact that they cover every branch--big or small, relatively simple or sophisticated--of technology. Naturally, there are certain inventions, mainly in the field of arms and warfare, which *cannot be published* because their publication could be prejudicial to national security. But, on the whole, such inventions constitute a relatively small percentage of all the inventions made.

8. Patent documents generally *contain information which is not divulged in any other form of literature.* Thus it is wrong to consider that all relevant information contained in patent documents will come to one's notice by other means. A recent investigation effected by the U.S. Patent and Trademark Office shows that as much as 70% of the technology disclosed in U.S. patent documents from 1967 and 1972 has not been disclosed in the non-patent literature.*

9. Many patent documents *contain an abstract.* Abstracts allow a general idea of the contents of the document to be formed within a few minutes, and in any case in a much shorter time than would be required to read the full text of the patent document.

10. Patent documents *bear classification symbols.* For the purposes of maintaining search files and performing searches (e.g. in the state of the art), Industrial Property Offices *classify* patent documents according to the field or fields of technology to which their contents relate. A number of different national patent classification systems exist and one international system, the International Patent Classification (IPC), has been established by an intergovernmental agreement, and is now applied by at least 40 Industrial Property Offices. These systems allow retrieval of patent documents belonging to any given branch of technology.

11. The main part of the *high cost of processing and classifying patent documents* for building-up search files, and of keeping the classification system up to date, *is borne*

* "Chemical Technology", May 1978, pp. 272-276.

directly by the Industrial Property Offices which publish large numbers of patent documents. Other users have access to patent documentation without incurring, in addition to their costs as users, the cost of maintaining, developing and classifying their own patent documentation collections.

12. Patent documents belonging to a given classification subdivision *contain a highly concentrated supply of usually technically advanced information* on a given technological field.

13. Patent documents normally *disclose information on new inventions earlier than other sources of technological information.* In at least some of the countries in which applications are likely to be made for important inventions, the documents are published quickly (from three months after filing the application in the country to 18 months after the first application in any country). The public thus has access to the disclosures made in the applications within a reasonable space of time.

14. Patent documents *bear a date* from which conclusions can be drawn as to the age of the invention and to the question of whether the inventions they describe are still under legal protection. If they are no longer legally protected, they can be used without the consent of the patentee.

15. Patent documents generally *indicate the name and address of the applicant,* the patentee, and the inventor, or at least one or two of these persons. These indications allow any potential licensee to contact the persons concerned in order to find out under what conditions he may be authorized to exploit the invention.

16. Patent documents often disclose not only concepts concerning the general utility of the invention, but generally, also detailed information on the possibility of its *practical application in industry.*

17. Patent documents published in different countries and relating to the same invention (usually referred to as patent families) can be identified by the identity of mere formal bibliographic elements, the so-called "priority data". This quite often makes it possible for the user not only to select a document in the language most familiar to him, but also to draw some conclusions about the importance of an invention from the number of countries in which protection has been sought for it--protection which, by the way, is quite expensive sometimes.

18. Since the *technological information contained in patent documents is not secret,* it can be freely used to support research and development activities; if a given invention is not protected by a patent in the country of the user (it is obvious from the statistics that only a tiny minority of inventions is ever protected in the majority of developing countries), the said invention can even be put to industrial application in that country, although the results of that industrial application cannot be exported to another country where the invention is protected by a patent.

19. The above-mentioned specific characteristics of patent documents make them eminently useful sources of technological information, with some clear advantages over other sources of technological information. There are, however, a certain number of limitations to this usefulness, which are the following:

(a) new technology is not always sufficiently inventive to be patentable;

(b) even where a patent has been granted by an examining Office, this is not a guarantee that the invention is absolutely new. Furthermore, judging whether the invention will be economically desirable to exploit--particularly if the invention or the technical field to which it relates is a sophisticated one--requires great experience in the technical field concerned. Even highly specialized experts may make mistakes in the judgment thereof. It is clear that purely technological information as contained in patent documents often needs to be complemented by information of other sorts (commercial or economic for instance);

(c) although patent documents are generally written in a way which allows the invention to be executed on the basis thereof, it will frequently be necessary, in practice, to execute it with the cooperation of the inventor (for example, by acquiring his know-how under a contract concluded with him).

THE INTERNATIONAL PATENT CLASSIFICATION (IPC)

20. The IPC is based on an international multilateral treaty administered by the International Bureau of WIPO (the Strasbourg Agreement Concerning the International Patent Classification of 1971). This IPC subdivides technology into eight sections, 118 classes, 617 subclasses and over 54,000 groups (main groups and subgroups), each of which has a symbol. The symbol or symbols of the subdivision to which the technical invention described in any patent document belongs are usually *indicated on the patent document* by the Patent Office of the country where the application was filed. Thus, the document will be retrievable according to its subject matter with the help of the IPC.

21. The IPC has been elaborated in two authentic versions: English and French. Official translations of the complete text have been prepared in Chinese, Czech, German, Japanese, Polish, Portuguese, Russian and Spanish; a translation down to subclass level exists in Finnish.

22. The IPC is now applied by at least 40 Industrial Property Offices and one international organization which, taken together, issue about 90% of the patent documents of the world. By the end of 1979, some ten million patent documents had been provided with the classification symbols of the IPC. Approximately 3.4 million of them are in Japanese, 2.2 million in English, 1.5 million in French and 1.3 million in German. The rest are in various other languages.

23. An intergovernmental Committee of Experts, set up under the Strasbourg Agreement, keeps the IPC up to date by periodic revision, ensures its further development

and promotes its uniform application. The Committee of Experts, taking note of the fact that the IPC is a means for obtaining an internationally uniform classification of patent documents, has agreed that:

"(a) as the primary purpose, the IPC ought to be an effective search tool for the retrieval of relevant patent documents by Industrial Property Offices and other users to establish the novelty and evaluate the inventive step (including the assessment of technical advance and useful results or utility) of patent applications;

"(b) as other purposes (equally important to developing and developed countries) the IPC is to serve as:

(i) an instrument for the orderly arrangement of patent documents in order to facilitate access to the information contained therein;

(ii) the basis for selective dissemination of information to all users of patent information, and

(iii) a basis for the preparation of industrial property statistics which in turn permit the assessment of technological development in various areas."

24. Keeping the IPC up to date and allotting its symbols to new patent documents is one of the largest international efforts, at least in terms of expert manpower at international and national levels, in information and documentation work today. At the international level, an estimated 120 work-months per year, and at the national level, an estimated 240 work-months per year, are devoted to revising the IPC and adapting it to newly developing technologies and the needs of the users. The yearly effort to allot the IPC symbols to new patent documents is estimated at approximately 600 work-months (90,000 hours) of work by highly qualified Industrial Property Office staff. It should be emphasized that such new patent documents can, subject to a possible check of the classification allotted, be directly inserted into the appropriate place in a search file arranged according to the IPC.

Structure of the IPC

Layout and Symbolism

25. The IPC is divided into eight sections, each designated by a capital letter (section symbol), as follows:

Section A	HUMAN NECESSITIES
Section B	PERFORMING OPERATIONS; TRANSPORTING
Section C	CHEMISTRY AND METALLURGY

Section D	TEXTILES AND PAPER
Section E	FIXED CONSTRUCTIONS
Section F	MECHANICAL ENGINEERING; LIGHTING; HEATING; WEAPONS; BLASTING
Section G	PHYSICS
Section H	ELECTRICITY

26. Each section is subdivided into:

- classes, further divided into
- subclasses, which are further divided into
- groups (which can be either main groups or subgroups; subgroups forming subdivisions under main groups)

27. Each class symbol consists of the section symbol followed by a two-digit number:

Example: A 01

28. Each subclass symbol consists of the class symbol followed by a capital letter:

Example: A 01 B

29. Each group symbol consists of the subclass symbol followed by a number separated by an oblique stroke either as:

- *main group symbol*, which consists of the subclass symbol followed by a one to three digit number, the oblique stroke and the number 00:

  Example: A 01 B 1/00

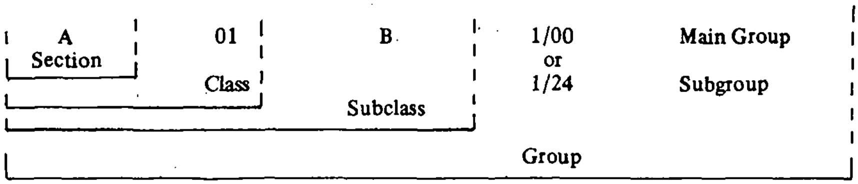
- Subgroup symbol, which consists of the subclass symbol followed by the one to three digit number of its main group, the oblique stroke and a number of at least two digits other than 00:

  Example: A 01 B 1/20

  Any third digit after the oblique stroke is to be read as a decimal subdivision of the second digit, e.g., "/215" is to be read as "twenty one point five," not "two hundred and fifteen."

30. A complete classification symbol comprises the combined symbols representing the section, class, subclass and main group or subgroup:

Example:



Hierarchical Structure

31. The hierarchy of the IPC is given by a differentiation of the entire technology into several levels, i.e., section, class, subclass, group and subgroup in descending order of hierarchy.

32. The hierarchy among groups is determined *solely* by the dots preceding the titles of subgroups. These dots are used in place of, and avoid repetition of, the titles of hierarchically directly superior groups:

Example: F 24 D 3/00		Hot-water central heating systems
3/04	.	with water under high pressure
3/06	. .	Arrangements or devices for maintaining high pressure.

Without the use of hierarchical levels, subgroup F 24 D 3/06 would have to have a title such as:

> "Arrangements or devices for maintaining high pressure in hot-water central heating systems with the water under high pressure."

As can be seen from Annex 2, further hierarchical subdivision may exist in certain fields.

33. In many cases, a class, subclass or group title is followed by a phrase in brackets referring to another place in the IPC. Such a phrase indicates that the subject matter identified by the phrase is classified in the place referred to (or in one or more places where several are referred to).

How to find the Relevant Subgroups of the IPC Concerned with Solar Energy and Its Applications

34. The aim of identifying basic technical information necessitates the carrying out of a so-called "informative search," which is made to familiarize the inquirer with the state of the art in a particular field of technology.

35. Before making a search, it is essential to establish clearly what is being sought, i.e., the technical subject has to be determined. Having formulated a clear statement of the technical subject which is being sought, the searcher has to identify the proper

place for this subject in the IPC. Although the IPC is a relatively logical subdivision of technology, it is advisable for the uninitiated searcher to approach the system by using the Catchword Index to the IPC, which has been elaborated in several languages, e.g., in English, French, German, Japanese and Spanish.

36. Consideration of the statement of the technical subject sought will bring to mind a word which covers broadly or specifically the field of technology with which this subject is clearly concerned. As most of the words in the Catchword Index are nouns, it is preferable to consider the name given to the relevant process or device, although it may be useful to consider other words. The Catchword Index may indicate to the searcher a precise group of the IPC as the proper place for the technical subject being sought, but often there can only be an indication of the subclass or possibly only the class or range of classes concerned.

37. A sample page of the Official Catchword Index appears in Annex I to this document and shows, for example, the catchword "SOLAR" with three subordinate entires with reference to specific places in the IPC. There are, of course, more classification units within the IPC containing technical solutions relevant to solar technology, but they are not specific for this application only and therefore do not have the word "solar" in their definition.

38. When trying to identify IPC units relevant to a given technical problem, one should also be aware of a certain dualism in its hierarchical structure of the IPC. In establishing a patent classification, two main approaches are traditionally distinguished, which are explained below.

39. Under one of the two approaches, inventions are classified according to the branches of industry, "art" or human activity to which they are characteristically relevant. This approach is usually termed "industry-oriented," "art-oriented" or "application-oriented." The former German patent classification, which had a certain influence on the IPC, had this approach.

40. Under the other approach, inventions are classified according to the function to which they are characteristically relevant. This approach is usually termed "function-oriented." The United States patent classification is of this nature.

41. The two approaches can hardly be applied in their theoretical purity. Some functions are so characteristically, if not exclusively, relevant to certain branches of industry that it is natural to classify them under such branches. For example, spinning, weaving and knitting mainly concern textiles and it is only natural to regard them as mainly relevant to the textile industry. And indeed, they appear in the International Patent Classification under Section D ("Textiles...").

42. On the other hand, in semiconductor technology the physical characteristics of the semiconductors concerned are determining both the technology applied for producing them and their possible application, the latter of which in most cases is a very widespread one. Therefore, semiconductor devices are mainly classified according to the physical

characteristics of the semiconductors, and all types of photovoltaic cells can be found in the groups belonging to IPC main groups:

H 01 L 31/00 "Semiconductor devices sensitive to infrared radiation, light, electromagentic radiation of shorter wavelenth, or corpuscular radiation and adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation; Processes or apparatus peculiar to the manufacture or treatment thereof of parts thereof; Details thereof" (see Annex 2)

whilst no specific entry like "photovoltaic cells for power generation" is to be found in the classification scheme.

43. It is clear, that in such cases a certain knowledge about the solution to be applied is needed before the relevant state of the art can be located. This and the obvious existence also of documents not referring to photovoltaic cells as such in the units referred to might be considered as a constraint. But one should not forget that a user searching in such parts of the classification not only finds solutions already applied for the use he is interested in, but also equivalent solutions having been used only in other fields of technology so far--which leads to potentially relevant material not being able to be retrieved otherwise.

44. The combination of both the application-oriented and the function-oriented approach in the IPC is the result of experience acquired by persons whose daily task consists of the comparison of inventions for which patent protection is claimed with similar inventions already disclosed in published patent documents. It is their judgment, based on such experience, which plays a decisive role in choosing, in each case, between the two approaches and in establishing the system.

45. If the use of the Catchword Index does not lead to a pertinent field of search, the "Contents of Section" (see Annex III to this document) appearing at the beginning of each section of the IPC should be consulted. The eight sections should be scanned and the possible classes should be selected. Thereafter, the searcher should turn to these classes in order to select the subclass (or subclasses) which most satisfactorily covers the subject. The references and notes appearing in the selected subclass title should be checked for an indication of subclass content and for possible distinctions between subclasses, which in turn may indicate that the location of the desired subject is elsewhere. It is also essential to consult any notes or references appearing in the title of the relevant class or section, since these may also affect the subclass content.

46. When the correct subclass has been identified, the main group which, in the light of its full title and any existing notes and references, most clearly includes the subject being sought should then be selected.

47. The most indented subgroup (i.e., having most dots), under the selected main group, which still covers the subject sought should be chosen for search.

48. After completing the search in a chosen group, it should be considered whether the higher level group (i.e., having fewer dots) under which it is indented should be searched, since a wider subject which includes the subject sought may be classified there.

49. Annex IV to this document shows an excerpt of the IPC where the whole of subclass F 03, relating to, *inter alia*, mechanical-power-producing mechanisms using solar energy appears, and Annex V shows photocopies of front pages of patent documents published by the United States of America (US Patents No. 4 089 323 and 3 994 435.

HOW TO RETRIEVE PATENT DOCUMENTS RELATING TO SOLAR ENERGY AND ITS APPLICATIONS

50. There are several ways to take cognizance of the enormous amount of technological information contained in patent documents, namely, the consultation of patent document collections organized according to the IPC or other (national) classification systems or the consultation of secondary sources of patent information, e.g., patent gazettes, patent abstract services, Selective Dissemination of Information (SDI) or international referral services which, in many cases, contain also references to patent documents.

51. In view of the enormous amount of patent documents published each year, the user will almost certainly like to restrict the number of patent documents which he is interested in reading to a strict minimum. It is, therefore, likely that he will first rely on a secondary information source for a first selection of relevant documents.

52. To illustrate the problem, one should note that about one million patent documents are published annually all over the world. A recent study made by the US Patent and Trademark Office identified 1,022 US patents on solar energy use granted and published during the 10 year period from 1969 to 1978 out of an overall total of about 700,000 US patents published in the same period.

Patent Gazettes

53. To assist users in identifying primary sources of patent information, most industrial property offices publish patent gazettes (also named official gazettes or official bulletins). These gazettes usually contain a certain number of indexes, e.g., by classification symbol, by name of application, etc., and contain entries consisting of bibliographic data relating to and marked also on the newly published patent documents. Some of these gazettes also contain abstracts of patent documents.

Abstract Services

54. As set forth above, many patent gazettes contain abstracts, as also do patent documents (see Annex V containing the first page of US Patent No. 4 089 323). There

are also many patent documents which are officially published in a given language but of which abstracts--that is, a description of their technological content in a few lines--are available in another language. For example, the Japanese Patent Office publishes since 1977 English abstracts of a substantial portion of its published unexamined patent applications, whilst Derwent Publications Limited, a private firm in London, publishes each year tens of thousands of abstracts in English of patent documents published in all kinds of languages, including Russian and Japanese.

International Referral Services

55. A truly international referral service for patent information came into existence in 1971. In that year, the International Patent Documentation Center (INPADOC) was created in Vienna by virtue of an Agreement between WIPO and the Republic of Austria. The said center stores, in a machine-readable data bank, the most important bibliographic data of each patent document, i.e., the title of the invention, its classification symbols, relevant dates, names and numbers. The said bibliographic data are either obtained from the Industrial Property Offices in machine-readable form or input by the Center on the basis of the announcements published in patent gazettes.

56. At present, bibliographic data pertaining to patent documents published by the following 47 countries are included on a current basis in the data bank of INPADOC: Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Cuba, Cyprus, Czechoslovakia, Denmark, Egypt, Finland, France, German Democratic Republic, Germany (Federal Republic of), Greece, Hungary, India, Ireland, Israel, Italy, Japan, Kenya, Luxembourg, Malawi, Monaco, Mongolia, Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Republic of Korea, Romania, South Africa, Soviet Union, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States of America, Yugoslavia, Zambia and Zimbabwe. The bibliographic data of the patent documents published by the European Patent Office (EPO) applications for European patents and the International Bureau of WIPO (international applications under the PCT) and the UK patents registered in Hong Kong are also recorded. The data bank is growing at a rate of 16,000 patent documents per week (more than 96% of the world total) and is the largest computerized data bank of bibliographic data relating to patent documents in the world.

57. INPADOC processes the bibliographic data and provides services to government authorities and the public. The data bank can be used for answering many kinds of questions, the two most important being the following: First, the data bank can be asked to identify all the patent documents belonging to any given group of the more than 54,000 groups of the IPC. Here lies of course the main usefulness of the Center in giving research and development centers, industry and other users access to the achievements of modern technology. Secondly, the data bank can provide all the patent documents which in the various countries have been filed for the same inventing by--usually, but not necessarily --the same person, company or enterprise. Thus, one can obtain information at a glance as to the likelihood of the invention being protected in various countries, and, which is of greater interest for the purpose of access to technological information, as to the

likelihood of the invention being described in different languages. INPADOC is also studying the possibility of using its services in the preparation of industrial property statistics.

58. To replace the burdensome scanning of various patent gazettes published by several countries, INPADOC publishes each week an international patent gazette: The INPADOC Patent Gazette (IPG). The IPG, which is published on microfiche, consists of three basic indexes, i.e., by number, by IPC symbol, and by standardized applicant's name, respectively, each containing reference to all patent documents stored in INPADOC's data bank in the previous week. Thus, users can follow easily and week by week the activity in any field of technology or of any given company, enterprise or applicant. Copies on paper of the three main indexes of the IPG and of both a cumulated IPC index ("Patent Classification Service" PCS) and applicants' index ("Patent Applicant Service" PAS) produced also by INPADOC in regular updating intervals are attached in Annex VI.

Access to the Primary Sources of Information

59. Each Industrial Property Office has a collection of the patent documents it has ever published. Each major Industrial Property Office also has complete, or almost complete, collections of patent documents published by the Industrial Property Offices of the other countries or at least most of them. These collections are either in numerical order or classified order or both. Some libraries have also more or less complete collections of domestic and foreign published patent documents. Members of the general public usually are allowed to consult such collections. In major Industrial Property Offices and major libraries, specialized staff is usually available to assist the public in locating published patent documents.

60. Industrial Property Offices and most libraries referred to above are usually equipped to furnish copies of published patent documents contained in their collections to anyone who wants them and pays the prescribed price. Unit prices, mostly independent of the number of pages of the patent document vary from library to library, in the order of US dollars 0.50 to US dollars 5.00. The average price per patent document, on standing order, is approximately US dollars 2.00.

61. It should be emphasized that the patent document collections available throughout the world are the result of broad free-of-charge exchange of currently issued patent documents among countries and, more especially, among the Patent Offices of those countries under bilateral and multilateral exchange agreements. The patent documents are exchanged in the form of paper copies or in microform. It is estimated that a total of more than 15 million copies of patent documents per year are exchanged in this way. Secondary sources of patent information in the form of patent gazettes are also exchanged free of charge on a broad basis. In order to promote national and regional infrastructures, WIPO has successfully developed and sponsored procurement and exchange of primary and secondary sources of patent information for developing countries.

State-of-the-Art Searches

62. WIPO's own activities in the field of patent information are not restricted to methodological, planning and coordination work but include also direct technical assistance, by providing, *free of charge*, to users in developing countries documentary search reports on the existing "state-of-the-art with regard to technical problems specified by the user, as reflected in patent office search files. The searches under the WIPO Program are carried out, on the basis of agreements concluded by WIPO with the national Industrial Property Offices of several industrialized countries, by competent specialists of those Offices. The cost of the search reports itself is financed outside the WIPO budget by voluntary contributions, whereas WIPO covers the necessary staff costs for the preparatory and monitoring work, those costs being about one third of the total costs of the program.

63. The search reports identify the key patents representing the different solutions known in the field according to a detailed search request drawn up by the user. Copies of the documents referred to in the search reports are provided with the report. Details of the search request and the intended use of its results are treated as confidential. About 40 search reports in the field of solar energy have been provided so far, which is about 5% of the total of search reports delivered under the program.

64. Interested users and institutions from developing countries may receive guidelines for the submission of search requests and corresponding request forms from the World Intellectual Property Organization, 34, chemin des Colombettes, CH 1211 Geneva, Switzerland. Preference is given to requests forwarded from countries out of the least developed ones in case of demands exceeding capacities available.

(Annexes I to VI follow)

References:

1. World Intellectual Property Organization (General Information). WIPO Publication No. 400CE)

2. The International Patent Classification, General Information Brochure. WIPO Publication No. 409.

3. The International Patent Classification, Third Edition, 1979, and the Official Catchword Index to the Third Edition (published by Carl Heymanns Verlag KG, Steinsdorfstrasse 10, Postfach 175, 8000 Munich 26, Federal Republic of Germany.)

4. Strasbourg Agreement Concerning the International Patent Classification of 1971, WIPO Publication No. 275.

5. World Patents Index; World Patents Abstracts (Derwent Publications Ltd., Rochdale House, 128 Theobalds road, London WC1X 8RP, United Kingdom).

6. Patent Profiles - Solar Energy. Office of Technology Assessment and Forecast, US Patent and Trademark Office, January 1980.

