RECENT EXPERIENCES IN RESEARCH, DEVELOPMENT AND DISSEMINATION OF RENEWABLE ENERGY TECHNOLOGIES IN SUB-SAHARAN-AFRICA

Nairobi, Kenya March 29-April 2, 1993

SEMINAR PROCEEDINGS

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FOREWORD

These proceedings are the result of a regional seminar held in Nairobi, Kenya. One of the objectives of the seminar was to review actual field experiences in the research, development and dissemination of renewable energy technologies (RETs) in Sub-Saharan Africa. Field experience clearly indicates that a number of RETs have actually passed the critical phase of laboratory research and development. These technologies are therefore ready for wide-scale dissemination.

With this in mind, various case studies (papers) were commissioned. By using the case studies, actual field experiences in dissemination were reviewed. The review focused on the effects different aspects of renewable energy technologies have on their dissemination process.

The proceedings are divided into five main parts. Thus,

PART ONE: TECHNOLOGY REVIEW

Two papers were presented. These papers briefly discuss the past, present and future directions in research and development of the various RETs.

Although both papers cover the same topic, the difference in presentation represents a differences in perception. In fact, the writers look at the issues from somewhat different angles. Effectively, a clearer insight into the technologies is presented by the two renowned specialists.

PART TWO: THE ECONOMIC VIABILITY OF RETS

A comprehensive review of the implications of the various economic and financial models on the widescale adoption of RETs is presented in this section. The section presents country experiences in the sub-region, and discusses the relevant market prospects and strategies used in the dissemination of RETs.

The paper also analyses the institutional and political aspects of implementing small and decentralized renewable energy projects. It also discusses new methods used to identify, plan and evaluate RETs in their respective environments. Another important area covered in the paper is the financing of RETs.

PART THREE: THE SUCCESSFUL ADOPTION OF RETS

One of the papers in the section discusses the unexpected intervening factors in the development, selection and implemention of appropriate options in meeting the energy needs of rural communities. The paper points to the growing consensus that RETs should be promoted as part of the wide range of options that include fossil fuel technologies.

The second paper reviews a number of factors which have been identified as having a direct impact on the widescale adoption of RETs. The paper notes that these factors need to be taken into consideration in the initial stages of any dissemination process.

PART FOUR: COUNTRY CASE-STUDIES

The country case studies presented at the Workshop included:

Ethiopia:
- a country profile of renewable energy technologies

Kenya:
- policy issues and their impact on RETs
- The Private sector in Solar Industry: The Case of Kenya
- a profile of solar cookers
- the role of meterological data

Sudan:
- potential application of solar thermal technologies

Tanzania: • anaerobic digestion of human and industrial wastes

Uganda: • education on solar energy

PART FIVE: AN EVALUATION OF THE "RENEWABLE ENERGIES" COURSE

The aim of the seminar was to provide a follow-up of the alumni of the "Renewable Energies" course, working within the Eastern African Region. This section covers: the course outline; an evaluation of the course by the course participants; a profile of the German Academic Exchange Service, DAAD which supports the course; and the list of participants.

Editorial Remark

Missing from these proceedings are two papers that were also presented during the seminar. Prof. Dr. Sigrid Jannsen of Odenburg spoke on *"Treatment of Human and Industrial Wastes by Anaerobic Digestion."* Prof. Dr. Joachim Luther, also of University of Odenburg presented a paper on *"Electrical Energy Supply by Renewable Energy Technologies."*

The editors regret that these papers are missing from the proceedings. Those interested in the papers can contact:

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Editors

PREFACE

The regional follow-up seminar for former participants of the German postgraduate course, RENEW-ABLE ENERGIES, was the first of its kind, within a German Scholarship Programme, Post-graduate courses with special relevance to the developing countries.

The programme was launched by the German Academic Exchange Service, DAAD, in conjunction with the Federal Ministry for Economic Cooperation (BMZ). The programme aims at providing special knowledge to young graduates and professionals from developing countries to solve specific problems of development in their home countries.

From its inception, follow-up measures for the alumni of the course have been included.

At the end of December 1992, a former participant of the course, then working with KENGO, Mr. Muiruri J. Kimani, together with the course management of the Carl von Ossietzky Universität, Oldenburg, submitted a proposal to DAAD for the follow-up seminar. The objectives of the seminar were to:

- update the former course participants and other professionals with scientific and technological developments in Renewable Energy Technologies;
- initiate a network for Renewable Energy professionals in the eastern Sub-Saharan-Africa; and,
- evaluate the course concept and curriculum of the Oldenburg programme on Renewable Energies.

DAAD and BMZ accepted the proposal within a very short time and provided the funds necessary to facilitate the seminar for former participants working within the region, resource people from Germany and other professionals.

It is widely acknowledged that RETs have a huge potential either as compliments or alternatives to traditional and conventional sources of energy. It is hoped that these proceedings make a positive contribution to the better understanding and appreciation of RETs in Sub-Saharan Africa.

By

Dr. Ekkehart Naumann

University of Oldenburg

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ACKNOWLEDGEMENT

The KENGO International Outreach Department and the course management of the "Renewable Energies Course" at Carl von Ossietzky Universität are grateful to the regional office of DAAD in Nairobi for the financial support for the seminar. Special thanks to Mr. Hans Helfer, Ms. Ada-Samira Osinski and Mrs. Roselyn Wekesa for their assistance. We also acknowledge the kind assistance of Messieurs Reiser and Etzold as well as Ms. Steuernagel of the DAAD central office in Bonn.

Our thanks go to all the former students who, at very short notice, were requested to contribute to the seminar, and managed to do so not only in time but very substantially. Their rich discussions open-mindedness and made the seminar an important event, both as a follow up measure and in the overall future dissemination of Renewable Energy Technologies in the region.

We acknowledge the contribution of the KENGO management and staff in organizing the event, and in making the seminar a success. Special thanks to Mr. Dominic Walubengo, Associate Director, Ms. Tameezan wa Gathui, Energy Specialist, Lynette Obare and Mwajuma Abdi all of KENGO for their splendid work. Last but not least, we thank Mr. Muiruri J. Kimani of the KENGO International Outreach Department, who did a tremendous job in ensuring the seminar was a pleasure for all participants.

We also wish to thank all those who have generously given their time in the production of these proceedings. Special thanks to Mr. Gilbert Arum for the computer time, Ms. Wa Gathui and Anjali Saini for their editorial assistance.

Finally, we thank Ms. Wagaki Mwangi of *EcoNews Africa* who, despite her busy schedule, agreed to be the consultant editor.

We hope the results of this first follow-up seminar of the postgraduate course will encourage the programme's funders to continue their support for similar activities.

Dr. Ekkehart Naumann
Manager
Postgraduate Course
"Renewable Energies"

Herr Edu Knagge (Msc)
Facilitator
Postgraduate Course
"Renewable Energies"

ACRONYMS AND ABBREVIATIONS

ADF	African Development Fund
AFREPREN	African Energy Policy Research Network, Gaborone, Botswana
BMZ	German Ministry of Economic and Development Cooperation
BTC	Botswana Technology Centre, Gaborone,Botswana
CAMARTEC	Centre for Agricultural Mechanisation and Technology, Arusha, Tanzania
CEMAT	Centro Mesoamericana De Estudios sobre Tecnologia Apropiada, Guatemala
ENDA	Environmental Development Action in the Third world
ERC	Energy Research Council, Khartoum, Sudan
ESMAP	Energy Strategy, Management and Assessment Division, World Bank, Washington, United States of America
ETC	ETC Foundation, Leusden, The Netherlands
FAO	Food and Agricultural Organisation of the United Nations, Rome, Italy
FWD	Foundation for Woodstove Dissemination, Nairobi, Kenya
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GTZ	German Technical Assistance Programme
IDRC	International Development Research Centre, Ottawa, Canada
IIED	International Institute of Environment and Development, London, United Kingdom
ISES	International Solar Energy Society
IT Pubs	Intermediate Technology Publications, London, United Kingdom
ITDG	Intermediate Technology Development Group, Rugby, United Kingdom
KCJ	Kenya Ceramic Jiko
KENGO	Kenya Energy and Environmental Organizations
KREDP	Kenya Renewable Energy Development Project
MCA	Multicriteria Analysis
MR	Manuscript Report (IDRC)
NASA	National Aeronautics and Space Administration
NGO-CC	Non Governmental Organisations coordinating Committee, Lusaka, Zambia
NIR	National Institute of Development Research and Documentation, University of Botswana, Gaborone, Botswana
ONATOUR	Office National de la Tourbe, Bujumbura, Burundi
RETS	Renewable Energy Technologies
SAREC	Swedish Agency for Cooperation with Developing Countries, Stockholm, Sweden

SAREC	Swedish Agency for Cooperation with Developing Countries, Stockholm, Sweden
SEP	Special Energy Programme
SERI	Solar Energy Research Institute, Colorado, United States of America
SREP	Sudan Renewable Energy Project
TEC	Total Energy Consumption
TOE	Tons of Oil Equivalent
TR	Technical Report (SERI)
UNCTAD	United Nations Conference in Trade and Development
UNDP	United Nations Development Programme, New York, United States of America
UNEP	United Nations Environment Programme, Nairobi, Kenya
UNHCR	United Nations High Commission for Refugees
UNITAR	United Nations Institute for Training and Research
UNU	United Nations University, Tokyo, Japan
VITA	Volunteers in Technical Assistance, Arlington, USA
WSG	Woodburning Stoves Group, Eindhoven, Netherlands
WWF	World Wide Fund
YWCA	Young Women's Christian Association
ZERO	Zimbabwe Energy Research Organisation, Harare, Zimbabwe

RENEWABLE ENERGY TECHNOLOGIES IN SUB-SAHARAN AFRICA: SEMINAR

By:
Muiruri J. Kimani;
Seminar Coordinator

These are the proceedings of a seminar held in Nairobi on March 29 to April 1993, in Nairobi, Kenya. The seminar was entitled: Recent Experiences in Research, Development and Dissemination of Renewable Energy Technologies in Sub-Saharan Africa. The purpose of the seminar, was to up-date and equip participants with the latest knowledge in research and development of RETs. It was a follow-up of the Renewable Energies Master of Science Course offered by the University of Oldenburg. The core of the participants were the alumni from East Africa. Others were drawn from various government, non-government, research, donor, private and development agencies involved in renewable energy activities.

Apart from the plenary sessions and a practical demonstration on solar cookers by the Transworld Radio Service, two workshops on Renewable Energy Education Training and Widescale Dissemination of RETs were held. The participants also met the technologies end-users. During the field visit, the end-users presented first-hand, their experiences with RETS such as improved stoves, biogas, solar lighting systems and water heaters.

During the seminar, several important issues were identified as crucial to the wide-scale dissemination and adoption of RETS. These include research and development, appropriate standards, training, education and promotion, financing and policy. Subsequently, the deliberations revolved around these issues.

Research and Development

The seminar recognized that several RETs, including solar water heaters and home lighting systems, improved stoves and biogas have already passed critical research and development stages. They are therefore, considered to be ready for wide scale adoption at the household level. However, limited support for research and development should be continued. Such support should focus on the use of locally available skills and raw materials to manufacture, maintain and service the technologies. In addition, enhancing the efficiency of existing technologies and user techniques need further investigation specifically to ensuRETs match identified user needs.

Appropriate Standards

The participants acknowledged the need to develop and promote minimum and appropriate standards for RETs. This would encourage local small-scale entrepreneurs to develop, adapt and disseminate RETs. Such standards would ensure that the end-users, who are usually unfamiliar with the technologies, purchase good quality products. But this requires cooperation between research institutions, relevant government agencies and private industry in the development and adoption of standards. These standards or codes should be objective and not hinder the wide scale adoption and acceptance of the technologies.

Training, Education and Promotion

The seminar recognized that trained manpower that is capable of developing and manufacturing the technologies is necessary in order to attain wide scale adoption. End-users, on the other hand, should be made thoroughly familiar with the technologies and should know where and how to discriminate between technologies, purchase, service and maintain them. Once end-users are knowledgeable, the RETs market will witness a marked improvement in the service and quality of technologies.

The participants also concluded that responsibility for initiating and supporting appropriate training programmes on RETS rests with the institutions of higher learning and other middle level training institutions. Such training, it was acknowledged, should target different people: researchers, technicians and local installation agents.

The participants also agreed that in order to substantially replace, substitute or complement existing conventional energy technologies - which are more established in the market - with RETs, more aggressive campaigns are required. They also recognized the importance of carefully structuring such promotional programmes and campaigns to suit the different types of end-users.

Financing

Although adequate financing of research, development, manufacture, promotion, purchase, service and maintenance of RETs is necessary, the seminar noted that financing the purchase of RETs has been particularly difficult. Few financial or credit institutions are willing to loan money to potential end-users. Nevertheless, it was noted that several innovative financing mechanisms have been successfully instituted in a number of countries.

For example, Ghana utilizes the "Petroleum Fund", which is a levy on petroleum products, to develop its renewable energy technologies. In Rwanda, a revolving fund with seed donor funds is available for the purchase of solar home lighting systems. In Kenya, commercial banks with external seed funds, support local, small scale entrepreneurs engaged in private businesses including those involved in renewable energy projects.

Policy

The seminar stressed the need for policies that create enabling environments conducive to the development and widescale adoption of RETs. Hence, it was emphasized that although the primary duty of enacting the right policies lies with governments, development agencies, the private sector and end-users should endeavour to influence government policy through lobbying and advocacy.

PART ONE: TECHNOLOGY REVIEW

Research and Development in Renewable Energy Technology (RET) In Sub-Saharan Africa
Herick Othieno

Apprisal on the effectivness of the recent Activities on Renewable Energy Technologies in Sub-saharan Africa.
David M. Hall

RESEARCH AND DEVELOPMENT IN RENEWABLE ENERGY TECHNOLOGY IN SUB-SAHARAN AFRICA

By
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Department of Physics, Maseno University College

1.0 INTRODUCTION

Material development has always been dependent on the availability of energy and the ability to efficiently harness and use it. The energy consumption rate is generally considered a good indicator of the industrial progress of a country. However, there has arisen global concern lately, that the high energy consumption is causing a great deal of pollution, leading to global warming and its associated climate change.

This awareness, and the finiteness of fossil fuels, has created the need to intensify energy conservation measures and to improve energy consumption efficiency. This has been a difficult task for developing countries that still lack the necessary modern infrastructures even for essential services. Thus the limiting factor in this transition is that they are neither endowed with fossil fuels nor the alternative energy choices to realize both environmental conservation and development (Lillethum, 1988). This situation is particularly worrisome in Sub-Saharan Africa that has the lowest per capita energy consumption; between 0.08 and 0.25kW. The global average for low income nations is 0.41kW while for high income nations it is 5.17kW (World Bank, 1986).

The present global power consumption could be provided by renewable energy sources alone. But at the moment, only 21% of energy consumption worldwide comes from renewable sources, thus, 15% from biomass and 6% from hydropower. Direct solar energy contribution is small on a global scale but is expected to increase substantially in future.

Sub-Saharan Africa has given some attention to the development of renewable energy technologies, but little progress has been made. In fact, talk of an imminent crisis in energy resources has to some extent, lost its urgency in favour of other issues which appear to be more pressing such as the structural adjustment programmes linked to development-aid. This situation has forced countries to intensify their efforts on the efficient utilization of resources including energy. But the appropriate means for this are still largely lacking.

2.0. ENERGY SUPPLY

Currently about 39% of the world's energy consumption is supplied by oil, 27% by coal, 15% by biomass and the rest by hydro, nuclear and natural gas. In the developing countries, oil accounts for 24%, biomass 44% and coal 26%. But in the Sub-Saharan Africa, biomass accounts for over 60% of the total energy consumed. For example, in Kenya, biomass provides about 74% of the energy consumed in the country (Othieno, 1992). This shows that for the region, biomass is at present an extremely important source of renewable energy.

To understand why the majority of the people in this region rely so heavily on biomass, it is necessary to understand the energy needs and the existing technologies to harness them.

Heat, chemical, electrical, mechanical and radiant [light] energy can be transformed easily from one form to another. But while technologies hat harness oil and hydro energy are, on average, well developed worldwide, these sectors are not well developed in Sub-Saharan Africa. Moreover, the distribution of electricity and oil are such that the rural populations do not have instant or easy access to them. In addition, the purchase and maintenance costs of the technologies that utilize these resources are too expensive for the people. Conversely, light and heat energies from the relatively readily available biomass resources using cheap and low level technologies can easily be harnessed.

3.0. RENEWABLE ENERGY RESEARCH AND DEVELOPMENT

Practically all Sub-Saharan African countries spend less than 1% of their GDP on scientific research. Consequently, very little resources, if any, are spent on renewable energy research and development. Most activities related to renewable energy technologies are externally funded. A good number of these projects are initiated by fresh researchers returning home from overseas training programmes. Usually the projects are merely a continuation or research work done abroad and may not have any significant impact on the country's renewable energy development programme. Gradually these scientists are "de-activated" by widespread internal bureaucracy and inadequate financial support which turns them to other activities.

In spite of this, a modest number of researchers mainly at the universities, are conducting serious research on renewable energy technologies. The private sector is mainly engaged in commercial production and installation of technologies such as solar water heaters, biogas plants, wind turbines, charcoal and wood stoves. Electricity generation by geothermal, hydro and large oil-fuelled generators are controlled by governments or parastatal corporations. Other agencies for example, NGOs are involved in extension work and rarely in research and development.

Biomass Energy

Biomass is the main, and indeed, traditional source of energy for the rural domestic sector in practically all countries in Sub-Saharan Africa. The fast growing population of the region is constantly increasing the demand for fuelwood so that forests are consumed much faster than they are regenerated. It is therefore necessary for the people to manage the fuelwood resource properly for it to remain renewable.

During the last two decades, deforestation for fuelwood has been a major concern for most non-governmental organizations. Subsequently, they have undertaken several activities to redress the situation. These include: improved charcoal; wood and sawdust domestic stoves; institutional stoves; energy conversion technologies such as wood to charcoal; rich husks to charcoal briquettes; animal dung to biogas and solid biomass to gas.

Some of these activities have been successful. For example, Sudan is briquetting agricultural wastes like cotton stalks and rice husks. Another example is the Kenya Ceramic Jiko (KCJ), a technology adapted from Thailand, which was first introduced in Kenya but has now spread to Tanzania, Uganda, Ethiopia and Sudan.

In many countries, biomass programmes are accompanied by agroforestry and afforestation projects. One aspect of biomass energy that has not received sufficient attention, is the extraction of fuel-oil from energy crops. Research in this area will be important especially if the search for direct substitutes for fossil oil is to continue.

Biogas, also classified as a product of biomass materials, has also been researched into and developed. Although biogas plants are advantageous in that the by product is useful as a fertilizer, the technology has not been successfully implemented on a wide scale. The initial investment cost is high and it requires qualified manpower and constant attention in order to operate efficiently. Countries like Tanzania and Burundi have demonstrated that some of these constraints can be overcome. However, further work is required to explore the possibility of commercializing the gas instead of the plants.

Solar Energy

The technology of converting solar energy into heat and electrical energies is rapidly picking up. Already, there exits a large number of solar water heaters installed in residential premises, hostels, hospitals and hotels. The application of the photovoltaic cells is also increasing but at a lower rate due to the high initial costs especially since they are mostly imported into the region.

For costs to fall, the challenge is two fold. At the development level, there is need to increase the energy conversion efficiencies and at the consumer level, the systems should be optimized. Unfortunately, research on solar energy requires fairly sophisticated technology. Therefore, it is mostly done outside the region.

Wind Energy

Through suitably designed mechanical linkages, wind power can be harnessed to drive water pumps or to generate electricity. However, wind is a highly variable source of energy because its speed changes with changing geographical locations, land forms, altitude, time of day and season. Hence, the challenge in the development of wind energy technology is to design machines that can produce optimum energy safely and reliably.

Although the basic technology is simple, meeting this challenge requires highly sophisticated technology built on aerodynamic principles and using advanced materials and electronics. Thus, to develop a good machine for a given set of conditions requires a lot of financial and technical support. Unlike solar devices, wind machines require a lot more financial and technical support.

Unlike solar devices, wind machines must be matched with the local conditions where the machine is to be located. These constraints have retarded the widespread development and dissemination of wind energy technologies in Sub-Saharan Africa. The majority of the installed wind machines are for water pumping. A relatively small number are used for electricity generation. In Kenya, for instance, there are only two 0.2MW machines installed by the Kenya Power and Lighting Company to generate commercial electricity.

4.0. GENERAL PROBLEMS AND CONSTRAINTS

At present, most of the activities in renewable energy technologies are of the extension type in which non-governmental and the private sector play the major role. Most of the funds for research and extension work come from external sources. Some research and development projects are conducted at the universities and national research institutions with hardly any collaboration with either the policy makers, funding and extension agencies.

The region's research and development programmes in renewable energy technologies are beset with numerous problems including insufficient man-power, lack of clear objectives, direction, analytical skills, adequate facilities, and poor incentives for researchers. Besides, large corporations involved in energy related activities do not conduct or contract research work on the development of renewable energy technologies. This has led to the inability of the local researchers to attract sufficient funding.

Most of these problems arise from weak and ambiguous renewable energy policies that most of the countries in Sub-Saharan Africa have adopted. In fact, some of the countries operate on the basis of haphazard public political pronouncements.

5.0 CONCLUSION

On average, the region is amply endowed with both biomass and solar resources. Both of these can be suitably used as small scale decentralized sources of energy in the rural areas where, for cost reasons, renewable energy systems may be the only option. However, the exploitation of these resources will depend, to a large extent, on the individual country's ability to create or strengthen institutions for this purpose.

Therefore, the lack of large scale adoption of these technologies should not be viewed as an indication of inappropriate conversion devices but as a reflection of the inadequacy of their development and diffusion.

Moreover, for the full benefits of these technologies to be realized, it is important that researchers appreciate the user needs and match them closely to the existing technologies. Unfortunately, many research programmes in the region do not address these issues at the initial development stages.

6.0 RECOMMENDATIONS

Renewable energy has considerable potential in Sub-Saharan Africa and should therefore occupy an important place in the region's energy programmes. Biomass, solar, hydro and wind power from small, decentralized units are capable of meeting a variety of energy needs in both the traditional and modern sectors. In this regard, the following recommendations, which are by no means exhaustive, should be considered by each country. In addition, the unique cultural and socio-economic factors and renewable energy endowments should be taken into account.

(i) A comprehensive national energy policy covering production, supply, utilization and conservation should be developed and implemented by the individual countries in the region;

(ii) each country should have an extensive programme on local capacity building for renewable energy technologies;

(iii) special attention should be given to the development of small scale, decentralized generating facilities for all sources, particularly for rural electrification programmes;

(iv) research and development should focus on the production of equipment to harness renewable energies, instead of concentrating on extension work for imported equipment;

(v) the production of biomass materials as an energy source should be intensified; and,

(vi) and research programmes to extract oil from crops as a direct substitute for fossil oil should be introduced.

These recommendations, if implemented, will speed up the development of renewable energy technologies in the region. Each country should, first and foremost, build a favourable, enabling environment in which the role of renewable energy can be defined well, priorities among the various technologies determined and adequate resources assigned.

In addition, specific policies and budgetary commitments must be made to facilitate the necessary coordination and cost-effective implementation of the programmes. This should include the extension and dissemination systems that are capable of reaching both the urban and rural populace, particularly the poor, with technical and social assistance and credit facilities.

It is important, that scientific research and development concentrate on appropriate energy conversion technologies. In the case of biomass, rapid regeneration and conservation measures should be an important component of the research programmes.

Some of the studies that have been conducted in the region have been very reluctant to recommend the development of certain renewable energy resources for the region [UNDP/World Bank, 1984]. Nevertheless, some of the countries have serious and deep-rooted energy problems that can only be eased through the development of renewable energy resources.

Some countries require risky bilateral or international arrangements in order to participate in the development of their energy resources, particularly hydro-power. For example, Rwanda which is a net importer of commercial energy has hydro potential at its border with Tanzania. There is also a large quantity of methane dissolved in the bottom strata of Lake Kivu which is shared with Zaire. Likewise, Senegal shares its hydro potential with Gambia and Mali; and Nigeria shares, in some cases, its hydro potential with Niger

[UNDP/World Bank, 1984].

These recommendations should not be taken as the sole survival recipe for all countries in the regions. Each country or sub-region will have to develop her own viable renewable energy resources to suit her local cultural and socio-economic circumstances.

Table 1: Use of firewood and charcoal in Sub-Saharan Africa as a percentage of total energy consumption [1979]

ANGOLA	63	MALI	84
BENIN	83	MALAWI	89
BURKINA FASO	93	MAURITANIA	39
BURUNDI	77	MAURITIAUS	68
CAMEROON	68	MOZAMBIQUE	74
CENTRAL AFRICA REPUBLIC	88	NIGER	82
CHAD	96	NIGERIA	81
CONGO	59	RWANDA	91
ETHIOPIA	92	SENEGAL	38
GAMBIA	80	SIERRA LEONE	89
GHANA	43	SOMALIA	44
GUINEA	68	SUDAN	81
GUINEA-BISSAU	71	TANZANIA	92
IVORY COAST	53	TOGO	38
KENYA	76	UGANDA	75
LIBERIA	62	ZAIRE	48
MADAGASCAR	70		

Source: Renewable Energy Source in Developing Countries: Successes and Failures in Technology Transfer and Diffusion LB-18, PFE, Rome, 1989.

Table 2: Energy Consumption in Selected Countries in Sub-Saharan Africa, 1986.

	Total [PJ]	% of Non Commercial / Total
ANGOLA	105	74.3
BOTSWANA	22	54.6
KENYA	332	71.7
LESOTHO	24	75
NIGER	33	82
MALAWI	165	91
MOZAMBIQUE	282	88
SIERRA LEONE	46	78.8
SWAZILAND	24	62.5
TANZANIA	439	90.4
ZAMBIA	150	57.4
ZIMBABWE	244	51.3

Source: Renewable Energy Sources in Developing Countries: Successes and Failures in Technology Transfer and Diffusion. LB - 18, PFE, Rome, 1989.

Table 3: Examples of Renewable Energy Research and Development in Sub-Saharan Africa.

Country	Institution	Research Area
Sudan	Energy Research Council	Photovoltaic Systems, solar Thermal, Wind and Biomass, Solar Stills
Ethiopia	Addis Ababa University	Photovoltaic Systems
Tanzania	University of Dar-es-Salaam	Solar thermal materials Photovoltaic systems
Zambia	University of Zambia	Solar radiation Solar thermal materials
Zimbabwe	University of Zimbabwe	Photovoltaic systems [Solar water heaters are manufactured locally]
Ghana	University of Science and Technology	Solar thermal for pumping

Sources: 1. Kivaisi, R. & Hasselaren, L., 1988. On Physical Science in East and Southern Africa.

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DISCUSSION

The following are some of the issues arising from the presentation:

- The gap between the large amount of biomass used and the limited on-going research on the respective technologies to optimize its use.
- The need for comprehensive national energy policies in Sub- Saharan countries. Ghana and Sudan, for example, have a national framework through which their energy policies are co-ordinated. In Kenya there is no proper coordination between the activities of the various parastatals and ministries in the energy sector

- The use of advanced technologies for cooking. People use insufficient technologies because they are cheap whereas advanced technologies - though more efficient - involve high capital costs.
- The need for a better working environment (proper equipment, better salaries) in research institutes in order to attract and retain local expertise. Good experts choose research institutes when searching for better working conditions.
- The proper utilization and regeneration of biomass resources, as well as improvement in the efficiency of biomass technologies as a means of ensuring sustainability of the resources.

APPRAISAL OF EFFECTIVENESS OF RECENT ACTIVITIES ON RENEWABLE ENERGY TECHNOLOGIES IN SUB-SAHARAN AFRICA

By
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1.0 INTRODUCTION

Renewable energy technologies can be classified in several ways. But for this paper, classification will not be accorded any importance. The classification used below is meant to present a range of renewable energy technologies in Sub-Saharan Africa. These include:

- Biomass energy;
- Solar energy;
- Wind energy; and,
- Water energy.

Although other forms of so-called 'renewable energy' such as geothermal energy, may warrant mention, only the four listed above will be discussed, as the major impact of the technology lies with them. However, it is impossible in a paper of this nature, to be comprehensive in presenting the entire range of research and development in Sub-Saharan Africa. Thus, the paper will only attempt to highlight efforts made to-date on each form of energy, and research and development in this area.

2.0 BIOMASS DERIVED ENERGY

This section will cover all aspects of energy derived from natural biological sources. These are a wide variety and include fuelwood, agricultural residues and organic wastes, briquetting of combustible products, charcoal, animal and secondary fuels derived from biomass such as fuel oils and gases, and other energy crops. By their very nature, renewable energies are attainable, although not necessarily guaranteed.

Fuelwood

It is noteworthy that fuelwood-related projects are well documented and will therefore not all be covered in this context. However, a number of "classical" examples will serve to reinforce this presentation.

In most Sub-Saharan African countries, fuelwood is by far the form of energy utilized by majority of the people. This significance which largely stems from cultural practices has justified expended efforts in research and development in fuelwood.

Research and development in fuelwood energy has been carried out two main areas that are not mutually exclusive:

- Renewable fuelwood supply; and,
- more efficient use of fuelwood.

The effects of deforestation in the search for fuelwood are a well known problem, and it is very serious in Sub-Saharan Africa. Total Deforestation in the tropics is estimated at 16.9Mha/yr[1], although this is not all for fuelwood.

One approach that is often used to solve this problem is through re-afforestation and agroforestry. Although re-afforestation is a vital component in fuelwood generation, there are other, more wide ranging reasons for research and development in this area. However, much of the efforts are remotely related to renewable homegrown technology in this assessment.

The research centres focus on one of a range of specific solar energy applications:

- Water heating;
- photovoltaic;
- water distillation;
- solar crop and food drying; and,
- solar cookers.

Solar Water Heating

Solar water heating (SWH) is widely used in Sub-Saharan Africa and is big business in most countries. However markets tend to be small. In Zimbabwe, it is blamed on the comparatively low electricity costs.[39] Kenya's experience seems to indicate that the problem lies in the lack of trust and adequate information, on the part of the consumer. Poor marketing of the products is also a major factor. In Kenya, there is clearly a need, not only to improve the marketing, but national (or international) standards in construction and performance as well.[40] In this respect, Botswana has already developed a code of practice which is mandatory for all government business in this sector.[41]

More research on the products and manufacture of solar water heaters is still necessary, but research on dissemination of RETs for wider adoption, is more urgently required. This requires the establishment of standards; possibilities for local manufactures; and how potential industries can be expanded.

Photovoltaic

Since Photovoltaic is a widely acceptable form of energy, as electricity, researchers and commercial people have a lot of interest in it. Hence the evident continuing large volume of research on PV electricity.

Notwithstanding, a number of points should be made clear on its status in Sub-Saharan Africa.

At present the manufacture of photovoltaic systems is dominated by Japan, Europe and the USA. In most developing countries the purchase of this equipment is expensive and a serious drain on foreign exchange. There is research into the science of photovoltaics but, in terms of genuine effectiveness in benefiting the countries concerned, this is very limited. There is a need for more research that looks at ways in which this technology can be manufactured entirely within the country of use. Only in this way will the technology become affordable in the countries where it is most effective. Although this is widely recognised, effective action is still a long way in coming.[42]

Second, if this manufacturing capability is attained, standards will be needed in both manufacturing and operation. But these standards should be initiated right from the start. Botswana has already adopted this approach and has been working on standards for some time now.[43,44]

However, research on solar crop and food drying and solar cooking are less developed. The technologies seem less 'fashionable' for research and development in renewable energy. But they are important technologies for Sub-Saharan Africa, and justify further studies on them.

Solar Driers

Numerous solar driers have been designed but more needs to be done. Currently, a project on the design and performance of solar crop dryers is underway at the ATC, in collaboration with the Energy Studies Unit of Strathclyde University in the UK and another one between Strathclyde and the University of Malawi.

The latter project is particularly interesting since it looks at the use of photovoltaic in a solar crop drying system. Field tests, are also being carried out in Nigeria.[45] This work centres on a variety of designs in use in Nigeria, and presents results which may be of value to those working on improved designs. An interesting application of this technology is being explored in Ghana, in a project investigating solar wood (lumber) drying.[46] The research so far, indicates that there are problems with the durability of the materials used. In order to run, electrically supported fans are used. The scale and size require more investigation and are now high priorities in the work at Strathclyde University.

Solar Cookers

In principle, solar cookers are also well developed but they have not been widely accepted. Research on how to improve the materials and design is still needed. Some research is being carried out currently[47] but, among the academia (research and development), interest seems on the decline. Solar box cookers, however, are widely used in refugee camps, and a number of individual organisations are providing a variety of designs. Solar cookers work well, hence the difficulty in understanding their non-acceptability in technical terms. But this should be investigated and a sensibly run dissemination project established.

Solar Stills

Solar energy is also used for solar water distillation. The solar stills that are developed nowadays are large scale units instead of increasing the input of smaller units. In fact, research in this field in Africa is decreasing, compared with India, Pakistan and China. What little is being done [48,49] seems isolated and uncoordinated. Water purification seems to be of less importance than other issues in the developing countries and possibly explains its apparent neglect.

4.0 WATER POWER

A variety of methods to extract energy from water exist, among them:

- Hydropower;
- tidal power;
- wave power; and,
- ocean thermal energy conversion.

Of these, hydropower is by far the most relevant to developing countries. Although hydropower is widely used for electrical power in most countries, in the developmental sense it is only widely used due to its capacity to be scaled down and is therefore, the only really appropriate technology. Large scale systems are generally felt to be inappropriate for environmental and social reasons.[50,51] Therefore, discussion here will be limited to small scale hydropower.

Small scale hydropower is a successful means of electricity generation in developing countries outside of Africa, yet it has not had any uptake in Africa itself. The local manufacture of components is possible and is the subject of several development projects in Asia and in South America. However, despite its potential in Africa,[52] progress is slow. It is clear that the potential is somewhat less than in the truly mountainous regions of the world, but research should be done in areas where it is possible in Africa.

A feasibility study carried out by GTZ indicated that there were 100 sites in Kenya capable of producing 50-100kW.[13] It concluded that because these areas tended to be close to the national power network, wide scale implementation would not be financially feasible. Burundi,[53] for instance, has potential, but very little has been done. In addition, there is scope to investigate low frequency revolving paddles for slower moving rivers at the coast.

5.0 WIND ENERGY

Wind energy is used predominantly for two reasons:

- Electricity generation; and,
- water pumping.

Wind energy for electricity generation is gaining acceptance in many parts of the world. In temperate regions, it is an alternative to solar energy, given the lower level of sunshine and comparatively higher wind activity. In developing countries, interest is mainly centred around electricity generation to supplement a national grid system. But in many parts of Sub-Saharan Africa it is more useful to run wind generators for battery charging. Nevertheless, Africa has great potential for wind power. A report to be published soon by the ATC shows that there is enough wind in certain parts of Kenya to supplement photovoltaic as a battery charging mechanism. Some work has already been done in South Africa on designing a generator for communities living in remote areas.[54]

Wind power for water pumping has gained acceptability and the technology required is also simpler and more accessible than that for electricity generation. That it is poorly developed attests to cases of "arrested development."[55] Many wind driven water pumps have been designed,[17] but it is likely that much of the research on this subject has been "work out". Thus, it is a technology that requires a major "dissemination effort."

6.0 CONCLUSIONS

From the foregoing, each technology seems to develop at its own pace. The salient points in the discussion are:

Biomass Energy

- there is much untapped potential for integrated energy production systems such as energy crop production as part of farming and food production or raw material production;
- the emphasis on fuelwood research is understandable, but there is clearly a case for devoting more effort to other energy crops and increase the use of biogas; and,
- the use of draught animals is severely neglected and requires research to investigate and dispel the apparent stigma attached to its use as an 'intermediate technology'.

Solar Energy

- Thermal technologies are well understood, hence more emphasis should be placed on research into:
  - i) Materials; and,
  - ii) manufacturing, standards, and enterprise creation to ensure widespread uptake of the technology.
- photovoltaic is a special case. It is still a developing technology in all countries of the world. Therefore, the development of this technology should be left to those with the capacity, resources and the finances to do so. Research in Africa's Sub-Saharan countries should be directed at methods that enable local manufacture; and,
- the other energy uses such as solar water distillation, solar crop drying and solar cooking are assuming less importance in global energy matters and, may therefore explain their neglect. However these activities are undertaken by a majority, and therefore research and development in these areas is necessary, in particular, in crop drying and cooking.

Water

- It is very disappointing how little is done in this area. However, this inherently simple technology can be researched into and utilised to a greater extent.

Direction of Future Research and Development

To draw all this to a single satisfactory conclusion may seem at first to be rather difficult. In determining when technologies should be eventually produced, developed and marketed by industries, research is extremely important and absolutely necessary. Incidentally, there is good quality research in many areas of Sub-Saharan Africa. In this, however, lies the major obstacle to our progress.

Too much research stays in the journals. Too much of our research is academic in nature and is not driven by the real needs of the target group. Not enough finds its way through to commercial development. Smillie is correct when he says that "the commercial sector must play a role in dissemination".[7] Development and acceptance of these technologies will only occur if there are markets for them, and if the markets and those who supply them are in close contact with each other. People will only use a technology if it is an easy option for them. They will only use a technology if they benefit from it themselves. The majority of the people living at the subsistence level are concerned with "getting through the day". They are not particularly concerned with the environment, the future or the limited supplies of energy available. Our research must be aimed at stimulating an environment where the technologies discussed in the paper become the easiest option for them. The technologies must create jobs for them. The reason for using the technology must not be that is a tidy, scientific solution postulated by someone who does not, and never will, use the technology themselves.[56]

The author's final plea is that we direct more research and development efforts to definite solutions: to benefit people more directly; to investigate aspects such as the ability to manufacture, maintain, sustain, and effect economic stimulation and scale; to ensure our research does not stay in the journals and on the conference tables; to practise what we preach and finally to question the point of all that we do.

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PART TWO: THE ECONOMIC VIABILITY OF RETS

Economics of Renewable Energy Technologies in Sub-Saharan Africa
Prof. Dr. Karl Wohlmuth

ECONOMICS OF RENEWABLE ENERGY TECHNOLOGIES IN SUB-SAHARAN AFRICA

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1.0 INTRODUCTORY REMARKS

In the last two years, the University of Bremen, Department of Economics, has worked on issues of relevance to the dissemination of renewable energy technologies, RETs in Sub-Saharan Africa, SSA, countries. In a research project headed by me, we have first identified the relevant factors in the marketing and dissemination of RETs. It entails focusing on the costs - investment and recurrent costs - and the market potential of the various technologies, and by highlighting the relevance of projections for assessing the future prospects of RETs, especially in SSA.

Second, we have analyzed the political economy of renewable energy promotion in SSA so as to assess the institutional and political aspects of implementing small and decentralized renewable energy projects. Thirdly, we have worked on new methods to identify, plan and evaluate RETs in their respective environments. In this context we have examined concepts and issues of new planning and evaluation tools (Multicriteria Analysis-MCA) and we have also discussed issues of economic policy adaptation so as to allow for the successful dissemination of RETs. We discussed how to adjust the economic policy framework so as to bridge the gaps between the financial and economic analyses of RET projects, by making financial decisions consistent with economic evaluation results.

In this discussion I would like to report on some of the results of our research work in Bremen. The main research results can be found in various publications (Wohlmuth/Oesterdiekhoff 1993; Wohlmuth/Kîllmann/Oesterdiekhoff 1993; Wohlmuth et al 1993).

These reports - partly done in English - give a detailed account of the prospects and possibilities of RETs in Sub-Saharan African countries, by considering not only the technologies and economic choices but also the institutional environment and the consistency of the economic and financial assessments of RETs.

2.0 ECONOMIC ISSUES OF RENEWABLE ENERGYTECHNOLOGIES IN AFRICAN COUNTRIES

On the whole, SSA has an increasing demand for initiatives to disseminate RETs. This demand has increased since the 1970s following the sharp oil price increases in 1973 and 1979. These led to a situation where energy was demanding a high share of the import bill of non-oil producing developing countries. But not only commercial energy imports caused problems in the balance of payments. The increasing food imports also had some effect on resources degradation. This is because, available resources were used to import food rather than energy supplies thereby increasing the reliance on fuelwood.

The 'energy transition' from fuelwood and other biomass sources to commercial fuels like coal and gas is extremely difficult in the SSA context. Many efficiency-related factors impede the effective use of modern as well as traditional energy in SSA. RETs therefore have increasingly become an important option in the supply of alternative energy in Africa's rural and urban areas.

The problem in Africa is the two-step energy transition process that has to be followed. African countries have to replace oil in the modern sector since oil is an expensive and depletable resource, while in the rural and urban areas they have to move away from traditional fuels so as to reduce pressures on the environment and improve health conditions (see ADF 1991, p. 6). Up to now progress is very slow.

Table 3: Status of Renewable Energy Technologies

Economic (in some locations)
Solar water heaters replacing electricity or with seasonal storage and for swimming pools Solar industrial process heat with parabolic trough collectors or large flate plate collectors Residential passive solar heating designs and daylighting Solar agricultural drying Small to medium photovoltaic systems Small to medium wind systems Direct biomass combustion Anaerobic digestion (of some feedstocks) Conventional geothermal technologies (dry flashed stream power generation, high temperature hot water and low temperature heat)
Commercial (with incentives)
Solar water and space heaters replacing natural gas or oil Electricity generation with parabolic trough collectors Non-residential passive solar heating and daylighting Biomass liquid fuels (ethernol) from sugar and starch feedstocks Binary cycle hydro-geothermal systems
Under Development
Solar space cooling(active and passive) Solar thermal systems (other than parabolic trough collectors) Photovoltaic power systems large-size wind systems Biomass gasification Hot dry rock geothermal Geothermal total flow prime movers wave energy systems
Future Technologies
Photochemical and thermochemical conversions Fast pyrolysis or direct liquidification of biomass Biochemical biomass conversion systems Ocean thermal energy conversion systems Geothermal magma
Definition of Categories Economics. Technologies are well developed and economically viable in some markets and locations , for which further market penetration will require technological refinements, mass production and / or economics of scale. Commercial (with incentives). Technologies are available in some markets , but are competitive with conventional technologies only with preferential treatments, so that they still need further development to be economically competitive Underdevelopment. Technologies need more R&D to improve efficiency, reliability or cost to become commercial. Future. Technologies have not yet been technically proven though they are scietifically feasible Source: IEA. Renewable Sources of energy, Paris 1987.

Source: Munasinghe, 1990[2], p.225

Table 4: Present state of the art and expected developments in renewable energy technologies

Technology	Presented State of the art	Expected future developments 1990	2000	2010	2020
1. Solar water heaters	R.D.P.C.E	C.E	E		
2. Active solar space heating	R.D.P.C	C	E		
3. Passive solar space heating and cooling	R.D.P.C	C	E		
4. Solar air conditioning	R.D	R.D.P.C	C.E		
5. Solar refrigeration	R.D	R.D.P.C	C.E	E	
6. Solar stills	R.D.P.C	C.E	E		
7. Solar dryers	R.D.P.C	C	E		
8. Solar evaporation	CE	E			
9. Solar cookers and food warmers	R.D.P.C.	C	E		
10. Solar sterilizers	R.D.P.C.	C	E		
11. Solar greenhouse	R.D.P.C.	C	E		
12. Non-convective solar ponds	R.D.P.C.	P.C	C.E	E	
13. Solar pumping and irrigation	R.D.P.C.	P.C	C.E	E	
14. Solar-thermol electric conversion	R.D.P	R.D.P	D.P	D.P.C	CE
15. Solar photovoltaics	R.D.P.C	R.D.P.C	C.E	E	
16. Sensible heat storage systems	R.D.P.C	R.D.P.C	P.C.E	C.E	E
17. Phase-change heat storage system	R.D.P	R.D.P.C	C.E	C.E	E
18. Thermochemical storage systems	R	R.D	R.D.P	R.D.P.C	CE
19. Wind-powered mechanical systems	R.C	C.E	E		
20. Wind-powered electrical systems	R.D.P	R.D.P.C	C.E	E	
21. Wind-powered fertilizer production	R.D	R.D.P.C	C.E	E	
22. Direct combustion of biomass	R.C.E	C.E	E		
23. Biogas plants	R.D.P.C	R.C.E	E		
24. Pyrolysis	R.D	R.D.C	C.E	E	
25. Alcohol production	R.D.P.C	R.D.P.C	P.C.E	C.E	E
26. Oil plants	R.D.P.	R.D.P.C	P.C.E	C.E	E
27. Hyraulic production of mechanical shaft power	R.C.E	C.E	E		
28. Hydraulic generation of electricity	R.C.E	R.C.E	R.C.E	E	
29. Geothermol energy	R.D.P.C	R.D.P.C	E		

Phases of development:

R = R&D D = Demonstration plants

P = Prototype plants C = Commercial plants economically competitive under special conditions.

E = Economically and technically feasible plants in most locations.

Source: Tasdemiroglu, opt cit, Ref. 5. Energy technologies classified according to T.A. Lawan. *The Potential of Renewable Energies in Planning the Development of Rural Areas.* Brace Research Institute Report No 1-126. Quebec Canada, 1978

3.0 ECONOMICS OF RENEWABLE ENERGY TECHNOLOGIES: CORE ISSUES AND IMPLICATIONS FOR AFRICA

Ten core issues in the economics of renewable energy technologies have to be identified and related to Africa:

Inconsistent Projections

Most of the projection on costs and market prospects are inconsistent and/or contradictory. Vague statements and wordings are used in making projections. For instance, there are different statements on how developed or how proven RETs are; that some technologies are often or usually considered economic, others show variable economics and others still are not economical at present; some RETs are considered widely deployed, others have mixed deployment, while others still are in an early deployment stage. There are such numerous sources of projections to consider that the financing, environmental or technical assumptions behind the projections are often heroic. Obviously, various actors contribute to these conflicting projections and results and thereby affect the real choice and investment behaviour. The costs of information in the RE market are high.