7. INPADOC, General Information, WIPO Publication No. 426 CEFG1

8. A Preliminary Study on an International Information system Relating to New and Renewable Sources of Energy. UNESCO document 21C/INF 10, October 8, 1980

9. WIPO State-of-the-Art Search Program. In: World Patent Information, vol. 2, No. 4 (1980) (in print.)

SNOW		
compacing – for traffic purposes	E01H	4/00
compositions for simulating – or ice	C09K	3/24
heating or blowing installations in roads for removing –	E01C	11/26
production of – artificially	F25C	3/04
removing – from electric lines or cables	H02G	7/16
removing – from railway or tramway tracks	E01H	8/00
removing – from roads	E01H	5/00
		6/00
– fences	E01F	7/02
– ploughs	E01H	5/00
		8/00
– shoes	A63C	13/00
– traps for roofs	E04D	13/10
SNUFF	A24B	13/00
cases for –	A24F	23/00
SNUFFERS	F23Q	25/00
SOAKING		
– bottles	B67C	1/00
– pits	C21D	9/70
cranes for –	B66C	17/12
SOAP	C11D	13/00
		15/00
casings or accessories for storing shaving –	A45D	40/00
		40/20
producing lather from shaving –	A45D	27/02
– bubble toys	A63H	33/28
– compositions	C11D	9/00
– graters	A47K	5/09
– holders or dispensers	A47K	5/00
– solutions	C11D	13/00
SOCKS		
– (= hosiery)	A41B	11/00
elastic –	A61F	13/08
– of footwear	A43B	17/00
suspenders for –	A41F	11/00
		13/00
SOCKET(S)		
electric –	H01R	
pipe –	F16L	21/00
– and-stud connections	F16B	21/00
for hand-tool handles	B25G	
– for poles or masts	E04H	12/12
for shanks or metal-cutting drills	B23B	31/04
SODA		
– water	A23L	2/00
SODIUM see also NON-FERROUS	C22B	26/10
carbonates, halides, nitrates, oxides, sulphates or sulphites of –	C01D	
– chloride	C01D	3/04
– hydroxide	C01D	1/04
other inorganic compounds of –	C01B	
	C01C	
	C01D	
	C01F	
	C01G	
SOFA(S)	A47C	17/00
– bases for mattresses	A47C	23/00
– convertible into beds	A47C	17/04
SOFTENING		
– fibres or fabrics	D06M	
– leather	C14B	1/40
– wood or similar materials	B27K	
SOIL		
agricultural – working	A01B	
pulverisers for agricultural – working	A01B	77/00
rollers for agricultural – working	A01C	29/00
shifting –	E02F	
– blocks for seedings	A01G	9/10
– conditioning and stabilizing compositions	C09K	17/00
– cultivation	A01G	31/00
– pans (= waste pans)	A47K	11/00
– sterilisation	A01G	11/00
	A01N	25/00 to 65/00
	C05	
	C09K	17/00
stabilising – for foundations	E02D	3/00
stabilising – for roads	E01C	3/04
		7/36
		21/00
SOLAR		
drying solid material by – radiation	F26B	3/28
using – energy	F03G	7/02
using – heat	F24J	3/02
SOLDERING		
making tubes with soldered seams	B21C	37/08
manufacture of – wire or – rods	B23K	35/40
soldered electric connections	H01R	4/02
– by using a mould	B22F	19/00

ANNEX II

29/50 . . carrying the current to be rectified, amplified, or switched and such electrodes being part of a semiconductor device which comprises three or more electrodes [2]

29/52 . . . characterised by their shapes, relative sizes, or dispositions [2]

29/54 . . . characterised by the materials of which they are formed [2]

29/56 . . . for surface barrier, e.g. Schottky barrier [2]

29/58 . . not carrying the current to be rectified, amplified, or switched and such electrodes being part of a semiconductor device which comprises three or more electrodes [2]

29/60 . . . characterised by their shapes, relative sizes, or dispositions [2]

29/62 . . . characterised by the material of which they are formed [2]

29/64 . . . for surface barrier, e.g. Schottky barrier [2]

29/66 . characterised by their operation [2]

29/68 . . controllable only by the electric current supplied, or the electric potential applied, to an electrode which does not carry the current to be rectified, amplified, or switched [2]

29/70 . . . Bipolar devices [2]

29/72 . . . . continuously controllable [2]

29/74 . . . . not continuously controllable, e.g. thyristors [2]

29/743 . . . . . Reverse blocking thyristors [2]

29/747 . . . . . Bidirectional thyristors [2]

29/76 . . . Unipolar devices, e.g. field-effect transistors [2]

29/78 . . . . with field effect produced by an insulated gate [2]

29/80 . . . . with field effect produced by a PN or other rectifying junction gate [2]

29/82 . . controllable only by variation of the magnetic field applied to the device [2]

29/84 . . controllable only by variation of applied mechanical force, e.g. of pressure [2]

29/86 . . non-controllable; controllable only by variation of the electric current supplied, or the electric potential applied, to one or more of the electrodes carrying the current to be rectified, amplified, oscillated, or switched [2]

29/88 . . . Tunnel diodes [2]

29/90 . . . Breakdown diodes, e.g. Zener diodes, avalanche diodes [2]

29/91 . . . Rectifier diodes [2]

29/92 . . . Capacitors with potential-jump barrier or surface barrier [2]

29/93 . . . . Variable-capacitance diodes, e.g. varactors [2]

29/94 . . . . Metal - insulator - semiconductors, e.g. MOS [2]

29/95 . . . . Ceramic barrier-layer capacitors (ceramic capacitors in general H 01 G) [2]

29/96 . . controllable by methods provided for in at least two of the groups 29/68, 29/82, 29/84, 29/86 [2]

31/00 **Semiconductor devices sensitive to infrared radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation; Processes or apparatus peculiar to the manufacture or treatment thereof or of parts thereof; Details thereof** (devices consisting of a plurality of solid state components formed in or on a common substrate, other than combinations of radiation-sensitive components with one or more electric light sources, 27/00; measurement of nuclear or X-radiation with semiconductor detectors G 01 T 1/24, with resistance detectors G 01 T 1/26; obtaining energy from radioactive sources G 21 H) [2]

31/02 . Details [2]

31/04 . adapted as conversion devices [2]

31/06 . . characterised by at least one potential-jump barrier or surface barrier [2]

31/08 . in which radiation controls flow of current through the device, e.g. photoresistors [2]

31/10 . . characterised by at least one potential-jump barrier or surface barrier, e.g. phototransistors [2]

31/12 . structurally associated with, e.g. formed in or on a common substrate with, one or more electric light sources, e.g. electroluminescent light sources, and electrically or optically coupled thereto (amplifiers using electroluminescent element and photocell H 03 F 17/00, electroluminescent light sources *per se* H 05 B 33/00) [2]

31/14 . . the light source or sources being controlled by the semiconductor device sensitive to radiation, e.g. image converters, image amplifiers, image storage devices [2]

31/16 . . the semiconductor device sensitive to radiation being controlled by the light source or sources [2]

31/18 . Processes or apparatus peculiar to the manufacture or treatment of these devices or of parts thereof (not peculiar thereto 21/00) [2]

33/00 **Semiconductor devices with at least one potential-jump barrier or surface barrier adapted for light emission, e.g. infra-red; Processes or apparatus peculiar to the manufacture or treatment thereof or of parts thereof; Details thereof** (semiconductor lasers with potential-jump barrier or surface barrier H 01 S 3/19; electroluminescent light sources *per se* H 05 B 33/00) [2]

35/00 **Thermoelectric devices comprising a junction of dissimilar materials, i. ex. exhibiting Seebeck or Peltier effect with or without other thermoelectric effects or thermomagnetic effects; Processes or apparatus peculiar to the manufacture or treatment thereof or of parts thereof; Details thereof** (devices consisting of a plurality of solid state components formed in or on a common substrate 27/00; refrigerating machines using electric or magnetic effects F 25 B 21/00; thermometers using thermoelectric or thermomagnetic elements G 01 K 7/00; obtaining energy from radioactive sources G 21 H) [2]

ANNEX III

SECTION F – MECHANICAL ENGINEERING; LIGHTING; HEATING; WEAPONS; BLASTING

CONTENTS OF SECTION
(references and notes omitted)

Sub-section: ENGINES AND PUMPS

Sub-section: WEAPONS; BLASTING

Sub-section: ENGINEERING IN GENERAL

ANNEX IV

1/00 **Wind motors with rotation axis substantially in wind direction (controlling 7/00)**

1/02 . having a plurality of rotors

1/04 . having stationary wind-guiding means, e.g. with shrouds or channels (1/02 takes precedence)

1/06 . Rotors

3/00 **Wind motors with rotation axis substantially at right angle to wind direction (controlling 7/00)**

3/02 . having a plurality of rotors

3/04 . having stationary wind-guiding means, e.g. with shrouds or channels (3/02 takes precedence)

3/06 . Rotors

5/00 **Other wind motors (controlling 7/00)**

5/02 . the wind-engaging parts being attached to endless chains or the like

5/04 . the wind-engaging parts being attached to carriages running on tracks or the like

5/06 . the wind-enging parts swinging to-and -fro and not rotating

7/00 **Controlling wind motors**

7/02 . the wind motors having rotation axis substantially in wind direction

7/04 . . Regulation, i.e. controlling automatically

7/06 . the wind motors having rotation axis substantially at right angle to wind direction

9/00 **Adaptations of wind motors for special use; Combinations of wind motors with apparatus driven thereby** (aspects predominantly concerning driven apparatus, *see* the relevant classes for such apparatus)

9/02 . the apparatus storing power

11/00 **Details, component parts, or accessories not provided for in, or of interest apart from, the preceding groups**

11/02 . Transmission of power, e.g. using hollow exhausting blades

11/04 . Mounting structures

F 03 G SPRING, WEIGHT, INERTIA, OR LIKE MOTORS; MECHANICAL-POWER-PRODUCING DEVICES OR MECHANISMS, NOT OTHERWISE PROVIDED FOR OR USING ENERGY SOURCES NOT OTHERWISE PROVIDED FOR

Note: In this sub-class, the term "motors" means mechanisms for producing mechanical power from potential energy of solid bodies.

1/00 **Spring motors** (spring-driven toys A 63 H; spring in general F 16 F; precision time mechanisms, e.g. for clocks or watches, G 04 B)

1/02 . characterised by shape or material of spring, e.g. helical, spiral, coil

1/04 . . using rubber springs

1/06 . Other parts or details

1/08 . . for winding

1/10 . . for producing output movement other than rotary, e.g. vibratory

3/00 **Other motors, e.g. gravity or inertia motors**

3/02 . using wheels with circumferentially-arranged compartments co-operating with solid falling bodies (3/04 takes precedence)

3/04 . driven by sand or like fluent solid material

3/06 . using pendulums

3/08 . using flywheels

5/00 **Devices for producing mechanical power from muscle energy** (driving cycles B 62 M)

5/02 . of endless-walk type, e.g. treadmills

5/04 . . Horsemills or the like

5/06 . other than of endless-walk type

5/08 . . for combined actuation by different limbs, e.g. hand and leg

7/00 **Mechanical-power-producing mechanisms, not otherwise provided for or using energy sources not otherwise provided for**

7/02 . using solar energy (solar boilers F 24)

7/04 . using pressure differences or thermal differences occurring in nature (7/06 takes precedence)

7/06 . using expansion or contraction of bodies due to heating, cooling, moistening, drying, or the like (using thermal expansion of non-vaporising liquids F 01 K)

7/08 . recovering energy derived from swinging, rolling, pitching, or like movements, e.g. from the vibrations of a machine

7/10 . Alleged *perpetua mobilia* (using hydrostatic thrust F 03 B 17/04)

ANNEX V

United States Patent [19] [11] 4,089,323

Trihey [45] May 16, 1978

[54] SOLAR TRACKING DEVICE

[75] Inventor: John Massey Trihey, Bayswater, Australia

[73] Assignee: Malz Nominees Pty. Ltd., Victoria, Australia

[21] Appl. No.: 704,674

[22] Filed: Jul. 12, 1976

[51] Int. Cl.[2] F24J 3/02
[52] U.S. Cl. 126/270; 126/271
[58] Field of Search ... 126/270, 271; 237/1 A; 353/3; 136/89 PC; 244/168

[56] References Cited

U.S. PATENT DOCUMENTS

2,141,330	12/1938	Abbot	126/271
2,712,772	7/1955	Trombe	353/3
2,999,943	9/1961	Geer	60/641 X
3,515,594	6/1970	Samuels	126/270 X
3,982,526	9/1976	Barak	126/270
4,022,185	5/1977	Von Hartitzsch .	126/271

Primary Examiner – William F. O'Dea
Assistant Examiner – Larry Jones
Attorney, Agent, or Firm – Cushman, Darby & Cushman

[57] ABSTRACT

Solar energy converting apparatus is disclosed which comprises:

(a) focussing means having a focal plane;

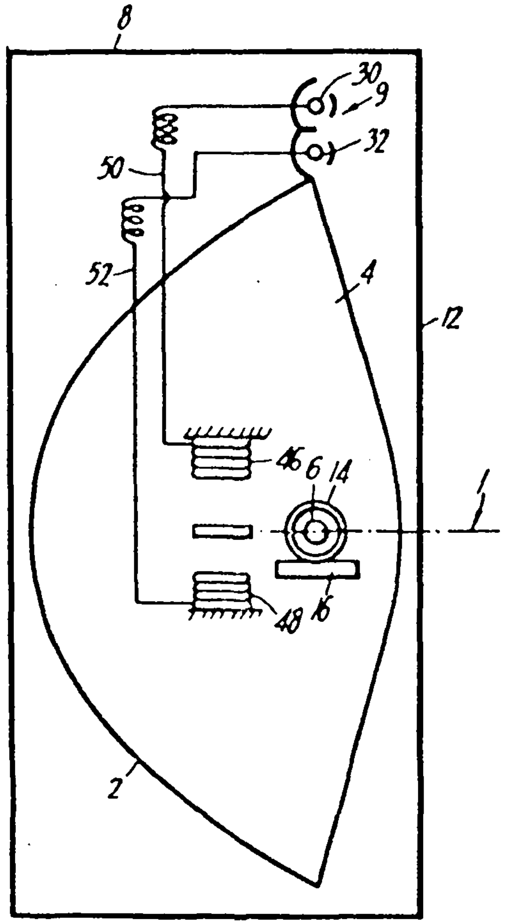
(b) solar energy absorbing means located along the focal line of the focussing means;

(c) a support structure including mounting means for rotating the focussing means about an axis which is co-incident with the focal line of the focussing means; and

(d) solar tracking means having an optical plane which is parallel to said focal. plane, said tracking means including two heat extensible members which are arranged to receive equal amounts of heat from solar energy when the optical plane is directed at the sun and to receive unequal amounts of heat from solar energy when the optical plane is not directed at the sun, said extensible members being coupled to act between the support structure and the focussing means to cause rotation of the focussing means in accordance with the heat received by respective extensible members.

Thus the energy required for tracking the sun is derived directly from the received solar energy.

12 Claims, 13 Drawing Figures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United States Patent [19] [11] **3,994,435**

Barr [45] **Nov. 30, 1976**

[54] SOLAR ENERGY CONCENTRATING AND COLLECTING ARRANGEMENT AND METHOD

[57] Inventor: Irwin R. Barr, Baltimore County, Md.

[73] Assignee: AAI Corporation, Cockeysville, Md.

[22] Filed: Aug. 20, 1974

[21] Appl. No.: 499,066

[52] U.S. Cl. .... 237/1 A; 60/641 126/271

[51] Int. Cl.^{2} F24J 3/02

[58] Field of Search .. 126/270, 271, 237/1 A; 60/641

[56] References Cited

UNITED STATES PATENTS

797,891	8/1905	Himalaya	126/270
913,051	2/1909	Pope	126/270 UX
2,791,214	5/1957	Poliansky	126/270
3,171,403	3/1965	Drescher	126/270
3,179,105	4/1965	Falbel	126/271
3,236,294	2/1966	Thomason	126/271 X
3,868,823	3/1975	Russell, Jr. et al	126/270

FOREIGN PATENTS OR APPLICATIONS

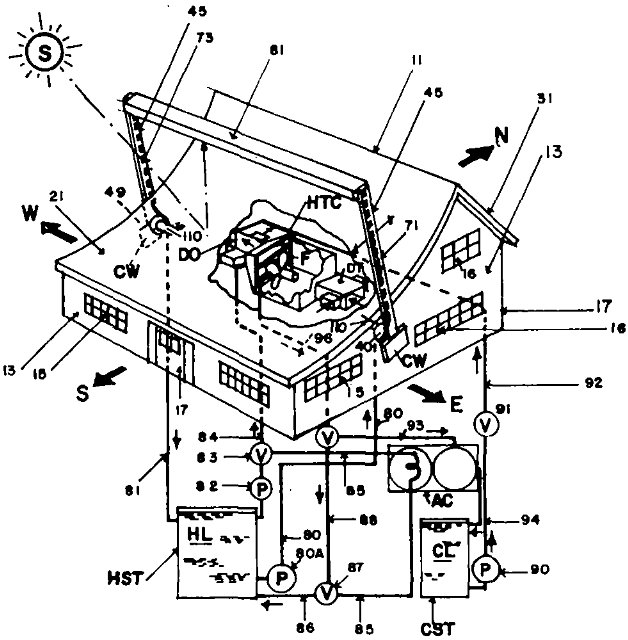
517,417	1/1931	Germany	126/170

Primary Examiner – William E. Wayner
Attorney, Agent, or Firm – Reginald F. Pippin, Jr.

[57] ABSTRACT

A solar energy concentrating and collecting arrangement and method in which a semi-cylindrical oblong concave reflector/concentrator forms the roof of a house, school or other building, particularly a heat utilization building. A collector is movably supported in spaced relation above and along the length of the oblong roof/reflector, for pivotal movement to a zone of maximum confluence of solar energy rays reflected from the roof reflector as a result of variations of sun path during the various parts of the year and also to further accommodate each day's movement of the sun. Movement of the collector is by pivotal movement about an axis parallel with the center of curvature or curvatures of the roof/reflector and disposed adjacent the roof/reflector. The roof/reflector has a plurality of radii forming respective semi-cylindrical arc segments, the smaller radius arc segment of which is inclined at a lesser angle to the vertical than an adjoining greater radius arc segment, for enabling accommodation of wide variations of the sun angles during the various seasons of the year and during each day of a given season, while still affording a desired concentration of solar energy on the collector. The concentrated solar energy collected by the collector is transferred to a fluid, such as water, passed along the length of collector, by a pump forming a part of a heat utilization system, which may include heating and/or cooling of the building and/or additional buildings or other structures. The roof/reflector is oriented with its center of curvature axes running East-West and with its surface tilted toward the Equator, the degree of tilt being dependent upon the latitude of the reflector.

82 Claims, 7 Drawing Figures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F24J 3/02					US 75-08-25 75	607568	US 78-10-31 A	4123002		
							US 78-12-12 A	4129120		
	US 80-05-06 A	4201190	F24J	3/02	US 76-08-21 78	935406			AKETEK, INC	SOLAR ENERGY COLLECTOR ASSEMBLY AND SUB-ASS EMBLIES THEREOF
	US 80-05-06 A	4201192	F24J	3/02	US 78-01-03 78	866545			JORDAN COLLEGE	SOLAR HEAT AIR SYSTEM
	US 08-05-06 A	4201194	F24J	3/02	US 78-01-06 78	867467			CHARLES, PAUL A S	SOLAR HEAT COLLECTOR WITH CHANNELED PANEL
	US 80-05-06 A	4201195	F24J	3/02	US 78-10-25 78	954727	DE 80-05-08 A1	2943159	THERMO ELECTRON CORP	JET IMPINGEMENT SOLAR COLLECTOR
			F24B	1/06			FR 80-05-23 A1	2439957		
			F24F	3/04						
	US 80-05-06 A	4201196	F24J	3/02	US 77-05-11 77	795855			ZANI, DAVID A	SOLAR ENERGY AIR HEAT-ING DEVICE
	US 80-05-06 A	4201197	F24J	3/02	US 78-03-02 78	888376			DISMER; RAYMOND H	SOLAR ENERGY COLLECTOR HAVING A FIBER-OPTICA-BLE
	US 80-05-13 A	4202319	F24J	3/02	DE 76-09-23 76	2642732	AU 79-03-29 A1	2903277	VINZ, SIEGFRIED	BUILDING ROOF WITH SOLAR COLLECTOR
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							BR 78-05-09 A	7706342		
							CA 80-05-13 A1	1077226		
							DE 78-03-30 A1	2642732		
							ES 78-12-16 A1	462562		
							ES 79-01-15 A5	462562		
							FR 78-04-21 A1	2365672		
							JP 78-04-22 A2	53045016		
							NL 78-03-29 A	7710405		
							NO 78-03-29 A	773238		
							SE 78-03-24 A	7710615		
							SU 79-10-30 D	695570		
	US 80-05-13 A	4202320	F24J	3/02	US 76-02-02 76	654407			AKETEK, INC	SOLAR ENERGY COLLECTOR ASSEMBLY
	US 80-05-13 A	4202321	F24J	3/02	US 78-05-30 78	910669			VOLNA, WILLIAM M	SOLAR TRACKING DEVICE
	US 80-05-13 A	4202322	F24J	3/02	US 77-05-11 77	795947			DEL MFG	SOLAR ENERGY COLLECTOR AND HEAT EXCHANGER
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			F28F	3/14						
	US 80-05-20 A	4203422	F24J	3/02	US 78-02-08 78	876022			BOTTUM, EDWARD W	SOLAR HEATING SYSTEM AND COMPONENT
	US 80-05-20 A	4203424	F24J	3/02	US 78-01-03 78	866546			JORDAN COLLEGE	SOLAR HEAT AIR SYSTEM
	US 80-05-20 A	4203425	F24J	3/02	US 78-07-31 78	929117			CLARK, DANA A	INFLATABLE SOLAR COLLE-CTOR
	US 80-05-20 A	4203426	F24J	3/02	US 78-08-11 78	933097			MATLOCK, PATRICIA	SOLAR ENERGY CONVERTER CAROUSEL MOUNTED RAC

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APPLICANT	CC PUB++DAT KD	DOC.NO CC PR.++DAT	PRIORITY NO.	I P C	EQUIVALENCES	(PUB.BL)	TITLE
VILLETTE ROGER	FR 80-05-23 A1	2439923		B60P 3/22	CH 80-05-14 R1	11045	
					DE 80-05-14 R1	11045	
					EP 80-05-14 A1	11045	
					GB 80-05-14 R1	11045	
					IT 80-05-14 R1	11045	
					NL 80-05-14 R1	11045	
					SE 80-05-14 R1	11045	
VILNYUSSKIJ ZAVOD SVERL	SU 80-06-05 T	738773 SU 77-12-26 77	2559500	B23B 3/30			AUTOMATIC MACHINE FOR
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VIMBA	US 80-05-13 A	4202174 US 78-05-16 78	906621	F15B 1/02			HYDRAULIC DRIVE
VIN LENYA R	SU 80-05-30 T	737096 SU 77-11-28 77	2548242	B22C 1/22			BINDER FOR MAKING SHELL MOULDS AND CORES BY HEATABLE PATTERN-CORE TOOLING AND METHOD OF ITS PRODUCTION
VINNIKOV NIKOLAJ M	SU 80-05-30 T	737649 SU 73-05-10 73	1915451	F04C 5/00			SINGLE-SCREW PUMPING UNIT
VINNITSKIJ POLT INST	SU 80-05-30 T	737861 SU 78-01-23 78	2572394	G01R 25/00			PHASE METER
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VINOKURSKIJ ARKADIJ L	SU 80-06-05 T	739316 SU 77-08-22 77	2521812	F25J 3/04			METHOD OF SEGREGATING AIR
VINTHER K	WO 80-04-17 A1	8000737 DK 78-10-04 78	4391	F16B 35/00	DK 80-04-05 A	439178	EXPANSION ELEMENT
				F16D 41/00			
				F16D 65/00			
				F16H 35/00			
				B23C 5/00			
				B23G 5/08			
				B25B 13/46			
				E21D 21/00			
VINYLE SA STE ARTESIENNE	FR 80-04-18 A1	2436927 FR 78-09-21 78	7827036	F16K 49/00	BE 80-04-02 R1	9441	VANNE DE VIDANGE ET PROC
				C08F 2/18	CH 80-04-02 R1	9441	EDE D'UTILISATION D'UNE
				C08F 14/06	DE 80-04-02 R1	9441	VANNE DE VICANGE
					EP 80-04-02 A1	9441	
					GB 80-04-02 R1	9441	
					IT 80-04-02 R1	9441	
					NL 80-04-02 R1	9441	
VINZ SIEGFRIED	US 80-05-13 A	4202319 DE 76-09-23 76	2642732	F24J 3/02	AU 79-03-29 A1	2903277	BUILDING ROOF WITH SOLAR
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					ES 78-12-16 A1	462562	
					ES 79-01-15 A5	462562	
					FR 78-04-21 A1	2365672	
					JP 78-04-22 A2	53045016	
					NL 78-03-29 A	7710405	
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					SE 78-03-24 A	7710615	

CC	DOC.NO	KD	PUB++DAT	CC	PR.++DAT	KP	PRIORITY NO.	EQUIVALENCES (PUB.BL)	IPC	APPLICANT	INVENTOR	TITLE
US										A	A	ONS
US										KOKINA, LIDIA S	KOMINA, LIDIA S	
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US	4202315	A	80-05-13	US	78-03-20	A	78	888121	F02B 53/00	LUTRAT, JACQUES	LUTRAT, JACQUES	SINGLE CYCLE ROTARY
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US	4202316	A	80-05-13	US	78-07-03	A	78	921314	F41B 5/00	BARNA, ALEX J	BARNA, ALEX J	COMPOUND BOW
US	4202317	A	80-05-13	US	78-03-31	A	78	892208	B24B 53/02	KUSHIGIAN, ANTHONY	KUSHIGIAN, ANTHONY	GRINDING WHEEL
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US								DE 78-03-30 A1 2642732				
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US								ES 79-01-15 A5 462562				
US								FR 78-04-21 A1 2365672				
US								JP 78-04-22 A2 53045016				
US								NL 78-03-29 A 7710405				
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US								SE 78-03-24 A 7710615				
US								SU 79-10-30 D 695570				
US	4202320	A	80-05-13	US	77-10-31	A	77	847250	F24J 3/02	AMETEK, INC	BOWEN, JOHN C	SOLAR ENERGY COL-
US				US	76-02-02	A2	76	654407				LECTOR ASSEMBLY
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US											M RIISE, HAROLD N	LECTOR AND HEAT
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US	4202323	A	80-05-13	US	78-04-28	A	78	900897	A61K 29/00	HERZ, MATTHEW L	HERZ, MATTHEW L	DRUG ACTIVATION BY
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US										WILLIAM	WILLIAM	
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						FR	75-10-28	A	75	7532921	RISATION RECHE	DITIONING INSTALLATIONS
						FR	76-06-30	A	76	7619960	RCHE	
US	80-04-22	A	4198953	F24J	3/02	US	78-03-28	A	78	891149	TERRA TEK INC	SOLAR ILLUMINATED ENERGY CONSERVING GREENHOUSE
US	80-04-22	A	4198954	F24J	3/02	NL	77-02-21	A	77	7701812	U S PHILIPS CORP	SORLAR COLLECTOR, COMPRISING SOLAR TRACKING MEANS
US	80-04-22	A	4198955	F24J	3/02	US	77-11-10	A2	77	850154	CANADIAN SUN SYSTEMS LTD	SOLAR ENERGY COLLECTION SYSTEM
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						GB	76-11-15	A	76	47564		
US	80-04-22	A	4198956	F24J	3/02	US	77-11-01	A	77	847567	JOE SIMPKINS	MULTI-PURPOSE SOLAR ENERGY COLLECTOR
US	80-04-22	A	4199406	C02B	1/04	US	75-10-28	A3	75	625850	DIGGS, RICHARD E	APPARATUS FOR DESALINATING WATER
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				F24J	3/02							
US	80-04-29	A	4200152	E21B	43/26	US	79-01-12	A	79	3122	FOSTOR, JOHN W; JONES, CLARENCE R	METHOD FOR ENHANCING SIMULTANEOUS FRACTURING IN THE CREATION OF A GEOTHERMAL RESERVOIR
				F24J	3/02							
				F28D	21/00							
US	80-05-06	A	4201188	F24J	3/02	US	78-05-04	A	78	902857	EXXON RESEARCH AND ENGINEERING	SOLAR COLLECTOR AND HEAT TRAP
US	80-05-06	A	4201189	F24J	3/02	US	77-05-09	A1	77	795101	SAUNDERS, NORMAN B	CURTAIN ASSEMBLY
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						US	75-08-25	A3	75	607568		
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US	80-05-06	A	4201192	F24J	3/02	US	78-01-03	A	78	866545	JORDAN COLLEGE	SOLAR HEAT AIR SYSTEM
US	80-05-06	A	4201193	F24J	3/02	+ FR	77-03-18	A	77	7708152	ELF UNION	SOLAR ENERGY ABSORBING ROOF
US	80-05-06	A	4201194	F24J	3/02	US	78-01-06	A	78	867467	CHARLES, PAUL A S	SOLAR HEAT COLLECTOR WITH CHANNELED PANEL
US	80-05-06	A	4201195	F24J	3/02	US	78-10-25	A	78	954727	THERMO ELECTRON CORP	JET IMPINGEMENT SOLAR COLLECTOR
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				F24F	3/04							
US	80-05-06	A	4201196	F24J	3/02	US	77-05-11	A2	77	795855	ZANI, DAVID A	SOLAR ENERGY AIR HEATING DEVICE
US	80-05-06	A	4201197	F24J	3/02	US	78-03-20	A	78	888376	DISMER, RAYMOND H	SOLAR ENERGY COLLECTOR HAVING A FIBER-OPTIC CABLE
+ US	80-05-13	A	4202319	F24J	3/02	DE	76-09-23	A	76	2642732	VINZ, SIEGFRIED	BUILDING ROOF WITH SOLAR COLLECTOR
US	80-05-13	A	4202320	F24J	3/02	US	76-02-02	A2	76	654407	AKETEK, INC	SOLAR ENERGY COLLECTOR ASSEMBLY
US	80-05-13	A	4202321	F24J	3/02	US	78-05-30	A	78	910669	VOLNA, WILLIAM M	SOLAR TRACKING DEVICE
US	80-05-13	A	4202322	F24J	3/02	US	77-05-11	A	77	795947	DEL MFG	SOLAR ENERGY COLLECTOR AND HEAT EXCHANGER
US	80-05-20	A	4203419	F24J	3/02	US	76-01-07	A1	76	647126	HONEYWELL INC	SOLAR CELL
US	80-05-20	A	4203420	F24J	3/02	US	77-11-25	A	77	854667	SCHOENFELDER, JAMES L	PORTABLE SOLAR HEAT TUBE
US	80-05-20	A	4203421	F24J	3/02	US	77-09-08	A	77	831423	BENCIC, DAVID M	SOLAR HEAT COLLECTOR
				F28F	3/14							
US	80-05-20	A	4203422	F24J	3/02	US	78-02-08	A	76	876022	BOTTUM, EDWARD M	SOLAR HEATING SYSTEM AND COMPONENT