Inappropriate Localization

There are mixed results in the transfer, through trade and development cooperation, of renewable energy technologies. In the process, there is lack of assimilation and adaptation of these technologies and a lack of follow-up and assessment of technology failures. This leads to severe localization problems: under-investment in indigenous R&D and in local manufacturing, and in the marketing of RETs. There is, also, a lack of exploitation of the local traditional production experiences, especially with regard to traditional RETs such as mini hydropower, wind energy and fuelwood conservation programmes.

Ignoring Substitution

There is a tripartite substitution relation. RETs compete with modern commercial fuel, traditional fuelwood energy and with the RETs themselves. Since both RET substitutes are largely underpriced, especially in African countries, an inherent bias against RETs exists. All RETs are competing in their respective uses against modern and/or traditional substitutes. Substitution also prevails among the RETs themselves. For instance, in photovoltaics, village stations supplying electricity compete with diesel generators; solar home systems compete with kerosine and mini wind generators; photovoltaics-based pumps compete with handpower, wind power and diesel power in irrigation; photovol-taics used for pumping drinking water compete with handpower, wind power and diesel.

These substitution relations exist for all the RETs and in their uses. Up to now, these generalized substitution relations have neither been identified nor considered as relevant by policy makers in the field. However, important substitution relations also exist between RETs, for example, photovoltaic or windpower pumping. The substitution relations that are of a more general nature are important at the level of household and company users, as alternatives to the use of RETs. For example: changing consumption attitudes, production technologies, inputs, time of energy use and changing the quality of output. It is important to understand the relevance of this generalized substitution calculus.

Payback Gap

The private RETs disseminator, who is the investor, has to chose between the high investment costs of RETs which are repayable over a long time and which require low maintenance costs, against the conventional energy technologies which although cheap, have high service costs and are less durable. To resolve this, new financing modalities need to be designed. Also, the use of local materials and or essential imported ones should not cause further increases in the already high investment costs per kWh. Local savings associations, sectoral credit institutions, revolving funds, national taxes on fossil fuels (like in Ghana) and other domestic and international financial mechanisms can help to bridge the payback gap.

3.0 ECONOMICS OF RENEWABLE ENERGY TECHNOLOGIES: CORE ISSUES AND IMPLICATIONS FOR AFRICA

Ten core issues in the economics of renewable energy technologies have to be identified and related to Africa:

Inconsistent Projections

Most of the projection on costs and market prospects are inconsistent and/or contradictory. Vague statements and wordings are used in making projections. For instance, there are different statements on how developed or how proven RETs are; that some technologies are often or usually considered economic, others show variable economics and others still are not economical at present; some RETs are considered widely deployed, others have mixed deployment, while others still are in an early deployment stage. There are such numerous sources of projections to consider that the financing, environmental or technical assumptions behind the projections are often heroic. Obviously, various actors contribute to these conflicting projections and results and thereby affect the real choice and investment behaviour. The costs of information in the RE market are high.

Inappropriate Localization

There are mixed results in the transfer, through trade and development cooperation, of renewable energy technologies. In the process, there is lack of assimilation and adaptation of these technologies and a lack of follow-up and assessment of technology failures. This leads to severe localization problems: under-investment in indigenous R&D and in local manufacturing, and in the marketing of RETs. There is, also, a lack of exploitation of the local traditional production experiences, especially with regard to traditional RETs such as mini hydropower, wind energy and fuelwood conservation programmes.

Ignoring Substitution

There is a tripartite substitution relation. RETs compete with modern commercial fuel, traditional fuelwood energy and with the RETs themselves. Since both RET substitutes are largely underpriced, especially in African countries, an inherent bias against RETs exists. All RETs are competing in their respective uses against modern and/or traditional substitutes. Substitution also prevails among the RETs themselves. For instance, in photovoltaics, village stations supplying electricity compete with diesel generators; solar home systems compete with kerosine and mini wind generators; photovoltaics-based pumps compete with handpower, wind power and diesel power in irrigation; photovol-taics used for pumping drinking water compete with handpower, wind power and diesel.

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payments and the fiscal budget) can be observed.

tegy		Description
	Cooking:	5100 kg of fuelwood gathered from common lands and 1200kg of maize resdue. Both fuels burnt in a traditional mud/clay stove.
	Lighting:	60 litres of paraffin. Burnt in three hurricane type of standing lamps.
	Space Heating:	Radiant heat from cooking and lighting activities.
	Cooking:	6170 kg of fuelwood from an agroforestry system. Burnt in a traditional mud/clay stove
	Ligthing:	109.8 litres of paraffin. Burnt in two hurricane type or standing lamps and one pressure lamp.
	Space Heating:	Radiant heat from cooking and lighting activities.
	Cooking:	2469 kg of fuelwood from an agroforestry system. Burnt in a portable metal stove.
	Ligthing	Same as for Energy Strategy B.
	Space Heating:	Partly form radiant heat from cooking and lighting activities. Partly from 1303 Kg of fuelwood produced from an agroforestry system and burn in a hearth.
D	Cooking:	1214 Kg of charcoal. Produced in an earth kiln from 8855 Kg of fuelwood grown under an agroforestry system. Burnt in a metal ceramic stove (joke).
	Lighting:	Same as for Energy Strategy B.
	Space Heating:	Partly from radiant heat from cooking and lighting activities. Partly from 1155 Kg of fuelwood produced from an agroforestry system and burnt in a hearth.
E	Cooking:	1214 Kg of charcoal. Produced in two 200 - litre oil drums from 5285 Kg of fuelwood grown under an agroforestry system. Burnt in a metal ceramic stove (jiko).
	Lighting:	Same as for Energy Strategy B.
	Space	Heating: Same as for Energy Strategy D.
F	Cooking:	1214 Kg of charcoal. Purchased commercially and burnt in a metal ceramic stove (Jiko).
	Lighting:	Same as for Energy Strategy B.
	Space Heating:	Same as for Energy Strategy D.
G	Cooking: 1095 cu	m. of biogas stove.
	Lighting:	865 cu. m. of biogas. Burnt in three 3-mantle gas lamps.
	Space Heating:	Partly from radiant heat from cooking and lighting activities. partly from 388 Kg of fuelwood produced from an agroforestry system and burnt in a heath.
H	Cooking:	805 litres of paraffin (kerosene). purchased commercially and burnt in a paraffin stove.
	Lighting:	Same as for Energy Strategy B.
	Space Heating:	Partly form radiant heat from cooking and lighting activities. Partly from 1255 Kg of fuelwood produced from an agroforestry system and burnt in ahearth.

Source: Wereko-Brobby/Hagan 1991, p. 32

A third option, the services of the Energy Sector Management Assistance Programme (ESMAP), was made by other countries. It relates to the rational use of traditional fuels and is aimed at saving energy by identifying potentials for energy substitution and savings in industry, agriculture, transport, the household and export sectors. This approach was also not that successful. More important, a neutrality of incentives between energy sources, progress in energy institutions and energy policies and the broadening of the scope of dissemination of RETs did not follow the implementation of any of these policies.

Strategic Energy Policy Decisions

All these policy and institutional weaknesses lead to more fundamental questions regarding policy failure and the prospects for reform. An important observation is that the strategic energy policy decisions are taken outside the major energy policy institutions and are concentrated in the Ministries of Finance and Planning.

Such strategic decisions relate to the objectives, investments and key energy prices. These decisions are drafted and executed by the Ministries of Finance and Planning. The strategy for the energy sector investment allocation - including foreign exchange allocation - and the pricing of electricity, fuels and oil products is intentionally linked to such policy objectives as growth, regional development, equity, security of energy supply, reduction of foreign economic dependence etc. However, in reality, the trade-offs between these objectives are not made clear and a hierarchy of the stated objectives is not revealed.

The coordination of authorities and institutions with the competence in the field of energy sector issues is difficult. But more important than the issue of coordination is the issue of hierarchy in the decision-marking process. The hierarchical structure of decision-making is working against the more competent Ministries of Energy and the National Energy Boards. Some countries tried to involve all relevant institutions in a National Energy Board or a National Energy Commission. These attempts have not been successful, and where successful as in Ghana, the Board ultimately was discriminated against because of a perceived conflict of interest with the Ministries of Finance and Planning. The Ministry of Energy is then left with minor responsibilities and areas of decision-making, especially the (small) Renewable Energy Programmes and/or the (insignificant) Energy Conservation Programmes.

Ineffective Forms of Development Cooperation

Development cooperation (DC) in energy, especially with regard to RETs, is ineffective.

DC is ineffective because the coordination between donor and local institutions neither work in the case of large-scale energy projects nor in the case of small, decentralized and NGO-based energy projects. The lack of coordination is obvious in large-scale electricity, hydropower and refinery projects and is explained by the hierarchical process of decision-making, the supply-side orientation of energy policies and planning, and the role of large-scale energy projects in foreign exchange generation and balance of payments policy. With regard to small and decentralized projects the lack of coordination is explained by the great number of stated objectives and by the fact that these objectives are not always revealed and quantified. The donors often prefer to escape national control (integration, screening, monitoring) of small projects, thus by-passing the Ministry of Energy even in small energy projects.

Development cooperation is also ineffective because of policy factors which enhance the supply-side orientation of energy planning. Because of the existence of coalitions between donor countries' institutions and public utilities in Africa, they share a common interest in favouring large-scale energy projects for financing. Balance of payments policies, international creditworthiness and financial autonomy of public utilities are issues in this context.

Most serious however, are the deficiencies of DC with regard to technology transfers in RETs. It is obvious from international comparisons that even in the case of standardized energy technologies such as diesel generators in use in various developing countries, in private as well as in public sectors, huge but varying differences exist between best practice and actual performance. The main reasons are that issues of incentives, relevant operational management factors and appropriate relations between donor institutions and local energy institutions are ignored. More problems arise in the case of RETs because technology is largely unproven, operations require still more support and a whole package of services in the process of technology transfer is required. Such packages are usually not provided for by DC, and the elements of the package are not systematically transferred in an unpacked form.

Discriminatory Strategic Prices

Strategic prices for electricity, fuel, oil products and kerosene are discriminating against RETs on the grounds of stated development objectives. Therefore, a justification for heavy subsidization element of these key energy sources is made. Non-neutral incentive policies favour so-called strategic sources of energy supply. There is, however, evidence that in African countries no clear, unambiguous and consistent policy of strategic energy pricing exists, and that clear priorities and a clear hierarchy of objectives are lacking. The continual subsidization of energy no longer sustains growth, employment creation, equitable and sustainable development, but discriminates against the RETs. These prices have increasingly became political prices, thus contributing to increasing budget deficits, inflation and balance of payments problems while preserving the survival of inefficient public utilities.

Myths on Renewable Energy Promotion

Four groups of myths on renewable energy promotion have been identified. In Group 1 we find myths relating to the attitudes of those actors confronted with RETs during production and technology use. When propagating afforestation, biogas and stove programmes it is implicitly assumed that neither the labour time allocation, the time budget of the users, nor the social acceptance issues matter. Many projects and programmes fail because the available labour time - at a given level of labour productivity - does not allow, say in a biogas project, for time to care for provision of inputs, maintenance and other activities in competition with other demands on time.

A second group of myths refers to the implicit assumption that small and decentralized projects only have limited problems in technological complexity and technology transfers. However, at least four levels of technological complexity have to be distinguished in this context: first, production efficiency concerning the feasibility/viability of the production of compo-nents and systems; second, the issue of operational efficiency concerning the actual working period when the RET is already installed; third, the issue of systemic efficiency when looking at the related incentives and the management environment; and fourth, the efficiency in the specific context of techno-economic flexibility of RETs, when considering the inherent flexibility of RETs to adjust energy services supply in case of increasing regional/local energy demand (as measured by the long-run marginal costs). If all or some of these four aspects of efficiency are ignored in the process of technological mastery and technology transfer, which is often the case, frustrating experiences occur in DC.

A third group of myths refers to the assumption that small and decentralized energy project have less demand for national political and planning integration. On the contrary, many projects fail because the demand for macro-economic and policy integration is considerably higher in the case of RETs than often assumed; and the demand for certain public goods: education & training, R&D, social and economic infrastructure, maintenance and standardization services and for various complementary private services.

A fourth group of myths relates to the assumption that the market for RETs is relatively transparent and that the overall market structure in the energy sector does not impede the identification and execution of RE projects. However, we identified many factors that characterize the RE market as highly politicized and influenced by non-market influences. Demand and supply of RETs are affected by political disincentives and impediments, subsidies, lack of information and lobbying, lack of informational transparency, tremendous market failures, highly erratic policy choices, and a lack of awareness. Adequate policies on education and training, finance, trade and investment, R&D, and new forms of DC have to compensate for these characteristics of political markets.

These six areas are of concern if we look at the Political Economy of Renewable Energy Promotion. There is detailed evidence that the slow pace of dissemination of RETs is much more a political and economic issue than a 'technological' issue; it is a complex systemic issue. The whole system of incentives, institutions and political choices is affected and has to be reformed.

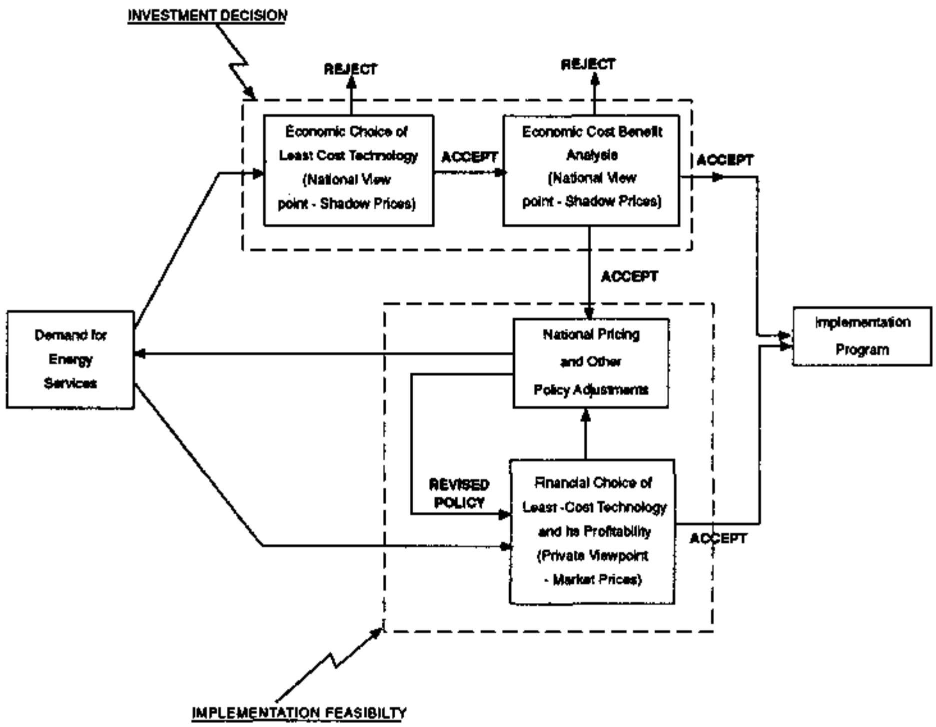
5.0 PLANNING, MONITORING AND EVALUATING RENEWABLE ENERGYPROJECTS

It is clear that for the accelerated dissemination of RETs not only the economic policy framework and an appropriate regime for technology transfers matter. The interaction of the economic policy framework, the economic analysis (national perspective) and the financial analysis (by the prospective investor) of RE projects also matter. The following section focuses, first, on this interaction, and then discusses the issue of more partici-patory planning and evaluation approaches.

In order to promote small and decentralized energy projects, it is necessary to consider the very close interaction of economic policy variables, economic analysis of projects and the response of private investors/public investors in their financial analysis. Table 6 points out the various principal steps to be followed in order to match the results of economic and financial investment analysis. In order to prepare for an investment deci-sion, the economic analysis (the national viewpoint) is relevant so as to see if a project is justified by national welfare reasons. When looking at the costs of a project, a RE technology is selected on the basis of least cost by national standards if it is to be accepted for further tests.

If not, it is rejected on the grounds of lacking cost-effectiveness. If accepted, another test is based on the economic cost-benefit analysis, thereby also taking into account in detail the output side of the project. If the technology is a) least cost and b) profitable (if the discounted costs are lower than the discounted benefits), the investment decision is economically justified. However, non-economic objectives are ignored at this stage. These include economic independence, self-sufficiency, mobilization of local energy sources, although all such objectives are very difficult to quantify. Therefore, at another stage of evaluation, the policy makers have to weigh the non-economic objectives in the context of their strategic objectives (see Munasinghe 1990[3]).

Table 6: Steps in Economic and Financial Analysis and Related Economic Policy Revisions



Source: Munasinghe 1990[3], p. 211

Project evaluation is therefore a multi-step process. After identification of demand for energy services (step 1), least cost analysis by national standards (step 2) and cost-benefit analysis by national standards (step 3) have to follow. A further step, 4, is the test of the feasibility of the project implementation. If the project is implemented by the government, the question is whether energy is demanded at the market for a financial price to be charged to the consumer. In order to meet the economic efficiency objective of pricing, the price should reflect the marginal economic opportunity cost or long-term marginal cost of supply, which is possibly modified by various national strategic goals (Munasinghe 1990[3]).

A more complicated decision is where, say, a private agricultural investor has to decide if it is profitable for him to switch from re-investing in diesel pumping for irrigation, into a RET, say photovoltaic water pumping for irrigation (see the case study by Munasinghe 1990[3], pp. 212-216). If the RET is proven to be (1) least-cost and (2) profitable, the private investor is likely to decide in a distortion-free economy in conformity with the results of economic analysis. However, because of so many price distortions in developing countries especially in SSA, this will not necessarily be the case.

In order to develop a project into a technology that is economically justifiable and attractive for private investors, the government has to consider and compensate for all the relevant economic policy distortions. For example, if the conventional technology (diesel pumping) has an advantage only because of a fuel subsidy, the removal of the subsidy may be the solution. However, if this is difficult to implement, other avenues can be pursued by government. Prices of inputs and outputs can be changed and regulations/ deregulations introduced in such a way that the economically justified technology is also attractive on a private basis. Only when all economic and financial tests are met, will the implementation and investment begin and the RET promoted (see Munasinghe 1990[3]).

Table 6 indicates that the implementation of RET projects as with all other projects often requires considerable policy changes with regard to national pricing, but that other policy adjustments may be necessary, so that revised policies then induce the choice of the least-cost and profitable RE technology. This iterative process is therefore highly dependent on appropriate policy changes so as to compensate for the distortions in the economy against RETs. The case illustrated by Munasinghe (1990[3]) compares a photovoltaic and a diesel pumping system for irrigation. The case highlights all these relevant policy issues (see Summary Table 7). The analysis is based on the Present Value of Costs (PVC) and the Present Value of Benefits (PVB) for Solar (S) and Diesel (D) technologies on the basis of Economic Analysis (E) and Financial Analysis (F).

Table 7: Investment Analysis and Economic Policy Changes - An Illustration for RETs

Economic and Financial Tests for Investment Decision (All amounts are in present value terms)				
	A	B	C	D
Item	National Viewpoint Shadow Prices (Border Rs.)	Private Viewpoint (Interim) Market Prices before Policy Changes (Domestic Rs.)	Private Viewpoint (Final) Market Prices after First Policy Change (Domestic R.s)	Private vie (Final) Market Prices After Second Policy Change (Domestic Rs.)
Solar PV Costs	$PVC_{SS} = 66.760$	$PVC_{SP} = 75{,}080$	$PVC_{SP} = 75{,}080$	$PVC_{SP} = 75{,}080$
Diesel Costs	$PVC_{DS} = 74{,}540$	$PVC_{DP} = 71{,}110$	$PVC_{DP} = 85{,}070$	$PVC_{DS} = 85{,}070$
Irragation Benefits	$PVC_{B} = 70{,}970$	$PVB_{P} = 73{,}670$	$PVB_{P} = 73{,}670$	$PVB_{S} = 78{,}000$

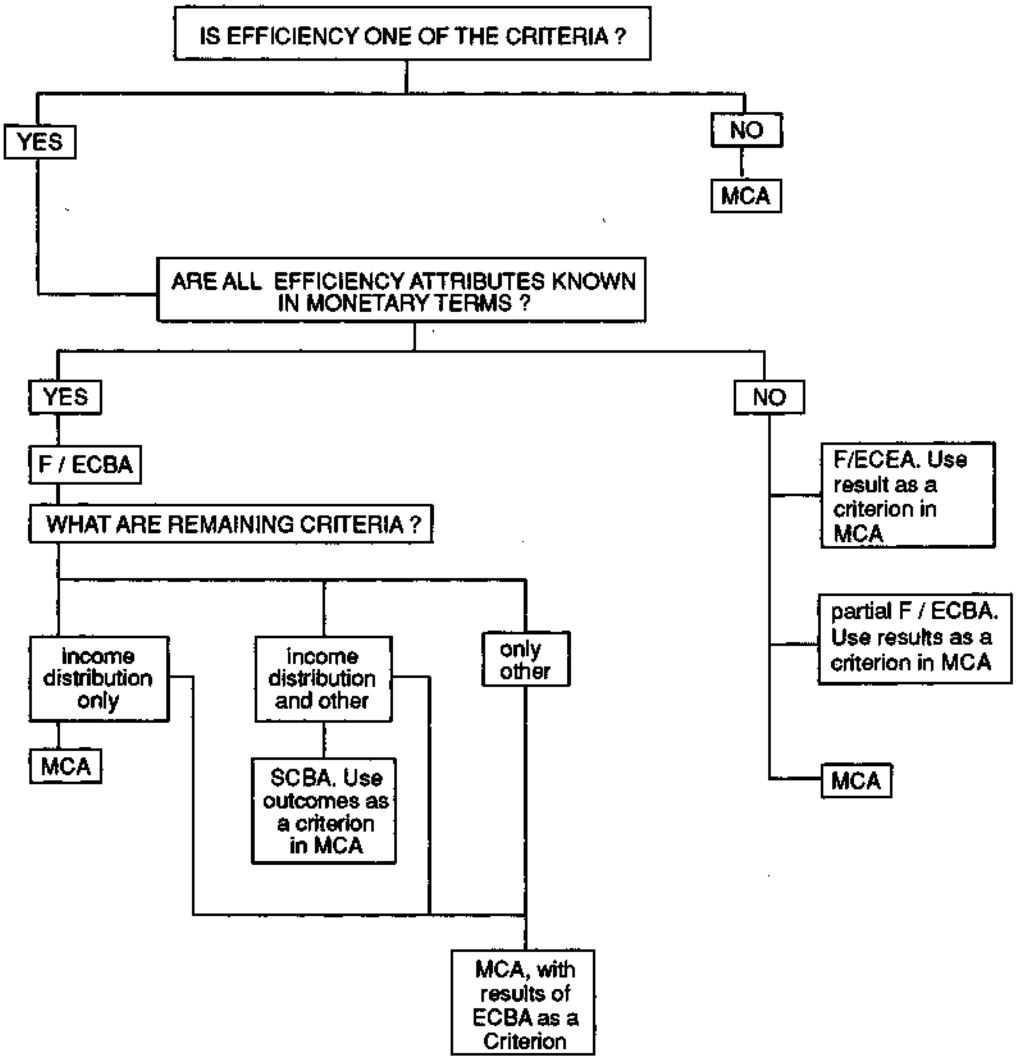
CONCLUSION

Condition		Consequences
A. Shadow Priced Values:		
$PVC_{SB} < PVC_{DB}$	-	Solar PV is the economically prferred least- cots technology.
$PVC_{SB} > PVC_{SB}$	-	Investment in Solar PV is economically justified.
B. Market Priced Values Before Policy Changes:		
$PVC_{SP} > PVC_{DP}$	-	Farmers will prefer diesel to solar PV pumps, Financially.
C. Market Priced Values After First Policy Change:		
$PVC \geq PVC_{DF}$	-	Farmers will prefer solar PV to diesel pumps, finacially.
$PVB_{P} < PVC_{SP}$	-	Farmers will find solar PV pumps financially unprofitable to install
D. Maket Priced Values After Second Policy Change:		
$PVC_{SP} < PVC_{DP}$	-	Farmers will prefer solar PV to diesel pumps, financially.
$PVB_{P} > PVC_{SP}$	-	Farmers will find solar PV pumps financially profitable to intall.

Source: Munasinghe 1990[3], p. 215

Looking at this case, at least two rounds of policy changes are required to come to the beneficial technology choice - a RET which is economically justified but also privately preferred. The policy makers have various options. The government could reduce import duty on solar PV systems first, or raise the subsidized price of diesel fuel second, or legislate that farmers could no longer buy diesel pumps third, or give low interest loans to buy solar pumps fourth, and remove the import subsidy on diesel motors as a fifth option. In column C (of Table 7) we can see that option 5 (removal of import subsidies for diesel motors) will make the solar technology attractive but that there are still no net benefits for the private investor.

Table 8. The choice of Method in Investment Analysis



Source: van Pelt, 1991, p. 30

Another policy variable has to be changed by the government. The government can increase procurement prices for agricultural products, so that solar technology is then least cost and also profitable on a financial basis (see column D).

This type of demand management for implementing RETs has, up to now, no real chance in many SSA countries, because of the one-sided supply management focus and the lack of any interaction between macro-economic and energy policies. We have argued that these tools and policies (economic and financial analysis in conjunction with policy changes) are indispensable for any promotion of renewable energy projects, but that still non-economic objectives have to be considered in a further round of planning and evaluation. Therefore, implementation of RETs has to be judged also with regard to non-economic objectives.

Non-economic objectives and more participatory planning approaches can be considered and introduced on the basis of multi-criteria analysis (MCA). Table 8 shows that even in cases where efficiency is the only criterion for evaluation, MCA analysis matters because some efficiency attributes may not be known in monetary terms. Therefore, the results of the Financial Economic Cost-Effectiveness Analysis (F/ECEA) or of a partial Cost-Benefit Analysis (F/ECBA) are used as a criterion in MCA. Another option is to go directly for a MCA.

Even in cases where all efficiency attributes are known, other criteria besides income distribution, as covered by the Social Cost-Benefit Analysis - SCBA, can only be incorporated on the basis of a MCA, using SCBA outcomes as a criterion. Using the results of an ECBA as a criterion is a way to combine MCA with cost-benefit analysis. This procedure looks complicated for small and decentralized RE projects but looking at energy programmes, this approach has advantages.

The case study on Kenya by Ramphall (1992) reveals how fruitful this approach can be. As shown in Table 9, eight energy strategies at the household level have to be compared and evaluated on the basis of revealed local experience. A rather complex set of evaluation criteria emerges (see Table 10).

Table 9: Evaluating feasible energy strategies in rural Kenya - Identification of Alternatives

Energy Strategy		Desciption
A	Cooking:	5100 kg of fuelwood gathered from common lands and 1200kg of maize resdue. Both fuels burnt in a traditional mud/clay stove.
	Lighting:	60 litres of paraffin. Burnt in three hurricane type of standing lamps.
	Space Heating:	Radiant heat from cooking and lighting activities.
B	Cooking:	6170 kg of fuelwood from an agroforestry system. Burnt in a traditional mud/clay stove
	Ligthing:	109.8 litres of paraffin. Burnt in two hurricane type or standing lamps and one pressure lamp.
	Space Heating:	Radiant heat from cooking and lighting activities.
c	Cooking:	2469 kg of fuelwood from an agroforestry system. Burnt in a portable metal stove.
	Ligthing:	Same as for Energy Strategy B.
	Space Heating:	Partly form radiant heat from cooking and lighting activities. Partly from 1303 Kg of fuelwood produced from an agroforestry system and burn in a hearth.
D	Cooking:	1214 Kg of charcoal. Produced in an earth kiln from 8855 Kg of fuelwood grown under an agroforestry system. Burnt in a metal ceramic stove (joke).
	Lighting:	Same as for Energy Strategy B.
	Space Heating:	Partly from radiant heat from cooking and lighting activities. Partly from 1155 Kg of fuelwood produced from an agroforestry system and burnt in a hearth.
E	Cooking:	1214 Kg of charcoal. Produced in two 200 - litre oil drums frum 5285 Kg of fuelwood grown under an agroforestry system. Burnt in a metal ceramic stove (jiko).
	Lighting:	Same as for Energy Strategy B.
	Space Heating:	Same as for Energy Strategy D.
F	Cooking:	1214 Kg of charcoal. Purchased commercially and burnt in a metal ceramic stove (Jiko).
	Lighting:	Same as for Energy Strategy B.
	Space Heating:	Same as for Energy Strategy D.
G	Cooking:	1095 cu. m. of biogas stove.
	Lighting:	865 cu. m. of biogas. Burnt in three 3-mantle gas lamps.
	Space Heating:	Partly from radiant heat from cooking and lighting activities. partly from 388 Kg of fuelwood produced from an agroforestry system and burnt in a heath.
H.	Cooking:	805 litres of paraffin (kerosene). purchased commercially and burnt in a paraffin stove.
	Lighting:	Same as for Energy Strategy B.
	Space Heating:	Partly form radiant heat from cooking and lighting activities. Partly from 1255 Kg of fuelwood produced from an agroforestry system and burnt in a hearth.

Source: Ramphall, 1992

Table 10: Evaluating feasible energy strategies in rural Kenya - Set of Evaluation Criteria

Criteria	Description	Unit of Measurement
Technical		
1	First Law Energy System Efficiency	percent
2	Second Law Energy System Efficiency	Percent
3	Fuel Conservation through Efficiency Gains	Megajoules per year
4	Technical Lifetime of Energy Strategy	Rank
5	Rapidity of Energy Development	Rank
Economic		
6	Absence of Time Recurrent Costs	Rank
7	Fuel Costs	U.S. dollars per utilize Gigajoule-year
8	Cost of Energy Conversion/End use Devices	U.S. dollars
Ecological		
9	Local Sources of Energy Inputs	Proportion
10	Present or Near-Term Deleterious Impacts on the Local Ecosystem	Kilograms of fuelwood cut per year
11	Absence of Resource competition	Rank
	(Fuel Versus Food for Humans)	Rank
12	Absence of Resource Competion (Fuel Versus Fertilizers)	Rank
13	Absence of Temporal Fluxes in Energy	Rank
14	Potential for Sustained Yield	Proportion
15	Absence of Uncertainties	Rank
16	Absence of Risk	Rank
17	Absence of Vulnerability	Rank
Social		
18	Non-Monetary Benefits	Rank
19	Absence of Distributional Ill Effects	Rank
20	Employment Generated Per Unit Capita Investment	Rank
21	Absence of Social Obstacles to Acceptance	Rank

Source: Ramphall, 1992

Besides economic efficiency, a variety of other criteria are included in the MCA. MCA requires definite steps: first, identification of alternatives; second, assessing the set of relevant criteria; third, determining the weights of the criteria; fourth, impact assessment and standardization of effects; fifth, integrated comparison of alternatives; and sixth, risk and uncertainty analysis (sensitivity analysis).

Standardization, as a concept means that cardinal criteria scores (see Table 10) - which are incommensurable units, e.g. dollars, acres, tons, ... - are standardized into dimensions/numbers between zero and one in a manner which preserves the degree of difference between alternative energy strategies (Ramphall 1992, p. 11; van Pelt 1991, p. 20). Standardization sets a minimum evaluation score at zero, and a maximum evaluation score at one, in order to space out linearly the other evaluation scores.

All this looks rather complicated relative to financial and economic analysis of projects, but allows for a more participatory assessment of alternatives, criteria, weights and impacts. Various methods can be used for MCA (see Oesterdiekhoff 1993). A number of suitable software support packages is available (see Wohlmuth/Oesterdiekhoff 1993).

In the research project a list of relevant criteria adapted to small and decentralized energy projects in developing countries were identified. In addition, two complementary roles of the MCA methods in project planning and evaluation were proven by demonstrating that MCA has inherent advantages. These include being permitted to work with weak data; considerable flexibility of the MCA methods; the possibility to discover methodical biases by using various MCA methods; participation as a basic ingredient of the whole assessment of alternatives, criteria and weights; identifying trade offs between project and programme objectives. Wohlmuth/Oesterdiekhoff (1993, Part B) and Ramphall (1993) also highlight the importance of this methodology for planning and evaluating alternative national, regional and local energy policies in SSA.

6.0 CONCLUSIONS

Analysis from the research project indicates that despite the favourable perspectives for renewable energies in developing countries, especially in solar energy, there are serious constraints to dissemination promotion.

The most important problem areas are: the economics of renewable energy technologies shows the complexity of the market characteristics with regard to the application of such technologies; the political economy of renewable energy promotion identifies various significant barriers for implementation of RETs; and the investment analysis of RE projects and programmes is up to now ignoring the interaction of economic policy changes and the investment analysis, as well as the necessity of more participatory planning and evaluation approaches.

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PART THREE: THE SUCCESSFUL ADOPTION OF RETS

Rural and Decentralized Energy Options:
Moving to Wide-Scale Dissemination of Renewable Energy Technologies in Sub-Saharan Africa
Stephen Karekezi

The Dissemination of Renewable Energy Technologies in Sub-Saharan Africa
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RURAL AND DECENTRALIZED ENERGY OPTIONS: MOVING TO WIDE-SCALE DISSEMINATION OF RENEWABLE ENERGY TECHNOLOGIES IN SUB-SAHARAN AFRICA

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1.0 INTRODUCTION

Renewable energy technologies (RETs) have, in the eyes of many, not yet fully fulfilled their promise. In the early 1970s, RETs were seen as a panacea to the developing world's deteriorating energy situation. They were perceived as low-cost and an appropriate alternative to conventional energy technologies and, most important of all, suitable for use by the rural and urban poor of the Third World (World Bank, 1980).

Over the last 15 years, significant financial resources were invested in RETs projects. Today, RETs continue to face daunting hurdles. A large number of them are beyond the financial reach of their principal target groups: the rural and urban poor. Others are not tailored to user needs. RETs that are low-cost, such as solar water heaters, continue to face enormous problems in mobilizing support at the policy level and in engineering large-scale dissemination at the level of end-users (Karekezi, 1987).

Before discussing the potential of RETs, this paper discuss one of the major drawbacks in the dissemination RETs: the tendency to perceive the identified technologies as stand-alone options. Too often, RETs were promoted in a fashion that ignored other equally attractive, compatible, conventional or fossil-fuel options. Past attempts to promote RETs tended to focus on specific technologies for generating energy whether it be a micro-hydro plant or a biogas plant (Bhattia, 1987). Insufficient attention has been paid to other equally vital components of the rural energy system such as:

(i) The national or district (as the case maybe) energy balance;
(ii) the transportation and distribution of energy;
(iii) the manufacture and maintenance of equipment and spare parts;
(iv) training of users, maintenance personnel and manufacturers; and,
(v) involvement of entrepreneurs in the manufacture, marketing and servicing of the equipment.

As a result, the current understanding of how stand-alone energy technologies perform is not matched by an adequate appreciation of the environment that is necessary for the successful introduction of rural energy technologies. There is growing consensus that RETs should be promoted as an important component of a wide range of energy options that include fossil fuels, technologies and efficiency measures. Consequently, instead of discussing renewables in isolation, the paper will broaden its perspective to cover rural and decentralized energy technologies in general.

Background

Over the past two decades, there have been numerous attempts to promote sustainable rural energy technologies in developing countries. Options that have registered encouraging results include:

- Biomass-fired cookstoves, kilns and baking ovens;
- diesel-powered machinery for mechanized agriculture, transport, agro-processing and the generation of electricity;

- micro hydro-plants for electricity generation and shaft-power;
- biogas units for cooking and lighting;
- wind-powered equipment for water pumping and electricity generation;
- direct solar energy devices for water heating and crop drying;
- photovoltaic equipment for lighting, refrigeration and communication; and,
- grid electricity for lighting and for providing power to rural agro-processing and manufacturing units.

A large number of rural and decentralized energy activities utilizing one or a combination of the above options were initiated in developing countries over the last 15 years. These initiatives were, partly, a response to the world-wide concern over the emerging energy crisis sparked off by the oil shock of the early 1970s. The rationale for these initiatives was based on the belief that the wide-scale application of appropriate energy technologies would have a significant ameliorative impact on the energy problems faced by a large majority of the rural inhabitants of the Third World.

Although the experience to date has increased knowledge on possible technical options for the rural energy sector, the results of many of the above initiatives have often been below expectations. The primary reason for this was the unanticipated complexity of developing, selecting and implementing appropriate technical options that adequately address the rural energy question. Key issues that compounded the situation include the :

i) Bias for urban over rural development, in general, and in rural energy issues in particular;
ii) access to information on the rural energy sector and energy technology options;
iii) needs and effective demand; and,
iv) user needs and participation.

Urban Bias in Rural Development

The rapid urbanization of developing countries is one of the most significant demographic changes taking place in the South. In the case of Asia and Latin America, urbanization is a long-established trend. Africa is the continent that has historically been the least urbanized. The urban population is expected to double in the next 12 to 15 years (World Bank, 1989). A recent report on African energy policy (Soussan, 1989) states:

> *"Urban growth rates of up to 10 % per year are the norm in Africa and what were rural societies are becoming increasingly urban focused.... The corollary of this conclusion is that urban energy demand is of increasing importance, and for some countries may become the dominant energy policy issue in the near future."*

This demographic shift is strengthening the historical bias for developing urban areas and has continued to push rural energy issues to the background. From this perspective, mobilizing support for developing and implementing technology options for rural areas has been and will continue to be an uphill task.

Access to Information on the Rural Energy Sector and Energy Technology Options

The scarcity and difficulty of obtaining information on the rural energy sector is a major constraint in the selection and diffusion of appropriate technology options. Past attempts to collect rural energy data have often been static in nature and content (Barnett et al, 1982). The results provided snap-shot pictures of the energy situation and have not been able to capture the dynamic and fluid nature of rural energy.

Most of these attempts were heavily dependent on formal questionnaires that were often based on questionable assumptions and rationales. To compound the problem, the questionnaires were, in most cases, administered either by external experts with limited local knowledge or by local personnel with limited training in the collection of survey data.

Partly as a result of the information shortfall, inadequate access to relevant data on energy technologies continues to be one of the key constraints that face decision-makers at both the policy and field levels (Board on Science and Technology for International Development, 1984). The information required may vary from an in-depth review of national energy resources to design drawings and specifications of a particular energy technology device.

In a number of developing countries, information on national energy resources, potentials and opportunities has been improving. But this type of information which is required by potential manufacturers of rural and decentralized energy technologies is particularly difficult to locate.

The unavailability of detailed engineering drawings of rural and decentralized energy technologies and related production equipment systems continues to be a major constraint. Nor is it easy to find reliable and current data on capital and financial requirements of rural and decentralized energy options. This greatly hampers attempts to prepare reliable business plans that are necessary for obtaining loans from banks.

User Needs and Participation

Addressing the needs of the users and ensuring their participation is increasingly viewed as being of critical importance to the development and wide-scale dissemination of rural and decentralized energy technologies. A recent study on the development and dissemination of improved cookstoves in Sudan (Gamser, 1988a) is more emphatic on this issue. It states:

> *"Bringing artisans, housewives, and retailers into the technology development process in its stoves programme was, in itself, an institutional innovation for the ERC (Energy Research Council of Sudan). It represented a departure from previous, more insular laboratory-based ventures. This institutional innovation to facilitate a more user-interactive technology development programme was a critical factor in the success of the overall stoves project"*

The study goes on further to stress that rural energy technologies are no different from the more conventional technologies. In both cases, user needs are paramount and user participation is an essential component of technology development. The study (Gamser, 1988) explains:

> *"In both industrialized and developing country situations, technology users play a key role in generating successful new products and processes. Both "high-tech" innovations, such as the design of the Boeing 747 and IBM computer software, and innovative technologies for the rural poor, such as Vietnamese expeller pumps and Bangladesh hybrid rice strains, owe much to the creativity and skill not of research scientists, but of local housewives, farmers and artisans. New approaches to technical assistance which increase the interaction between R&D institutions and these technology users are needed in order to tap this important innovation resources."*

User needs and participation are no longer in the category of development buzzwords but are pre-requisites to the successful implementation of rural energy technologies. This is true of virtually all rural energy technologies, a selection of which are discussed in greater depth in the next section.

Welfare Orientation

One of the major reasons for the limited success of rural and decentralized energy technologies is the tendency to limit their application to subsistence energy needs such as household cooking and heating. Little emphasis was placed on examining how available energy technology options can be used to increase productivity, income and employment in rural areas.

Recent successes in the promotion of rural and decentralized energy technologies have often been realized mainly where a significant creation of employment and income generation occurred. This created conditions for the sustainable and growing dissemination of the relevant technology. Without the provision of employment and income generation, rural and decentralized energy technology programmes become dependent on a continuous, non-ending level of external subsidies and support. This may, in part, explain why many of the rural energy technology programmes launched in the late 1970s and early 1980s came to a premature end as soon as external donor support ceased.

With the focus on income generation and employment creation, there is a growing consensus that wide-scale dissemination of the technologies will largely depend on the extent to which local, small- and medium-scale entrepreneurs are the central target of ongoing and proposed programmes. Initiatives that perceive entrepreneurs as central to all aspects of the dissemination of the technologies are likely to register better success than those programmes that keep to the welfare approach.

2.0 RENEWABLE ENERGY TECHNOLOGIES

Having discussed rural and decentralized energy technologies in a broad sense, the paper will now turn to examining the performance and track record of several specific renewable energy technologies (RETs) with specific reference to experiences in Sub-Saharan Africa.

Since the early 1980s, a number of RETs have, despite the aforementioned obstacles, demonstrated an unexpected level of success in addressing energy problems faced by agriculture and development initiatives in the rural areas. In particular, the following technologies have demonstrated a promising level of performance in rural areas:

- Improved household and institutional biomass cookstoves;
- small hydro plants for shaft power and electricity generation;
- wind pumps for water lifting;
- biogas plants for cooking and lighting; and,
- solar water heating and photovoltaic units for residential and institutional use.

Improved Household and Institutional Biomass Cookstoves

An estimated 2 billion people, many of whom reside in the rural areas, depend on fuelwood to meet their cooking and heating needs (Food and Agriculture Organization of the United Nations, FAO, 1985). Other rural uses of fuelwood include charcoal production, post-harvest crop processing, such as tea drying and curing of tobacco and brick manufacture. Fuelwood technologies that have been developed to date can be sub-divided into three categories, namely:

- production and supply;
- conversion; and,
- end-use.

The focus of R&D work in the above categories has centred on enhancing the efficiency of these three processes than on the development of new innovations. In the case of fuelwood production and supply, attention has been given to the development and promotion of fast-growing species (National Academy of Sciences, 1983); inter-planting food and cash crops (agroforestry); and the development and wide-scale dissemination of multi-purpose species for fuelwood, fruits, fencing, shade, extraction of pharmaceutical and industrial raw materials (El Mahgary, 1985).

While substantial progress has been registered in identifying fast-growing and multipurpose tree species, tree planting for fuelwood production is still faced by many constraints. These include: poor returns from fuel-trees plantations or plots; unfavourable land ownership patterns that discourage tree planting or any other land improvement measures (O'Keefe and others, 1988); lack of sufficient water supply (a critical factor in the case of newly-planted trees) and inadequate technical assistance and support.

Of equal importance is the work done to improve the efficiency of fuelwood conversion (Yamba, 1986). Particular attention has been paid to the production of charcoal which is often cited as one of the main causes of deforestation. There are now a multitude of designs of energy-efficient charcoal kilns for use in both small-scale and industrial-scale charcoal production units (Foley, 1988). In the case of small-scale charcoal production, the introduction of improved techniques and equipment has been severely hampered by the informal, and sometimes, illegal nature of charcoal production.

Significant efforts have been expended in developing more efficient briquetting techniques and processes. In particular, substantial investment has been made to develop appropriate binders for briquettes and small-scale equipment suitable for rural areas. The main limitations to briquetting include the high cost associated with the collection of the raw material to be briquetted and the high investment, operations and maintenance cost of briquetting machines.

At the end-use level, extensive laboratory-based and field-based work aimed at designing improved cookstoves that use a wide range of fuels including wood, charcoal and a variety of biomass residues (rice husks, maize stalks, etc.) has been undertaken (Prasad, 1985). The continued use of wood as a "free good" is a major limitation to the wide-scale adoption of improved cookstoves in the rural areas of the developing world (Krugmann, 1987). Traditionally, a large number of rural households do not buy either stoves or fuel (Karekezi, 1988). Another major limitation to the wide-scale dissemination is the prohibitive costs associated with establishing sustainable dissemination networks for rural stoves (Caceres, 1989).

In spite of these obstacles, there are still numerous ongoing improved rural stoves projects in the developing world. The projects range from small-scale activities carried out by grassroots communities or small-components of existing forestry and rural development projects, to large-scale rural stove programmes. Although rural stoves programmes have been in existence for a long-time, there is still some debate over the potential role of improved rural stoves in reducing woodfuel consumption and, thus, assisting in mitigating the negative environmental impacts of deforestation and desertification.

There is, however, a growing consensus that the overall benefits of rural stoves programmes are substantial. The notable advantages of improved rural stoves include: reduced smoke emissions; improved safety and health kitchen conditions; cleaner cooking environment; creation of employment and income generation in the rural areas; and, development of rural women - the sector of the population that has the unfortunate distinction of being by-passed by most conventional development programmes (Klingshirn, 1992).