APPLICANT	CC	PUB++DAT	KD	DOC.NO	CC	PR.++DAT	PRIORITY NO.	I P C	INVENTOR	TITLE
MOBIL OIL	NO	80-03-03	B	142017					SEXTON, JAMES HOWARD,	ERASJONER I BOREPULL
	NO	80-06-11	C	142017	US US	72-07-18 72 72-07-18 72	272819 272838	G08C 23/00 E21B 47/00	HARRELL, JOHN WOODROW PATTON, BOBBIE JOE, SEXTON, JAMES HOWARD,	FREMGANGSMAATE TIL OG AN LEGG FOR STYRING FRA JO RDOVERFLATEN AV MAALEOP ERASJONER I BOREPULL
MOBIL OIL AG IN DEUTSCHLAN	DE	80-08-07	A1	2903537	DE	79-01-31 79	2903537	C10M 3/40 C10M 3/26	HUEBNER, JUERGEN, DR. , 2000 HAMBURG	SCHWER ENTFLAMMBARE FLUE SSIGKEIT
MOBIL TYCO SOLAR ENERGY CO	IL	80-05-30	A0	59341	US	79-03-12 79	19473			BELT-ROLLER CRYSTAL PULL ING MECHANISM
	CA	80-06-17	A1	1079612	US	77-01-24 77	761949	B01J 17/00	JEWETT, DAVID N.	METHOD AND APPARATUS FOR REDUCING RESIDUAL STRE SSES IN CRYSTALS
	AU	79-11-01	A1	44871/79	US	78-04-24 78	899497	B01J 17/06	VERNON E. WHITE, JR.	CRYSTAL GROWING CAPILLAR Y DIE
	AU	79-10-25	B2	504739	US	77-01-24 77	761949	B01J 17/18 eeeeeee/eee	D.N. JEWETT	CRYSTAL PULLING CARTRIDG E WITH INCORPORATED ANN EALING DEVICE
	AU	80-05-08	B2	509354	US	77-01-24 77	761941	B01J 17/18 F27B 14/06	B.H. MACKINTOSH D.N. JEWETT	MULTI-COMPONENT CRYSTAL PULLING CARTRIDGE AND F URNACE
	DE	80-07-24	A1	3001259	US	79-01-15 79	3278	B01J 17/18	SACHS, EMANUAL, WATER TOWN, MASS. (V.ST.A.)	VERFAHREN, SYSTEM UND VO RRICHTUNG ZUR UEBERWACH UNG UND GEGEBENENFALLS STEUERUNG DES ZIEHWACHS TUMS EINES KRISTALLKOER PERS AUS DER SCHMELZE
	DE	80-08-21	A1	3005049	US	79-02-12 79	11527	B01J 17/18	KALEJS, JURIS P., WEL LESLEY CHALMERS, BRUCE, FAL MOUTH MASS. SUREK, THOMAS, ENGLE WOOD, CCL. (V.ST.A.)	VERFAHREN ZUM ZIEHEN EIN ES KRISTALLKOERPERS AUS EUBER SCGNEKZE, INSBES ONDERE FUER DIE HERSTEL LUNG VON SOLARZELLEN, S OWIE KAPILLAR-FORMGEBUN GSTELL HIERFUER
	US	80-01-22	A	4184907	US	77-03-17 77	778589	B01J 17/18	YATES, DOUGLAS A	CONTROL OF CAPILLARY DIE SHAPED CRYSTAL GROWTH OF SILICON AND GERMANIU M CRYSTALS
	US	80-01-22	A	4185076	US	77-03-17 77	778577	B01J 17/18	HATCH, ARTHUR E YATES, DOUGLAS A	APPARATUS FOR CONTROLLED GROWTH OF SILICON AND GERMANIUM CRYSTAL RIBBO NS
	FR	79-11-23	A1	2424060	US	78-04-24 78	899497	B01J 17/20		FILIERE CAPILLAIRE POUR FORMER DES CORPS CRISTA LLINS PAR CROISSANCE
	IL	79-09-03	A0	56786	US	78-04-24 78	899497	B01J 17/20 +		APPARATUS FOR GROWING CR YSTALLINE BODIES
	FR	80-08-08	A1	2446333	US	79-01-15 79	3278	C30B 15/22 C30B 35/00		
	NL	80-08-14	A	8000851	US	79-02-12 79	11527	C30B 15/24		WERKWIJZE EN INRICHTING ON KRISTALLEN TE VERVAA

V. COUNTRY REVIEWS

SOLAR ENERGY RESEARCH AND DEVELOPMENT IN AUSTRALIA

by

W. BRAZIER

The attendance of delegates from Australia to this Symposium on Solar Science and Technology indicates the awareness of Australians that they are a part of the region. In areas of alternative energy (particularly solar) research, government policy promotes co-operation with other nations.

Australia is approximately 60% self sufficient in oil, has large reserves of coal and uranium and so is fortunate in terms of energy reserves. However, recognizing the finite nature of fossil fuels and the environmental and social problems associated with uranium, there is a growing awareness of the need to further research and development in the field of solar energy.

As most of Australia lies in the Sunshine Belt referred to previously, the potential for development of solar technology is obvious. The following is a list of the areas in which solar research and development is being undertaken. The list is not comprehensive.

1. Passive heating and cooling of buildings (Architectural aspects)
2. Active heating and cooling of buildings (L_iB_r systems, heat pump systems)
3. Collector material research (carried out at NSWIT, Sydney and CSIRO, Melbourne)
4. Solar-thermal systems for industrial process pre-heating
5. Salt production (some discussion on using solar ponds as an additional heat source)
6. Electricity generation for remote areas

   a. individual systems *solar thermal* — high temp (e.g.) using "omnium-G" system / low temp (e.g.) Routine cycle

      photovoltaic e.g. Concentrating systems

   b. small town systems (*solar chemical* e.g. NH_x-H_o-N_2 system proposed for white cliffs in New South Wales)

      (*powertower.* A system is proposed for a tourist village at Ayros Rock)

7. *Telecommunications - photovoltaic systems*
(recognize that as efficiency a cost of cells arrays is improving, so the power requirement of telecommunication equipment is decreasing)

   Use of this technology is well established

8. Solar Pond research. There new exists in Australia an informal group to share expertise in solar pond technology. A government grant for a large solar pond at Alice Springs is being negotiated. The State Electricity Commission of Queensland is hopeful of producing a 150 kW size generator using a solar pond and is currently proceding with a feasibility study.

9. Solar chemical. Some work is being undertaken on a liquid electrolute Gallium Arsenide solar cell.

10. Swimming pool heating. There is a well developed industry in solar-heating of swimming pools, in both large and small sizes.

11. Hot water heating. This is an accepted industry with approximately 80,000 units mainly based on selective surface flatplate collectors in service.

Funding.

Although funds are made available for selected research and development projects, there is still some difficulty in convincing government funding bodies of the level of funding needed and the promotional incentives useful in continuing research, development and application of the technology. Incentives that are available include the freedom from import duty of apparatus actually used for solar energy applications such as collectors, photovoltaic cells etc; and government assistance and promotion in export of solar technology and apparatus to other countries.

Awareness.

I do not believe that solar scientists and technologists in Australia have been successful in convincing government agencies responsible for energy policy of the directions in which development of solar technology (and energy technology in general) should proceed for the good of the country, and the world in general. An example would be the tendency to overlook the possible benefit of solar produced hydrogen for high energy density fuel.

Standards.

The Commonwealth Scientific and Industrial Research Organization (CSIRO) has for some time been active in the area of testing solar collectors and hot water systems. The University of Queensland is entering the above field, in that a Central Solar Test Facility has been established on campus to enable solar hot water systems and solar collectors to be tested, and results compared with the manufacturers' specifications.

The facility also enables solar research and demonstration activities to be undertaken in an environment where sophisticated instrumentation and data analysis are available.

Concluding Statement

Scientific minds recognize that the current availability of fossil fuel represents a very small time component on the time scale of energy usage. The problem is to convince governments and the general public of the need for energy conservation and development of renewable energy (in particular solar) sources.

SOLAR ENERGY RESEARCH AND APPLICATION IN CHINA

by

GONG BAO and LIN AN ZHONG

With a surface area of 9.6 million square kilometres, China has abundant solar energy resources.

Two thirds of China has bright sunshine for a minimum of 2,000 hours in a year and in western and northwestern China, the figure is closer to 2,500 hours. The semi-arid Xinjiang Autonomous Region receives 3,200 hours per year.

China began to tap solar energy at the end of the '50s. In the beginning, attention was mainly focused on developing solar cookers. In recent years, a dozen or so provinces and municipalities, have built solar collectors and solar cells, and are using the heat from the sun for distillation and power generation.

In Beijing alone, which lies 40° north and receives a total of 2,700 hours of sunshine a year, there are more than 30,000 square metres of flat plate solar collectors in service. Most of these collectors are of the tube and sheet type. The hot water systems take advantage of the natural circulation.

One barbershop in Beijing has installed a 40-square-metre solar collector on its roof to supply hot water. Between April and October the water temperature sometimes reaches as high as 60° C. In addition to supplying water for hair washing, the collector provides enough hot water for the 30 staff members to have hot baths when they want.

Altogether, 23 other barbershops, six hotels, six public bath-houses, four restaurants and one laundry-and-dye shop have also installed similar collectors in Beijing.

To standardize methods for rating solar collectors in terms of their thermal performance and design, tests on the existing solar collectors of all kinds are being conducted by the Beijing Solar Energy Research Institute, the Shanghai Mechanical Institute and Tianjin University.

A solar energy research group in Qinghua University is now engaged in developing vacuum-glass-tube solar collectors. At present, China has succeeded in producing highly-effective selective coatings and some vacuum-glass tubes.

To raise the water temperature in solar collectors, the Beijing Solar Energy Research Institute and the Shanghai Silicate Institute is now conducting research into spectrum-selective coatings.

Solar air driers for heating and drying purposes are now being developed in some solar energy centres throughout the country. A medium-sized solar grain drier has been tried out. Installed in a grain storehouse, it can dry more than three tons of grain in an hour and is effective in killing insects.

Solar cookers, both of the box-type and the focus-type, are currently being used on a trial basis in the countryside. To reduce the costs of the solar cookers (now around US$30 each), researchers are concentrating on trying to develop cheaper reflective materials.

Large-sized solar cookers with 5-metre diameter parabolic concentrators have also been trial-produced. The steam produced in this type of cooker can both cook meals and provide boiled drinking water for 100 people.

In Gansu province, northwest China, a 30-square-metre passive solar house and a 35-square-metre active solar house were built in 1977 and 1978 respectively. At present, tests are being made to determine the effectiveness and economic viability of these projects.

In Xining city, capital of northwest China's Qinghai province, a five-storey office-building with a floor space of 3,000 square metres has been built, in which 700 square metres of floor space are used for an experimental solar space heating unit "powered" by solar energy. Last year it saved 80 per cent of the fuel normally used for heating during the winter months.

Absorption refrigerators and solar cooling facilities are being trial-produced in Tianjin University and some other research institutes.

An experimental research project on solar distillation is being conducted. A solar-powered desalination installation has been set up on an island in the South China Sea. At present it can produce one ton of fresh water per day by distilling sea water.

Since 1976, researchers in Haian county, Jiangsu province, have succeeded in producing solar welding devices. A single parabolic glass mirror of 2.5 metres diameter is used to focus the sun's rays onto the focal dot and achieve a temperature of about 1,800 °C. At this temperature, it takes about three minutes to weld a cutting tool of lathe.

Research into the generation of electricity from sunlight has also been carried out in China.

An experimental one-kilowatt simulated solar thermal power installation was built at the Shanhai Mechanical Institute in 1976. It consists of two solar collectors-- an 80-square-metre flat plate collector and a 44-square-metre cylindrical parabolic focusing collector. The hot water temperature can reach as high as 87°C. And its electric power is 850 watts.

Tianjin University has made a plan to set up a tower-type solar power installation to generate one kilowatt of electricity. The system will use 60 heliostats to focus the sun's rays.

China has been conducting research on silicon solar cells for about 20 years, and today there are some factories and workshops. The efficiency of the silicon cells has reached 10 per cent and it has raised to 15 per cent in laboratory tests.

Apart from being installed on China's satellites, the silicon cells are now used for lighting installation, communication and meteorological observation in remote mountain areas where electricity is not available.

The beacon on the lighthouse in Shanghai Harbour, is now equipped with silicon cells instead of batteries and the beacon can be seen from a distance of 14 nautical miles. Its capacity is such that a month of cloudy, rainy weather will not significantly affect its operating efficiency. At present, all the navigation signals in the East China Sea and Bohai Sea are equipped with silicon solar cells. The highest power attained is 280 watts.

However, due to its high costs (US$80-100 per watt), silicon cells is not in wide use. Research work to reduce its cost is being carried out in some institutes.

Some Research Institute have begun research on the CdS (Cadmium Sulphur) solar cells. The efficiency of the CdS solar cells has now reached five to eight per cent. Research works on policrystal and amorphous silicon solar cell are started but still in the early status.

Two national solar energy conferences were held in Shanghai and Henan province in 1974 and 1975. A national solar cell meeting was held in Shanhai in 1976, and a national solar energy work meeting in Dacin county, Beijing in 1973.

Following these conferences, institutions specialising in solar energy research have come into existence and the China Solar Energy Society was founded in September 1979. Another national solar energy conference was convened about the same time in Xian, capital of northwest China's Shaanxi province, to discuss the best ways of promoting research work on solar energy. During this conference, there was a large solar energy exhibition from many of the provinces of China, and also exhibits from United States of America and Federal Republic of Germany.

The Chinese government pays more attention to developing the solar energy technologies and encourages the solar energy utilization than ever. We believe, through the scientific exchange and cooperation among the scientists around the world, the application of solar energy will be more popular in near future.

RENEWABLE ENERGIES SOLAR ENERGY DEVELOPMENT IN FRANCE AND POLICIES

by

MAX CLEMOT

France is importing about 70% of its total energy consumption (particularly oil import). The total energy consumption in 1980 is estimated to be about 190 Mtpe (190 x 10^6 tons petroleum equivalent) with:

Coal	15%
Petroleum	58%
Gas	13%
Hydro	7%
Nuclear	7%
Renewable energies	0.2%

It is planned to be about 300 Mtpe in 2000 (Table 1) with:

Coal	10%
Petroleum	33%
Gas	15%
Hydro	6%
Nuclear	33%
Renewable energies	5%

To decrease oil imports, the french energy policy consists efforts for energy saving, implementation of an important nuclear programme and developing renewable energies. To achieve this objective, a National Agency for energy savings and conservation and a National Agency for Solar Energy were created with incentives.

France was active at the individual and at Research level in Solar Energy for more than 30 years. The National Agency for Solar Energy or Commissariat de l'Energie Solaire known as COMES was established in March 1978 and as it is a government agency, it has full authority on the National Solar Energy Programme.

"COMES" coordinates the activities of the many existing national laboratories engaged in solar research development or demonstrations(R&D), such as: the National Center for Scientific Research (CNRS), the Atomic Energy Commission (CES), the Scientific and Technical Center for Building (CSTB), the National Institute for Agronomy (INRA) (Table 2).

These teams represent *a community of over 500 scientists* and technicians.

"COMES" receives budgetary appropriations (about 120 MFF in 1980) for incentive grants: public as well as private institutions or industries, or even individuals, are eligible for subsidies.

Table 1: CONTRIBUTION OF SOLAR ENERGY TO ENERGY CONSUMPTION IN FRANCE (YEAR 2000) (ESTIMATE)

WATER HEATING AND SPACE HEATING	BETWEEN	4 AND 5 M TPE
INDUSTRIAL HEAT		0.25
UTILIZATION OF AGRICULTURAL WASTE AND SPECIFIC CULTURES	BETWEEN	3 AND 5
ENERGY PRODUCTION FROM WOOD	BETWEEN	6 AND 8
SOLAR ELECTRICITY		0.25
	BETWEEN	13 AND 16 M TPE

WHICH MEANS 5% OF FRENCH NEEDS ESTIMATED AT 300 M TPE

The wide financial autonomy which has been granted to "COMES" makes it possible to offer the most appropriate solution to each programme. For instance, "COMES" can:

be the operator of a project,
subcontract it, with a 100% financial coverage,
submit R&D requests for proposal (generally on a shared cost basis),
subsidize local authorities or individuals for demonstration purposes,
purchase solar equipment or components,
support the solar industry through grants or loans,
enter in joint-ventures with private or public corporations.

The budget allocated to solar energy development and uses is shared as follows for the fiscal year 1981:

Photovoltaics	31%
Solar heating and cooling	40%
Biomass	12%
Power stations	16%
Wind energy	1%

The government effort for this fiscal year will be about US$125 million, including industry effort, the french effort is estimated to be nearly US$190 million.

Corresponding to a figure of ≃ US$3.5/capita

Table 2.: SOLAR NATIONAL AGENCY POLICY

WHAT IS COMES?	AN INTER-DEPARTMENT COORDINATING AGENCY
POLITICAL DECISION (concerning solar energy policy)	MINISTERIAL DEPARTMENTS (INDUSTRY, ENVIRONMENT, AGRICULTURE, HIGHER EDUCATION, FOREIGN AFFAIRS, COOPERATION . . .) Foreign aid
	COMES
COORDINATION	- BUDGET - PROGRAMME MANAGEMENT (R+D, APPLICATIONS) - INTERNATIONAL COOPERATION - INFORMATION, PROMOTION, EDUCATION
OPERATORS	R + D : UNIVERSITIES : CNRS (NATIONAL CENTER FOR SCIENTIFIC RESEARCH) : INRA (NATIONAL INSTITUTE FOR AGRO RESEARCH) : CEA (ATOMIC ENERGY AUTHORITY) : EDF (NATIONAL ELECTRICITY BOARD) : PLAN CONTRUCTION (HOUSING + CONSTRUCTION BOARD)
	INDUSTRY: MORE THAN 80 FIRMS, PRIVATE, SEMI-PUBLIC OR PUBLIC - FLAT-PLATE COLLECTORS, WATER HEATERS - PHOTOVOLTAICS - SOLAR THERMODYNAMIC PLANTS - AEROGENERATORS, WINDMILLS - BIOMASS FOR ENERGY PRODUCTION

A. THE FRENCH PROGRAMME

SOLAR HEATING AND COOLING (SHAC)

R&D	-	40 scientists in government laboratories
	-	40 scientists in industry
INDUSTRY	-	About 50 manufacturers of flat-plate collectors
	-	1980 production: about 1 million sq. ft (100,000 sq. meter)
	-	Total number of SHAC installations: about 20,000 end of 1979)
GOVERNMENT ACTION	-	Loans for solar water heaters (1980 expectations: 50,000 units)
	-	Active and passive architecture competition (lender for 5000 houses)
	-	Nation-wide public swimming pool heating programme
	-	Technical training for professionals (over 1000/year)
	-	Subsidies to regional authorities (20 MFF/year)
	-	Subsidies to experimental homes and buildings (40 MFF/-year)
1985 OBJECTIVES	-	500,000 water heaters
	-	30,000 solar heated dwelling and buildings

SOLAR THERMODYNAMICS (TD)

R&D	-	About 50 scientists in government laboratories
	-	About 20 scientists in industry
INDUSTRY	-	Low temperature technology: one company, on a commercial basis.
	-	Medium temperature technology one company in each field,
	-	High temperature technology on an experimental basis
EXPERIENCE	-	Low temperature technology: about 100 installations in the third-world (Africa, Latin America, Asia), with a total power exceeding 1 $MW_{(e)}$.
in 1981	-	Medium temperature technology: one experimental 100 kW(e) power plant under construction in Corsica.
Targassone 1981	-	High temperature technology: one experimental 2 kW(e) power plant under contruction in the south of France - Participation (one third) in the European plant in Sicily.
GOVERNMENT ACTION	-	R&D: about 25 MFF/year)
	-	Experimental plants: 40 MFF/year
	-	Demonstrations: 8 MFF/year, mostly overseas

1985 OBJECTIVES	-	To build up a market, in the low and medium temperature technologies, of over 4 $MW_{(e)}$ peak/year
	-	To experiment various high temperature facilities in the 1 to 10 $MW_{(e)}$ - peak range

PHOTOVOLTAICS (PV)

R&D	-	100 scientists in government laboratories
	-	50 scientists in industry
INDUSTRY	-	3 manufacturers (early 1980)
	-	1980 capacity: over 500 kW-peak
	-	Export: over 90 per cent
FIELD EXPERIENCE	-	More than 500 installations in France and the third world (Africa, Pacific Ocean), up to 27 kW-peak for the largest unit.
GOVERNMENT ACTION	-	R&D: 40 MFF/year
	-	Demonstation: 8 MFF/year
	-	"COMES" procurement: 8MFF (about 150 kW) in 1980
1985 OBJECTIVES	-	To build up a capacity of over 5 mW-peak, with prices below 13 FF/W-PEAK.

BIOMASS

R&D	-	50 scientists in government laboratories
	-	More than 50 in industry
INDUSTRY	-	Strong in the field of lean gas units (gasification and gas engines), mostly for export
	-	Strong in the combustion field (many thousands of homes fitted with wood-burning central heating systems)
	-	Experimenting biogas (fermentation) and methanol production
GOVERNMENT ACTION	-	Routine subsidies for wood or straw uses: 400 FF per ton of equivalent oil displaced per year.
	-	R&D programme: 16 MFF/year
	-	Demonstration programme: 30 MFF/year
1985 OBJECTIVES	-	Raise the energy form biomass to 5 million tons of equivalent oil/year (from 2 million in 1980)
RESOURCES	-	France has the largest potential of western Europe - 14 million hectares (about 35 million acrea of forest) - 20 million tons of agricultural waste disposal
	-	Good possibilities in French Overseas Territories (French Guyana, Reunion Island, Pacific Territories).

WIND ENERGY (WE)

R&D	- A national programme is just being launched, with about 8 MFF funding in 1980 (2 million US. dollars)
INDUSTRY	- Very strong experience in the sixties (several megawatt-size machines) - Presently, commercial units up to 10 kW are being built.
GOVERNMENT ACTION	- Increase productivity of industry for small and medium wind generators (about 4 MFF/year) - Resume activity for large machines (about 4 MFF/year) - Boost government procurements for small and medium wind generators, including cooperative programmes with third-world and overseas territories.
1985	- Implement a competitive industry for small and medium power wind generators - Experiment larger units (megawatt-size)

B. WHAT COMES DOES OVERSEAS

a) *COMES means requests* for expertise from international or regional organizations, whether finance or aid agencies, public banks, or scientific and technical agencies:

. European Economic Community: as a member State, France is very active in setting up and implementing the pluri-annual EEC renewable energies programmes both in R + D and in demonstration projects.

. United Nations and related organizations frequently ask COMES to recommend or designate experts at various levels for a wide range of tasks, from national renewable energy resources to recommending action for specific programmes or applications (UN/CNRET, UNESCO, UNDP, UNEP, regional economic commissions . . .)

. Other regional organisations (OLADE in Latin America, NATO . . .)

b) *COMES provides expertise* through 120 top experts, belonging to public or private establishments or companies; they are available for

. energy programming (needs, resources, means)

. Feasability studies (technical, financial)

. Project design

. Other related tasks (e.g., setting up solar energy laboratories, training programmes, etc. . .)

c) *COMES provides technical assistance* when expertise has proven this advisable:

. R & D: design, setting up and evaluation of programmes, laboratories, equipment.

. Project management on a turn- key basis or with transfer of technology.

. Teaching/training through scholarships or exchange programmes, as part of bilateral or multilateral agreements.

d) *COMES ensures programme management* on behalf on Government Departments

. Overseas Departments and Territories (e.g. Polunesia Programme, jointly with the French Atomic Energy Commission)

. Cooperation (e.g. Sahel Programme)

. Foreign Affairs (bilateral or multilateral agreements)

e) *COMES can undertake financial studies* for possible French Government participation in national, regional or international ventures, or advise on programmes.

f) *COMES promotes* French industry and commerce through technical, financial and export advice, expecially for the smaller firms wishing to develop expert or transfer of technology activities.

g) *COMES organizes or co-ordinates exhibits* as was the case of the French stand at the 1979 Atlanta (Ga.) meeting of ISES (International Solar Energy Society). It also takes care of conferences, workshops and provides information.

C. INTERNATIONAL COLLABORATION

. . . *is widespread:*

. growing from one programme area (West Africa)

. to new zones of cooperation (Latin America, Asia, Gulf countries . . .)

. . . *is development-oriented:*

. through development aid

. through expertise and training

. through setting up national programmes/projects

. through increasing local assembly/manufacture of components

... *meets genuine identified needs for:*

- . Human settlements
- . Cattle
- . Crops
- . Land

... *uses most available technologies:*

- . Photovoltaics
- . Solar thermal/thermodynamic
- . Wind
- . Micro-hydro
- . Biomass and biogas
- . Mixed systems.

... *is evolving towards:*

- projects with improved economic viability (= alternative to traditional energy supply)
- better use of aid programmes (= higher local expertise and manufacture)
- wider international cooperation
  - . with other countries
  - . with multilateral institutions.

D. THE "SAHEL RENEWABLE ENERGIES" PROGRAMME (MAIN DATA)
1976 - 1978

- Covers countries of Sahel arid zone: cap Verr Islands, Senegal, Mauritania, Mali, Upper-Volta, Niger, Chad, Cameroon.
- Means:-
  - 32 MFF for 3 years (US$7 million for 3 years)
  - 30 French technicians working in the field
- Existing projects:
  - Solar thermodynamic 80 kW power plant, 400 kW h/day
  - irrigation 100 hectares + water and lighting for 7000 people: Dire (Mali)

- 5 kW wind generators for an agricultural training centre, 60 kW/day, for a hospital, 25 kW/day: San (Mali)
- 30 solar or wind-powered pumps in various countries (0.5 to 5 kW each)

- Possible extension for 1979:
  - other African countries
    additional techniques: biomass, micro-hydro
  - new applications.

SOLAR ENERGY DEVELOPMENT IN HONG KONG

by

C.T. LEUNG

1. *Introduction*

The population of Hong Kong is about 5 million confined in a total area of 400 sq. miles. Less than 10% of the population is rural and the economic and social structures are mainly urban.

The energy supply in Hong Kong has been solely dependent on imported oil. However, in the near future, Hong Kong will diversify her energy alternatives to coal for the generation of electricity. At present, the utilization of solar energy in Hong Kong is still very limited.

2. *Solar research activities*

The research on solar energy has been conducted in the various departments of the University of Hong Kong, such as the engineering, architecture, physics and chemistry departments. Some of the essential areas of research on solar energy undertaken by the Department of Mechanical Engineering are listed below:

(a) systematic analysis of local solar radiation data;

(b) the setting up of a solar collector testing facility to test local and foreign made collectors,

(c) the launching of a solar cooling programme to investigate the performance characteristics and economic viabilities of a lithium bromide water absorption cooling system under the local climatic conditions.

Other research work on solar photovoltaic cells have been undertaken in the Electronic Department of the Hong Kong Chinese University while limited research work on solar thermal systems are also performed in the Hong Kong Polytechnic.

3. *Solar projects*

So far, there have been no large solar projects built in Hong Kong. However, a few government sponsored solar projects for the heating of public swimming pools and providing hot water for government hospitals and public bath houses are in the planning stage.

In the private sector, projects for providing hot water in several large hotels by solar energy are also economically viable and are therefore presently under serious consideration.

4. *Manufacturers*

Because of the present limited demand and the small profit margin, there are at present no solar collector manufacturers in Hong Kong. However, if the economic conditons are favourable, Hong Kong has the technical know-how and the skill labour to produce collectors in large quantities at reasonably low cost.

There is at present one manufacturer on solar cell powered appliances, such as calculators, watches and toys, etc.

5. *Some constraints*

The fluctuation of solar radiation in Hong Kong is considerably large particularly during the transition between the winter and summer seasons. There may be five or six consecutive days that have no sunshine. Usually, large capacity storage is often needed and this would make the solar systems in Hong Kong even more expensive.

Existing buildings are usually not built structurally for solar system installations and the roof areas available for collection are very limited in most multi-storyed buildings, not even to mention the shading effect from adjacent buildings.

Perhaps, the biggest hindrance to the advancement of solar energy utilization in Hong Kong is due to the lack of economic incentives. There is absolutely no government funding available to subsidize any domestic or commercial projects. Moreover, even for domestic solar hot water systems, the pay back period may be over ten or twelve years which is definitely too long compared to other investments in Hong Kong.

6. *Conclusion*

At present, the utilization of solar energy in Hong Kong is still very limited because of the constraints mentioned earlier. However, there are good reasons to believe that solar energy will definitely play a role in the Hong Kong energy scene if economic situations are favourable in the years to come.

STATUS OF THE SOLAR ENERGY PROGRAMME IN INDIA

by

M. RAMAKRISHNA RAO

During the past decade the total global consumption of conventional fuels like coal and oil have reached such an alarming level that the danger of dwindling resources has become a reality. To reduce the consumption of coal and oil and at the same time to meet the increasing energy demands, one of the most promising sources of energy from the point of view of availability, cleanliness and ecology is the tapping and utilization of Solar Energy. The Department of Science and Technology (DST), Government of India launched an Integrated Solar Energy Research and Product Development (RPD) programme, about four years ago. In this programme, national R & D centres, teaching institutes and public sector manufacturing organizations were assigned specific goals and objectives with clearly defined priority areas. The current status of activities in these areas is being briefly given in the text to follow:

1. *SOLAR THERMAL*

1.1 *Solar Collector Development*

The collector development has been given special attention. This programme ensures that while the solar based products are being developed, the collectors will be available for different temperature and fluid applications through this independent continuing activity. BHEL has designed and has also initiated commercial manufacture of flat plate collectors with aluminium absorber on a limited scale; mainly for closed cycle water heating demonstration projects. The R & D work is being done by BHEL, IIT - Delhi, NPL - Delhi, and others towards the development of solar air and water heating collectors including the development of evacuated tube type and other advanced flat plate collectors.

In the area of concentrating collectors, R & D work is in progress at several institutions for the development of both line and point focusing systems. The NPL - Delhi and IISc. - Bangalore, IIT - Bombay are actively engaged in the programmes related to optimization of large size parabolic through concentrators. BHEL is working jointly with CEL, India, JPL of USA and MBB of West Germany to design 5 to 6 meter diameter paraboloid dishes of two different configurations for solar thermal power generation applications.

1.2 *Selective Coating*

In order to improve the efficiency of collectors, the R & D work in the selective coatings has advanced fairly well on a laboratory scale. The black nickel, black chrome have been developed by NPL Delhi, IIT, Delhi and IISc, Bangalore respectively with

α = 0.95 and ϵ = 0.2 - 0.3. The laboratory technology is being upgraded to a pilot plant scale. Besides these coating absorbers, coatings of metal carbides and metal nitrates by sputtering deposition techniques, and semi-conductor treatment coatings are also being developed by the above-mentioned organizations. The absorption emissivity measuring instruments based on the principles of steady state calorimetric and reflectivity measuring techniques are also being developed by these organizations.

1.3 *Solar Heating, Cooling and Refrigeration*

The direct use of solar energy as thermal energy has a wide range of domestic and industrial applications. Therefore, the development of solar water heating systems has attracted attention of almost all the R & D institutions in the country. Already, BHEL has designed and installed a number of solar water heating demonstration systems ranging from 15 sq. meters to over 700 sq. meters of collector area for different projects. A few private and public industries are involved in manufacturing of solar water systems. The DST has launched a commercial programme to install over 50 large size solar water and air heating projects in different sectors through BHEL and NRDC. The work on solar cooker was started by NPL as early as 1950s. At present, further development has been carried out by a number of other organizations resulting into its commercial production in a small scale by a few private industries.

The work on solar cooling is being done on three different systems (Ammonia-water, Ammonia-sodium thiosynate and Freon-DMF), to design intermittent and continuous systems. The major organizations involved are IIT (Bombay), IIT (Madras), IIT (Delhi) NPL and BHEL. It is expected that after the testing of these ¼ ton to 1 ton size laboratory models, the system will be scaled up for possible rural applications. The IIT (Delhi) has designed and tested a 7.5 ton Ammonia-water system for geothermal applications.

1.4 *Solar Water Pumps*

The main effort on solar thermal pump has been to use 75 to 90°C hot water to operate organic fluid (Freon-11) closed cycle system to produce 1 kW to 20 kW electrical power. The 2 kW turbine system at NAL and a 1 kW scroll expander unit at NPL have been tested. R & D work is in progress for 10 kW double stage turbine system at IIT (Bombay) and 20 kW single stage turbine unit at BHEL. BHEL with Dornier System of West Germany has initiated joint activity for the development of a laboratory size reciprocating engine design working with Freon-11. R & D work is in progress at Hindustan Brown Borin-Baroda and CSMCRI-Bhavnagar for the development of non-moving type of pump (liquid piston type). Another activity in the solar thermal pump area is to develop 2 HP size reciprocating engine being conducted by PAU-Ludhiana.

1.5 *Solar Power Generation*

As a first step in this sphere of activity, a 10 kW experimental-cum-demonstration solar power plant using flat plate collectors was designed, fabricated and installed at IIT, Madras under the Indo-German Technical Co-operation Programme. The project which was initiated in August 1976 was successfully commissioned in January 1980. BHEL - as project manager and IIT (Madras) constituted the Indian team and MBB represented the West German team.

Another project which is being jointly executed by BHEL and CEL with JPL of USA as collaboration agency is the setting up of a decentralized energy system. This project will have about 12.5 kW of solar thermal and 12.5 kW of photovoltaic energy generation along with other systems for a selected rural site.

1.6 *Storage, Grain Drying and Other Solar Thermal Systems*

A number of organizations are working on the development of solar thermal energy storage systems like oil-pebble bed (BHEL), PCM (BHEL) and Panjab University and Solar Ponds.

The solar crop drying activity has a special interest in our agricultural based economy. The major working in the area of paddy, tobacco drying and sericulture is being done at Annemalai University, Arid Research Laboratory, Jodhpur. The NIDC has designed and installed two large systems based on the technology developed by them at rural sites. The IIT - Delhi, NPL and REC - Srinagar are also working in this area.

An attempt has been made at IISc, Bangalore to melt low-melting point alloys such as Al-tin by utilizing the parabolic dish design.

The NAL, BHEL and few private organizations are working on the development of windmills for water pumping and for wind generators (vertical axis).

The solar desalination of water is another area in which R & D efforts are being made by many organizations. The CSMCRI - Bhavnagar is the pioneering institution which has installed several large size solar desalination systems at rural sites. R & D work is being done at IIT - Delhi, NDL and TERI for development of better and more efficient systems.

R & D work is in progress at IIT - Delhi, IIT - Madras, BHEL and at KVIC for the development of bio-gas operated engine for rural water pumping and for electricity generation as a part of rural energy programme.

1.7 *Integrated Energy Systems (IES)*

In order to meet the total energy needs of the rural community, BHEL is working on the development of Integrated Energy systems. These systems use solar, wind and biogas as the basic energies (depending upon availability at various sites) for meeting the electrical and/or thermal energy needs of the rural community.

While the sub-systems are being developed, BHEL is simultaneously working on the establishment of IES (by the end of 1981) totally on its own. This system will have solar thermal energy generation (75 kWh per day), vapour absorption refrigeration system operated cold storatge and availability of thermal energy for domestic and small scale industrial applications. The system will use bio-gas as back-up source of energy.

Another large size IES project is being designed for installation by the end of 1982 at a village in Andhra Pradesh - DST's Salojipalli Project. This project, funded by Department of Science and Technology, is being jointly executed by BHEL and CEL with Jet Propulsion Laboratory of USA as the collaborating agency. The project has plan for providing electrical energy needs of the village (via solar thermal and with photovoltaic conversion) and for meeting the thermal and mechanical energy needs for this essentially 'high irrigation' demand village.

2. *SOLAR PHOTOVOLTAIC*

As back as mid-sixties, some activities were visible in the area of photovoltaics in our country. A few universities and national institutes were carrying out research in this area but only in an isolated and scattered fashion. In 1975 the Government of India launched a National Solar Photovoltaic Programme as a part of its overall Solar Energy Utilization Programme through its Department of Science and Technology (DST). DST sponsored a solar photovoltaic project at Central Electronics Ltd. (CEL) to carry out the R, D & D programme on photovoltaic in our country. Simultaneously, a number of R & D projects were initiated in different universities and institutions on different aspects of photovoltaic materials, devices and systems.

In the field of photovoltaic materials, main emphasis is on the development of low cost silicon material. A number of institutions like National Physical Laboratory, IIT, Kharagpur, IIT, Madras and Indian Association for Cultivation of Science, BARD, Tata Institute of fundamental research, Regional Research Laboratory, Bhabaneswan, etc. are working on the development of low cost silicon material from rice husk, metallurgical grade silicon and also amorphous silicon. A few private chemical industries are also engaged in developing suitable low cost silicon materials. Development of associated photovoltaic materials like AR coatings, encapsulants, conducting paste, etc. are being carried out by CEL, NCL and other private organizations.

In the field of photovoltaic devices, monocrystalline Si p-n junction cells have received maximum attention so far. CEL has set up a pre-commercial plant for production of these cells and modules. Space-qualified Si cells are also being developed by ISRO, BARC and CEL. Development of polycrystalline Silicon Solar cells is being carried out at NPL and CEL. Development of MOS Si cells, amorphous Si cells and also high concentration Si cells are being carried out at IIT Kanpur, IACS, Calcutta and CERI, Pilani.

In the area of Cadmium Sulphide solar cells, considerable work has been done so far at IIT, Delhi, NPL, Jadavpur University and a few other institutions. GaAs Solar cells are also being developed at CERI, Pilani.

In the development of photovoltaic systems, with particular emphasis for rural applications significant progress has been achieved at CEL. Photovoltaic systems for water pumping for irrigation and drinking purposes, community TV centres, Radio telecommunication systems, navigational aids, domestic lighting, etc.have been designed and developed. Some work has also been initiated in the university of Kalyani for the assessment of balance of system costs.

A comprehensive programme is currently underway for the demonstration and field trials of different photovoltaic systems developed by CEL. Photovoltaic water pumping systems at a number of places in India have been installed and are being evaluated.

3. *EDUCATIONAL PROGRAMMES*

The main requirement for launching the programmes on a large scale is the technical manpower. It is essential to draw upon the innovative talents of young scientists and engineers for this programme. Besides this, the popularization of this newly emerging renewable energy field brings the enthusiasm and keen interest of the large sectors of people in its effective implementation.

To carry forward this path, the educational institutions in India which are actively involved in R & D programmes of solar energy have started organizing the short-term and long-term programmes. Under continuing education programme which is meant to refresh the knowledge of the teachers from various colleges and universities, the short-term courses were organized by Indian Institute of Technology at Madras, and Delhi, Roorkee University, Indian Institute of Science, Bangalore, TERI, for 2-4 weeks during the last four years. Special mention may be made of the course organized by Indian Institute of Science, which is the first laboratory oriented course successfully conducted.

The other course is the solar energy application to architectural aspects organized by CBRI Roorkee in collaboration with IIT, Delhi and Roorkee University.

The centre for energy studies at IIT, New Delhi has started a regular two year course in M. Tech in energy Government post M.Sc and Post B.E. candidates. One year Diploma in Energy is being planned with United Nations University assistance. There are other institutions like IIT, Madras, Bombay and BITS, Pilani, Universities such as Roorkee, Annamalai, Punjab Agricultural University have been conducting regular and selective courses at graduate and under-graduate levels. Many engineering colleges in India encourage their students to undertake projects/dissertations in renewable energy. In all the above-mentioned institutions also in some universities like Jadavpur and Kalyani, Ph. D programmes have been undertaken in various areas of energy field.

In order to popularize the energy programme and infuse interest in college and high-school studies, a series of exhibitions have been organized at Delhi, Bombay, Madras, Hyderabad, Ludhiana, Bhavnagar, Calcutta, etc.

The metreology department of Government of India has been collecting the solar radiation data in the country and compiling it for the benefit of the solar energy scientists.

CONCLUSIONS

Within the next few years, the detailed results of the presently-initiated solar energy R&D projects would have been carefully evaluated from the stand point of technical performance and economic viability in the Indian context. At present, however, the solar energy programmes in the country are at too early a stage to draw any firm conclusions. As in the case of all new technologies developed in the past, efficient and economically justifiable utilisation of solar energy can come about only by passing it through an exhaustive initial stage of experimentation and evaluation as is presently being undertaken.

POTENTIAL PROBLEMS AND EXPERIENCES OF SOLAR ENERGY APPLICATIONS IN INDONESIA

by

PARANGTOPO

The status of progress at the present time is still in the development support phase. The Government finances the research and development activities done by several institutions and by establishing demonstration plants. A proper institution dealing with solar energy will be decided in the framework of an integrated and comprehensive energy policy which is still in formulation.

On the potential of solar energy, based on preliminary observations, the following can be presented:

Solar energy has been used extensively in a traditional way. Preliminary measurements indicate that the average insolation is about 1800 kWh/m^2 per year, which is above the limits of application. This may yield an average of about 75 BOE/capita throughout the year with the assumption of today's population (140 million inhabitatns), a 5 per cent conversion factor, and 7 per cent of the land to be used as captive areas. But this will only be available if solar technologies acquire greater maturity and are diffused on the market. It is also unlikely that solar potential could be fully exploited in densely populated areas, such as Java, where the land availability per capita is very limited.

Direct solar energy has been used widely in the villages for drying purposes. Technology may help increase the efficiency and reduce the efforts of climatic changes; the development of an underground heat storage for the supply of dry air for crop drying has been tried.

Heated water and distillated water supply for rural medical centres has been introduced as a demonstration project.

Other efforts have been made to use photovoltaic cells to generate electricity for very special purposes such as communication between remote stations and villages.

Adoption of solar parabolic mirrors for household application has been proposed and tested for economic viability.

The problems faced and experiences gained are the following:

Several projects have been running for several years both in using solar radiation directly and by using photovoltaic cells. There are (i) crop dryers with and without coupling with hot air storage, (ii) solar water heaters and solar stills, (iii) solar cookers, (iv) photovoltaic water pumps and refrigerators.

Basic project data are in general incomplete, so the proper planning becomes difficult. To prove the viability, observations over a longer period are still needed.

More studies on the socio-economic views of the population have to be made to establish the acceptability of such projects in the long run.

A demonstration plant for studying alternative sources of energy was established and run by the Agency for the Application of Technology about a year ago. Through these kinds of demonstration, the government succeeded in cooperating entrepreneurs, cooperative manufacturers and industrialists to participate in the dissemination of solar technology in the viable way. This demonstration plant, called Solar Village of Indonesia, is a joint cooperation between the Federal Republic of Germany and the Republic of Indonesia, for a five year period. The Indonesian government's share is approximately US$ 4 million.

Two experimental villages situated in West Java have been chosen as the project sites. Some of the solar devices have already been installed for testing and investigation. Part of the study includes the impart of the social and economic aspect of the application of solar energy.

According to the plan a solar energy laboratory will soon be built at the Science and Technology Centre at Puspiptek, near Jakarta. This solar energy laboratory will comprise of the following:

- solar thermal pump
- ice-making plant which simulated collector field (0.5 ton/day capacity)
- collector test stand
- solar cell laboratory (solar cells of 5.5 kW/peak are partly monocrystaline and partly polycristaline)
- gasifier 140 kW thermal
- thermophylic biogas plant
- desalination plant (5 m^3/day capacity)

Experimental tests on solar cells for water pumping, ice-making, use of wood chips as fuel, fish-drying and desalination have been conducting since October 1979.

PRESENT STATUS OF SOLAR ENERGY DEVELOPMENT IN JAPAN

by

IZUMI USHIYAMA

Nowadays in Japan, R&D of alternative energy are progressively going on under the cooperation of governmental and private sectors, aiming to replace as much as possible the amount of oil now imported. Especially in 1974, just after the oil crisis, a national project of developing alternative energy started under the name of SUNSHINE PROJECT. This project is sponsored by the Ministry of International Trades and Industries of Japanese government, and consists of four main items as follows:

1. Solar Thermal Power Generation
2. Coal Liquefaction
3. Geothermal Energy Application
4. Hydrogen Application as Storage Medium of Energy

Each item has finished its research and experimental stages and is now going into a stage of actual utilization. An attention should be paid to general geothermal plants that are successfully being operated to feed electricity to utility grids of electric companies, the average output being 500 MW. One of the solar thermal plants is also now under construction having a tower type in SHIKOKU district (South-Western part of Japan), and is expected to be in operation next year with an output of 2,000 kW.

Solar water heating facilities are very widely distributed throughout Japan, the number ranging from 2 to 3 millions, and there are about 50 manufacturers in Japan including large and small companies. The system is spreaded from simple apparatus to sophisticated selective absorption coating types, and their costs are ranging between ¥ 100,000 and 300,000.

As for the Photovoltaic Cells, Japan is perhaps one of the very advanced countries in the world. The main efforts in the development of the photovoltaic cells are focussed into cutting down the production cost of cells, and not only a silicon cell but various non-crystalline cells are being developed for this purpose.

In addition to the above mentioned four items, we have been striving on three more projects since 1978. The one is Ocean Thermal Difference Power Generation, another Wind Power Generation, and the third Biomass Energy Development. The total amount of budget funded to the Sunshine Project as a whole reaches about ¥ 20 billions per annum.

As for the wind power generation, the utilization is not so active in general, compared with the other countries, because the strong typhoon attacks Japan every year with a lot of rain fallen down to the very mountanious country. In the past days water mills were, therefore, widely used as a power source for grain grinding, water pumping and other agricultural works. For these years, however, the wind power generation has become quite active in development both in governmental institute or universities and private sectors.

There are three projects now going on sponsored by the government. The first one is a large scale wind power generation project by the Ministry of International Trades and Industries (MITI) aiming to develop one mega-watt scale wind power plant to feed the electricity into the utility grids. The first prototype generator is to be built next year in cooperation with TOKYO Electric Company. This generators, a two bladed propeller type, has 28 m in diameter and 100 kW output. Secondly, the small and middle scale wind power generation projects are now being performed by the Science and Technology Agency. The small scale project entitled "Futopia Project" has been carried out since 1978 to date, collecting a lot of interesting data. Five private companies have participated this project to have prepared eight small scale windmills that are set in three different places in Japan chosen due to their typical wind behaviors. The last one sponsored by the Ministry of Agriculture, Forestry and Fisheries is named Green Energy Project with a large scale and long term service for agriculture as power sources for water pumping and aeration of water and a heat source of green-houses.

Other developments of wind power generation are also actively being implemented, e.g. small power sources for a light house sponsored by the Maritime Safety Agency and for a relay stations performed by Japan Telegraph and Telecommunication Corp. In addition, an Automatic Meteorological Data Accessing Station is in operation as the AMCDAS Project by the Meteorological Agency, having collected meteorological data on wind, sunshine, rain, etc. at 830 places that meshes Japan by every 21 km.

Summarizing a lot of projects on solar science and technology in Japan, it seems to be recognized that the governmental and private sectors are actively developing the application of solar energy. A lot of methods and thereby obtained results in these developments are thought to be rather sophisticated. Some of them may, however, be certainly useful and helpful to developing countries. Japanese government must be very pleased to transfer these solar energy application technologies to developing countries.

STATUS OF SOLAR ENERGY R AND D AND UTILIZATION IN MALAYSIA

by

NOEL MONERASINGHE

Malaysis is a small developing country lying just north of the equator. She is fortunate in having vast hydro potential and is at this present time a nett exporter of oil. However, it is estimated that by the year 1983 she would be a nett importer, based on present known reservers and consumption patters. New gas and oil fields are being concurrently discovered and explored, and therefore the fuel situation may not be that critical.

There is no national energy policy, except that the national is committed to a policy of conservation of energy at all levels. The Government of Malaysia has indicated that priority would be given to developing mini-hydro schemes and hydrid thermal stations powered by oil and natural gas. Against this energy availability background, solar energy has not gained very much backing. The We in Malaysia are infants in the art when compared to the spectacular development we have just heard about in some of the other countries. Any work on solar energy is done in our four universities, Standards Institute and Research Institution Malaysia and the Institute Technology Mara. All these bodies are, in some way or other, either by research or teaching, involved in solar energy. Malaysia is now also becoming a playground of some local and foreign entrepreneurs. In Malaysia we are careful to emphasise on local and locally available material and the use of local technical expetise. Of the various solar energy applications, only solar hot water heating for domestic, commercial, and industrial application has been employed - on a limited scale. There is no large commercial set up as the present moment. There are a few local firms marketing solar water heaters, some are joint ventures with Australian, Japanese and other foreign firms. Solar photovoltaic systems for rural electrification is also being marketed. Solar crop drying has a vast potential in Malaysia for drying padi, timber agricultural and marine products, but is still in the R&D stage. Solar air conditioning and refrigeration would find an application if proven reliable and economical, for rural and urban application. Solar ponds for the collection and storage of solar heat for large scale drying of plantation products like rubber and cocoa beans might proven possible. Technology has to be developed for this application. Solar energy studies began as early as 1955 in the University of Malaya. It was not until 1972 that a more comprehensive programme on solar utilization in Malaysia started. In 1978, biogas and wind energy studies were initiated.

Solar energy studies at the University of Malaya concentrated on water heating for domestic, commercial and industrial applications, air heating for crop and timber drying, distillation of brackish water for human or animal consumption, dehumidification for conditioning of air and selective surface preparation for high temperature solar heaters. The topics selected were mainly based on and geared to the needs of the country. University of Malaya decided not to research into sophisticated systems like solar-thermal power generation and photovoltaics, until the basic and more economically viable applications, like water heating and crop drying systems were fully investigated and proven reliable under local environmental conditions. Later studies would be based on improving their efficiencies, reliability and durability.