Rural stoves initiatives have continued to gain support in the developing world and encouraging results are now starting to emerge. The GTZ's Women and Energy programme in Kenya is an example of a rural stove initiative that has registered notable success. The project was started as a component of the GTZ Special Energy Programme. It was carried out under the auspices of the Ministry of Energy and Kenya's largest Women's organization, Maendeleo ya Wanawake. The programme has attracted interest from a large number of institutions ranging from local grassroots Women's groups to Government Ministries and international development groups such as the Intermediate Technology Development Group (ITDG), of the UK.

The Maendeleo stove is a one-pot stove constructed on a stone base with a mud-sand mixture surrounding a combustion chamber made of a ceramic (fired clay) liner. The stove's height can be adjusted to suit the needs and the wishes of the user. The fired clay liner provides heat resistance and ensures that the most critical dimension, that of thermal performance, are retained. In addition, the fired clay liner ensures greater durability and higher efficiency. According to laboratory and field tests, the Maendeleo stove reduces specific fuelwood consumption by 40% (Mildeberger and Klingshirn, 1989 and Klingshirn, 1992).

A recent study on the impact of the Maendeleo stove programme identified the following eight (8) important benefits associated with its use (Klingshirn, 1992):

- Time saving;
- household budget savings;

- income generation;
- decreased workload/status of women;
- improved innovation and organizational capacity;
- better health and safety in the household;
- greater awareness of environment issues; and,
- strengthened self-initiative and self-confidence.

According to the study, time saving was cited by most users as constituting the most important benefit. It was estimated to vary from 3 to 20 hours a week depending on the size of the household and whether the wood was simply collected or had to be chopped into smaller pieces. The time saved was generally used to undertake either additional productive activities or other essential household chores.

The reduction on expenditure on purchasing of fuelwood roughly correlated with fuelwood savings - about 40%. In one of the remote Women and Energy project locations, the income generated by activities relating to the production, installation and marketing of stoves turned out to be the major source of extra cash because of limited cultivation of cash crops. In one particular case, a teacher who produced and sold ceramic liners for the Maendeleo stove on part-time basis found that her profits were more than her monthly salary.

The Maendeleo stove initiative has enhanced the organizational capacity of rural women and has been instrumental in creating greater environmental awareness. The health benefits of the Maendeleo stove are equally important. A study carried out by a researcher at the University of Nairobi showed that use of the Maendeleo stove reduced by 2.6 times the emission of pollutants. This was corroborated by reports of a reduction in the incidence of chronic eye irritation and coughs.

As of 1987, over 10,000 Maendeleo stoves had been disseminated in the rural areas using an owner-built strategy (Mildeberger and Klingshirn, 1989). Since then, the project has evolved a wide range of innovative dissemination techniques that includes small-scale producers and distributors of ceramic liners; income-generating projects of women groups in which liners are produced and sold locally; intensive training and awareness raising at both local and national levels; and most importantly, the use of a nation-wide network of home science extension workers of the Ministry of Agriculture.

The deployment of a wide range of outreach techniques has resulted in a dramatic increase in stove dissemination. The total number of stoves disseminated annually is now estimated at about 20,000 stoves (Special Energy Programme, 1990). The cumulative total of disseminated Maendeleo stoves is estimated to be over 74,000 stoves in Kenya alone (Klingshirn, 1992 and Chavangi, 1992). Similar designs are now being disseminated in Uganda, Tanzania, Rwanda, and Burundi.

The most striking feature of the Maendeleo stove programme is its ability to establish a system for the production, distribution and installation of improved rural stoves that is, in many respects, self-sustaining, an objective that very few rural stoves initiatives have managed to realize. This was largely due to an innovative and pro-active dissemination strategy that sought to maximally utilize all available channels of stove dissemination.

Improved stoves have had an equally successful track record in urban and peri-urban areas. One of the most successful urban stove projects in the world is the Kenya Ceramic Jiko initiative. Over 500,000 stoves of this new improved design have been produced and disseminated in Kenya since the mid-1980s (Davidson and Karekezi, 1992). Known as the Kenya Ceramic Jiko, KCJ, the improved stove is made of ceramic and metal components and is produced and marketed through the local informal sector. One of the key characteristics of this project is its ability to utilize the existing cookstove production and distribution system to produce and market the KCJ. Thus, the improved stove is fabricated and distributed by the same people who manufacture and sell the traditional stove design.

Another important feature of the Kenya stove project is that the KCJ design is not a radical departure from the traditional stove. The KCJ is, in essence, an incremental development from the traditional all-metal stove. It uses materials that are locally available and can be produced locally. In addition, the KCJ is well adapted to the cooking patterns of a large majority of Kenya's urban households. The KCJ design was not selected or identified at the onset of the stove program. It underwent a series of iterative and dynamic R&D steps that involved a large number of individuals including existing artisanal stove producers, interested NGOs, Government Ministries and research agencies.

Other important factors that contributed to the successful commercialization of the KCJ is the conscious decision made by the project not to provide subsidies. This was instrumental in compelling the key actors in the project to utilize the existing stove production and marketing system and to convince interested private sector entrepreneurs to invest in improved stove manufacture. In their bid to recover their investment, private sector entrepreneurs contributed to ensuring self-sustained commercialization of the KCJ. They also ensured competition between producers. This reduced the price from a high US $15.00 per stove to the current prevailing price of US $2.50. This brought the stove within the purchasing reach of a large section of Kenya's urban low-income households (Karekezi and Walubengo, 1989).

The KCJ stove design has now been successfully replicated in Uganda, Rwanda, Tanzania, Sudan, Malawi and Senegal. In Tanzania, it is now estimated that the national stove project financed by the World Bank has disseminated over 50,000 KCJ-type stoves over the last two years (Otiti, 1991). By the mid-1990s, the KCJ is expected to be the stove design widely chosen in most urban centres in Sub-Saharan Africa.

There are now hundreds of improved stove projects all over Africa. A wide range of institutions are involved in stove work. These institutions range from small, independent grassroots communities to Government Ministries undertaking large-scale and centralized national programmes. Some of the more notable agencies include FWD, GTZ/GATE, KENGO, ITDG, VITA, ADF, ESMAP, ENDA and ZERO. Grassroots initiatives in Africa have developed innovative dissemination approaches that are low-cost and sustainable. Many of these approaches are usually incremental improvements on traditional and existing marketing and information networks.

Using both grassroots approaches and centralized mechanisms, impressive numbers of stoves have been disseminated. In terms of the number of stoves disseminated in the developing world as a whole, there has been a notable improvement in the 1980s as shown in the Table 1 below (Joseph et al, 1990; Young, 1991; ESMAP/UNDP, 1991; Otiti, 1991).

Table 1: Number of Bio-Fuelled Stoves disseminated in Africa by the year 1991

Country	Number Built
Kenya	550,000
Burkina Faso	200,000
Niger	200,000
Tanzania	50,000

The more startling finding is that these totals were realized in increasing orders of magnitude. For example in Kenya, by 1981, an estimated 6,000 stoves had been disseminated by a USAID-financed stove project. By 1990, the figure was estimated at well over half a million. These impressive numbers testify to the importance placed on the development and wide-scale dissemination of bio-fuel cookstoves in the region.

While the above figures appear impressive, a more perceptive way of assessing the success of dissemination is by evaluating the market penetrations (Young, 1991). Using the above figures, Kenya has a penetration rate of about 20%. Although this estimate for market penetration does not fully reflect the replacement market, it does provide an indicative assessment of the work that remains to be undertaken if a substantial majority of households in the region are to be equipped with an improved stove.

Improved biofuel stoves reduce the proportion of household budgets allocated to the procurement of the requisite fuel for cooking. This liberates the much-needed cash for other essential household needs such as the supply of food, medicine and other items essential for survival.

There are other intrinsic and often-ignored benefits of biofuel stoves.

- Reduced indoor air pollution: By the removal of smoke through chimneys. Indoor air pollution from smoke is considered to be a major contributor to respiratory diseases - a major cause of death in the developing world.
- Reducing time for woodfuel collection: This is particularly important for rural women whose onerous household and family responsibilities leave them with precious little time to spend collecting woodfuel. The problem of time availability is particularly acute for households headed bywomen - often the male spouses move to urban areas in search of work. In Kenya, it is estimated that between 1/3 to 2/3 of rural households are headed by women. The time freed by improved cookstoves can be used to undertake recreational or other income-generating activities.
- Enhanced kitchen safety and cleaner cooking environment: An important benefit particularly when one considers the amount of time, women and children spend in the kitchen.
- Income and employment generation through the manufacture and installation of improved stoves: Improved stoves can be an important generator of jobs and cash in rural areas that traditionally offer few opportunities.
- Stimulus for the emancipation and general development of women: As proven by stove projects in India and Kenya, improved stoves are an important stimuli for the emancipation and general development of women. A housewife who adopts an improved stove is often more amenable to other development projects and more willing to be pro-active in enhancing her living conditions.
- Energy security: Unlike kerosene and electric stoves, woodstoves are made locally and use fuel that is in most cases locally-available. Households in developing countries that are dependent on either electricity or petroleum-derived cooking fuels, often go through extensive periods of energy insecurity as a result of blackouts (common in many African countries) and petroleum shortages (often a result of inadequate convertible currency for importation). A woodfuel-based household energy sub-sector is less vulnerable to energy insecurity.

Small Hydro

The small hydro has a long and established track record of success as an energy technology for rural areas. The best-known examples are the small hydro programmes in China and Nepal. It is estimated that there are over 90,000 small hydro plants in China. Nepal has at least four manufacturers of small hydro plants with the largest making over 50 units per year (Hurst, 1986).

In both countries, but in particular, Nepal, the small hydro programme was built on existing traditional water management know-how, expertise and local entrepreneurs. A local rural development bank was particularly instrumental to the success of the micro-hydro programme. In addition, the Government of Nepal allowed any individual or institution to generate, distribute and sell power of less than 100 kW (Hislop, 1987). This measure is credited with a large measure of the success of the Nepal small hydro programme. Apparently, a similar measure has just been passed in Tanzania with the hope that it will unshackle innovations and entrepreneurship in rural energy and decentralized energy services.

A recent study carried out in Ethiopia (Mariam and others, 1987) showed that small hydro was competitive with electricity supplied from the grid or a diesel generator. There has also been micro-hydro initiatives in Madagascar and Lesotho. Many of the difficulties faced by these field programmes are related to the determination, on the part of the nationalized power utility, to retain control of the projects. This significantly increased the design, construction, commissioning and operation of the hydro plants.

While small hydro offers significant opportunities for the generation of both shaft power and electricity in rural areas, it has several inherent technical limitations. Topography is an important criterion (Inversin, 1986). Suitable small hydro sites can be far from demand centres in which case the cost of transmission can be prohibitive. In addition, highly skilled civil engineering skills are required to keep the cost of civil works within affordable limits while ensuring a satisfactory level of plant safety and durability.

Windpumps

Windpumps have registered notable successes particularly in Kenya and Argentina. In Kenya, the manufacture of windpumps is now an established industry. By 1982, an estimated 37 windpumps were in operation (van Lierop and others, 1982). In Argentina an estimated 2000 wind machines are produced every year. The Argentina wind technology industry was estimated to account for one fifth of world production (Hurst, 1986).

Wind-powered technologies require favourable wind conditions and access to well-equipped engineering workshops. A certain minimum density of units is required if maintenance and service is to be provided on a cost-effective basis. In both Kenya and Argentina, wind-powered technologies have increased the productivity of rural agriculture and, in addition, contributed to industrial development by giving rise to a new manufacturing industry.

Biogas

Biogas technologies for rural areas are perhaps the best known RETs. The extensive use of biogas has been undertaken in the rural areas of India and China. In both countries, the Government's role was important. Biogas technologies developed in China and India are now being replicated in many other developing countries.

Perhaps the most important merit of biogas is its ability to use biomass to generate energy-fuel while maintaining the potential to use the residual sludge as a fertilizer. Biogas technologies are however not as low-cost as it was initially thought. Depending on the design, the investment required for a Biogas plant can be prohibitive. So can the cost of collecting biomass necessary to run the biogas plant.

In Sub-Saharan Africa, countries that opted for heavily subsidized biogas programmes, as in Lesotho, have not realized much success. However, Burundi which has concentrated on developing a cadre of biogas entrepreneurs has registering greater levels of success. The most successful biogas market segment is the institutional market where septic tanks for sewerage also serve as biogas plants.

Solar Water Heaters and Photovoltaics

Solar water heaters constitute one of the most attractive renewable energy options available. For example, it is estimated that about 15 percent of the 3,443 TJ of wood energy consumed in urban areas is used for heating water, the bulk of it in an inefficient manner (J. Diphaha, 1993). If only 10 percent of this water was heated by solar energy, then, on an annual basis, over 50 TJ of wood energy could be saved.

Solar water heating technology constraints are of an institutional and financial nature rather than related to design. It is estimated that in Botswana, over 8,500 solar water heating units are currently in operation but many of these are confined to middle or high-income households. The average cost of a typical 200 litre solar hot water system is about US $1,900, equivalent to over a six-month total income of a primary school teacher (US $320 per month after tax).

Photovoltaic technologies have experienced one of the most exciting developments in the last 10 years. The cost of photovoltaic cells have dropped dramatically. It is estimated that in 1978 the cost per peak Watt of a photovoltaic cell was approximately US $25. In 1988, the cost for large orders, excluding the additional cost of delivery and taxes, in the United States was estimated to have dropped to US $4-5 per peak Watt (Derrick and others, 1989).

The dramatic drop in the cost of photovoltaic cells is bringing a much larger market within the reach of photovoltaic equipment, in particular, photovoltaic for lighting and refrigeration. Photovoltaics are now increasingly the energy technologies of choice for rural clinics, hospitals and schools. They provide the impetus for the establishment of a small but thriving solar industry in a number of African countries.

3.0 FINAL OBSERVATIONS

Lessons learned from the above experiences have implications for the dissemination of RETs in Sub-Saharan Africa. The new dissemination strategies that are showing promise largely revolve around the idea of participation, income generation and small-scale enterprise development. The rationale is that if RETs producers and distributors can make an attractive income from the manufacture and marketing of RETs and users are fully involved in the dissemination process, then the issue of sustainability is easily resolved.

The second important innovation is the idea of using existing systems of production, marketing and information dissemination. By using an existing production system, for example the traditional stove artisans of Kenya, the cost of disseminating RETs is dramatically reduced.

This piggy-back principle has also been used in the rural areas. RETs are disseminated through an existing infrastructure of health extension workers or a home science field network. As mentioned earlier, the GTZ/GATE stove project in Kenya has realized remarkable results using this approach. Similarly, RETs projects can be a component of an existing integrated rural development project or forestry initiative or income generating initiative.

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DISCUSSION

The following are some of the issues that arose from the presentation:

- There are problems associated with dissemination strategies that rely on government subsidies
- Hindrances to the dissemination of RETs such as the small hydropower as a result of restrictions imposed by monopolies. For example, the Kenya power and lighting company
- The need to encourage competition in the private sector while ensuring that standards are maintained.
- The need for adequate research before a new technology can be ready for marketing.

THE DISSEMINATION OF RENEWABLE ENERGY TECHNOLOGIES IN SUB-SAHARAN AFRICA

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SUMMARY

Recent global events have shown clearly the dangers of the world's over-dependence on conventional sources of energy. This has re-affirmed the importance of continued research and development of renewable energy technologies. The Gulf war, global warming and climate change, balance of payments problems, and environmental degradation can all be checked if a switch to renewable energy technologies were effected.

African countries, like other developing countries have been hard hit by the changing global energy trends. Further, these countries are beset with other more immediate problems like famine, poverty, diseases, lack of housing, poor educational services and bad governance. Consequently, the development of renewable energy technologies has not been a priority.

Notwithstanding, there are success stories. Improved stoves, biogas plants, solar water heaters and grain dryers and more recently, photovoltaics are some of the technologies with a high potential.

But technology per se, no matter how good, is not an end in itself. Until the technology is widely disseminated and accepted by the users, it remains useless. Yet, dissemination is difficult. It is plagued by constraints such as finance, socio-cultural values, and government policies.

This paper discusses some of the aspects affecting the dissemination of renewable energy technologies, especially in Sub-Saharan Africa. In addition, an attempt is made to point out the conditions that must exist for technology to be disseminated successfully.

1.0 RETs IN AFRICA

Most of Africa depends on non-conventional sources of energy. These include biomass (wood, crop residues, animal waste), animal power and solar. RETs in Africa have concentrated on biomass and solar energy. Wind energy and micro-hydro technologies are present, but not on a wide scale. In this paper therefore, emphasis is laid on the following technologies:

- biomass (charcoal making, improved stoves and biogas plants); and,
- solar (water heaters, photovoltaic).

Biomass Energy Technologies

Charcoal Making

Charcoal making is fairly widespread in Africa. It is well developed in Burundi, Ghana, Kenya, Malawi, Mozambique, Nigeria, Rwanda, Senegal, Somalia, Sudan, Tanzania, Zaire and Zambia. The technology is relatively simple. The principle involves the burning of wood in an atmosphere that is short of oxygen. This is often done in earth mould kilns.

Although various improved charcoal making technologies have been introduced in Africa, they have not been widely disseminated. This is mainly because charcoal makers lack the incentive to use the improved techniques. Most of them do not buy the wood and have therefore, no reason to invest in "improved" charcoal-making technologies which do not necessarily increase the charcoal production.

Improved charcoal kilns have been introduced in Kenya, Rwanda, Senegal and Sudan. However, in Sudan, it was discovered that improved kilns do not necessarily perform better than traditional kilns (RWEPA NEWS No.8). Thus while traditional kilns are said to have efficiencies ranging from 10 - 13%, efficiencies of up 30% have been realized in Sudan, using such kilns but with better management. What matters most in charcoal production is the management of the kiln.

Another problem is the fact that in many countries, charcoal making is illegal. Thus, "trespassing" charcoal makers prefer not to erect permanent kilns. But while charcoal-making remains illegal, transporting and distributing it is legal.

In Kenya, Sudan and Uganda, charcoal has been produced from coffee husks and cotton stalks through briquetting. Briquetting technologies requires high investment costs which casts doubt on its increase in Africa. There have been efforts to use hand presses for briquetting. However, the production rates are so low, sometimes as low as 50kg per day, that it is not worth the effort.

Since charcoal will remain an important fuel in many African countries, there is need to continue work on improving conversion efficiencies. The positive contribution of the industry should also be recognized and accorded appropriate policy support.

Improved Stoves

This technology has had more success than many other RETs. Two main types of improved stoves have been introduced: charcoal and wood stoves. Charcoal is predominantly used in Burundi, Ghana, Kenya, Malawi, Mozambique, Rwanda, Senegal, Somalia, Sudan, Tanzania, Zaire and Zambia. Woodfuel is the main fuel in Botswana, Burkina Faso, Lesotho, Mali and Zimbabwe. Charcoal is mainly used by urban dwellers while the rural population uses wood.

While stove designs differ from country to country, emphasis has been laid on: shielding the fire from drafts; controlling combustion; insulation; reduction of emissions; concentration of the fire onto the pot; durability; and portability. In most projects the aim is to replace an existing (traditional) stove with an improved one.

Generally, improved urban stove projects have been more successful than rural ones. This means that in those countries where charcoal is an urban fuel and wood a rural one, charcoal stoves have had a better record than woodstoves. This is certainly the case in Kenya - where so far more than 500,000 charcoal stoves have been disseminated, compared to 74,000 woodstoves.

Biogas Plants

Majority of the biogas plants promoted in Africa are those that use animal and not human waste as feedstock. Subsequently, biogas plants have been introduced in those countries with large numbers of cattle like Burundi, Kenya, Lesotho, Tanzania and Uganda. Of these countries, it is only Burundi which has registered a large number of biogas plants.

Biogas plants require a certain minimum number of cattle, depending on plant size. They also require that the cattle be congregated in one area to facilitate the easy collection of dung.

The successful dissemination of biogas plants in Sub-Saharan Africa has faced several difficulties. These include inhibiting social taboos that prevent people from gathering dung, lack of adequate supplies of water, free-range grazing and the high cost of construction materials.

Besides, biogas plants have to be constructed to a high degree of precision. Quite often, the rural areas which are most suitable for biogas plants lack qualified or trained manpower to carry out the construction and maintenance of installed plants.

Once biogas plants are in operation, the owners quickly realize that the end-use appliances are either not available, or are very expensive. Because of low gas pressures, LPG appliances cannot be used with biogas. Special cookers and lamps are needed for biogas.

Awareness raising campaigns and end-user education has also not been given adequate attention. While many people do not know the potential of biogas plants, those who own installations are unable to carry out simple maintenance procedures.

Solar Energy

Although sunshine may be available in plenty, its conversion to other useful forms of energy is expensive. Solar water heating and lighting are common in the region.

Water Heating

Although solar water heating is a simple technology, its dissemination has been hampered by the "protection attitude" of companies who have monopolized the market. A number of small scale informal sector artisans have started getting involved in solar water heating but so far, their contribution is minimal. Many solar hot water systems have been installed in new housing estates, hotels and public institutions like schools and colleges.

Photovoltaic

Although PV technology dates to as far back as 150 years ago, it did not feature as a prominent commercial energy and was not recognized as an attractive energy option until the 1980s. Photovoltaic electricity is used for lighting, water pumping, refrigeration, livestock fencing (electric fence) and telecommunications. The technology is expensive and is only justified where:

- grid electricity is not less than 15km away;
- other sources of energy cannot be more economically exploited;
- environmental considerations are paramount; and,
- only small amounts of electricity are required at a time. For instance, among the majority of dispersed communities in rural areas.

The majority of PV systems installed across Africa have generally been in remote and inaccessible areas and are usually financed by external donors. However, there exists a growing small scale PV industry for lighting and the supply of power for small equipment like radios, TV and sewing machines.

2.0 DISSEMINATION STRATEGIES

Once a technology has been invented or improved upon, it must be taken to the users. Its adoption is the ultimate test.

Improved RETs projects in Africa use several dissemination strategies:

- the private sector;
- voluntary development agencies;
- government agencies; and,
- institutions of learning.

Private Sector Involvement

Both the formal and informal private sector are involved in the dissemination of RETs. Their involvement is based purely on the profit motive. They recognize that they can make money from marketing these technologies. Usually, the formal private sector markets the bigger technologies like windpumps, solar energy technologies, biogas plants and briquetting, while the informal sector concentrates on the simpler technologies like charcoal making and improved stoves.

The involvement of the private sector in RETs is crucial, as it ensures the sustainability of the technology.

It also ensures that the technology receives adequate publicity. In spite of the advantages accrued from the private sector's being involved in the dissemination of RETs, setbacks exist. This can be best illustrated by examples from Kenya and Uganda. In both countries the dissemination of the improved metal/ceramic stove is considered.

Kenya

In Kenya, the Kenya Ceramic Jiko (KCJ), is now completely in the hands of the private sector. The KCJ has two major components: the ceramic liner and a metal cladding. Traditionally, stoves in Kenya have been manufactured and sold by informal sector artisans at open air markets.