Biogas studies were initiated in the University of Malaya in 1978 with the construction of a biogas plant capable of digesting approximately 0.196 cubic metres of slurry. Initial results using chicken droppings, as raw material has shown that, assisted by solar heated water, an average gas production of about 0.098 cubic metres over a 30-day period could be obtained. Quality of the gas producted shown a methane proportion of about 70% and a calorific value of 24.118 MJ/m^3. Future work would include the use of other raw materials and the design of devices for the utilization of the gas produced.

Research on producing an ideal model for building design using a computer programme is being carried out under various orientations and using different building materials, it will be possible, hopefully, to obtain the solar influence on buildings, thereby giving researchers the opportunity to design and plan for best results. The particular researcher at University Malaya is working with a fellow researcher in the University of Queensland, Australia.

Present studies at the University of Malaya are focused on crop drying, flat-plate and non-tracking (non imaging) concentration, capable of performing at reasonably high efficiencies (40%) and at temperatures of around 100^{o}C. The latter would provide industry with hot water, power solar air-conditioners and for dehumidification of silica gel.

A Solar Energy Group exists in the University Science Malaysia (USM), which directs all solar energy activities in the various faculties of the University. In 1974 USM commenced studies on photovoltaics and have carried out extensive work in the way of testing and evaluating a number of commercially produced panels. We are now in the process of producing our own silicon cells. This has been made possible by the generous aid from the French Government who have given us the equipment to fabricate the waffers and have sent us scientists to help in the programme. Out scientists and technicians are being trained in France on the process. Negotiations are in progress with the French Government, to use USM, for testing a 1 kW solar generator for rural electrification.

Research on biogas production is being carried out in USM and a workable model is available for immediate application. Work on conservation of energy together with solar energy usage on air-conditioners is being carried out, and a proto-type that saves electrical energy on air-conditioners while it produces hot water of 95^{o} C in three hours, with no loss of efficiency in the unit. During the day the storage tank is heated by flat-plate solar panels. Work on solar parabolic concentrating systems for air and water heating is being carried out at USM and very encouraging results have been obtained.

The University of Agriculture at Serdang is carring out studies on solar drying of padi, tobacco and fish. University of Technology at Kuala Lumpur is in the process of carrying out research on solar air-conditioning. The Institute of Technology Mara in Shah Alam is actively involved in solar wter heating and crop drying. The Standards Institute and Research Institution Malaysia is conducing testing on solar air heaters and are evaluating some commercial photovoltaic panels.

RENEWABLE ENERGY REQUIREMENTS IN NEPAL

by

A. BACHMANN

In Nepal the research, development and demonstration of solar energy is at its very beginning. At the Research Center for Applied Science and Technology (RECAST) of the Tribhuvan University one is working with the different possible applications of solar energy, such as solar water heaters, stills, drier, cooker and over, and also on insolation measurements. This works at the RECAST have started in 1977. There is a "Energy Research and Development Group" (ERDA) also at the Tribhuvan University, which has formulated Nepal's energy need in a report. This group has different committees for the various possible applications: biogas, solar, wind, hydro, etc.

Practical works are older; the first solar water heater has been made some 13 years before, and the enterprise BYS- Sanitary Engineering has taken up development and production in autumn 1974. Other practical appliances are also taken up by Govt. Agencies, by organisations for telecommunication and by a few individuals using solar cells for house lighting.

A very interesting project is the cheese factory at Pauwa. At an altitude of 1800 m -where the temperature drops considerably in winter- biogas in produced from pig dung, pigs are fed by the whey milk (a waste product from the cheese processing) and solar collectors for the boosting of heat losses into the insulated house.

All this demands for energy are in a country where no fossil fuels are available and no (significant) natural resources are existing (except for water power). Interesting enough one has to realise that in Nepal several processes have gone a very practical way, different to that what is often thought or explained: the applications of renewable energy resources, such as biogas, solar, hydro and wind are normally originating in local workshops. From there they have then found the way to the public and government agencies, and this before the locally developed scientific measurement facilities were available. This is also possible due to information exchange with other countries, such as Australia, USA, Israel, etc.

This is doubtless a very effective, economical -and so to say- a successful way of introduction of applied science and technology. However, this may not be regarded as final solutions: many investigations and improvements have still to be done and this hopefully with the cooperation of concerned people.

But why this has not happened before? This for example has a connection to Nepal's tradition and history, and for sure the year of 1973 and following fuel payments to be made in hard currencies have assisted in the awareness.

Nepal -with its appr. 145000 km^2 and 13.5 million inhabitants- is to 85-90% agro based and just about self-sufficient in food. However, with the population growth, fuel demand and erosion problems, etc. the tasks for the Nation will become tougher, doubtless, and is also recognised. One of the many problems is *Conservation*, for example of harvest (=solar drying and food storage); and this may be even before increased production. And of course there is the fuel demand and that for cooking the most needed: appr. 70-75% are used for this and made up with wood, straw and cowdung. Note that of the appr. 14% electricity production somewhat 5% are still not met by hydro power application! And until 1951 the country was a forbidden place to foreigners, the science and technology needs and applications on the level of the traditional knowledge. With the opening of its borders a process for fast additional technologies has started.

Despite of huge water power potentials only a small fraction is being used at present. Many of the proposed schemes are of very big sizes, -good for towns and for the export- and doubtless necessary, but of little use to the individual small farmers in the hills and mountains of Nepal. With the development of towns the worsening of living standard of individuals -due to limited food protection and production, scarcity of fuel for cooking, erosion, etc. the migration from the hills and mountains to the plains are additional burdens. This facts are becoming known more and more to the population. In the recent speach of the Finance Minister of Nepal for the fiscal year 1980/81 it was clearly pointed out that the development of renewable energy resources is strongly recommended by the Government. This includes research, production and distribution of fuel saving stoves, electric power, biogas and natural gas as alternative sources of energy. Afforestation programmes are strongly supported. And one is very happy to tell that on Nov. 13, 1980 the "National cooking stove seminar" of RECAST, the first of its kind, was innaugurated by the Finance Minister. A "common and simple" problem has found attention and recognisation by the authorities.

This does not mean that solutions are easily available. Contrarily: as more one is involved in this works as more variations are opened to the involved people. Stoves, for example, should be: social acceptable, being of nice, handy shape and size, cheap, from locally available materials, owners and fastly built, smokeless and of course fuel efficient in use. This are not easy take to fullfil indeed! And more, many may be surprised to know that often the traditional cooking places are more effective than the so-called improved ones: the chimney draws the heat out of the stove. However, and this is an important factor, it is often depending on instruction and training: often the same stove is satisfactory after explaining the function and handling again and again.

And a word of economics. There can be no doubt that applications must be economical. However, where is the standard? And is it not first of all important to show (Speaking of small scale) alternatives, available and workable, whatever the costs may be? Economics are changing very fastly. Who would have predicted a rise of price of kerosene (being an important fuel for house lighting) and petroleum? Beginning of the month of November this has increased in 20%. But development of skills and technologies need time and should be available now, or at least when the economics are interprated accordingly.

Competition should be encouraged. It widens the awareness and the market. And what about the profits? An imported electric geysir (in comparison to its content) does not significantly cost less than a locally made and careful priced solar device!

Using solar means also to reduce the load on electricity production, -and this may be more important- less investment on the power distribution grid (which is in a country in the Himalayas a very expensive task).

The proof of the ability lies in action. Nepal has already achieved promising results in application and technology transfer of solar water heaters. And what can be said for the time being is that Nepal has many interesting applications of renewable energy resources applications. This must be for several reasons: The people are -with their daily needs and struggle for the living standard- in need of solutions *now, today*: they cannot and do not want to wait for "the best solution" (which may well be the enemy of the good, the available)!

People do accept new suggestions, especially if:

- it can be done with locally available skills,
- made locally available materials (and therefore with the own currency)
- training is provided, developed on technical and manual level as well,
- designs on the standard which enable an own maintenance
- being supported by organisations, agencies, government, etc.
- there are proposals for extensions and further applications (e.g. small scale industry).

For sure supports are needed; this can be in form of technical assistance and/or financial assistance, but should be based on the population's need and nations improvement. The exchange of technology is a vital part. And often the support for an application of a prototype could/can be more helpful than further R&D until perfect performance in a later time to come!

Agencies could be of very valuable help by supporting locally available skill and knowledge, this to Government Agencies and the University, and also very much by the much opened support to interested parties, small scale industry and individuals.

For example: solar water heaters to be put at buildings (and not to be cancelled due to little more expenditures at the moment of construction). Support of demonstration plants, or providing of plans good for construction.

- Support also of national meetings and workshops, to encourage technology transfer within the country,
- Acceptance and support of individual nationals, especially to those who have already proofen to be effective through action. This support will assist in application for and to the masses.

- Support and encouragement to Government, University and very much also towards individuals and enterprises working in the fields of renewable energy resources (Test, proposals for improvement, study of markets, teaching to public, user, investigation, follow-up, etc).
- Promotion of solar energy towards rural application and small scale industry: driers (storage) wood seasoning kilns, etc. and industrialisation (for example milk processing, botteling industry, dying factories) etc.

It is clear that the exchange of technology has successfully started: it is the backbone of such developments and applications. But also the cooperation of R&D towards and vice-versa manufacturing is essential for an even more successful development and dissemination.

SOLAR ENERGY UTILIZATION IN PAPUA NEW GUINEA

by

Q.A. AHMAD and P.F. LOGAN

1. *Introduction*

Between 1956 and 1976, oil imports to Papua New Guinea doubled every 7 years and the per capita growth rate in energy use was 8% per year. Between 1970 and 1974 oil prices trebled and between 1975 and 1980 they have doubled again. Oil imports are growing at about 5% per annum. The total oil imports cost Papua New Guinea K56 million in 1978, K77 million in 1979 and at least K128 million in 1980. Hence cheap and secure energy supplies are essential for Papua New Guinea's economic development and these can be provided in Papua New Guinea by renewable energy sources.

At present about 33% of energy needs are met by firewood and 55% by petroleum products. The remaining 12% is obtained mostly from hydroelectricity. About 90% of energy demand in rural areas is obtained from firewood while 90% of hydroelectricity supply is used in urban areas. Even if hydroelectric power is increased in the future, it is not possible to minimize the demand for firewood as the rural areas would still be unable to obtain hydroelectricity due to the high cost and difficult transmission. The supply of firewood is itself a problem as the deforestation of rural areas in turn increases soil erosion and destabilises agriculture productivity. Thus the firewood and petroleum products are the main sources of energy in the rural and the urban areas respectively; one requires strict resource management and the other is highly expensive. The only way to minimise high demands of these two unavoidable conventional sources of energy is to introduce the renewable resources of solar energy, power alcohol and hydropower.

The Government of Papua New Guinea has formulated an eight-point plan for self-reliance. In the light of this plan, the following points are considered for meeting energy demands from renewable locally-available energy sources.

(i) The development of locally-available renewable energy sources is a significant move to self-reliance and economic independence.

(ii) The amount of foreign exchange used for direct purchase of fuels on the world market can be saved for use within the country for establishing Papua New Guinean owned industry.

(iii) Most alternative energy sources will prove economical first in rural areas where delivered costs of conventional energy are high. Energy industries developed in rural areas can help self-reliance on a regional basis with the attainment of a balanced rural development.

(iv) The alternative energy industries can all be geared for significant smallholder participation of nationals, thus increasing the equity in the participation in national economic growth.

Broadly speaking, solar energy includes all renewable energy derived from the sun either by direct collection of the sun's rays or by use of its indirect effects (biomass, wind, water). However this paper concentrates on the direct use of the solar radiation.

There are several important reasons for considering solar energy as an energy resource to meet the needs of Papua New Guinea. First, Papua New Guinea is in the tropics and has substantial solar radiation available. Secondly, Papua New Guinea does not have widely distributed, readily available supplies of conventional energy resources. Thirdly, Papua New Guinea, being characterised by dispersed and inaccessible populations and a lack of investment capital is faced with practically insuperable obstacles to the provision of energy by conventional means. In contrast to this, solar energy is readily available and is already distributed to the potential users. Fourthly, because of the diffuse nature of solar energy, smaller units may be easily developed to fit into the rural situation. Moreover solar energy may serve as a vehicle for further development in terms of providing better living conditions, more food production and preservation and generating labour skills and employment. All these can be achieved by the

(a) Creation of a technological attitude in rural areas,

(b) Analysis of the specific needs and conditions of energy use in Papua New Guinea,

(c) Involvement of local persons at all stages of its development and use and,

(d) Cooperation with South East Asian and Pacific countries and Australia for joint design of projects, complementary production and development of indigenous skills.

The criteria for assigning priority should relate to the economic performance and compatibility of technological development with the National Development goals of Papua New Guinea, emphasising in particular the contribution of solar energy applications to self-reliance and energy independence. Hence the alternatives for solar energy utilisation in the near future are seen as follows:

(i) Low grade and high grade heat requirement.

(ii) Power alcohol.

(iii) Biogas.

(iv) Energy from sawmill and forestry wastes.

(v) Solar refrigeration and air conditioning.

(vi) Charcoal and producer gas.

(vii) Photovoltaic cells.

(viii) On-site alternative for rural electricity.

The Ministry of Minerals and Energy has many projects to utilise renewable resources of energy in order to reduce Papua New Guinea's dependence on imported fuels. A commercial demonstration project is designed to produce two million litres of fuel alcohol per year from cassava in the Baiyer River valley of the Western Highland Province and another is being studied to produce two million litres of ethanol per year from sago palm in the East Sepik Province.

This paper describes briefly some of the solar energy research and development projects currently being undertaken in Papua New Guinea.

2. *SOLAR RADIATION DATA*

Many countries have equipment for radiation measurements, but their equipment covers only few areas and is often inappropriate. For monitoring, meteorological equipment is too expensive too sophisticated in maintenance and in data handling.

Therefore, priority should be given to; the setting up of regional stations well equipped and serving as local agent for collecting and distributing methodology and data; the analysis of the data of the regional centres in conjunction with satellite data in order to get more reliable information on the spatial distribution of solar radiation; and the testing and development of cheap devices for meteorological monitoring with simple maintenance, data acquisition and handling.

The amount and distribution of solar radiation received at ground level determines the feasibility of direct applications of solar energy. Unlike conventional appliances, the solar appliances cannot be used anywhere or anytime. Solar appliances work only when the sun is shining, and therefore the study of the sunshine distribution with time at any specified location is essential. Secondly solar appliances are installed at places where people live and work. Since 1974, the University of Technology has housed solar radiation monitoring equipment belonging to CSIRO of Australia and has now five year of data collection from which reliable data for design purposes are evaluated.

There is an elaborate plan for the preparation of maps for Papua New Guinea showing the geographical distribution of solar radiation in relation to the geographical distribution of population. This work is being taken by Dr. Q.A. Ahmad, Department of Mechanical Engineering. As a first attempt the solar radiation data are compiled for Lae. The Department of Mechanical Engineering published 'Solar Radiation at Lae,' by Dr. Q.A. Ahmad as the Research Report in 1979. The maximum mean hourly radiations for Lae are 810 ± 2.4% W/m^2 and the highest mean daily radiations are 6 ± 3% kWh/m^2. For Lae an empirical relationship gives the values of solar radiation estimated from the sunshine data without direct measurements. For the design of solar appliances this estimation is quite reliable. The analysis and compilation of so-far available radiation data in Papua New Guinea shows the utilisation of solar energy as a future prospect.

3. *SOLAR WATER HEATER*

Water heating technology is well established and efforts are to be made to use the indigenous materials and local manufacturing capabilities for commercial ventures. Solar water heating is already economic for the provision of low grate heat, e.g. 50°C and less. Only 1-2% of industrial energy use is for heating water to this temperature, solar energy can substitute directly for electricity in this role. The manufacture of solar water heaters that can perform this task has begun on a commercial scale in Papua New Guinea, and could become a significant local industry. The local production of solar collectors is also highly competitive with imported collectors. Solar pre-heating of water to be raised to higher temperatures, or for steam production, could also be economic, saving a direct proportion of the total heating bill.

Between 18 and 20% of all industrial energy use in Papua New Guinea is for the production of low grade heat up to 150°C and ultimately solar energy could replace imported oil products in this demand. In restaurants, hotels, motels, and in retail food outlets, low grade heating accounts for about 10% of total energy use and again can be effectively provided for by solar energy.

High grade evacuated tube solar collectors to produce steam at 150°C to 300°C, are now utilized commercially in the U.S.A., and are undergoing extensive testing for further development in many countries in the industrialized world. This option could well be justified by real price increases for conventional fuels within five years. Technical co-operation has been agreed to informally by C.S.I.R.O. in Australia, and the University of Sydney Solar Energy Studies group for the introduction of these technologies within the industry and commerce in Papua New Guinea when reasonable demonstration projects are designed, in collaboration with the University of Technology, Lae.

The assessment of the various designs of solar water heaters evolved in both developed and developing countries in terms of (a) thermal performance in the particular climatic conditions of Papua New Guinea, (b) operational problems eg. corrosion and maintenance requirements and (c) suitability for local manufacture and/or assembly has been done by Professor D.E. Fussey and Dr. W. Wong, Department of Mechanical Engineering. The University of Technology, Lae was asked to undertake all three assessments by the Industrial Development and the Department of Labour and Industries.

A solar heater thermal testing rig has been build to the same specification as that used by the CSIRO in Melbourne, Australia. This operates within a steady flow rate through the heater (using a constant head tank) and a controlled inlet temperature. The thermal efficiency of the heater is then obtained by careful measurements of the differential temperature across the heater, the flow rate and the total incident radiation.

4. *SOLAR REFRIGERATION/ICE MAKER*

Of all the uses of solar radiation, cooling is perhaps the most interesting since this is needed most when the solar radiation is most intense. In the rural third world, cooling and refrigeration are needed to store food both for the community itself and possibly for sale in urban areas.

Solar radiation can be used in the refrigeration cycle. Refrigeration cycles involve the evaporation and condensation of a refrigerant; the heat is extracted from the freezer when the refrigerant evaporates. Another cycle involves the absorption-desorption of a vapour in a liquid in which heat is extracted when the vapour evaporates (desorbs) from the liquid. This cycle is suitable for use with solar radiation.

In Papua New Guinea vast amounts of fresh fruit, vegetables and fish are lost or their value depreciated by spoilage. This spoilage could be prevented by cooling them with ice. Ice is an important commodity of commerce, fetching as much as 25 cents per kg in remote areas because of its high cost of transportation (due to melting onroute or the alternative high cost of making it locally at the remote place by electricity or fuel).

Solar icemaking facilities can either be of domestic size or of community size for local conditions. Community size solar ice makers can have manual participation because there would be an operator available for each ice maker.

A prototype solar icemaker producing 25 kg/day and 0.2 m^3 of cold storage capacity for vegetables has been designed by Dr. Q.A. Ahmad and fabricated in the workshop of the Department of Mechanical Engineering. A present it is being tested. Once the tests are satisfactory, it would be taken to a village - Ali Island for demonstration and performance in the rural area. It works on a one-day intermittent cycle based on Ammonia-Water Absorption-Desorption Refrigerant System. No pump is required for the circulation of the liquid. A person will be required to open and close the values in the morning and evening every day and such a system would be very suitable for community purposes, in a village shop or community centre. The idea is to develop Community Icemakers installed in different villages.

5. *SOLAR AIR CONDITIONING*

Field surveys in Papua New Guinea indicate that about 15% of the electricity used in industry, 45% of that used in commercial activities is for air-conditioning and refrigeration. Without addressing the question of appropriate design to remove the need for air-conditioning, it is clear that a significant portion of the total cooling load can be met by direct solar radiation driving air-conditioning and refrigeration systems. Solar air-conditioning is available in Australia, and is being implemented in isolated mining towns. With the high cost of hydro-power in Papua New Guinea these units should soon be competitive here. Again the collector type which will ultimately service air-conditioning and refrigeration units effectively with high grade heat requirements are evacuated tube collectors. The utilization of this resource for this purpose is determined by two factors. One is the thermodynamic compatibility of the source with the end-use, and the other is the cost of the electricity now used to power air-conditioners. It is clear that as soon as the cost of the solar systems are comparable over a period of, say, five years with electricity, they ought to be promoted strongly in order to reduce the demand on centrally generated electricity, and to shift the use of electricity to more appropriate end-uses.

At present a solar air conditioning demonstration unit with a 5 kW cooling load capacity, has been chosen to aircondition a room in the Mechanical Engineering Department. The Yazaki Li-Br Continuous Absorption system has been selected for this purpose with a modification of utilising evacuated tube heat collectors made by the University of Sydney in Australia. The design has been made by Dr. Q.A. Ahmad, Mechanical Engineering Department and the installation and other work is being done by the technical staff. In order to maintain the temperature of the fluid at the entrance of the generator, an auxiliary boiler and a cold water tank is utilised to cool or heat the fluid coming out of the tube collector. The problem of the control of temperature for lithium bromide to avoid crystallisation is quite critical. The three-way valve and the control systems are to be placed in the most economical way.

6. *SOLAR WATER PUMP*

Solar energy would seem to be a logical alternative to fossil fuels for irrigation pumping because solar conditions are favourable at the time of the year when irrigation is required. There have been a number of practical demonstrations of solar irrigation and many laboratory experiments and suggestions. This work has been conducted and is under investigation by Mr. R. Burton of the Mechanical Engineering Department.

As with any design, that of a solar water pump involves compromises. On the one hand sophistication can pay off in terms of higher efficiency, on the other, sophistication increases costs and reduces the likelyhood of reliable field service. Many designs, and proposed designs, have tended to strive for simplicity of this component. This ignores the fact that potential efficiencies for solar water pumps are low and that the major cost item is the collector. The difference between 1% efficiency and 1.5% is considerable in terms of collector area. Devices such as the Kleen pump are at first sight attractive, but the practice would require focussing collectors of sophisticated design to achieve viable efficiencies. Devices such as the Sofrestes pump introduce problems of sealing and lubrication, since they produce a rotative power output from turbines or piston engines. For short lift irrigation, rotative output is unnecessary, since mechanical linkage to a pump element down a bore hole is not required. Pressure can be used to directly pump water.

A diaphragm-pump layout is chosen by R. Burton for the engine with the flexible diaphragm forming an annulus around a solid piston. Because of the low temperature of the cycle it was possible to build the working space entirely out of plastic material. This has great advantages from the point of view of reducing thermal losses since the poor thermal conductivity of the plastic both reduced steady heat loss and cuts down the transient losses caused by the heating and cooling of the working space. Only the valves (of Poppet type) are metal and the valve operating mechanism is outside the working space. Since the pump is designed to operate at low speed (20 strokes per minute) it was necessary to devise a rapid change-over system for the valves to avoid long overlap times and subsequent stalling.

Currently the pump has been run successfully on hot water circulated from a tank. Water was pumped through 3.5 m with a lift of 0.5 m and a delivery of 3m. Start-up was no problem, it being necessary only to circulate the hot water for the pump to commence work (after a warm-up period of 10-11 min). Some trouble was experienced with neoprene rubber diaphragms which ruptured after less than one hour's use. However a nitrile rubber material with rayon was substituted and shows no signs of splitting. Some modifications to the feed pump valves were necessary as the original valves were too restricted and cavitation was occuring on the suction side. At present the pump is being set up with commercially available flat plate collectors and full instrumentation, for detailed testing.

7. *PHOTOVOLTAIC SOLAR PANELS*

These are cells, commonly made of silicon or cadmium sulphide, which generate electricity directly from sunlight. Their costs have so far been prohibitively high, thus preventing widespread application but for remote areas they are already economic. In Papua New Guinea the Posts and Telecommunications Department use photovoltaic cells for providing power for transmitting stations. Recent developments following huge R & D investments in the U.S.A. in particular have changed the economics of solar electricity so much that it is possible that they will produce commercially competitive electricity, even in urban areas, by 1985. They cost $5,000 per installed kilowatt and by 1981-1982 the cost should be between $1,000 and $2,000 per peak kilowatt.

The most important characteristics of the photovoltaic cell include a capacity to be installed in very small units, to supply demand of even a few watts and to add to this as demand grows. Photovoltaic cells are also rugged, with low maintenance requirements. In many ways these are the most promising of all on-site generation technologies. The cost of storage facilities, and the absolute cost of the solar cells themselves are still such that this option will not be favoured where micro-hydro, wind or other options are available. Nevertheless, the price of solar cells is falling remarkably quickly, and it is believed that they would become competitive for rural electricity within two to three years. It is important, then, for Papua New Guinea to gain experience in the implementation and operation of this technology to enable informed decisions to be made when widespread application is possible.

Our interest in the application of these technologies is two-fold. Firstly, we believe that in comparison with the cost of diesel-generated power in rural areas, or even with micro-hydro facilities, solar cells may soon be economically competitive and socially desirable technologies. They are extremely rugged, easy to install, and are almost maintenance free for a 20 to 40 years life. Solar cells can be installed and maintained by individual companies; they can be added to in direct proportion to company load growth, and they represent a strategically stable supply not subject to the transmission failures, or generation failure, which now effect electricity supply.

Very few large factories in Papua New Guinea have an electricity demand which is greater than can be generated off their existing roof areas. For example to satisfy a demand of 1,000 kilowatt per day, a common level of energy consumption for industry in Papua New Guinea, a 2,000 square metre collector area is required, or a roof of 20 metres by 100 metres.

A research project in the Electrical Engineering Department is conducted by Mr. L.J. Carter using solar panels to power radios in remote areas. The project is looking at the problems of emergency communications in such areas and an experimental installation has been made at Baindoang in the Morobe Province.

A low cost HF radio links the local community school with the National Emergency Services network. This radio is in turn linked to outlying villages in the area by means of UHF radios. Hydropower is available at Baindoang and powers the HF set. However in the outlying villages no power is available and solar (photo-voltaic) panels will be used to charge batteries for the UHF radios.

In addition, the UHF radios operate through a talk-through repeater located on a mountain top and this will also be solar-powered.

Solar electricity is also being investigated for use, in refrigeration for medical preservation and lighting in rural health centres; in outstations to replace diesel power; and, in village electricification at various sites throughout Papua New Guinea.

8. *SOLAR POND*

Solar energy is by nature intermittent, hence if the energy is required at night or on cloudy days, it must be stored. The solar pond provides a means of storing heat energy which can easily be recovered.

A pond is constructed with a black lining and filled with concentrated brine (salt water). A layer of fresh water is placed over the brine, resulting in a gradient in the salt concentration. The solar radiation passes through the water and heats the black bottom of the pond and hence the brine. As salt water is much denser than fresh water the warm salt water cannot rise to the surface and loose its energy by convection. There is a 0.8 ha solar pond near the Dead Sea, that operates a 150 kilowatt power station by using the temperature difference between the top and bottom levels in the pond to drive an Rankine-cycle turbine. It is envisaged that there will be a 5 megawatt pond working in 1983 and a 20-25 megawatt plant by 1985, in the same area. There were plans to build a 10 kilowatt solar pond in the Western Province of Papua New Guinea, however this is not proceeding at the moment.

Small, or model, ponds are not as effective because the heat loss from the side becomes appreciable. In the large pond the heat absorbed by the underlying ground is not lost because dry earth is a poor conductor and heat passing into the ground is recovered when the temperature of the water in the pond decreases. Several days of solar heating are required to bring the pond up to its maximum temperature. A film of oil or a plastic cover can reduce evaporation and convertion looses at the surface.

By means of both laboratory and field experiments Dr. Logan at the University of Technology has developed a mathematical model for the behaviour of a model pond. Future research will involve a study of large model ponds and the possibility of using a model pond as a solar water heater by placing a plastic bag of fresh water at the bottom of the pond. Other areas of research include the absorption of the solar radiation as it passes through the salt water and the diffusion of the salt water which, in time, destroys the salt gradient.

9. *SOLAR DISTILLATION*

An important third world need is the provision of an adequate quantity of clean water. Drinking surface water can often leave the villager with debilitating illnesses, so obtaining fresh water from salt or brackish water is very important. Probably the oldest intentional use of the sun's ability to produce heat occurred when man allowed pools of salt water to evaporate and produce salt. Controlled evaporation to produce fresh water from salt water came much later.

In a solar still, the salt water is placed in a black trough with an inclined roof above it through which the solar radiation can pass. Water is evaporated and condenses on the sloping roof, but because of the material from which the roof is made, the condensed water does not drop back into the salt water but runs down the inside of the roof and is collected at the side.

Solar desalination using such simple technologies has been employed in many developing countries, although difficulties has are often encountered mainly associated with corrosion. Funds have just be allocated for Dr. Logan to undertake a study of the solar distillation of both water and alcohol.

10. *SOLAR DRYING*

To preserve food, it can be heated, cooled, dried, treated with chemicals or irradiated. At the University of Technology in Lae, the Chemical Technology department has initiated a project to investigate the operation of different designs of solar driers, and their utilization in drying local produce. The initial project involves bananas.

If the moisture content of wood is below 30%, fungi do not readily attack wood, hence it is important to dry wood to below this moisture content. The Mechanical Engineering Department at Unitech is at present designing a solar kiln especially to dry balsa wood for a sawmill in the East New Britain Province.

11. *OTHER SOLAR ENERGY APPLICATIONS*

Another use of solar energy in a third world country is in solar cookers. With a simple flat plate collector the maximum temperature is limited to about 100°C. Higher temperature are required for other applications like cooking, necessitating a focussing device such as a concave mirror. There are a number of small devices on the market in Papua New Guinea.

Another possible use of solar radiation is in water conservation using plastic greenhouse which increase productivity while greatly reducing water consumption.

12. *CONCLUSION*

This paper has described some of the research and development projects on solar energy that are currently being carried out in Papua New Guinea.

Some of these projects have been staged in the hope that the Government and public sectors become interested in the manufacturing of solar energy appliances. The greatest hurdle is the economic competition at this stage. If we consider the social benefit and the rural uplift as the factors to be included in the economic consideration, there is no doubt that these solar energy appliances can be used. The Government, at the early stage may have to subsidise and encourage this manufacture.

The projects described here are part of Governments National Energy Strategy which involve not only direct solar application but also other renewable energy sources such as pyrolysis, waste combustion, charcoal, biogas, power alcohols, power oils and microhydros.

DEVELOPMENT AND PROSPECTS OF SOLAR ENERGY APPLICATIONS IN THE PHILIPPINES

by

LAURIE O. BAUTISTA

Introduction

Ever since the energy crisis of 1973, the world has been shocked into realizing that oil is not an inexhaustible supply. Countries greatly dependent on oil for their energy requirements were faced with the severe problem of looking for enough fuel supply bearing the stiff effects of inflation.

The Philippines is one country that is highly dependent on crude oil for its commercial energy requirements. Fifteen years ago, it had an annual consumption of 36 million barrels of oil equivalent (MBOE). In 1980, it has more than doubled to 91.8 MBOE. Oil consistently accounted for at least 93 - 95 percent of annual national consumption. Because of its near total dependence on one single energy source, its oil import bill ate up its foreign-exchange reserves.

Until the 1973 oil crisis, oil importations have never gone beyond 13 percent of the total import bill. Within the eight-year period, however, cumultive price increase until 1980 showed more than double the figure at 32%. The balance of the country's energy requirements is supplied by hydroelectric and a small amount of coal. In 1979, oil from offshore exploration started to be produced, but it is so far contributing only 10% of the total oil requirements. To alleviate dependence on the costly and depletable fossil fuel supply, diversifying the country's energy sources becomes imperative.

Solar Energy Potentials

The Philippines lies on the sunbelt of the planet. As such, it gets an abundant heat from the sun averaging 400 cal/cm^2 per day to a maximum of 600 cal/cm^2 per day during summer with a total yearly sunshine hour of 2000.

In many places throughout the country, wind speed exceeds 10 km/h. This prevailing wind velocity is a highly potential power source for water pumping. It is a fact, however, that these same areas are very often visited by typhoons with exceedingly high wind velocities.

Considering the bountiful sunshine and seasonal rain in the Philippines, biomass growth rate is indeed remarkable. Non-commercial use of agricultural and forestry wastes is estimated at no less than 10 million barrels of oil yearly. Taking into account the total biomass potential, this degree of utilization is still not significant. A lot of available agro-forestry wastes remained to be tapped.

The Non-conventional Energy Development Programme

It was in January 12, 1977 when the Bureau of Energy Development (BED) of the Ministry of Energy was mandated by through Presidential Decree 1068 to accelerate the research, development and demonstration (R,D & D) of non-conventional energy technologies. Through the BED's Nonconventional Resources Division (NCRD), local grant was made available to initiate R, D & D projects.

Because of meagre financial resources, the national programme gave priorities to simple, readily adaptable and low cost technologies, those that need little research to make them useful. At the same time, emphasis was given to rural-based technologies as it has been a national policy to give major attention to the upliftment of rural living conditions. Capital intensive and long term researches are given to the hands of the more advanced countries who are financially capable. With these guidelines, projects in the areas of direct solar, wind, biomass and other alternative energy technologies were implemented through private and government agencies and individuals. Such was the stepping stone towards a more energy conscious community. R, D & D projects gave fruitful results and pilot and demonstration projects gained strong foothold. Commercialization of established technologies thus began.

The national and international developments in the field of solar energy demanded for a more intensive and updated energy programme.

It is in this respect the Centre for Non-conventional Energy Development (CNED) was created in mid-1979. As the expanded vision of the then NCRD, it was tasked to embrace the responsibilities as the government's lead agency in carrying out R, D & D on non-conventional energy development. With no doubt, local research capabilities have to be developed. Priority development areas not being given immediate attention especially in the local scene have to be worked on. This is primarily the reason why the CNED is a research complex.

The CNED is primarily a funding agency. The national programme on non-conventional energy has spent a total of approximately US$ 4.5 million from local grants. Since its inception in 1977, to date, 68 projects have been formed out to local implementors from private and government agencies and individuals. Eighteen (18) projects have been completed; 27 are on-going and 23 are on their initial stages. Several of these projects are in the field of solar energy applications.

In the field of direct solar, solar drying, a technically simple and relatively established technology has gained public interest and acceptance. Some 25 units have been strategically dispersed throughout the country for the purpose of evaluating its techno-economic and social impact and acceptance on and by the users. Primarily for fish and crop drying, its use on a co-operative or small-scale business nature is being encouraged. Feedbacks from the field test sites are major inputs in gauging the success of the dispersal programme. With such inputs, modifications for improving system performance and implementation schemes are made easier.

Solar water heating is another direct solar application where significant progress has been made. It is proven to be technically and economically viable. It cannot be denied that the increasing interest and industrial applications are fruits of the non-con programme. From only one (1) firm in 1977, there are now ten (10) local companies engaged in the design, installation and marketing of solar water heating systems and one firm locally manufacturing solar collectors. To date, some 76 units of the 55-galoon domestic SWH were dispersed in key cities throughout the country. Another 24 units are programmed for immediate dispersal under very easy financing terms. Currently, there are now 4 industrial applications of SWH in the country.

The government realizes that one drawback for popular use of non-con device is its high initial cost. To alleviate this, incentives are given by way of deduction from gross income for purchase of any non-con device; exemption from tariff duties and compensating tax for any imported machinery and equipment, spare parts and all materials required in the establishment and construction of non-conventional energy facilities or equipment; and lastly, priorities for government financing for non-con devices.

Within the next 5 years, the above applications of direct solar energy are expected to provide a total of 13.2 thousand barrels of oil equivalent. SWH will contribute 2 MBOE in 1981 and steadily increase to 12 MBOE in 1985. This will represent a total flat-plate collector area of 198,860 sq.ft. by 1985. Solar drying provides the rest of the energy contribution corresponding to a collector area of 17,893 sq.ft.

Realizing the potential of wind energy, the non-conprogramme is currently working out the implementation of a windmill water-pumping project where some 3000 wind power plants will initially be installed in 1981 and to reach 10,000 plants in 1985 contributing approximately 600 barrels of oil equivalent.

In the field of biomass, utilization of agricultural wastes to generate producer gas and supplement diesel oil requirement of dual-powered engines has been successfully demonstrated. A 45-kW irrigation system in Siniloon, Laguna, a province in Luzon, irrigates 50 hectares of riceland. In Kalayaan Laguna, a 30-kW electrification system provides lighting to some 100 households. A one-ton per day pyrolytic converter which transforms agricultural residues to high energy fuels was also developed and is now being used at the National Grains Authority Centre in Cobanatuan City in Central Luzon for drying operations. This project is in co-operation with the Georgia Institute of Technology and UNIDO. Under the same programme, a low-cost continuous flow rice hull fired grain dryer has been developed at the University of the Philippines in Los Banos.

Biogas technology finds practical application in an agricultural country like the Philippines. Its first industrial application was demonstrated by Maya Farms, an integrated swine raising and food processing firm which draws 50% of its total energy requirement from its biogas plants with waste inputs from its present stock of about 17,000 hogs producing approximately 50,000 ft^3 of gas a day.

The proliferation of biogas is one of the government's immediate thrust. Through the Ministry of Agriculture, 300 installations of 91,500 ft^3 per unit capacity are targeted for 1980. A total of 27.5 million cu.ft. or 4 MBOE will be generated.

As of the end of 1979, there are 399 known biogas plants in the Philippines. One hundred one (101) are government demonstration plants and 298 are private installations. In the promotion of industrial-scale use of the technology, the Ministry of Energy conducts series of biogas seminars for large scale hog raisers.

It is obvious that the adoption of the biogas technology is a pollution abatement measure and it is this non-BTU benefit in addition to its energy contribution that are seriously being considered in the programme.

In February 1980, the government embarked on a national fuel alcohol programme through the creation of the Philippine National Alcohol Commission (PNAC) which will formulate and define the policies, plans and programmes and guidelines for the production and distribution of alcohol for blending with gasoline. The Philippines Sugar Commission has been tasked with the accelerated establishment of distilleries and plantations all over the country. With the production of alcohol, the programme aims to displace 20% of gasoline consumption with the gasoline-alcohol blend (20-80) in 1985. This would amount to 96.2 MBOE in 1981 and increase to 2,451.5 MBOE by 1985. By that year, the amount would correspond to a production of 397.3 million litres of alcohol and require a total of 60,170 hectares of new sugar plantations. This calls for the installation of 25 distilleries during the 5-year period.

For 1980, major emphasis has been given to integrated village energy applications especially in rural villages with nil hope of conventional electrification through the power grids. On its initial phase of implementation is the Integrated Village Energy Systems (IVES) project in the small island of Pinamuc-an in Southern Philippines. Different alternative energy technologies like biogas, producer gas, alcohol distillation, solar drying and others will be introduced in the hope of attaining energy self-sufficiency in the island.

International co-operation

The Philippines, just like any developing country recognizes the need for international co-operation in the field of solar science and technology development. By way of exchange of information, experiences and expertise, it does not underscore the mutual benefits that can be derived.

Specially with the ASEAN countries and other countries with similar needs and resources, it only wishes to be a part of whatever co-operative endeavours towards development will be taking off.

SOLAR ENERGY DEVELOPMENT PLAN OF THE REPUBLIC OF KOREA

by

JONG-IN LEE

PART I

1. Preface

Korea is heavily dependent upon imported oil. In 1977 the share of oil imports to the total energy requirement accounted for 65.3% and it is expected that the figure will go up to more than 95% in the year 2000. Sound long term energy policy targets will be required to bring down the level of such a large overseas dependence and to develop new energy sources that are basically inexhaustible, most efficient and cleanest and also as replacements for conventional ones. Greater emphases will have to be placed to sustain economic growth, safeguard the national security and achieve the national goals of self-sufficiency in energy, environmental protection and welfare. It is also urgently needed to tap the indigenously recoverable energy resources, shift the patterns of energy consumptions toward more efficient uses of them, protect and improve energy-related sanitation, safety, well-being and environment and conduct basic R&D in energy explorations and utilizations.

Energy consumptions worldover will double in the time span of 20 years, whereas oil production in the same period will record no measurable increase over the current level. Price rises in the crude oil by OPEC countries are expected to continue in the future as in the past. Moreover, OPEC's practices to cut back or suspend oil supplies on-again and off-again depending on the political and military situations not favourable to the cartel's interests will be ever-present.

By the turn of the current century the total energy need for Korea is estimated to increase by 8.4 times over those of the 1977 level, of which more than 95% will be provided by oil imports which will cause the spending of hard currency to an enormous amount.

To cope with the situations like these, an immediate review of the current energy policy is needed on the aspects of its justification and reliability. The cost determination of which one would be more economical between renewable energy technology and the conventional technology to be replaced by its is not certain right now in consideration of the various elements involved. But it is important to recognize the fact that the alternate technology is capital-intensive and that payback spreads over a longer period of time. It is too late if investments are planned based on the assumptions that oil prices have come up so high that there appears no risk at all for the investors. Such a posture on the part of investors will have serious impacts on other sectors of economy. Therefore, readiness of investments regardless of what the energy alternatives would be is very important.

Nuclear power and solar energy are the two forms that are the most promising alternatives for Korea. Solar energy is virtually inexhaustible, non-pollutant and available everywhere. And no cartel can control it. It can meet a considerable share of domestic needs. Solar uses are no longer imaginary and are fully demonstrating their practical availability, technologically and economically. MOST countries are actively engaged in solar projects. With the advancement in technology and development, cost-down in solar systems and their increased uses, solar energy has been receiving increased attention.

The project proposals to be made in the field of energy alternatives are expected to exert a great influence upon overall energy applications including solar utilizations. It is considered that now is the opportune moment to take active energy measures with solar energy as a major component of all possible alternatives to be incorporated in the long term national development will largely lie not so much on technology as on policy priority.

Table 1. **Long Term Energy Needs and Imports**

Unit: Quads

Figures in brackets: %

	Total Needs	*Local Supplies*	*Imports*
1965	0.49 (100.0)	0.43 (87.6)	0.06 (12.3)
1977	1.33 (100.0)	0.46 (34.7)	0.87 (65.3)
1986	3.35 (100.0)	0.45 (7.8)	2.90 (92.2)
2000	11.12 (100.0)	0.49 (4.4)	10.63 (95.6)
Annual average rate of increase of years 1978-2000	9.7%	0.2%	11.5%

1 Quad = 10^{15} Btu = 2.5×10^{14} kcal

* By courtesy of the Korea Development Institute

2. Energy Problems

Korea has very limited solid fuel reserves and other domestic energy resources. Major conventional resources consist of wood and charcoal, coal (hard) and hydropower. Nuclear power and solar energy are among the promising alternatives.

As of 1976, coal deposits total approximately 1,500,000,000 MT, but variations and irregular formations of coal beds and the width to be mined and in-depth mining of coal seams bring the volume of recoverable coal reduced to roughly 600,000,000 MT or about 40% of the total. On the other hand, the future annual maximum production is estimated to stand at 24,000,000 MT. Calculated based on this figure, availability of coal life-time will last no more than 25 years.

Hydro potential is assumed to be around 3,000,000 kilowatts, but, owing to such natural configurations as the meanders of most of the inland rivers, dearth of water flow or imbalance of annual rainfall by different local sites, the capacity to be used for power generation is less than 1,360,000 kilowatts.

When nuclear power is adopted as an alternate solution, factors to be considered include price rises involved in the safe supply of uranium fuel, safety features, radioactive waste management and treatment, etc.

On the other hand, an estimated 2,780.9 x 10^{12} kcal (11.2 quads) of energy will be consumed for Korea in the year 2000 which is 8.4 times over the 1977 level of 333.7 x 10^{12} kcal (1.33 quads). Import dependence by the turn of this century will increases to more than 95% from 65.3% in 1977.

3. Solar Potential

Of the total energy consumption throughout the world, about 20% comes to end-users from wind power, hydropower, biomass fuels and solar resources like direct sunlights. The major energy forms that the earth planet receives from the sun and are used for day-to-day services include:

(i) Direct thermal applications:

* Solar heating and cooling for houses and buildings
* Agricultural and industrial process heat

(ii) Applications of solar electricity:

* Wind power conversion
* Photovoltaic conversion
* Solar thermal power conversion
* Oceanic thermal energy conversion

(iii) Included in addition to these are the total energy systems (TES) which provide both electricity and heat and can be used both in the building sectors (residential and commercial) and in industrial processes and the satellite power systems (SPE) which would capture solar energy in stationary orbit above the earth, convert it to electricity, and beam energy to earth in microwave form. Solar characteristics of these kinds have of the following features:

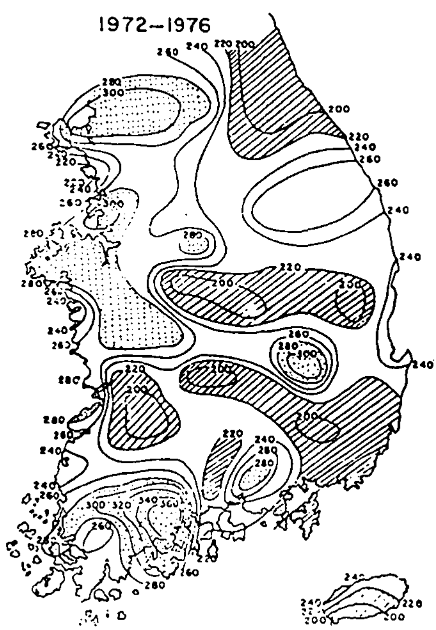
A. Solar energy is virtually of no depletion. The energy which the earth receives from the sun is the volume that is far beyond our imagination. This energy will continue to be made available as long as the sun continues to function. The solar energy emitted on the soil of Korea is calculated to be in the range of 400 quads annually.

B. Solar energy is available everywhere. It is the resources that no man can interfere in any forms.

C. Solar energy causes no pollution. It does not produce air pollution like coal or oil nor is there any radiation dangers inherent in nuclear power.

D. Solar technology has favorable effects upon economy and employment. It can contribute to expanding employment opportunities as the solar industry accelerates its activities. The national economy will also benefit by turning in into export-oriented.

Figure 1. The annual and the average distribution of observed global radiation in Korea



With all aspects being considered together, solar energy presents a possibility of being tapped not as an auxiliary resource but a major one. Technology and resources guarantee that it would be able to meet all energy requirements of the world if only the utilizing efficiency is increased. But at present solar portion represents very low percentage point.

This explains the fact that solar equipment and materials are too expensive because of the limit of production capacity of a small-scale industry. The current status of the not-yet-maturity of full-fledged technology development and the resulting uncertainty on the part of endusers assuring them to spend a considerable amount of money for solar utilizations pose major reasons. The point stresses the need for an increased use of solar energy through the acceleration of technology development, cost reduction of solar products by market expansion and implementation of government policy goals. Consequently, the problems are when it would enable solar energy to attain the highest levels of a wide range of consumptions. They are also dependent upon efforts of both private and government sectors to which extent they would be willing to support and participate in solar development and applications. All of these require a long term planning and implementation with for more sustained R&D in solar energy than ever.

At present, the domestic solar utilizations with the exception of hydropower account for very low percentage points (Table 2), but it is of vital importance for the government to take viable measures involving technology, economy and policy goals to pull up the solar portion up to some percentage of all energy requirements by the year 2000.

Table 2. **Demonstration of Solar energy Utilization**

year / *activities*	*1978*	*1979*	*1980*	*Total*
Solar Hot water	10	67	70	147
Solar space Heating	13	33	108	154
Crop and Food Dehydration		1	2	3
Photovoltaic Conversion		1	1	2

PART II

1. Objectives

The objective is to secure a stable energy source for future energy requirements that will be essential to the sustained national economic growth and environmental conservation with the use of technology and applications of solar energy, non-polluting, inexhaustible and available to every country with no cost, being converted into thermals, electricity and fuel.

2. Research Development and Demonstration Program

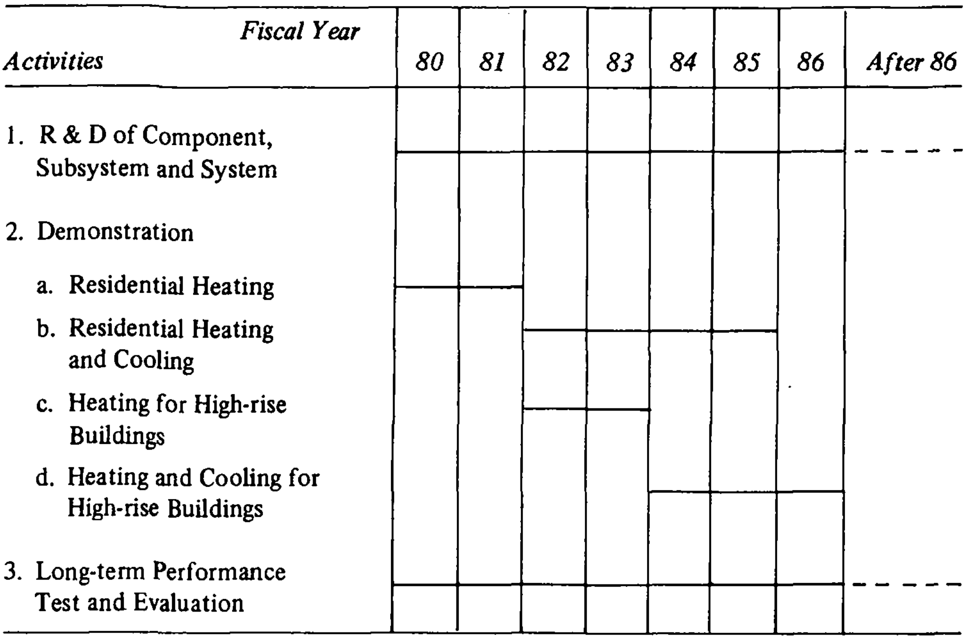
A. Technical R & D and Demonstration

1) Solar Heating and Cooling of Buildings and Domestic Hot Water System

a) Program Activities

- o. Solar heating and cooling system
- o. Solar collectors
  - Flat plate collector
  - Solar concentrator
  - Tubular type collector
- o. Thermal storage system
- o. Insulation material
- o. Solar house construction and demonstration
- o. Experimental system for high-rise buildings
- o. Long-term performance test and evaluation

b) Program Milestones



2) Agricultural and Industrial Process Heat Applications

a) Program Activities

o. System development

o. Development of collectors and thermal storage system

o. Crop and food dehydration R & D and demonstration

o. Heating of animal shelters R & D and demonstration

o. Green-house heating and space conditioning R & D and demonstration

o. Survey of industrial process heat consumption

o. Industrial process heat application test and demonstration

b) Program Milestones

Fiscal Year / *Activities*	*80*	*81*	*82*	*83*	*84*	*85*	*86*	*After 86*
1. R & D Component, Subsystem and System	—	—	—	—	—	—	—	- - -
2. Demonstration								
a. Crop and Food Dehydration	—	—	—					
b. Heating of Animal Shelters	—	—	—	—				
c. Green-house Heating and Space Conditioning	—	—	—	—				
d. Low Temperature process Heat		—	—	—				
e. Medium Temperature Process Heat				—	—	—		- - -
f. High Temperature Process Heat					—	—	—	- - -
3. Long-term Performance Test and Evaluation	—	—	—	—	—	—	—	- - -

3) Solar photovoltaic conversion system

a) Program Activities

- o. Investigation of Low-Cost Solar array project in U.S.A.
- o. Silicon solar cell fabrication process
- o. Low-cost silicon material production process
- o. Large-area silicon sheet production process
- o. Encapsulation materials and encapsulation system for solar cells
- o. Development of automated processes and equipment for low-cost high-volume production of solar arrays.
- o. Concentration photovoltaic conversion system
- o. Storage and power conditioning system