When improved stoves were introduced, it was natural to use these markets to disseminate them. However, the open air artisans specialized in the production of traditional metal stoves and other metal items, yet the Kenya Ceramic Jiko had a ceramic component. A decision was therefore reached to train the artisans in the manufacture of the metal component of the KCJ, and leave the ceramic part to potters. The artisans were further trained on how to assemble the stoves.

Currently, the situation with the Kenya Ceramic Jiko in Kenya is such that the potters produce liners (ceramic) and sell them to the metal artisans, who then assemble the stoves. The artisans also sell the stoves. The system works very well.

A few months after the introduction of the KCJ, it was discovered that the ceramic liner was a major bottle neck in the production of the stove. This is because not all potters used good quality clay. In addition, the potters did not all use standard moulds and did not fire the liners properly. The result was almost catastrophic because liners started cracking too often and the buyers began to lose faith in the stoves. To remedy the situation it was necessary to re-train the potters.

What really saved the situation was the entry of a crop of serious entrepreneurs into the ceramic scene. These entrepreneurs modernized their production equipment from simple potters' wheels to automatic jigger jollies and pug-mills capable of producing a liner every minute.

With the modernization of liner production, stove production increased dramatically. For example, by mid-1986, only 4000 liners were produced throughout the country every month. After the modernization production rose to 13,500 liners per month. Currently, there are at least six major liner producers in Kenya.

The involvement of the private sector has ensured that the Kenya Ceramic Jiko is found in all the major urban centres of Kenya.

Uganda

In Uganda, like in Kenya, household stoves have, traditionally, been produced and sold by the informal sector artisans. Again, the traditional charcoal stove in Uganda is all metal, yet the improved stove is a metal/ceramic one. However, unlike in Kenya, the informal sector in Uganda was not fully harmonized. The production of the stoves revolves around two formal liner producers.

These producers buy claddings from the informal sector artisans, assemble the stoves and then sell them. Consequently, the informal sector artisans see the stove as belonging to the liner makers. They feel left out and have therefore concentrated on producing the traditional stove.

Because the liner producers have monopolized the production of the improved stove, stove sales in Uganda are very low. Furthermore, the liner producers are situated at least 10km away from Kampala, the major stoves market. Moreover, stove buyers are used to obtaining their stoves from the informal sector artisans, and not from factories or shops.

These examples indicate the importance of not only involving the private sector in the dissemination of stoves, but of doing so in a rational manner.

Voluntary Agencies

The voluntary agencies, both the local and international involved in the dissemination of RETs initially concentrated on research and public education. Since they were non-profit making, they were able to remain neutral in the dissemination of RETs. However, due to their limited finances, they avoided the more complicated and expensive RETs. Hence, windpumps, solar energy and briquetting were left unattended. Instead, they concentrated on charcoal making techniques, improved stoves and biogas.

The voluntary agencies which have played a major role in the introduction of RETs in east and southern Africa include CARE International, Intermediate Technology Development Group (ITDG - UK), the Woodburning Stoves Group (WSG, Netherlands), Kenya Energy and Environment Organizations (KENGO, Kenya), the Bellerive Foundation (Kenya), Zimbabwe Energy Research Organisation (ZERO, Zimbabwe), the Foundation for Woodstove Dissemination (FWD, International), Volunteers in Technical Assistance (VITA-International), the Non Governmental Organizations Coordinating Committee (NGO-CC, Zambia), the Young Women's Christian Association (YWCA, Uganda), and the Maendeleo ya Wanawake (Women in Development, Kenya).

Their neutrality also meant that these agencies were able to test as many technologies as possible, without bias. In addition they went on to promote those RETs which they found were really viable.

Perhaps the most important functions that the voluntary agencies performed were training and public education. Training was carried out through workshops and formal training courses. Public education was done by distributing newsletters, books, posters and calendars on improved stoves. However, the agencies have experienced three major problems: government interference, donor fatigue and over-ambition.

Government interference takes many forms including the registration of a Non Governmental Organisation (NGO). Generally, most African governments are suspicious of NGOs for various reasons. Sometimes it is because some NGOs have succeeded at providing social services more than the governments, or because NGOs are perceived as competitors for donor funds.

Donor fatigue is another issue. Sometimes, donors want quick results, without taking into account the underlying constraints of a given environment. On the other hand, donor funds allocation seem to be determined by the issues under discussion by global institutions, which then take precedence over local needs. Thus, developments in Eastern Europe and the Middle East may attract much more attention in donor circles than a RETs project in Sub-Saharan Africa.

Voluntary agencies are sometimes over-ambitious in their project plans and goals and they try to run too many projects at the same time and spread themselves thin. The most successful voluntary agencies projects are those that have focused on one or two technologies over a long time.

Government Agencies

Government agencies have mostly concentrated on raising funds and providing an enabling environment through policy support for the dissemination of RETs. In some cases, private sector agencies and voluntary agencies are contracted to carry out technology development. Government agencies have also played an important role in providing public education through seminars, publications and posters.

In most African countries, the government agencies involved in the development and dissemination of RETs are either departments of energy or parastatals working in energy. These agencies have been more successful at laying down policy guidelines than in actual project implementation.

To get around the government bureaucracy, some energy departments have established parastatals or special projects to deal with RETs. Thus, in the early 1980s, Kenya used the Kenya Renewable Energy Development Project (KREDP), Burundi had the Office National de la Tourbe (ONATOUR), Tanzania had CAMARTEC, Sudan had the Sudan Renewable Energy Project (SREP), Botswana had the Botswana Technology Centre (BTC) and Zambia, the Charcoal Stoves Project. These Quasi-non Governmental

Organizations (QUANGOs) were run independent of their parent ministries and were thus able to make decisions quickly and effectively.

Although government agencies are useful in the dissemination of RETs, they can also be a hinderance. This was especially the case before the era of high oil prices. Most policy makers then thought that the way to go in development was to imitate the European or American lifestyles. These policy makers' vision of the future was households countrywide using electricity or LPG to satisfy their energy needs. Therefore, the government sectors involved in RETs were poorly funded and lacked locally trained personnel when the crises arose. This may explain the high number of expatriate experts on the continent working on RETS.

Institutions of Learning

Many institutions of learning have participated in the development and testing of RETs. But with the exception of Sudan and Burundi, most of them have concentrated on solar water heaters and dryers, and improved stoves.

Unfortunately, most African institutions are still managed by traditional academics who are notoriously conservative. Thus, few such institutions teach courses on renewable energy technologies. For example, in Kenya, there are only two charcoal experts teaching at the four public universities, yet, at least 30% of the population uses charcoal for their energy needs.

This general lack of interest in renewable energy technologies at African institutions of learning have resulted in the creation of centres of appropriate technologies. The notable ones include: the Appropriate Technology Centre [ATC] of Kenyatta University; the Development Technology Centre [DTC] of the University of Zimbabwe; the Appropriate Technology Research Development Bureau of the University of Sierra Leone; and the Technology Development Advisory Unit [TDAU] of the University of Zambia.

Furthermore, almost all these centres are under-funded, understaffed, and are housed in some of the worst university premises. Notwithstanding, some of these centres have played an important role in the research and development of RETs.

3.0 FACTORS THAT AFFECT THE DISSEMINATION OF RETs

The main factors which affect the dissemination of RETs in Africa include:

- Renewable energy institutions ;
- government policies;
- the poverty level;
- suitability of the technologies;
- the level of public education; and,
- the existence of an enabling environment.

Renewable Energy Institutions

There is a lack of renewable energy institutions in Africa. Those institutions that exist do not have adequate facilities or manpower to carry out sufficient research and development work. There is a high turn-over of the few professionals in these institutions. As a result work on RETs at these institutions does not go beyond the research and development phases.

On the other hand, the institutions working on RETs tend to work on several RETs at a time thereby lacking in focus. This is partly due to donor driven financial support. For instance, institutions interested in solar photovoltaic may obtain funds to disseminate lighting systems instead of water pumping systems, even where there may be critical need for water than electricity. Yet, with a little additional resources, both needs may be adequately met.

The other problem is the development of technologies that are not user-driven. For instance, the development of the solar cookers which was not consistent with the people's culture has faced dissemination problems.

Therefore, renewable energy institutions need to focus on technologies which are workable and which respond to the needs of end-users.

Government Policies

Although the dissemination of RETs depends heavily on government policies, most Sub-Saharan Africa governments pay very little attention to policy issues related to RETs. The governments seem to be more interested in the conventional sources of energy and large prestigious energy projects for example, petroleum, large hydro-electric and coal power stations. Large scale projects are easier to deal with and data on them is easily available. Preference for large energy projects is rooted in the desire to 'catch up' with the developed countries. This is further supported by the easily available funds for such projects from the world finance markets.

This narrow focus on conventional sources of energy, leaves out majority of the people especially those living in the rural areas. These people depend on biomass for energy. Ironically, and although biomass is difficult to quantify, it involves little expenditure on foreign exchange, yet it remains undeveloped. It is estimated that the cost of building one hydro-electric dam capable of generating 100MW could finance the afforestation of 500,000 hectares of land.

In those countries where RETs have been successfully disseminated, the governments have played a minor role. Where governments have tried to play a major role, dissemination has not been carried out successfully. This contradictory situation is caused by the high-handed manner in which governments intervene. For instance, in Burkina Faso, the government ordered all households to adopt an improved woodstove. And in Gambia, the government required all its citizens to use an improved briquette stove with groundnut briquettes as a fuel. In both cases the success was minimal.

The policy interventions that if properly addressed could promote the dissemination of renewable energy technologies are:

- Lifting of taxes on RETs;
- the use of public education through media as a vehicle for dissemination;
- the introduction of an energy development fund;
- the subsidization of RETs;
- the provision of credit facilities;
- the support for institutions working on RETs; and,
- the support for both the informal and formal private sectors.

Level of Poverty

The poverty level is an important factor in the dissemination of RETs. The poorer the end-users are, the less their priority on RETs. This is why the dissemination of RETs such as solar water heaters, photovoltaic and biogas plants is difficult and ends up with the rich, who can otherwise, afford other alternatives.

The first researchers on RETs were mistaken in thinking a technical solution could solve a social problem. Due to the high levels of poverty in most Sub-Saharan African countries, RETs may either have to be subsidized or introduced as part of an integrated project. Both of these methods of dissemination have their advantages and shortfalls.

The use of subsidies in the introduction of a RET may not be advisable if there are plans to remove the subsidies later. Once subsidies are removed, the RET becomes too expensive for the poor. Such subsidies also benefit the rich, who then enjoy the technology at minimum cost.

For RETs that attract high taxation, it is better to waive the tax than to introduce a subsidy, an experience gained from Kenya's photovoltaics. The establishment of credit facilities can also play an important role in the dissemination of RETs. Such credit facilities can be organized along the same lines as the agricultural and housing facilities.

Introducing a RET as part of an integrated project may reduce its cost. If, for example, a rural health project also disseminates improved stoves, then the stove project will not have to bear the full cost of marketing and transportation.

The high level of poverty in most of Africa suggests that for any RETs to be disseminated successfully, they must be both affordable and easy to maintain.

Suitability of the Technologies

Initially, RETs attracted more enthusiasts than experts with the result that many technologies that were unsuited to the target group were introduced. Solar cookers which used mirror concentrators, gasifiers, charcoal refrigerators and micro-hydro-electric plants in villages that needed shaft power more urgently, all fall in this category.

For a technology to be accepted, it must be suited to the needs of the target group. It must be used for the stipulated purpose and do so at minimum cost and maximum convenience. The technology must transform the lifestyles of the users drastically. And the technology must be seen by the users as an improvement to their standards of living.

Promoters of RETs must test their products thoroughly, before introducing them to the market. Failure to do so may cause disillusionment among the target group on the technology. For example, the first windpumps lost their vanes in strong winds and although this happened many years ago, some people still think windpumps are dangerous.

Level of Public Education

The level of public education is important in the introduction of any technology. The public must identify with the particular technologies. If the public is not ready for a certain technology, then it should not be forced onto them. An example, of poor timeliness, is the introduction of solar photovoltaic panels that are often vandalized a few days after installation.

The introduction of RETs should always be preceded by a public awareness campaign. This may involve a demonstration on how the RETs work. If possible, the target group should participate in the demonstration. However, it should be noted that the level of public awareness depends on several factors. Some of these are the school system, radio and television, the print media, finance and government policy.

Existence of an Enabling Environment

The successful dissemination of any technology is accompanied by a favourable environment. This is especially the case where new technologies are being introduced. Most RETs can be placed in this category. Part of this environment is the market, the people, and the economic climate of the country.

If a technology is to be sustainable, the market for it must exist. This is especially so if the technology is introduced by the private sector. Some of the first entrepreneurs in RETs in Kenya, Sudan and Uganda made reasonable profits out of manufacturing these technologies.

Also the development of RETs was favoured by the presence of people with the technical know-how who were willing to work for those institutions promoting RETs. Thus, NGOs like KENGO and Bellerive Foundation in Kenya attracted scientists and engineers from other sectors to work in RETs with the effect that the promotion of RETs increased. Economic hardships do not provide the environment necessary for the dissemination of RETs: more attention is paid to survival needs.

4.0 HOW TO START A DISSEMINATION PROGRAMME

As stated earlier, the successful dissemination of a technology is a good indicator of its acceptability. In theory, getting a good technology to the users should be a simple matter. In reality, it is not. A new idea or technology will always be resisted. This is because people are resistant to change: the future is less certain than the present. Hence, dissemination programmes should be well designed.

Once an appropriate RET has been identified, the dissemination process could take the following general steps:

- identify the target group that is in need of the RETs;
- introduce the RETs on a pilot scale and as part of a field test;
- continuously monitor the performance of the RETs and improve it to suit the target group; and,
- introduce the improved RETs on a wider scale.

While the early stages of dissemination are in progress, it is necessary to carry out the following activities:

- educate the target group on how to use the RETs;
- train local people to manufacture or maintain the RETs; and,
- mount a public education campaign on the advantages of using the RETs.

By the time a public education campaign is complete, the RETs should be available on the market, and within the proximity of everyone in need of them. If this is not done, the target group may think that the promoters of the RETs are not serious and give up altogether.

5.0 LESSONS LEARNED

Several lessons can be drawn from the dissemination of RETs in Sub-Saharan Africa. These include:

- sometimes existing technologies are grossly under-estimated and should be improved upon instead of introducing new ideas;
- more time and effort should be devoted to the development and testing of RETs;
- greater effort to understand target groups should be made before RETs are introduced;
- public awareness and user education should be accorded more attention and priority;
- government intervention does not always assist in the dissemination of RETs;
- agencies working on RETs should avoid spreading themselves thin, and instead focus on the RETs they are most comfortable with;
- there is plenty of room for everybody to participate in the development and dissemination of RETs;
- if RETs are to spread on a wide scale in Sub-Saharan Africa, no attempt should be made to patent them; and,
- the private sector should be involved in the dissemination of RETs.

DISCUSSION

These were the issues that arose from the presentation:

- The primary role played by NGOs in Kenya in rural energy supply, as compared to the government which has concentrated on the use of conventional fuels, and the implementation of large scale power projects.
- The Kenyan experience in dissemination of charcoal stoves and its implication for other countries in the region. The implication of the move from the other sources of widely used fuel: for example, from the use of kerosene to charcoal, in the Sudan.

- Income generation as an important aspect in the development of RETs.
- An assessment of the break-even costs between grid connection and decentralized power supply. This can be carried out from the power demand, RE system costs, and the cost of connecting to the grid.
- The role of NGOs, governments and the private sector in the dissemination of Renewable Energy Technologies.

THE PRIVATE SECTOR IN SOLAR INDUSTRY: THE CASE OF KENYA

By
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SUMMARY

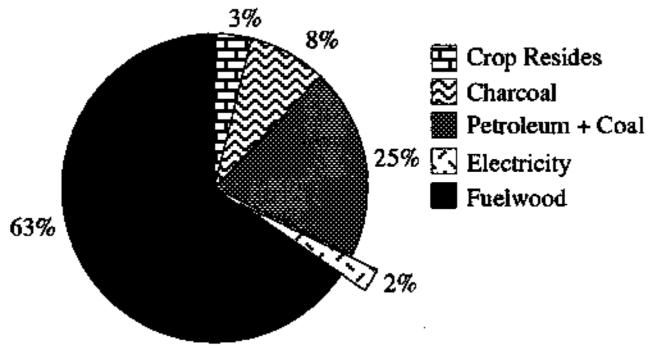
Rural Kenya is sparsely populated and requires small amounts of energy, on a per capita basis. One of the attributes of PV is its ability to supply such energy requirements. Thus, Kenya could meet a significant proportion of her future energy needs through photovoltaic power. However, the high cost, lack of awareness and limited resources are major obstacles to the successful dissemination of photovoltaic systems.

1.0 INTRODUCTION

Kenya has a population of about 25 million (1992). Of this, only 15% is urban based. Grid electricity is available mainly in the major towns. Currently, electricity accounts for about 3% of the total energy requirements. It is estimated that its consumption will double by the year 2005.

Apart from its unavailability, electricity is expensive for most rural people. Notwithstanding, the on-going rural electrification programme is slow paced, and uneconomical.

Figure 1: Energy Supply in 1980



(Source: Ministry of Energy)

The increased use of Photovoltaic technology and its incorporation into Kenya's energy plan, is likely to be an important strategy for meeting future energy requirements. This will require policy support which has largely lacked in the past.

2.0 SOLAR ENERGY IN KENYA

A review of the Solar Energy Policy in Kenya shows that, despite the Government's recognition of the important role Solar Energy can play, the government's contribution to the dissemination of the technology has been minimal. Thus, at the on-set of solar technology in Kenya, the National Energy Plan identified the following factors as the key constraints to its wide-spread use:

- the high cost of Solar Systems;
- the absence of facilities for research, development and manufacturing of photovoltaic components;
- lack of institutions to oversee research, quality control, licensing and training;
- lack of standardization; and,
- the absence of an effective promotional campaign for solar energy technology.

In order to overcome these obstacles, the plan proposed the following policy interventions:

- provision of a favourable climate for the establishment of a local manufacturing industry;
- encouraging the exchange of ideas among interested agencies, in order to promote wide-scale utilization of solar energy;
- making the use of solar energy mandatory, where necessary. For example, institutions, such as hotels and hospitals, should use solar water heaters; and,
- initiation of awareness campaigns on the role of solar energy.

This paper discusses these policy interventions, with regard to what has actually happened, and the current situation of the solar industry in Kenya. Special focus will be given to Photovoltaic (PV) technology. The water heating technology will only be mentioned when the need arises.

The solar industry in Kenya is one of the most dynamic renewable energy technologies (RETs) activities. It owes its existence to indirect donor support. The projects range from PV water pumping and lighting systems to the UNICEF-sponsored vaccine refrigeration programmes.

3.0 THE INFANCY STAGE: THE MID '70s

The industry has been characterized by four phases. Phase one saw the introduction of the technology to Kenya in the mid '70s following the oil crisis. Then, the industry was in the hands of multi-national corporations such as, Petro-Sun, Beasely Solar System and Neste Advanced Power Systems (NAPS).

This aspect coupled with the fact that there was no government intervention, and that all the PV components used including the wiring accessories were imported, made solar energy costs prohibitive. Thus inhibiting the local participation.

4.0 THE FORMATION OF KENYA'S SOLAR INDUSTRY

The second phase started in early to mid '80s. A number of international and local companies mushroomed and formed what is now known as the Kenya Solar Industry.

Policy makers started paying some attention to the technology. This is reflected in the 1980 Economic Survey which states, "Solar energy is available in the climatic conditions of the country, and it is hoped to be utilized in the future."

This period coincided with a tremendous drop in the price of photovoltaic modules worldwide, and with the removal of taxes on solar modules by the government. This brought about the installation of a large number of donor-funded water pumping, lighting systems and vaccine refrigeration systems.

The Solar industry could, at this stage, be subdivided into two categories:

(a) Large international solar concerns and medium scale companies. The former specialized in donor funded projects, for example, large PV water pumping systems. These contributed a lot in the initial awareness raising but were plagued with setbacks like:

  - ineffective technology transfer, since most of the technical design and manufacture was and is still being done outside the country. In addition, local components, are hardly used in most of the systems;

- repatriation of funds; and,
- Notwithstanding, these corporations brought benefits such as R&D leading to new designs and improvements in quality. For example, the introduction of self-regulating modules, which do not require the use of control units. By using such modules, the danger of over-discharge in stand-alone photovoltaic systems is eliminated.

(b) Medium scale companies, fully or partly owned by foreigners, but not directly connected to any parent solar company abroad. These include, Total Solar, Kenital, Chloride Exide and Animatics. In this category, we shall review Total Solar - Kenya as a case example, because it has done more than any other solar company in disseminating solar technology in general, and PV in particular.

Total Solar

The Company was founded in the'70s, under different ownership and names. Total Solar is acknowledged as the pace-setter in ensuring the wide-scale adoption of PV technology. Since its formation, it hired a number of local engineers and technicians whom it trained both locally and abroad. The use of local personnel was a milestone in the history of solar technology in Kenya. It ensured effective technology transfer to the indigenous people.

Unlike the international companies, Total Solar set up full-fledged workshop facilities, run by local personnel and a few expatriates. It also embarked on a nationwide sales promotion by setting up what was known as the Dealer Development Network. Taking advantage of the existing Total petroleum products service stations in the country's network, the country was sub-divided into several marketing zones.

In each zone a dealer was appointed to sell both PV, and water heating systems. Training was also offered to the dealers' staff, free of charge. The objective of this network was to reduce dependence on the head office through the decentralized management of the technology, in the hope that it would result in large sales volumes and awareness raising throughout the country. This same marketing strategy was adopted by other solar companies in this category, but to a lesser scale.

All these efforts to create awareness were carried out without any donor or government intervention and in full recognition of the associated financial constraints and business risks of creating awareness for rival companies.

The training of local personnel was advantageous in that eventually, solar companies fully owned by local people were established later.

This marked the onset of the third phase of the solar industry in Kenya.

5.0 THE ENTRY OF LOCAL ENTREPRENEURS

The third phase, mid- to late 80s, was marked by a full scale entry into the industry by local entrepreneurs. Most of these had worked with companies during the second phase. Companies like Solar World, Alpa Nguvu and other smaller "one-man operation" companies were established.

The 'one-man' companies have only concentrated on photovoltaic technology. Their emphasis is on rural based domestic projects which form the bulk of PV activities in Kenya. These one-man companies have given rise to the current fourth phase of the solar technology in Kenya. The one-man companies owe their existence to a local company known as Solar Shamba.

The company offered PV technology training to electrical apprentices and technicians. Thereafter, the graduate trainees ventured into the installation of PV systems as an occupation. Hence, a new breed of solar entrepreneurs who offered a challenge to the well-established solar companies was created. They would carry out installation and maintenance at lower costs due to their lower overhead costs. Their only draw-back has been their poor grasp of PV systems design. For example, the systems sold by Argos Furniture, a business set up specializing in hire purchase services, have been of questionable quality.

The market competition that was thus created, helped stabilize the product cost. The demand for PV systems was dominated by the need for rural domestic systems and institutional lighting kits. In addition, there was a nationwide UNICEF sponsored project on vaccine refrigerators which positively promoted the technology. The only remarkable difference was the drop in the number of PV water pumping projects carried out.

One of the most notable developments that took place during the third generation of the solar industry in Kenya, was the incorporation of a number of locally manufactured components into PV systems. This helped lower the costs of the systems. A customer could now go for an expensive, imported component system or opt for a PV kit incorporating affordable locally made light fittings, electrical wiring, accessories and batteries.

Associated Battery Manufacturers (ABM), the only battery manufacturing plant in Kenya, started making a range of lead-acid solar batteries. Similarly, a few locals ventured into the production of solar incandescent and fluorescent light fittings.

It was during the third phase, that the government's interest in PV technology increased considerably. This is illustrated by the formation of a Renewable Energy Department in the Ministry of Energy. This was followed by the installation of a pilot water pumping system at Kiserian, 25Km from Nairobi. Technical and financial support were provided by the German Agency for Technical Cooperation (GTZ). The pumping system has since been replaced by an electric pumping system, powered by the grid.

The third phase also marked indirect government support to the PV industry. This was manifested by the installation of PV systems in a number of primary schools, with funding provided by the World Bank. Due to the current economic uncertainty, the viability of such projects is not only hanging in the balance, but has given rise to the fourth phase of the Industry.

6.0 SOLAR INDUSTRY AT THE CROSS ROADS

In the current phase, dubbed as the fourth, Kenya is facing difficult economic times. Consequently, the requisite convertible currency needed to purchase most of the crucial components such as the module and control units is not easily available. Though the future looks gloomy, it is widely believed that the companies which survive the current inflation and recession will be the ones that shall be the flag bearers of Kenya's Solar Industry for the 90s and beyond.

Another interesting internal development within the PV industry in Kenya is that, even though the "one-man" companies appeared to have snatched the rural domestic market from the medium scale companies, the current economic situation has reversed the tide. Since the smaller companies tended to rely solely on procuring solar panels and control units from the bigger companies, they are being pushed out of business by the sky rocketing prices demanded by the former.

There are prospects for the future of PV technology. There is an already well established solar market in the country. In addition, several charitable organizations working in refugee camps have provided a new market for PV equipment. These are mostly for vaccine refrigerators and solar power packs for running office equipment.

Finally, the fourth phase has seen an entry into the Kenyan market, of affordable South African products. It is hoped that this will provide an alternative supply to the traditional expensive European and North American sources.

7.0 CONCLUSION AND RECOMMENDATIONS

It is evident that during the period between mid- to the late '80s, a lot of PV projects were undertaken in

Kenya. This was mainly as a result of: an intensive marketing strategy adopted by private companies; the global drop in the cost of PV modules; and the exemption, by the government, of tax on PV modules. However, all these factors have been down played by the persistent depreciation of the Kenyan shilling against other 'hard' currencies.

The '90s will see the cross-road of Kenya's PV industry. The unfavourable economic situation, coupled with too much competition is slowly killing a number of solar industry giants.

It is becoming evident that for the solar industry to survive the turmoil, its over-reliance on imported components has to be reduced. Only the module should be imported and the remaining components manufactured locally.

The government therefore must provide an enabling environment for the establishment of a local manufacturing industry. But it must also collaborate with other interested parties in setting up institutions for research, testing and development of PV technology.

The Private sector, NGOs and research institutions should develop cheaper components, to replace those that make the cost of PV systems prohibitive. These include the control unit and imported fluorescent tubes. For these developments to have a sustainable impact, local personnel should be involved. Past experience justifies this argument.

Though the 'one-man' operation companies are selling systems to most rural homes at affordable rates, they have contributed quite substantially in negating the widespread use of PV technology. This is because most entrepreneurs lack the necessary technical know-how for system sizing. On the whole, they are responsible for the installation of undersized systems.

The, 'one-man' companies could be improved through developing policies that ensure consumer awareness and the setting of standards, which encompass quality control, licensing and training.

Despite all the developments in the Kenya Solar Industry, after-sales service has always been poor. This can be attributed to two factors:

- the high cost associated with providing the service; and,
- the small number of people who understand the principles of the PV system.

Poor after-sales service has, had a negative impact on the dissemination of PV technology. One way of solving the problem could be by setting up an NGO, private sector and government committee to oversee quality control and adherence.

A directory of competent PV technology dealers should be compiled, which would enable the consumers to access the available technology.

Unlike the prestigious, large-scale, hydro-power projects, PV systems are designed for small-scale use and are often not given the policy support that a typical power plant attracts. Systems price reductions, and local government incentives like the removal of both direct and indirect taxes, might provide the necessary pre-condition for the wide scale application of PV technology in Kenya.

PART FOUR: COUNTRY CASE STUDIES

ETHIOPIA

RENEWABLE ENERGY TECHNOLOGIES: THE CASE OF ETHIOPIA

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1.0 INTRODUCTION

Ethiopia, a country with 1.2 million Km^2 surface area, has a population of more than 52 million. Over 87% of the people live in rural areas, deriving their livelihood mainly from agricultural activities.

The country is one of the world's most multi-ethnic countries. There are about 72 different ethnic groups and languages. Amharic is the official language while English is the second main language. An estimated 35% to 40% of the country's population is Muslim, 40%-45% is Ethiopian Orthodox and the rest are animist or followers of other religions.

The country is marked by a central plateau and mountain range divided by the Great Rift Valley. The plateau and mountain ranges represent only 1/3 of the country's surface area, but are inhabited by more than 88% of the population. The average per capita land holding of the Ethiopian farmer is only 0.5 hectares, which in addition has very low agricultural productivity. By World Bank standards, more than 60% of the Ethiopians live below the absolute poverty level.

The country's economy remains hampered by its weak infrastructure, low productivity in agriculture, heavy dependence on one export commodity (coffee), small industrial base and a shortage of skilled manpower.

Closed forests that used to cover about 40% of the total land area of the country at the turn of the century, are now down to 2.7%: a deforestation rate of 250,00 acres per year or 1 hectare every five minutes. This can be explained by the fact that the overall energy consumption of the country, 84.9%, is met from biomass fuels.

The annual loss of soil due to erosion is now estimated at 1 billion tons, of which 10% are lost for good. Cropped areas lose 20 tons/hectare per year. Apart from the topography, the main reasons for the enormous erosion include lack of woodlands, wind breaks, and bare ground during the heaviest rainfall seasons during ploughing.

Organic matter is removed for food and fuel without being replaced, resulting in reduced soil fertility. Much of the land degradation and decline in agricultural productivity is the result of: population pressure (particularly in highland areas); heavy biomass dependent energy utilization patterns; and the agricultural practices.

2.0 PATTERNS OF ENERGY CONSUMPTION IN ETHIOPIA AND THEIR CONSEQUENCES

Presently, Ethiopia is undergoing a major energy crisis. The value of oil imports accounts for 40% to 48% of Ethiopia's total exports, whereas oil contributes to only about 4% to 5% of the national energy consumption. Considering the current need for the importation of capital goods, energy has become a major constraint to the country's development.

The development of modern energy resources is compounded by the rapid depreciation of traditional fuel supplies, and it affects the majority of the country's population.

Poor or non-existent forest management has led to extreme deterioration of forest reserves in many areas. The overall biomass resource in Ethiopia is estimated at 13 million Tcal/yr in standing stock and about 935 thousand Tcal/yr, in annual yield. However, 3/4 of the resources are found on 1/3 of the surface area, where the population density is smaller. Hence, 75% of Ethiopia experiences fuel wood scarcity (It is estimated that by the year 2000, this will increase to 89%). The estimated average per capita consumption of fuel wood is 1.34m^3/year and the accumulated fuelwood need in the rural areas is 2.5 times its availability. In rural areas, women and children travel an estimated average of 5 to 7 km a day in search of fuelwood.

Since fuelwood supplies have diminished, the consumption of manure and crop residues as fuel have increased with the result that less organic matter and nutrients are available for animal food and recycling into the soil. This has resulted in a decline of agricultural production.

If annual dung and crop residues were to be diverted to agricultural use for soil improvement and animal fodder, another 10 million cubic metres of fuelwood would be required.

Modern energies contribute less than 5% of total final consumption, of which Addis Ababa accounts for 39.6%. The rest is shared among other urban and semi-urban areas, leaving out rural areas completely. As shown in Tables 1 and 2, the dominance of traditional fuels is overwhelming. By far, the largest contribution to final energy consumption is the household sector with 82.0% of the total, of which 97.1% is from traditional fuels.

Table 1: National Energy Consumption Patterns by source.

Source		%	Total %
Primary Energy	Fuel wood	69.9	84.9
	Dung	7.9	
	Crop resude	7.0	
	Bagasse	0.1	
Secondary Energy	Charcoal	1.0	5.7
	Electricity	0.5	
	Oil products	4.2	
Animate Power	Human	5.0	9.4
	Animal	4.4	

Due to this consumption dominance of the household sector throughout the country, traditional fuel consumption patterns do not vary significantly between regions, and the contribution of each region to the total basically depends on the population of the area.

The rural settlements that essentially consist of peasants, account for 87.8% of the total domestic consumption. The contribution of modern fuels is small: only 0.02% of the total, whereas modern fuels account for approximately 38.9% of total consumption in urban settlements. Therefore, since more than 87% the Ethiopian population is rural, the whole country literally depends on traditional fuels.

The government of Ethiopia is involved in combatting land degradation and wood shortages through: catchment rehabilitation; hill-side reafforestation; community woodlots and peri-urban tree plantation programmes; the development and dissemination of different fuel-saving technologies and alternative fuels; and the promotion of environment-friendly technologies such as biogas.

The Rural Energy Promotion Programme of the Ministry of Agriculture deals with the development and promotion of various energy technologies in the rural areas. These include: renewable and non-renewable energy technologies such as solar, wind and micro-hydro power, briquettes, charcoal from agricultural residues, biogas and diesel. The first Ethiopian version of the Kenya Jiko, was introduced into the country through this programme. It also pioneered in introducing photovoltaic technologies such as solar pumps, solar lighting systems and solar fridges.

Table 2: Energy Requirement and Source by Sector.

Sector	% of Total	Fuel wood	Dung	Crop residue	Bagasse	Charcoal	Electricity	Oil products	Human power	Animal power
Agriculture	5.90					1.2	0.02	3.3		66.4
Industry	6.10	74.0	5.3	4.8	0.8	0.4	3.70	11.0		
Transport	5.60							51.4	39.7	8.9
Public & Commercial	0.36						85.1	14.9		
Household	82.00	79.7	9.2	8.2		1.2	0.2	0.3	1.2	
Others	0.04						4.4	95.6		

3.0 BIOMASS, BIOGAS AND ALTERNATIVE FUELS

Improved Stoves

In the Rural Energy Development Programme efforts are being made to develop a variety of stoves.

(a) The Soda Stove: is adapted from India. Tests conducted on the stove showed 10% fuel savings compared to the 3-stone stove. Though the fixed stoves developed and promoted by other parties save up to 40% fuel over the three stone stove, the Soda stove has the advantage of mobility which is crucial for rural households. Further improvements to this stove are still to be made.

(b) The Bako Charcoal Stove: was originally adapted from the Kenya Ceramic Jiko. It was first introduced by the Rural Technology Promotion Centre in the belief that it would create savings on wood by saving charcoal. Studies have shown that it saves between 20% to 30% over the traditional stoves.

(c) The Assela Saw Dust Stove: burns saw dust, straw and other agricultural residues efficiently. Once ignited, it gives a continuous smokeless flame for four to five hours. Some problems in the use of straw have been observed and therefore, further improvements are needed.

The Ethiopian Energy Authority has also been actively and successfully promoting improved charcoal stoves based on the experience of the Ministry of Agriculture. and is further improving their quality. It has developed an improved charcoal stove - the Lakech (another version of the Kenyan jiko) which has an average fuel savings of 25% compared to traditional metal stoves. To date, more than 4000 of these stoves have been sold in Addis Ababa.

Biogas Energy

Biogas technology has a very high potential in Ethiopia. The Ethiopian livestock population is the largest in Africa. There are about 27 million cattle, 24 million sheep, 8 million goats and 8 million horses and camels. Cattle dung alone, if properly recycled, can generate 6 million cubic meters of biogas daily, which could meet the fuel needs of 4 million Ethiopian families. This is equivalent to 20 million people.

Besides meeting the demand for cooking fuel or generating electricity, 11.8 million tons of organic manure rich in N2 contents, can be collected each year to replace the chemical fertilizer needs in the country. In addition, re-cycling of night soil can meet the cooking demands of 5 million families and increase organic manure by 2 million tons every year.

A modest biogas initiative is introducing biogas plants in needy provinces such as the Arsi, Gojam, Wollo, Sidamo, Bale, Tigray, Keffa and Hararge regions, whose energy demands are high but resources very scarce. To date, a meagre 100 plants, mostly with family size production capacity, have been constructed.

In all cases where biogas plants have been constructed, training has been provided for the users, especially women, on the running and use of the plant. Though major maintenance is carried out by staff from the centres, the users have also been trained on some preventive and minor maintenance procedures. Several attempts have been made to develop appropriate appliances.

For example, two types of biogas stoves: a small burner for cooking "wool" and boiling "coffee"; and a big burner for baking *injera* have been developed.

The small burner consumes about 0.35m^3 gas/hr and to date, out of the 850 stoves produced in zonal rural technology promotion centre workshops, 140 have been distributed for use. The stove for *Injera* baking was a result of extensive trials of several innovations developed by the energy development staff of the department. Although, some refinement is still required in the manufacturing techniques and some of the design aspects, the stove is ready for dissemination. It consumes about 0.90m3 gas/hr (for 15 *injeras*). After some minor improvements are incorporated, some prototypes shall be manufactured and disseminated.

Solar Technology

In Ethiopia, solar drying of various foods is common. The use of solar energy for heat generation is not widespread. However, small attempts are being made to develop solar cookers and solar water heaters by the Ministry of Agriculture, private individuals and other sectors. The use of solar energy for electricity generation through the photovoltaic technology is gaining momentum.

Photovoltaic technology is mostly used in community programmes for lighting, water pumping, radio communication and refrigeration. Unfortunately, most of the components that make up photovoltaic technologies are not found on the local market except for non-specialized components like cables, switches and lamps. This makes solar technology too expensive for many people.

Micro-hydro Power

Ethiopia is among the few countries in the world endowed with vast potential for hydro-power development. Ethiopia's hydro-power potential is estimated to be in the order of 650TWH/Yr. Considering the country's topographical and hydrometric features, 75% of the resource could be harnessed from mountain reservoirs, and about 20% from direct river flow. Of the total utilizable potential of the country's hydro-power, only less than one percent is used to generate electricity, more than 60% of which the generated power is consumed by town centres between Addis Ababa and Dire Dawa.

Most of the big rivers are fed by tributaries flowing from the highlands. This favours the development of micro hydro-power plants in almost 10% of the territory. The resource could easily supply electricity to more than 3200 rural villages of roughly 1.5 million households, or a population of about 6.5 million.

A pre-feasibility study on the development of micro hydro-power was carried out in the south, west, central and north eastern parts of the country. Out of the 57 sites identified whose generating capacities range between 100kW to 200kW, 27 were found suitable for short-term development. They are economically viable and involve minimal design complications. However, their development will start once financial resources are identified.

4.0 PROBLEMS ENCOUNTERED

Apart from the lack of an enabling socio-political and economic environment that has prevailed in the past years, the main problems affecting the development and promotion of renewable energy technologies in the country are:

Government Policies

In the past, development activities focused on producer cooperatives. Subsequently, the Rural Technology Promotion Programme focused its activities on producer cooperatives that dealt with community based projects. This approach was flout with management problems which ultimately reflected on the renewable energy technology projects.

Logistical Problems

The lack of the requisite raw materials for different renewable energy technologies is another major constrain. This is primarily due to foreign currency shortages, which is needed for the purchase of appliances, raw materials, testing and measuring instruments and demonstration prototypes.

Communication problems as a result of the underdeveloped infrastructure causes delay in the execution of projects.

Socio-economic Problems

The biggest hinderance has been the high investment costs of the technologies. Furthermore, few banking and special credit facilities to finance the purchase of technologies exist in the rural areas. In addition, the Government does not have clear policies on subsidies that would be required if renewable energy technologies like biogas were to be widely adopted in the rural areas.

The Technical Know-how

In spite of the lack of awareness among many people on RETs, the lack of skilled manpower hinders their adoption. Upgrading the skills by staff training, in particular, design skills, construction, manufacturing and the maintenance of the technologies, energy planning, and promotion are all required urgently.

Disintegrated Development

In Ethiopia there are more than 60 non-governmental, as well as religious organizations involved in rural development activities with considerable potential in terms of finance and facilities. However, due to various socio-political reasons and bureaucratic procedures, most of them operate in relative isolation. This has greatly hampered the progress of development and promotion activities.

However, with the changing socio-political scene, more integration in technology development and promotion will, hopefully, occur.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The energy situation in Ethiopia is desperate. There are indications that unless the energy situation improves, the country may never be able to feed it's people for a long time to come.

The rate of deforestation, which got worse due to social unrest, has reached devastating proportions.

The lack of electricity and other infrastructure in the rural areas means that the vast majority of Ethiopians live a life that is paradoxically remote and backward. The current economic growth offers no hope for future electricity development.

The development of a policy and strategy on energy and the coordination and integration of all energy development activities is a pre-requisite to Ethiopia's sustainable economy. Since the rural energy development involves different sectors, the development of biogas will require coordinated efforts.

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RURAL ENERGY POLICY - AN END USE METHODOLOGY FOR DEVELOPMENT-ORIENTED ENERGY PLANNING: THE CASE OF KENYA

By
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1.0 BACKGROUND

Conventional "Wisdom" on Energy Planning

Conventional wisdom on energy planning for developing countries is usually based on the following two propositions:

Development = Growth ....(1)

Growth = Energy..............(2)

The development = growth proposition requires that the focus be shifted from development to economic growth and that assumptions be made regarding future rates of growth. If the past rates of growth have been satisfactory, "a business as usual" attitude can be adopted and the future can be assumed to be an extrapolation of the past. If the past has been disappointing, a resolution to do better can be expressed by assuming higher growth rates for the future.

The growth = energy proposition links these economic growth rates to estimates of future energy demand through the so called energy-GNP correlation. According to this "correlation", increase in the gross domestic product necessarily requires a proportional increase in energy consumption. Hence, a doubling of the GDP is assumed to require a doubling of the energy consumption.

The proportionality constant is often taken as unity so that the increase in energy is roughly equal to the increase in GDP. Once estimates of the future energy demand are available, attention is then diverted to the supply aspects of energy.

Thus, discussions on energy usually become preoccupied with energy carriers, electricity and oil, and with energy consuming sectors such as transport and industry. Also, this "conventional wisdom" inevitably results in the neglect of several crucial aspects of the lives of the rural and urban poor - the basic human needs, their settlements (slums and villages), their fuels (particularly fuelwood), the end uses (cooking and lighting) energy utilization devices (cooking stoves) and health (environment) - all of which are important to them.

The Anti-development Bias of Conventional "Wisdom"

Unfortunately, both propositions underlying conventional "wisdom" on energy planning are highly questionable, if not patently false.

The equating of development and growth ignores the fact that most developing countries have *stratified societies*. One manifestation of this is the skewed income distribution. In effect, these countries consist of "dual societies" with a vast chasm of incomes, aspirations and life styles separating the elite from the poverty-stricken masses in the rural and urban areas. In this regard, the process of development, if it is to work in the developing countries, must necessarily be directed towards alleviating the problems of the poor.

Notwithstanding, it is possible that, in "dual societies", there can be growth without development. This is because the affluent, having both the economic and political control over decision-making, become the main beneficiaries of growth. The needy who lack the purchasing power and political "clout" are unable to influence the composition and distribution of goods and services in order to satisfy their basic needs.

Despite this, growth is absolutely essential in developing countries. This is because the total assets in a poor country are inadequate for their population, and therefore, redistribution alone is unlikely to raise the standard of living of the poor. However, the nature of economic growth should be a central issue in development, since growth by itself is not guaranteed nor is it a sufficient condition for development. If development is to lead to the eradication of poverty, the structure and content of growth, as well as the distribution of its benefits among the various sections of society, is as important as its magnitude. Thus, if development is the objective, the emphasis must be on the immediate and direct satisfaction of basic human needs, starting from the needs of the neediest.

The second proposition, viz, the "correlation" between energy consumption and gross domestic product (GDP) is questionable. It ignores the empirical evidence that energy and GDP can get decoupled. For instance, between 1973 and 1982, the GDP of the OECD countries went up by 20% even though the OECD energy consumption remained the same during this period. This phenomenon is understandable on the basis of simple theoretical analysis.

The analysis shows that the energy - GDP "correlation" assumes that, not only will the product-mix of the economy, that is, the composition of goods and services, remain the same, but also the technologies with which these goods and services are produced. In the OECD countries however there were two types of changes:

(a) structural changes in the product-mix of the economy involving a trend a way from energy intensive, low-value- added basic materials, to low-energy, high-value-added services and finished products; and,

(b) technological changes comprising improvements in energy efficiencies.

The shortcomings of conventional "wisdom" on energy planning necessitates an alternative approach to energy planning in which:

(i) economic growth is not treated as the sole function to be maximized;

(ii) future energy demand is not estimated simply from the growth of GDP; and,

(iii) the exclusive obsession with energy supplies is abandoned.

2.0 ENERGY AND DEVELOPMENT

Energy is not explicitly mentioned in the list of basic human needs, yet the need for energy is implicit in all the basic needs. If, therefore, the satisfaction of basic human needs is accepted as a direct immediate objective of development, then the provision of energy for this purpose should be assigned priority.

Likewise, the emphasis on self-reliance may be frustrated if there is large-scale dependence on other countries for energy sources as is the case in many countries today, in regard to oil. In such circumstances it is important for indigenous sources of energy to strengthen self-reliance.

Urgent and serious consideration must be given to renewable sources of energy so that the energy system becomes sustainable.

3.0 PATTERNS OF ENERGY CONSUMPTION IN DEVELOPING COUNTRIES

The Case of Kenya

Since there are wide variations in the detailed patterns of energy consumption in different developing countries it is more effective to deal with a specific case study. As such, Kenya will be used as an example.

The Household Sector

Kenya's household sector is the largest consumer of energy in the economy. It accounts for 56%, more than half of the total energy used (including non-commercial energy). Most of this energy comes from non-commercial sources. The commercial sources of energy used in the household sector are charcoal, kerosene, electricity and liquefied petroleum gas.

The trends in energy consumption in the household sector over the last 20 years is as follows:

(i) non-commercial energy supplies have been declining, while its aggregate consumption has been increasing;

(ii) the consumption of all commercial energy sources has been increasing; and,

(iii) there has not been any major inter-source shifts, but there has been a small tendency for the share of electricity to increase.

The Industrial Sector

This is the second largest consumer of total energy in the Kenyan economy: 24% of the total energy. This is largely commercial energy.