- o. Solar cell performance and test standards established
- o. Small-scale application and system field tests
- o. Solar photovoltaic conversion system demonstrations with installed capacity of 1okW-1MW

b) Program Milestones

Fiscal Year / *Activities*	*80*	*81*	*82*	*83*	*84*	*85*	*86*	*After 86*
1. Investigation of Low-Cost Solar array project								– – –
2. R & D of component, Subsystem and system								– – –
a. Solar cell material								
b. Solar cell fabrication process								
c. Encapsulation material and techniques								
d. Automated process for high-volume production								
e. Storage and power conditioning system								
f. Concentration photovoltaic conversion system								
3. Solar cell performance and test standards established								– – –
4. Solar photovoltaic conversion system demonstration	2 kW	5 kW	100 kW	500 kW	1 MW	2 MW		

4) Fuels of Biomass

a) Program Activities

o. Design and test of methane generation (anaerobic fermentation) plant.

o. R & D of alcohol (ethanol, methanol) Production process.

b) Program Milestones

Activities / *Fiscal Year*	*80*	*81*	*82*	*83*	*84*	*85*	*86*	*After 86*
1. R & D of fuels of biomass								----
2. Demonstration								
a. Methane generation plant								
b. Alcohol production plant								

5) Solar Basic Research

a) Program Activities

o. Hydrogen production

o. Research on solar photochemistry

o. Research on photosynthetic process

o. Advanced concepts of solar energy utilization

b) Program Milestones

Activities / *Fiscal Year*	*80*	*81*	*82*	*83*	*84*	*85*	*86*	*After 86*
1. Solar Basic Research								----
a. Hydrogen production								
b. Photochemical conversion								
c. Photosynthesis								
d. Advanced utilization concepts								

B. Technology Support and Utilization

1) Solar Energy Resource Assessment

a) Program Activities

- o. Standardization of existing solar energy data
- o. Selection of insolation measurement network
- o. Standardization for measurement and analysis
- o. Data collection
- o. Localization of insolation measurement instrument
- o. Publication of Data Hand Book

b) Program Milestones

Activities / *Fiscal Year*	*80*	*81*	*82*	*83*	*84*	*85*	*86*	*After 86*
1. Standardization of existing data	- - -							
2. Selection of network	———							
3. Standardization for measurement and analysis	———	—						
4. Data collection			———	———	———	———	———	- - - -
5. Localization of measurement instrument					———	———	———	- - - -
6. Publication of Data Hand Book			———	———	———	———	———	- - - -

2) Standardization of Solar Equipment

a) Program Activities

- o. Establishment of Performance test and inspection criteria
- o. Solar equipment performance standards

b) Program Milestones

Activities / *Fiscal Year*	*80*	*81*	*82*	*83*	*84*	*85*	*86*	*After 86*
1. Establishment or performance test and inspection criteria								- - - - -
2. Solar equipment performance standards								- - - - -

3) Support for Accelerated Uses of Solar Energy

A. Provision of financial assistance for purchase of water heater

B. Loans and tax write-off for new houses using solar system

C. Loans and tax write-off for retrofiting houses

D. Provision of the structure and directional line based on the architectural code to retrofit the solar systems after new non-solar houses have been built

E. Making it mandatory for owners of government or public buildings to install solar systems

F. Increased supply of back-up thermal sources or electricity and fuel for solar houses by reducing their rates of bills

G. Increased encouragement for small and medium industry to employ solar energy by providing them low-interest loans and other incentives

H. Provisions of low-interest loans and other incentives for solar manufacturers.

I. Establishment of inspection criteria applicable to solar equipment and components

J. Making it mandatory for the Korea housing corporation to go solar a certain quota of its new housing constructions.

SOLAR ENERGY IN SRI LANKA

by

B.N. WIKKRAMSURIYA and A.N.S. KULASINGHE

Sri Lanka's use hydro electricity, oil products and traditional fuels for their day to day energy requirements. The total energy consumption for the year 1977 was about 10,000 GWh and it had been used as follows:-

1200 GWh from Hydro electricity

2800 GWh from oil products

6000 GWh from traditional fuels

Limitations to above resources

At present Sri Lanka's electrical energy is met mostly by her hydro-power resources. The total resources in Sri Lanka of large scale hydro power and energy, estimated as available, is very limited and it is about 1590 MW and annual energy of about 6225 GWh. The actual load growth, which is presently about 11 per cent per annum depends upon various factors and hence it is very difficult to predict the electrical power and energy generation requirements over a medium or long term periods. The said estimated hydro power and energy will only be sufficient to meet the demand for about another 10 to 12 years.

About 40 per cent of the export earnings will be necessary for importing the requirements of petroleum fuels of the country. This as well as the frequent increases in fuel prices will be a great burden over the country to continue with its mass development projects.

Sixty per cent of the energy consumption of the country is met by traditional fuels such as firewood and agricultural residues. This has resulted in adverse effects on the environment such as changes in rainfall patterns and soil errosions.

The energy demand will rapidly grow due to the giant projects such as Free Trade Zone (FTZ), accelerated Mahaveli programme, other industrial growth, Rural development schemes, etc., and high fuel cost and resulting changing over of oil operated machinery, cooking etc., to electricity. This rapid increase in demand with the limitations of resources create the necessity to find alternate resources to meet the future energy demand. There are no known resources of coal, gas or oil in Sri Lanka. So it is very necessary to engage in experimental generation from solar energy, at least to meet some percentage of the Sri Lanka's future energy demand. Even though this being a new field for Sri Lanka a certain amount of research and development work are being carried out at various institutions and organisations.

1. The University of Moratuwa is conducting research work on solar boilers and solar air driers for agricultural drying.

2. The University of Peradeniya is carrying out research work concentrating on solar collectors, resistence type vertical axis wind turbines, variable stroke wind operated water pumping systems, etc.

3. The National Engineering Research and Development (NERD) centre is carrying out research in the following fields:-

   (a) Flat plate collectors. A boiler feed water system is already in operation.

   (b) Small concentrators for high temperature cookings.

   (c) Hot box type solar cooker.

   (d) Tracking fresnel mirror concentrator for power developments on a small scale.

   (e) Rotary steam engine for use with concentrating collectors.

   (f) Solar power operation of mechanical vapour compressor cooling system.

   In addition to research in related fields such as:-

   (a) Low cost bio-gas generators.

   (b) Deduction in cost of wind-mills by using new materials and manufacturing techniques.

   (c) Use of wind-mills for power generation and pumping.

   (d) Developments of new and low cost water turbines.

   (e) Use of the hydrolic compressor for power generation.

Sri Lanka Institute for Scientific and Industrial Research (CISIR) is carrying out research on solar driers.

The water resource board is carrying out studies on wind regimes in different parts of Sri Lanka and developing small scale water pumping windmills for irrigation purposes in rural areas.

Rural Energy Centre- Pattiyapda

This is a joint venture between the Sri Lanka government and the United Nations Environment Programme (UNEP). The implementing agency of this project is the Sri Lanka Electricity Board. The objective of this project is to study on an experimental basis the possibility of harnessing locally available sources of energy (solar, wind biogas) and their socio-economic impact on rural populations. The following projects area in operation in the site.

(a) Photovoltaic panels converting solar energy into electricity and used for battery charging and water pumping.

(b) Solar collectors convert solar energy into thermal energy which is again converted into mechanical energy in a Rankine Engine. This mechanical energy is used to generate electricity and feed the village distribution system or to charge batteries. Provisions are also available to operate the Rankine unit using firewood, biogas etc., during insufficient sunlight periods.

(c) Four windmills each giving an output of 2 kW (at 40 km/hr wind regimes) of electrical energy for battery charging and water pumping.

(d) Biogas digester to produce biogas and used directly for cooking or to generate electricity. The fertilizer displaced from the biogas unit used in the fields where crops are grown.

SOLAR ENERGY DEVELOPMENT IN THAILAND

by

ORAN RATANAPRATARN

1. Energy Situation in Thailand

As an agricultural and developing country, Thailand needs basic infrastructure and energy to be able to achieve the national development goals. Demands of energy in the form of electricity and petroleum products are at an increasing rate as the government pushes for new industrial and agricultural development projects. During the past 10 years, the total energy consumptiôn in Thailand increased more than double and the electricity consumption increased by 5 times. Fossil fuels accounted for 81 percents; hydroelectric power 9 percents; lignite and imported coal 2 percents; wood, charcoal, baggasse and paddy husk 8 percents.Though Thailand used fuel oil at about 60 millions barrels annually or only 1.5 barrels per capita which is much less than all developed countries but the fuel oil accounts for 22 percents of Thailand's import bill. Statistics indicated that Thailand suffered a total trade deficit around 2,000 millions U.S. dollars annually while the payment in having petroleum energy was around 1,600 millions U.S. dollar per year.

As fossil fuel costs continue to rise and there is an indication that world fossil oil reserves will soon be depleted unless major discoveries will be striked, the government of Thailand has been putting greater emphasis on the exploration, research and development of new and renewable energy resources as an alternative to reduce imported oil since 1973. This fact is reflected upon by the energy development plan of the fourth five years national economic and social development plan. The general policies pertaining to the development of new and renewable source of energy which were adopted can be summarized as follows:

1. The development of new and renewable energy is a key element to the national survival and is a matter of urgent needs with an ultimate goal of self-sufficient of energy.
2. The development of new and renewable energy must serve the people equally throughout the kingdom.
3. Research and development of new technologies to exploit new and renewable energy are fully encouraged and supported.
4. Private sectors and semi-government agencies are encouraged and supported to commercial fabricate equipment, components, and energy producing system by local skills and materials.
5. Cooperation with international organizations or other cooperating nation are encouraged to exchange of information, personnel, and technology for the development and utilization of new and renewable energy.

2. Potential of Solar Energy

Thailand situates between 5° -21° north latitude, and 96° -106° east longitude, covering an area of about 514,000 km^2. Annually average daily solar radiation in Thailand is about 17 MJ/m^2 per day which is reasonably high. The climate of Thailand has strong seasonal nature, with a wet rainy season from May to November and a dry season from December to April. There is, however, comparative little variation in the amount of available radiation, varying about ± 15 percents from the norm. Even during the rainy season, long unbroken period of cloudiness are rare, with rain clouds often building up in the near afternoon after a bright sunny morning. Thus, there is usually adequate radiation over most part of Thailand to run solar energy equipment effectively. The atmospheric in Thailand tends to be slightly hazy and to have a high level of absolute humidity, both of which make the diffuse component of solar radiation comparatively high.

3. Marketing of Solar Equipment in Thailand

3.1 *Hot water heating application*

There are about 13 flat plate solar collector distributors available in Thailand. 5 of which are local manufacturer. Present cost of flat plate solar collector is varied from 75-200 U.S. dollars per square meter. Potential users are identified as hotel, hospital and industrial sector. About 500 square meters of flat plate collector have been installed in various places, mostly for hot water utilization in hotels, and about 1,000 square meters of collector will be installed under a contract. Moreover, it is predicted that the market for hot water heating using a flat plate collector will be more than 1,000 square meters.

3.2 *Photovoltaics application*

Presently, the market of photovoltaics cell is only in the area of telecommunication. The telecommunication department will be award a contract worth 10 million U.S. dollars this year to establish a telecommunication network for the remoted rural areas using a solar cell as a power source.

4. Solar Energy Programme

The activities of solar energy programme in Thailand are summarized as follows:

4.1 *Resource Assessment*

Solar radiation network will be set up; more than 22 solar radiation measurement stations have been established. Nevertheless, only total radiation intensity are recorded. It is expected that one or two direct solar radiation measurement stations will be added to the network. As a consequence, various empirical formula to predict solar radiation intensity will be tested and analyzed in detail.

4.2 *Research and Development*

Research and development programme will be conducted for all solar energy applications with different emphasis: For less sophisticated technologies such as solar drying, emphasis will be on improving system efficiency, being easily duplicated by villager with readily available materials, and lowering the investment cost while emphasis for those of high sophisticated and less investment R&D such as small scale solar electricity generation. Solar air-conditioning system will be directed to a technology introduction and testing its technology and economic viability and relevant component development. Another important study will be on performance testing of a solar collector, a component of a system or a system itself, a reliability testing of a system, a social testing of a prototype unit.

Since solar electricity is one of our main interest, the Electricity Generation of Thailand has given a contract to educational institutes to undertake a feasibility study for conversion of solar energy to electricity by using available man power, technologies, and materials. The Chulalongkorn University will study the heliostate recover system capable to produce 100 kW of thermal energy while the King Mongkut Institute of Technology will study the cylindrical parabolic trough capable of generating 10 kW. of heat. With regard to generation of electricity by photovoltaics cell, several researchers at the Chulalongkorn campus are investigating new approach to produce a low cost silicon solar cell.

4.3 *Development and Demonstration*

As great need for air-conditioning is demand for Thailand, in 1979, the government installed a demonstration project which utilizes a two-tons air conditioning unit donated by the Yazaki Company of Japan. However, the cost of solar airconditioning system is still expensive, being as high as 10,000 U.S. dollars per refrigeration ton. Also, there is a programme to demonstrate a large scale solar distillation plant. A 300 square meters of solar distillation plant is expected to commence early next year. The unit will produce pure water for laboratory purposes. For heating system, perhaps, three hospitals, three hotels and two industries will be selected for a demonstration of a solar hot water system; two more industries will be chosen for a solar process heat utilization. For solar drying, since there is a number of solar dryers developed in research institutes, it is expected that a large scale demonstration programme will be initiated shortly.

4.4 *Demonstration and Promotion*

This activity will be examined at a later phase of the project. As incentive must be provided but available information are not sufficient to determine any criteria for judgement.

5. Conclusion

Development of solar energy in Thailand is still in the initial stage. Strengthening of her capabilities for the development of solar energy would require technical cooperation. Development of technical personnel is currently undertaken by educational institutes, both in undergraduate and graduate level.

As stated in the fifth national economic and social development plan, for the solar energy, the goal is to reach a 3 million barrels of fossil fuel substitution in 1986. Incentive policy to promote solar energy utilization will be formulated after necessary information related to energy saving, social acceptance, experience from other countries and marketing situation are fully assessed.

OUTLINE OF SOLAR ENERGY ACTIVITIES IN THE UNITED STATES OF AMERICA

by

J.D. WALTON

The major growth in solar energy R&D began under the direction of the National Science Foundation (NSF) about 1970-1971. During the period 1970 through 1973, the total budget was less than $1 million. In 1974, the Energy Research and Development Administration (ERDA) was formed to co-ordinate all energy activities including solar energy. As energy became more important and the annual budget for solar increased to about $500 million in 1977-78 the Department of Energy was established (DOE). The current 1980-81 budget is essentially $1 billion. It is now uncertain what the future of government support for solar energy will be since our President elect, during his campaign, promised to abolish the DOE. This does not mean the abolition of solar energy support since the programme is currently popular and grew very well under the operation of ERDA. It does mean, however, that there is likely to be a major re-organisation with a period of uncertainty before we will know at what level it will be supported in the future.

Solar energy activities are carried out by a multitude of universities, national and private laboratories and the industrial sector. Most of the R&D activities are monitored by the Solar Energy Research Institute (SERI) in Golden Colorado. SERI also participates directly in R&D work and has major responsibility for co-ordinating the Government's solar energy activities, organising and conducting seminars and workshops on specific national programmes and with the dessimination of information and promoting solar energy with the public. National laboratories involved in solar energy programmes include Sandia Laboratories at Albuquerque, New Mexico and Livermore, California; the Jet Propulsion Laboratory (JPL) at Pasadena, California and the National Aeronautics and Space Administration (NASA) Lewis Laboratory in Cleveland, Ohio. A few of the universities include the University of Wisconsin, University of California, Colorado State University, New Mexico State University, University of Houston, University of Florida and the Georgia Institute of Technology.

The major national programmes are divided into the following eight principal areas:-

1. *Solar Heating and Cooling of Buildings (SHACOB)*

This area has essentially reached the commercial stage with the primary government support in the area of tax incentives and large-scale demonstrations. About one million square meters of flat plate collectors, or may be some multiple of that number, are manufactured annually with an established commercial base. Most of these systems use for hot water heating. Seats Roebuck and Company is reported to be ready to come out with their own solar hot water heater system (a good indicator of the maturity of the technology). The National Bureau of Standards (NBS) (work by Dr. James Hill) and the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) have established standards for the testing of commercial flat plate collectors for air and water heating.

2. *Agricultural and Industrial Process Heat (AIPH)*

The agricultural programmes are directed primarily in the areas of food processing, grain drying, crop drying, heating of animal shelters and heating and cooling of greenhouses. Since the temperature requirements generally are relatively low, emphasis has been on the use of individually designed, very low-cost systems using readily available materials, which can be constructed by farmers with technical assistance from the extension service. Two major demonstration drying projects are for raisin drying in Fresno, California and for soybean drying in Alabama. A project for drying peanuts was described in my paper on Tuesday. A number of other projects are concerned with water heating for food processing operations.

Two major water pumping projects for irrigation have recently been completed. One is a 25 kW system at Willard, New Mexico and the other, a 150 kW system in Cooldge, Arizona. Both use parabolic troughs and organic Rankine cycle heat engines.

Numerous industrial process heat projects are underway, most using linear concentration. Cost analyses show such system to be near the point of economic viability in many areas of the United States.

3. *Solar Thermal Programmes*

These activities include solar thermal systems for electrical or mechanical power generation and advanced technology for such activities as the production of fuels and chemicals from high temperature process.

Typically, solar electric power is being generated by distributed systems using either linear or point focusing concentrators and by a control receiver or power tower system. The most notable power tower system is the 10 MW_e pilot plant being built at Barstow, California. To aid in the development and evaluation of second generation power tower receivers (using air, moltar salt or liquid metals as heat transfer media) a 5 MW_t Central Receiver Test Facility (CRTF) was constructed at Saudia Laboratory at Albuqurque, New Mexico and a 350 kW_t Advanced Component Test Facility (ACTF) at Georgia Institute of Technology, in Atlanta, Georgia. High temperature chemical reactions to produce synthetic fuels are currently being studied at the ACTF. Air and molten-salt cooled receivers have been evaluated on the CRTF.

Total Energy Systems also are being developed and demonstrated as part of the Solar Thermal Programme. A system using 200 parabolic dish concentrators, seven meters in diameter is being constructed near Atlanta Georgia (at Shenandoah, Georgia).

These concentrators will be used to heat oil which will power an organic Rankine cycle expander to drive a 500 kW_e generator to supply electricity to a knit-wear factory. Excess heat will be used to make steam for pressing and provide heat for hot water and to power an absorption air-conditioning system.

4. *Photovoltaic Systems*

There are presently about six commercial manufacturers of photovoltaic (PV) cells in the United States. Major demonstration projects include a 25 kW_e water pumping system in Mede, Nebraska and a combination PV-Solar Thermal System for a new school in Arkansas. Other demonstration include the two village projects, one at Schchuli, Arizona and the other in Tangaye, Upper Volta, West Africa; both previously described in my paper on Tuesday.

R&D activities are being carried out on thin film and amorphous silicon and on galium - aluminium - arsenide solar cells and on PV systems using concentrated solar energy.

5. *Ocean Thermal Electric Conversion (OTEC)*

OTEC has received increased funding during the past year and has reached the stage of pilot scale testing of the heat exchanger. Major problems have been anticipated with respect to corrosion and biofouling of the very large surface area heat exchangers required boiling with working fluid (ammonia) with a ΔT of only about 10° to $20^{\circ}C$. Luckheed, Sunnyvale, California is developing the pilot plant system.

6. *Wind Energy Conversion Systems (WECS)*

The World's largest wind machine generation 1 MW of electricity is currently being tested on a mountain top at Boone, North Corolina. Although in a more or less remote area nearby residents have complained of the low frequency vibrations accompanying the operation of this machine (Blades believed to be about 200 feet long), a 2 MW_e machine is under construction and a number of designs in the 10 to 100 kW_e range are undergoing test at the WECS test facility at Rocky Flats New Mexico.

7. *Biomass*

Biomass activities include alcohol from grain and wood (and other cellulosic materials) and biogas from various sources of animal and plant waste. Pyrolysis of agricultural waste and the use of such materials either for direct combustion or gasified also are being demonstrated. In Georgia and North Carolina, continuous fired brick kilns are being operated directly on saw dust as the only fuel. This process is commercially viable to the point that one operator purchased more than $1 million in equipment to harvest, transport and pulverize trees to produce saw dust to fire his kiln. Several small-scale power plants, previously operating on natural gas have converted to the use of the gas produced by the gasification of wood pellets with essentially no modification to the gas burners. Georgia Institute of Technology has recently completed an experimental pilot plant wood gasifier that is undergoing test and evaluation.

8. *Solar Power Satellite*

NASA is continuing a programme to study the feasibility of the collection and conversion of solar energy into micro-wave energy on a space satellite and beaming the energy to earth where it will be converted into electrical energy and fed to the grid. I believe the current annual funding is about US$10 million. Economic viability is projected only for multiple satellite system produce about 500,000 MW_e. Much depends on the success of the current space shuttle programme and even then technical viability remains to be demonstrated at a meaningful power level.

SOLAR ENERGY RESEARCH AND UTILIZATION IN VIET NAM

by

NGUYEN THO NHAN and NGUYEN THUONG

In the decade of the seventies, many world events had strongly influenced the energy economy of many industrialized countries. A series of energy crises had helped modifying the way of thinking of economic planners all over the world. Under the pressure of the crises, in many places, special attention had been devoted to research and use of new and renewable energy resources among which solar energy occupies an envied position in the forefront.

Developing countries, especially the ones situated in our region of South East Asia also follow that trend of the scientific and technological evolution. However, we might say that the research and utilization of solar energy had so far not yet given transcendent results. Presently, in the energy structure of many a nation, renewable energy resources are not yet occupying an important share. Symposia, like this one are, in our opinion, very useful because they help giving scientists and engineers opportunities to meet, to exchange experiences and also, they will encourage technological transfer in a very important sector of national economics.

VIET NAM AND SOLAR ENERGY.

Situated in the tropical region, covering 15 parallels of latitute (from latitude 6°N at the southernmost tip to latitude 23°N at the northern border,) Viet Nam possesses many favorable conditions for using solar energy. The annual duration of insolation in some places is quite high: more than 2300 hours in the South and in the North around 1600 hours. However, during summer months, the solar radiation is appreciable with mean temperatures in the range of 29°C.

Through the distribution curve of solar radiation on a horizontal surface at Hanoi, we can see that during the winter season, (from November to March) the solar radiation averages at $65\text{-}87.10^3$ kcal/m^2 per month but during the rest of the year, this radiation rises up to $130\text{-}148.10^3$ kcal/m^2 per month. In HoChiMinh City the annual average of solar radiation is as high as 145.10^3 kcal/m^2 per month.

Solar energy is thus considered as a natural resource of the country and it must be exploited. This is not only a need for solving the problem of optimal utilization of all energy resources, but this "decentralized" source of energy is well adapted to the geography and topology of Viet Nam.

As of now, in our country, the main energy resource is still coal since we possess a coal reserve that had been exploited from the beginning of this century. Vietnamese coal consists of an anthracite of high calorific value (above 6000 kcal/kg) therefore very fit for using in the production of electricity and heat. The hydroelectric potential in Viet Nam is also important but still remains unsufficiently exploited. Other sources of energy are also in the course of evaluation and planning for use.

After many years of war, Viet Nam is currently rebuilding and developing its economy with the aim of rapidly raising the level of living of its people. Naturally, the problem of fulfilling needs in the domain of energy must be given a top priority and we are intending to use all available sources of energy. Therefore, thanks to its natural advantages and taking into account the exploitation possibilities in the country, solar energy had been considered for use from many years. As for the means of using solar energy, both classical utilization forms: thermodynamic as well as photovoltaic conversions could be applied.

The utilization of solar water heaters will help economizing an appreciable quantity of fuel. These equipments are not only needed in cities for using in nurseries, hotels, hospitals but in rural areas, the public health and educational networks have many units such as rural health stations, nurseries, kindergartens... which require a permanent supply of hot water (under 100° C) especially during the winter months in the Northern part of our country. Solar energy is very well adapted for a wide use for this purpose if solar heaters could be produced at a reasonable cost.

As for many other countries in this region, in Viet Nam, the drying of agricultural products had been always an important problem. If main products such as paddy, maize... could be dried quickly in solar dryers, the damage due to rain or humidity will be lessened and an appreciable amount of post-harvest lost will be recovered. Besides, in our country, many varieties of fruits are being produced and exported to temperate countries. The drying and conservation of these products using solar energy can improve the quality hence the exporting capabilities of the country. Also, a large number of other products could draw a large benefit from solar drying to the effect of raising their quality and decreasing their damage: marine products, forest products, medical herbs....

For people lining along the 300 km odd of the Vietnamese coastal line as well as inhabitants of its numerous islands, solar energy through fresh water stills will be a major factor to ameliorate their conditions of living when these equipments can be widely available.

In the near future, solar refrigeration will play an important role in the domains of food preservation and habitat air-conditioning.

It is considered that solar energy, through the techniques of thermodynamic conversion will certainly be used for electricity generation. But meanwhile, through photovoltaic conversion, it can contribute much in solving immediate needs where a small electrical source is required in isolated places for water pumping, telecommunication transmission, meteorological and hydrological data collection.

The above mentioned fields are those in which we wish to explore in research and direct application of solar energy but there are still numerous fields of indirect application through the utilization of biomass, biogas, wind energy... for which a parallel effort must be devoted.

THE STRUCTURE OF SOLAR ENERGY RESEARCH IN VIET NAM.

The activities pertaining to solar energy research and application of research results in the national economy of Viet Nam are carried out in numerous research institutes and centers of higher learning such as:

- The National Center for Scientific Research of Viet Nam (Hanoi)
- The Branch Center of the National Center for Scientific Research at HoChiMinh City,
- The Electricity Utilities of the Southern Region (HoChiMinh)
- The Electrical Science and Technology Research Institute (Ministry of Electric Power),
- The Polytechnic University of Hanoi,
- The Polytechnic University of HoChiMinh City,
- The Scientific and Technological Commissions of various provinces and cities (Hai Phong, Da Nang, HoChiMinh City...).

In the same manner as with other fields of research, solar energy research activities are programmed in annual and five-year plans for Science and Technology. The authority in charge of planning, funding and administration of research programmes in the whole country is the State Commission for Science and Technology. Since energy research has a great importance for developing the national economy, all energy research activities, among which solar energy research, are reassembled in an interdisciplinary priority programme. It is placed under the responsibility of a Programme Directorate which comprises many scientists and engineers belonging to institutions which participate in the programme. A permanent secretariate of the Programme Directorate is established at the State Commission for Science and Technology, its duty is to follow the progress of the programme. Each year, the Energy Research Programme Directorate builds the detailed research plans for all participating institutions and the funding plan to be allowed by the Government. The Programme Directorate follows research activities in each establishment and plan the introduction of research results into the national economy.

This way of functioning is convenient thanks to the fact that the State Commission for Science and Technology (equivalent to a Ministry of Science and Technology or a National Scientific Research Council in other countries) is an organism which centralizes all scientific and technological research activities all over the country. Periodically, the Programme Directorate, in conjunction with the State Commission for

Science and Technology, organises symposia and seminars on new sources of energy including problems of potential needs of energy presented by prospective utilizers.

Apart from central institutions, scientific and technological commissions of various provinces and cities also participate in new energy research programmes. Being regional organisms dealing with scientific and technological activities, those commissions play an important role in the propagation of research results to their region.

PRESENT SITUATION IN SOLAR ENERGY RESEARCH AND UTILIZATION.

The research activities in the domain of solar energy in Viet Nam have in fact seriously taken place from some years back, after the reunification of the country. During the war, a certain number of scientific works of fundamental character mainly those pertaining to the Physics of solids had been carried out. With the establishment of the Energy Research Programme, the coordination among research institutions had been improved.

1.- *Solar radiation measurements.* In the domain of solar data collection; those obtained from many years back at meteorological and hydrological stations had been gathered and analyzed but these data are not very fit for using in energy research (direct radiation, total radiation, diffusive radiation...). Therefore, parallel to developments of solar energy conversion technologies, an important task attributed to the Energy Research Programme is the collection and measurement of solar data more fit for energy research. This task is currently being carried out by the General Department of Meteorology and Hydrology and the active participation of physicists, mathematicians of other research institutes.

2.- *Solar water heating.* Solar water heaters are among equipments which attract great interests in solar research. Technological research are being carried out aiming at low costs using existing local materials. Apart from solar water heaters installed at universities or research laboratories, we have put in use some heaters at other establishments for the purpose of producing hot water and also for measuring data to be used in the design of future heaters. For example, a solar heater having a flat plate collector of 10 m^2 producing about 1000 liters of water at 50-60°C in a day (efficiency around 50% was installed at an administrative building of a city near Hanoi, another solar water heater with a flat plate collector surface of 20 m^2 capable of producing 2000 liters per day of 60°C water was installed at a Hanoi nursery, a heater of 60 m^2 collector producing from 6000 to 10000 liters of water per day (efficiency 60-70%) is being installed, completed with a 3 m^3 hot water storage tank, at a hotel.

3.- *Solar drying.* Solar dryers are being studied in all places for various final applications. Their main use is however for drying agricultural products mainly paddy. Many prototypes had been built and used for assessing their efficiencies and economical values. A certain number of solar dryers are used in the traditional pharmaceutical industry to dry medicinal plants at 40°C-60°C. Some of them are used to dry fruits.

A solar paddy drying system with a flow of hot air of 900-1200 m^3/h at 80°C is currently in the testing stage. Another paddy drying system of higher capacity using forced convection and flat plate collector to heat water before entering a heat exchanger is being manufactured to equip a solar energy demonstration station in the countryside near HoChiMinh City. In industry, solar dryers are also used for drying plywood or compressed bamboo boards. A dryer was used to process rice seeds for the purpose of raising their germination capabilities and reducing their rate of disease contamination: the germination rate was found in some experiments increased by 10°/o.

4.- *Solar cooking.* Many types of solar cookers for domestic use had been produced by various research institutes. The tests to evaluate the use of reflectors were also carried out. However, due to the cooking tradition in our country, this new type of cooker has so far not met a warm public acceptance.

5.- *Solar water distillation.* Many types of solar stills had been developed but their yield is still in the range of 3-4 liters of fresh water per day per square meter. An intersting type of still had been produced using the capillarity phenomenon to raise water. Presently, many experiments are being carried out to improve the stills by assessing the influence of the inclination angle, of reflectors, of the heat absorbing material, of the film condensation or dropwise condensation.

6.- *Solar refrigeration.* In a near future, solar refrigerators will be needed for the purpose of food preservation and medical service in the rural areas. We are presently designing and testing two types of solar refrigerator at two different institutions. Although in both places the equipments are built using the intermittent absorption cycle, at one place the solid absorption medium is used and at the other place it is a liquid medium.

7.- *High temperature furnaces.* At an Engineering School, an applied research was carried out from many years aiming at the utilization of solar energy in the domain of high temperature. Here, a paraboloid collector was used to produce high temperature at its focus. This collector has a diameter of about 2 m and it is placed on a mobile support having an electronic tracking system to aim its axis at the sun. The high temperature obtained was used by the Department of Physics at the school to test a certain number of materials. Besides, at this Department, many tests were carried out to compare the efficiency and to collect optical, mechanical etc.. data of a certain number of materials used for the manufacturing of the reflective surface of the collector. These materials are either made by the researchers themselves or already available in commerce.

8.- *Photovoltaic conversion.* At the Solar Energy Laboratory of HoChiMinh City, a research group is carrying out research in the domain of photovoltaic conversion at various fundamental phases: production of silicon crystals, manufacturing of photocells, assembling of solar panels. In the same time, many researchs pertaining to the fundamental aspects of photovoltaic conversion were also undertaken. A certain number of photocell panels were produced to serve experimental purposes.

PERSPECTIVES FOR THE PERIOD TO COME.

The results obtained so far permit us to believe that solar energy research and utilization in Viet Nam will know a larger expansion in order to contribute to the economic development of the country and raise the level of living of the people. In the coming five-year plan (1981-1985), we shall concentrate our efforts in consolidating and developing further the results obtained, gradually introducing solar energy for direct applications into various sectors of the national economy.

For the near future, we shall establish the insolation map of the whole country in order to plan the use of solar energy for each region according to the needs. Solar water heaters produced with local materials by regional manufacturing shops will be installed in many nurseries, hospitals and health stations, hotels. . . Solar dryers of higher capacities will be developed and solar stills will find a wider use throughout the country. Parallel to research efforts in new photovoltaic materials, a programme of investigation using concentrating collectors will be initiated for the purpose of producing high temperature, high pressure steam needed for electricity generation.

We hope that, when the use of this new source of energy has demonstrated its firm hold, solar energy planning will be part of the overall energy balance of the country with a high degree of precision. We are also convinced that solar energy will represent a higher proportion in the energy structure of our country.

CONCLUSION.

As many other countries of South East Asia, Viet Nam has the same need and the same potential in the domain of solar energy research and utilization. Apart from our own efforts, we highly appreciate the technological transfer to help us advancing surely and steadily in this field. If the scientific and technological co-operation with industrialized countries is a need, the co-operation among developing countries will bring many advantages. In fact, scientists and engineers belonging to countries having the same level of scientific and technological development, being at the same stage of economic growth, possessing the same kind of natural conditions and natural resources can exchange between them many practical and useful experiences. We think that symposia like this one will contribute greatly to this purpose and international bodies like ESCAP, UNESCO...can lend a helpful hand to develop further scientific and technological co-operation on a regional or sub-regional basis.

VI. SOLAR EXHIBITION - SOLEX '80

SOLAR EXHIBITION – SOLEX'80

It is believed that during the decade 1980-1990, world oil production will reach its peak and begin to decrease. This will considerably harm the economies of developing countries.

There is, therefore, an urgent need for research and development in the field of energy, more specifically to improve the efficiency of energy use, develop local energy resources and introduce appropriate alternative energy technologies.

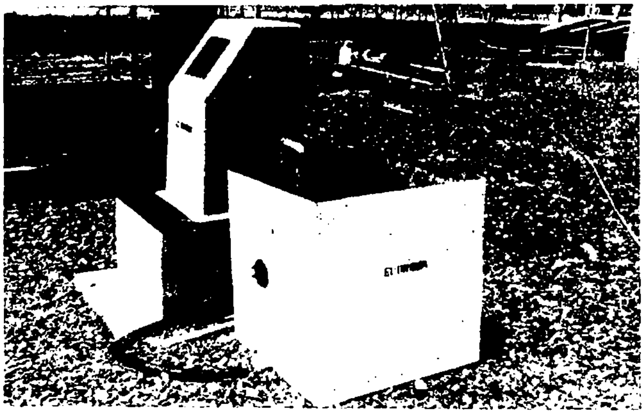
In order to contribute to the efforts towards alternative solutions, ESCAP in collaboration with FAO and AIT, organized the Exhibition of Solar Equipment of SOLEX'80 as part of the Symposium on Solar Science and Technology. As the equipment displayed is of interest to the region, the exhibition is now being established by AIT as its Energy Park.

The equipment on display ranges from well-known manufactured solar water heaters to newer prototypes in their various stages of development. This includes locally designed and manufactured rice dryers and refrigerators as well as sophisticated solar tracking, photovoltaic thermal devices. It is hoped that the wide spectrum of equipment displayed illustrates some of the most fundamental questions at the forefront of the future development of solar energy utilization:

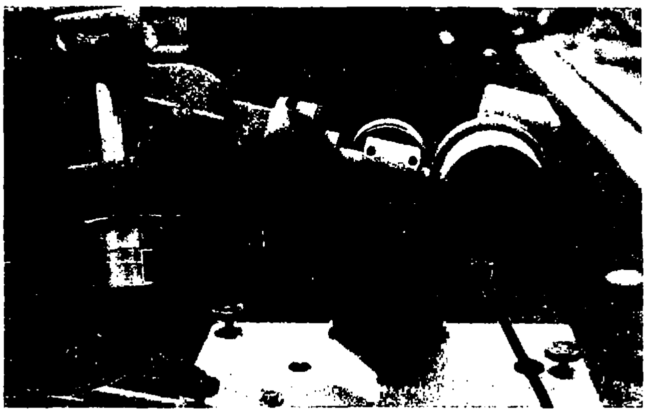
- What are the actual research and development trends?
- What is the actual equipment available on developed countries' markets which are susceptible to a technological adaptation to the Asian and Pacific economy context?
- What are the prospects for purely local innovations?

This Energy Park is currently being used by post-graduate students and staff of the Energy Technology Division of AIT for research and testing purposes. The Energy Park is also open to all people concerned with the development and utilization of renewable sources of energy in developing countries, especially for engineers, scientists, planners and decision makers from all over the region.

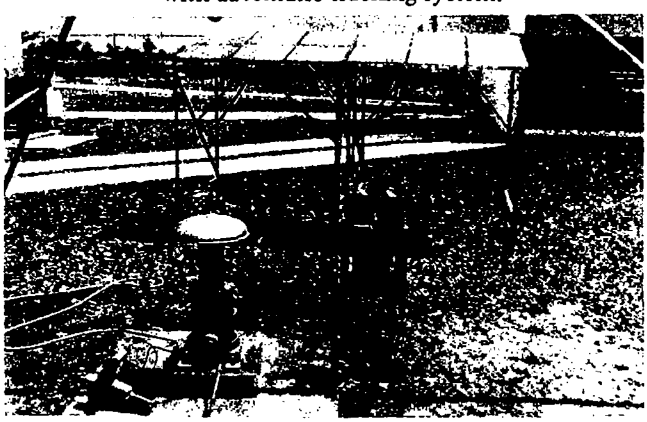
If this realization even slightly contributes to boosting efforts in searching for answers to the energy crisis, it is due to the generous support of the Governments of France and the Federal Republic of Germany which responded to the request to provide some of the solar equipment displayed at SOLEX'80.



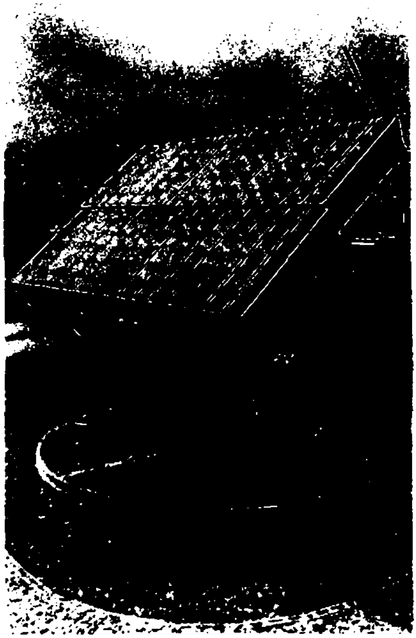
Briau pump powered by photovoltaic cells.



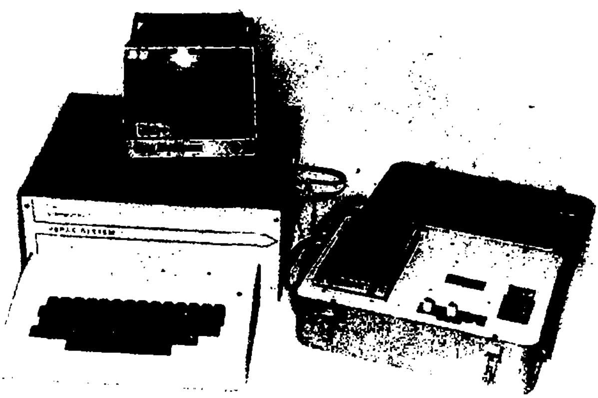
Phrheliometer measuring direct solar radiation, with automatic tracking system.



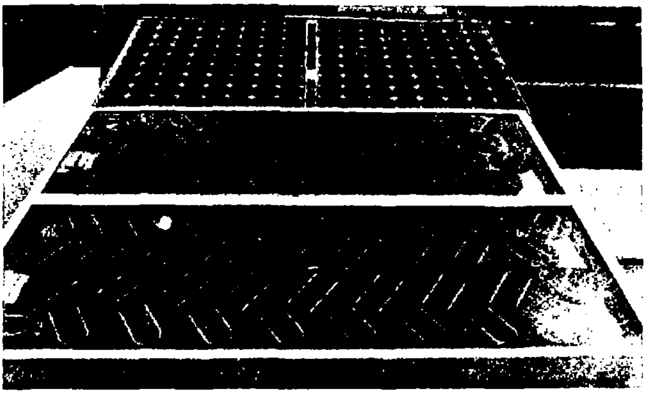
Guinard pump and its photovoltaic cells.



400 watt peak Sophocle system.

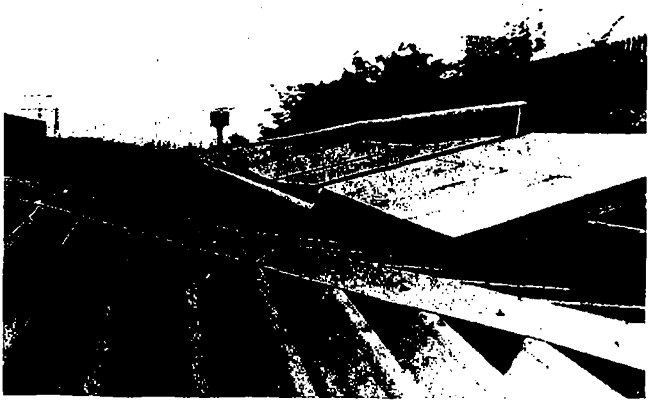


Automatic data recorder-decoding part connected to a mini-computer.

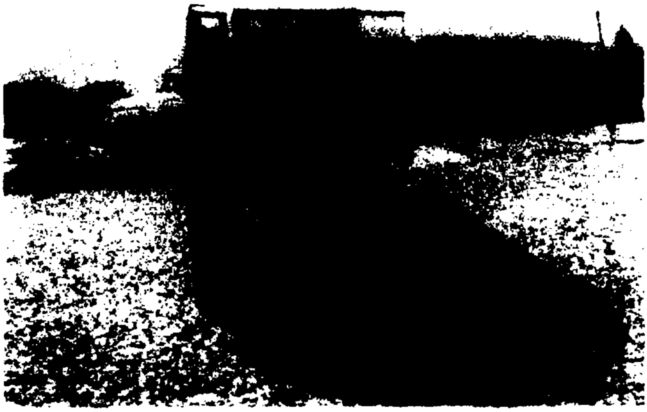


Two types of photovoltaic cell panels – each panel delivers 35 watt peak.

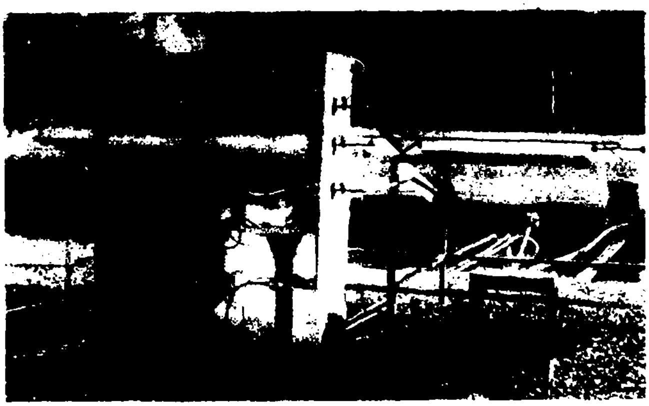
Solar rice dryer built at AIT.



Some solar collectors used for water heating at AIT.

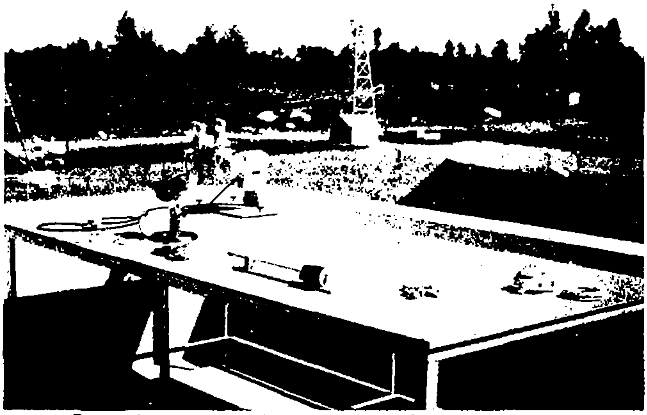


Solar dryer – cabinet type.

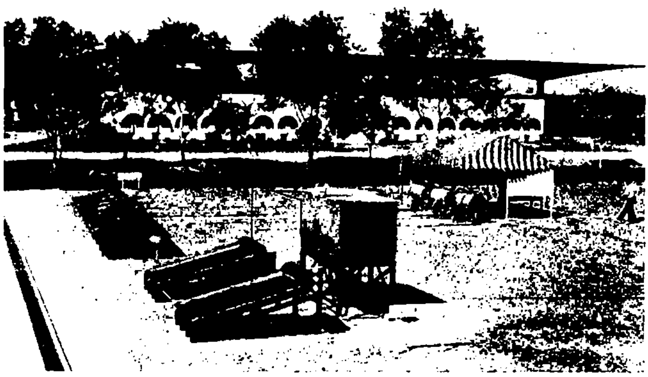


Freon cycle water pump.

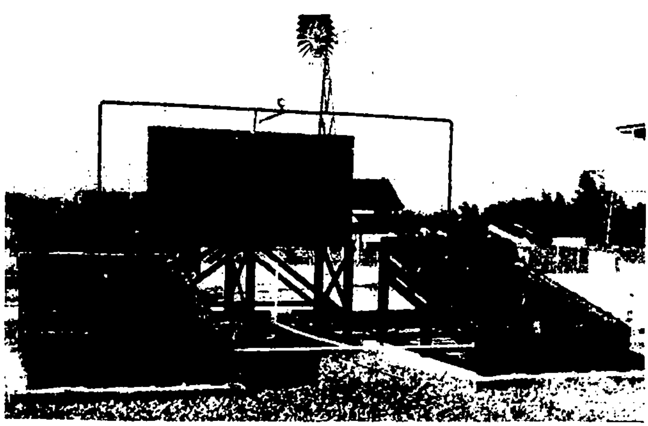
Temperature, pressure and humidity measuring devices.



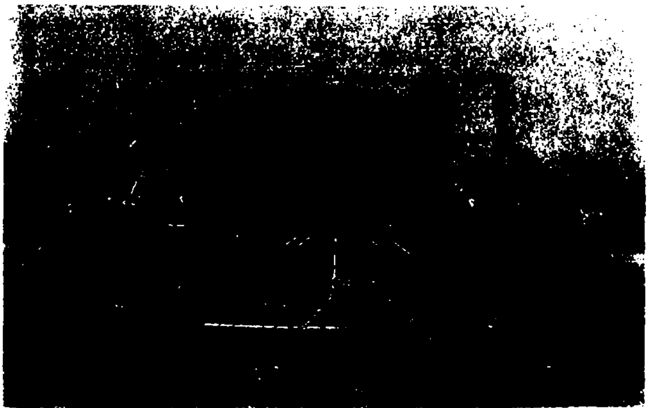
Pyrheliometer and radiometers for measurement of solar radiation.



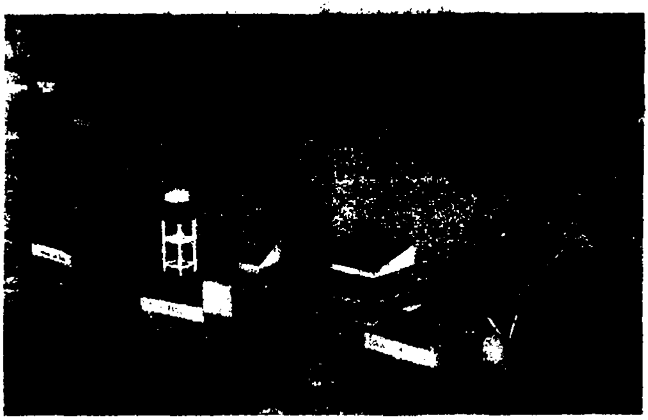
Solar refrigerator (front) and water heaters (back).



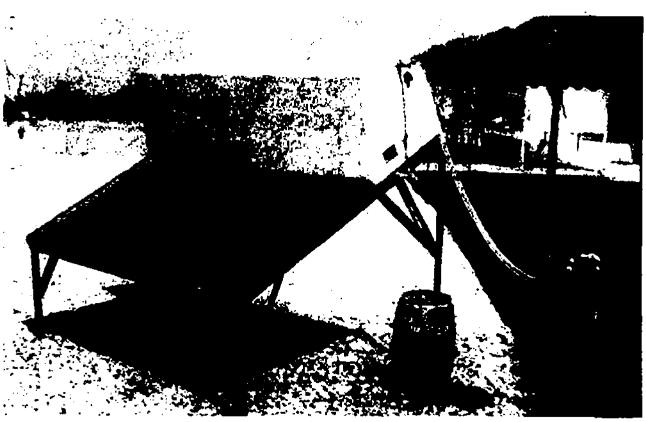
Solar refrigerator made at AIT (Model 1).



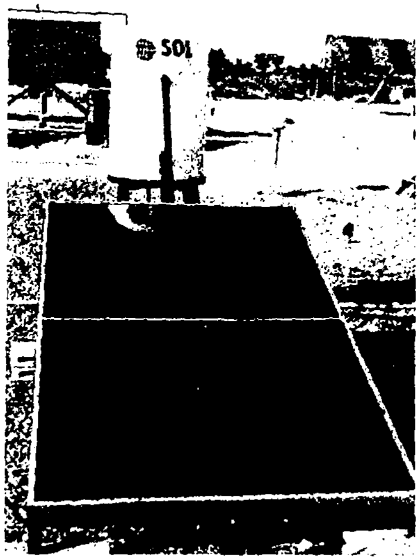
Solar refrigerator made at AIT (Model 2).



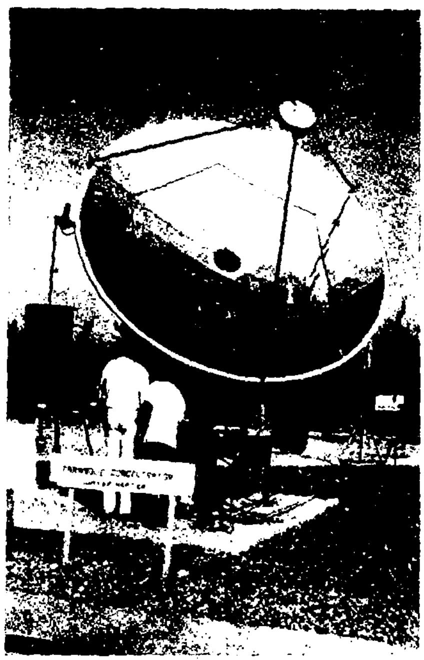
Different solar stills (front).



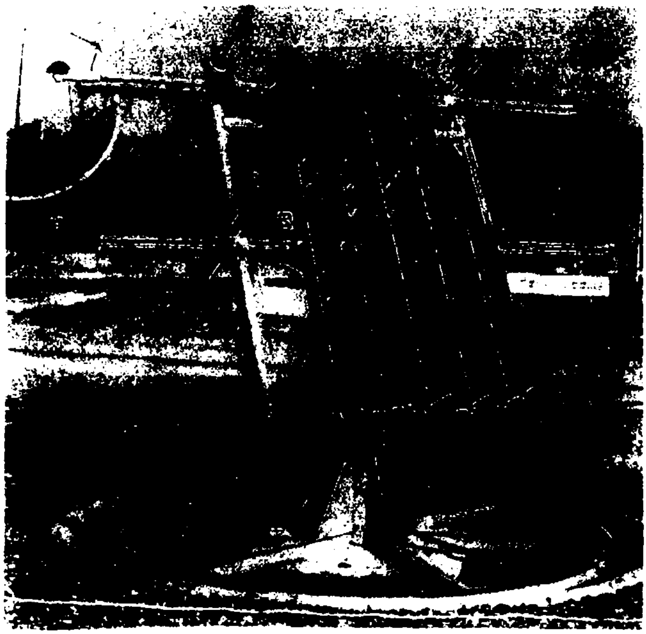
Solefil solar still.



Domestic water heater:
collector and hot water storage tank.



Parabolic concentrating system.



100 watt peak Sophocle system.

Solar cooker.

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