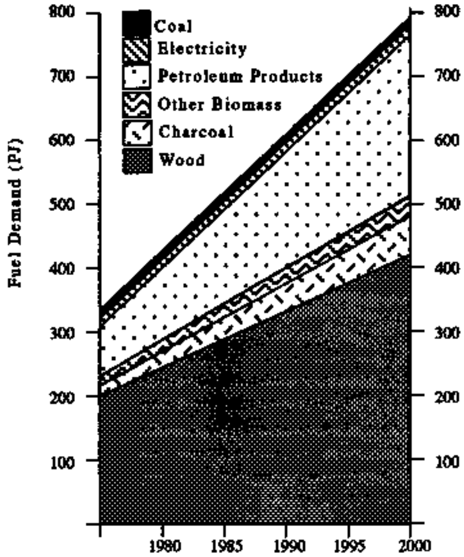
The Transport Sector

This is the third largest energy consumer with 14% of the total.

Base Case Projections

The growth of end use demand is shown in Figure 1. The total demand is expected to grow at an average annual growth rate of 4.6%. Wood and charcoal consumption will grow at 3.8% and 5.9% per annum, respectively, reflecting an increasing trend towards urbanization. Oil consumption will grow at a rate of 6.1% per annum; from 15.4 million barrels annually in 1980 to 41.5 million barrels in the year 2000.

Figure 1: Base Case Forecast of End-Use Fuel Consumption



4.0 DEMOGRAPHIC CONSIDERATIONS

Kenya's population is growing more rapidly than any other national population in the world: an annual rate of 3.5%. The rapid population increase expected during the 1980 - 2000 period will put a heavy burden on the use of limited productive land in Kenya.

5.0 WOOD SUPPLY - DEMAND RELATIONSHIPS

Kenya is presently in a situation where stocks are being depleted in order to satisfy fuelwood demands. Ever since the early 1980's demand increasingly exceeded wood yields, as shown on Table 1, and Figure 2.

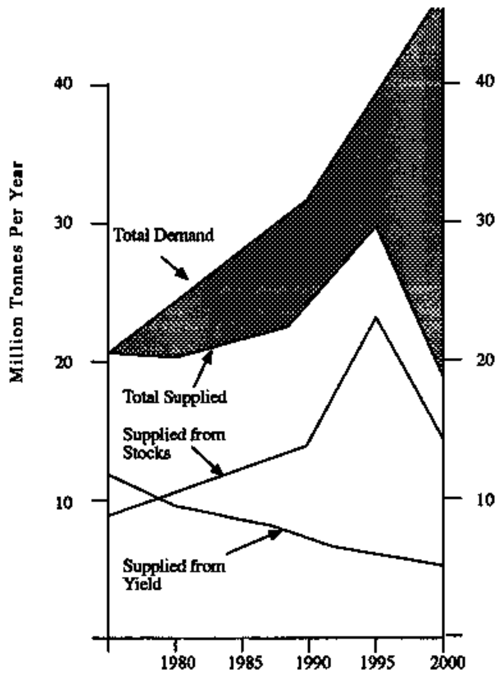
Table 1:National Wood Resource Supply-Demand: Relationship in Kenya (millions of tonnes).

	1980	1985	1990	1995	2000
Demand	20.41	26.42	32.37	41.04	49.74
Supplied					
Form Yeilds*	11.07	9.41	8.06	6.29	4.97
Form Stocks+	9.26	10.94	13.51	21.62	12.16
Shortfall	.08	6.07	10.80	13.13	32.61
Standing Stock	934.82	885.41	829.36	744.49	674.40

* Yields: Net annual prodiction. Only accessible yields service demand

\+ Yields: Net reduction in accessible standing stocks service demand when demand exceeds accessilbe yields

Figure 2: National Wood Supply Report: Demand and Supply Base Case



The results of the base case analysis demonstrates that a deepening energy crisis looms over Kenya and there needs a programmatic effort to avoid it.

6.0 POTENTIAL INTERVENTIONS

The first step in this direction is to:

Increase wood supply through:

(a) Agroforestry;

(b) reforestation;

(c) peri-urban plantations;

(d) industrial forests; and,

(e) management of natural forests.

Increase conversion efficiency by improving the efficiency of:

(a) Wood stoves;

(b) charcoal jikos; and,

(c) kilns used for converting charcoal from wood.

The second step is fuel-switching. This is where renewable sources of energy come in:

(a) Alcohol production. This could be used for blending with gasoline for motor vehicle transport;

(b) producer gas. An efficient substitute for the liquid hydro carbons in virtually all of their applications;

(c) biogas. For household heating and lighting needs, it can also be used for engines that run on diesel;

(d) wind mills. For grinding of grain, water pumping and electricity generation;

(e) solar electrical generation, heat engines, water heating and crop drying; and,

(f) micro hydro schemes. Electrical generation, grinding.

Despite the detailed consideration of alternative renewable energy technologies, the next twenty years of Kenyan energy demand will be met from oil and wood.

7.0 THE POLICY ON RENEWABLE ENERGY TECHNOLOGIES

The government policy on renewable energies is as follows:

Solar

Constraints

Production costs of solar energy systems are very high at present. In addition, the country lacks local manufacturing facilities of Photovoltaics (PVs). It also lacks adequate research, testing, and development facilities. No performance standards have been established for the design and installation of solar water heaters, hence, some units have failed to operate as expected. Effective promotional campaigns of solar energy technology are lacking. There is no legislation requiring the building industry to incorporate solar hot water systems in new buildings.

Policy

The establishment of a local manufacturing industry for solar energy should be encouraged by providing reasonable incentives. Research, testing and development facilities will be enhanced, including quality control, licensing and training. It will be government policy to have solar energy systems installed in suitable public institutions and buildings, and in all appropriate centres in the rural areas.

It will work with all appropriate organisations to determine the most effective manner of utilizing solar water heaters. The government will draw up a legislation with a view to making it mandatory for all institutions that require hot water, such as hotels and hospitals, to install solar water heating systems as part of their permanent fixtures.

Wind Energy

Constraints

The main constraints in the development and installation of wind technologies are: a high initial cost; lack of adequate wind energy data; lack of research; testing and development facilities for quality control, demonstration and training; and the lack of after sales maintenance.

Policy

Credit facilities will be extended to consumers and manufacturers through appropriate financial channels. The Ministry of Energy's Regional Development programme for wind data collection will be enhanced. The government will support the installation of pilot wind systems. Therefore, it will encourage the testing of hardware by foreign manufacturers, so long as the attendant costs do not unduly burden the available resources.

The government itself will continue utilizing wind mills for water pumping and other uses where appropriate as part of its water supply policy.

Biogas and Producer gas

Constraints

There are many biogas units already installed in Kenya, mostly on individual farms. These units have had varied successes. The reasons for this are many: faulty design, inadequate maintenance and upkeep, and poor extension services and follow-up on the part of the suppliers before and after sales.

The high initial capital costs of biogas units, which place the technology beyond the reach of many potential users, and lack of artisans to construct and maintain the units further constrains the wide-spread adoption of the technology. Also, in some cases, the effective use of the unit is hampered by the inadequate supply of vital inputs like biomass and water.

Producer gas technology is still in its infant stages of development.

Policy

The present biogas training and extension programme will be continued and strengthened. The on-going research, and development efforts of low cost but efficient and durable family size units, as well as community and institutional plants will be intensified. Coupled with this, is the development of biogas implements, such as stoves, lamps, burners etc. The current credit schemes will be expanded to include local agricultural development funding agencies. The ministry will cooperate with the commercial sector on the dissemination of proven and cost-effective designs of biogas technology. Research to improve the gasifier technology will be undertaken and its economics will be evaluated using various biomass raw materials.

8.0 CONCLUSION AND THE WAY FORWARD

From the above information on policy, the government's approach can be considered very supportive. However, the approach by the implementing agencies has to be tailored to the needs of the recipients. The current approach starts with the establishment of a few demonstration plants that are funded by the agencies. This is supposed to be followed by a technology up-take at their full costs albeit with little tangible benefits to the end-users. This approach is an expensive "indulgence" and not self sustaining.

In the search for alternatives to meet the household energy demand, "improved" utilization methods through more efficient stoves and burners, the variety of uses of the original stove (largely the three stone stove) should not be under-estimated. Also the traditions attached to the stove and the part it plays in the customs of the different communities should be taken into account.

It then becomes necessary that the introduction of the technology in the area be first identified emphasizing tangible benefits such as increased earnings. This approach meets the immediate felt needs while at the same time improving the end-users standards of living. Even if it means higher investment costs, and maybe, more input from the promoting agency, the returns are guaranteed to be successful.

This may require that the first recipients be the business-oriented people. It may be easier to obtain financial assistance from banks and financial agencies if the technology is attached to a business venture. It will also ensure that end-users look after the energy systems in terms of repair and maintenance.

The other factor to be considered by the promoting agency, in the dissemination strategy, is privatization. This is because at the end of the dissemination campaign the technology is expected to be self sustaining. Presently, the approach has been to encourage selected private entrepreneurs to take up one particular technology and market it.

However the drawback with this approach is viability. The technology is not widely used for the sustenance of the entrepreneur, hence the need for a more self sustaining approach. The approach requires that the entrepreneurs working on renewable energies be conversant with all the alternatives available in the market so that they can advise the recipients which technology is best suited to their needs. Thus, financial ability instead of the blanket approach to marketing, which may be beyond one's means, is best.

If the recipient have all the available options at their disposal, the possibility of picking one of them is high and the entrepreneur is most likely to survive in business. It may be necessary for the disseminating agency to carry out training to make the people in the private sector more conversant with different technologies.

DISCUSSION

The following were the main issues raised after the presentation:

- The possibility of energy services being sold to every body at equal prices as is done in the Philippines. Entrepreneurs will then realize that Renewable Energy Technologies are competitive with grid electricity or diesel power stations in rural areas.
- The role of energy distribution in poverty reduction.
- The inappropriateness of linking GNP increase with an increase in energy consumption.

PHOTOVOLTAIC TECHNOLOGY: THE CASE OF KENYA

By
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1.0 INTRODUCTION

The discovery of the solar (photovoltaic) cell, also known as the PV cell, dates back to the early 1840's when Becquerel observed voltage caused by sunlight, on one of the electrodes of an electrolyte. In 1954, the conversion of sunlight to electricity by use of the P-N junction, a device known today as a solar cell (or a photovoltaic cell), was thereafter, successfully demonstrated at the Bell Research laboratories in the United States.

It was not until the 1960's, during space explorations, when NASA (North American Space Agency) was looking for power generators for space crafts that the solar cell was used. This was followed by the production of the solar cell, in use today, for electricity generation.

The advent of RETs has boosted the possibility of PV technology in areas far from the grid, especially in Africa and other developing countries. There are several reasons for this:

- The potential for its demand exists;
- 80% of the population lives in rural areas and there exists little hope for grid electricity in these regions; and,
- rural electrification using grid is very expensive - in Kenya it costs more than US $10,000 to put up one kilometre of grid electricity.

This paper discusses the current status of PV technology in Kenya and some selected African countries, paying particular attention to its achievements and limitations to-date. It also gives some suggestions on how to improve PV dissemination and increase awareness of PV technology among the region's rural communities.

2.0 PHOTOVOLTAIC TECHNOLOGY IN KENYA

Kenya's national power generating capacity is about 650MW. 30% of it is used in the domestic sector while the rest is used in the industrial and other commercial sectors. The power is generated from hydro, geothermal and thermal sources.

Power generation by photovoltaics has not been fully developed. However, a number of projects including: remote post office repeater stations; railways, police and army communication networks; immunization projects; school and home lighting systems depend on PV electricity. There are also a few PV water pumping projects in the country.

At present, there are about 15 companies dealing with solar PV technology in Kenya. They supply equipment that ranges from single PV modules to complete ready-to-instal systems. Among these companies are large concerns like BP Solar, Chloride Solar, Chroner, Kyocera and Siemens. Kenya's PV industry also benefits from a rich hardware enterprise market for various non specialized electrical gadgets. These companies have appointed agents in different rural areas.

3.0 APPROACHES TO PV TECHNOLOGY DISSEMINATION

Kenya boasts over 10,000 PV installations. Very few of these have attracted any government support. The common PV dissemination strategies used in Kenya are:

- Grass-roots;
- Individual awareness;
- Lobbying; and,
- NGO support.

Grass-roots Approach

This approach is mostly used by technicians who have previously worked with large PV companies. They set up their own PV businesses or contact points up-country. These technicians know the people who can afford the PV systems. Equipped with this knowledge, they sometimes carry out door-to-door marketing campaigns. Often, you will find them prying the major shopping centres, maize, coffee and tea plantation zones where they sell their services to the farmers and other middle income groups.

Individual Awareness

This strategy focuses on public education and advertisement through the mass media, public demonstrations and bill boards. The approach is aimed at people who like 'a good taste of life' and who usually have an 'eye' for things they consider to have 'class'.

Lobbying Approach

The big PV companies are either foreign owned or subsidiaries of international companies. The directors of these companies usually interact with other senior officials in foreign missions (embassies) and senior government officials. In the process, they find out in advance which foreign donors are giving aid or loans and in what form. They then lobby their countries and other donor agencies to include PV in the projects. Usually, this approach is limited to large projects. Examples of such projects are the: health immunization projects of the WHO and UNICEF; UNHCR for the provision of water and electricity in refugee camps; and WWF for solar electric fencing of national parks.

Non-Governmental Organizations Initiatives

There are approximately 400 non-governmental organizations in Kenya. They undertake a variety of development projects that include: health care, community development, environment, small scale industries, energy conservation, technology development and family counselling services. Some of these projects require electrical energy and PV has often been considered.

4.0 SETBACKS TO THE GROWTH OF PV INDUSTRY

Although the PV technology has been looked at as a potential alternative for supplying electricity, its use is still minimal. This is partly because of the following setbacks:

Government Policies

Most Sub-Saharan Africa governments lack clear policies on PV technology. For example, a Kenya energy policy document released in 1992 does not state how the government will support the technology. Nor are there funds earmarked for research or any dissemination process.

The same applies to most other countries in the region. There are a few exceptions such as Zimbabwe. A Zimbabwean local company, Solarcomm (Z) Ltd, is assembling PV modules. The government on its part is negotiating with the UN Global Environment Facility (GEF) for funds. The funds will be used to finance a PV rural electrification programme.

Technical Capacity

Most African countries lack qualified PV technical manpower. This is especially so at the grass-roots level where the technology is disseminated. Subsequently, the buyers, like the sellers, never get to know the full benefits of the technology or its limitation. Moreover, good technical manuals on PV installation, service and maintenance are not readily available.

Maintenance of PV Technologies

The cause of most PV systems break-down is poor maintenance. For instance, the PV water pumping system at Kiserian in Kenya, broke down due to poor maintenance. Unfortunately, there is no locally trained capacity to ensure the systems function well.

Systems failure from dust accumulation or the failure to use distilled water for batteries are a common occurrence. It is necessary, therefore to ensure an after sales maintenance team makes frequent advisory, service and maintenance visits.

Investing in PV Technology

Although arguments for PV technology in areas remote from the grid have been put forward, the proponents of this theory often over-look the income group in such regions. Regions far from the grid are the ones that suffer calamities such as famine and health care problems. This means that the people are already financially strained.

Therefore, incentives should be given by donors and the government through indirect subsidies and soft loans at low interest rates. This will ensure that the PV industry grows faster and benefits more people.

Funding mechanisms for PV technology can be worked out especially through cooperative banks. Governments should also set aside some of their development funds for PV development. Tax on imported PV equipment should not be excessively high.

5.0 SOME EXAMPLES OF PV TECHNOLOGY IN AFRICA

The growth of PV technology is very similar from one country to another, especially, in Sub-Saharan Africa. However, it's growth in Zimbabwe and Botswana are worth highlighting.

Zimbabwe

PV technology in Zimbabwe was introduced in 1979 when the government purchased some systems for rural hospitals. However, the failure of some of these PV systems prompted the Government, a year later, in 1980, to re-define its role in PV technology with regard to the private sector, NGO's and end users.

The government has acknowledged that grid electricity will not reach the entire rural population soon. Consequently, the relevant ministry has developed PV technology policies and has set up a specialized Sector to deal with the dissemination and follow-up of PV programmes. As a result, a private company, Solarcomm (Z) Ltd, now assembles PV modules in the country. The modules are sold in the local and export markets.

Due to its forward planning and PV technology policy, Zimbabwe will receive the UN GEF funding. In total, US $7 million will be spent to finance a revolving fund for rural solar electrification.

Botswana

Botswana is largely made of desert or semi-arid land. 80% of the population lives in the towns on the eastern side. The electricity supply is obtained from South Africa and priority is given to industrial and commercial sectors. This makes PV technology a more common feature in urban areas than in the rural areas.

Botswana's PV industry has benefitted from the country's good relations and trade agreement with

Zimbabwe and South Africa. These two countries are quite advanced in PV technology. In addition, the Botswana Technology Centre [BTC] is playing an important role in the promotion of PV technology. Apart from training personnel in PV technology, BTC is also involved in research, development, production and testing of PV components.

6.0 CONCLUSION

Although the 1981 Nairobi Programme of ACTION was aimed at providing a major thrust to renewable energy, there are doubts that this will be achieved as planned. This is because of:

- Lack of initiative from the developing countries in terms of concrete policies on PV technology;
- lack of adequate awareness and dissemination strategies;
- socio-economic problems;
- inadequate infrastructure; and,
- lack of funding mechanisms.

But if the Sao Paulo Declaration of installing one million PV units by 1995 is to be achieved or nearly met, then developing countries, the World Bank, IMF and other donor countries have to adopt the recommendations made by the International Solar Energy Society (ISES).

Some of the recommendations are:

- Social and environmental cost and benefit: The PV technology should reflect the benefits derived from social environmental aspects and the cost governments would have undergone to improve people's standards of living and, the non-pollutant aspect of the technology.
- Financing: A major obstacle in the utilization of PV technology is the lack of funds which can be overcome by making capital available for financing PV activities. Financing can be done through local banks or financial institutions as revolving funds.
- Public awareness: Public awareness of PV technology should be emphasized. The awareness should be well designed and executed by competent personnel.
- Economic incentives: Governments should give attractive incentives combined with infrastructural support. These incentives should be in the form of tax relief and indirect subsidies on PV equipment.
- National planning and policy making: Governments should embark on current and future utilization of PV technologies. They should also create policy-making frameworks based on practical strategies for aggressively taking part in a global transition to a more sustainable energy economy. This should include increased reliance on renewable energy technologies.
- Database centre: Countries should set up centres for keeping data on national energy assessments. The database centres would serve as clearing houses for technology information. They would also become an integral part of the regional database network in the continent and in the rest of the world.

RENEWABLE SOURCES OF ENERGY IN KENYA: A METEOROLOGICAL OVERVIEW

By
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1.0 INTRODUCTION

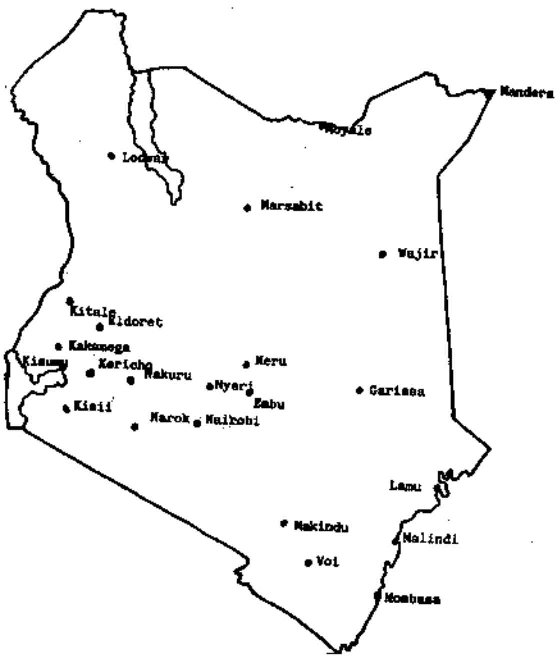
The conventional sources of energy are getting depleted. The threat of a significant climate change caused by emissions from burning of fossil fuels and deforestation is predicted to be enormous. There is, therefore, a need to re-examine the existing energy sources with a view to exploiting new forms of energy that are less costly both to the environment and end-users.

The sun is one of the major primary source of energy and is responsible for life on earth . The sun's energy is renewable and can be safely harnessed by mankind. To date, the setback has been the slow development of appropriate technologies to harness this energy.

2.0 ENERGY POTENTIAL IN KENYA

In this paper, data from all major meteorological stations are used in order to ensure the country is covered fairly well. The net-work of stations is shown in Figure 1.

Fig 1: Sources of data collection



(Source: Kenya Meteorological Department)

The long-term annual daily mean of radiation, temperature and windrun are shown in Table 1. The windrun is shown both in miles per day and kilometres per day. The daily radiation data has been converted to kilowatt-hours per square meter, since it is a more familiar energy unit

Table 1: Long-term annual daily means of radiation, temperature and windrun

STATION	Mean Daily Maximum Temp. (Deg. C)	Mean Daily Minimum Temp. (Deg. C)	Mean Air Temp. (Deg. C)	Mean Daily S/Shine (Hours)	Mean Daily Radiation (Langleys)	Mean Daily Radiation (MJ/Sq. m)	Mean Daily Mean Radiation (kw-hr sq.m)	Mean Daily Wind Run (miles)	Mean Daily Wind Run (km)	10% of Mean Daily Radiation (kw-hrsq.m)	60% of Mean Daily Radiation (kw-hrsq.m)	Amount of Water Heated By 20 Deg. C litres
Eldoret	22.8	10.3	16.6	8.0	528.0	22.59	6.14	162.0	260.7	0.61	3.68	160
Embu	24.0	13.4	18.7	6.4	433.0	18.53	5.03	73.4	118.1	0.50	3.02	133
Garissa	34.4	22.7	28.6	8.7	479.0	20.50	5.57	116.4	187.3	0.56	3.34	147
Kericho	22.7	9.0	15.9	6.5	454.0	19.43	5.28	82.0	132.0	0.53	3.17	139
Kisii	25.1	15.0	21.1	6.5	417.0	17.84	4.85	104.0	167.4	0.48	2.91	128
Kisumu	29.4	16.9	23.2	8.3	543.0	23.24	6.31	143.1	230.3	0.63	3.79	167
Kitale	25.4	11.2	18.3	7.2	512.0	21.91	5.95	75.4	121.3	0.60	3.57	157
Lamu	29.8	24.3	27.1	8.8	475.0	20.33	5.52	81.7	131.5	0.55	3.31	146
Lodwar	34.8	23.8	29.3	9.8	535.0	22.89	6.22	126.2	203.1	0.62	3.73	164
Makindu	28.6	16.6	22.6	7.6				109.3	175.9			
Malindi	29.6	22.9	26.3	8.6	437.0	18.70	5.08	237.5	382.2	0.51	3.05	134
Mandera	34.5	23.4	29.0	8.8	457.0	19.56	5.01	116.7	187.8	0.58	3.19	140
Marsabit	24.7	15.3	20.0	7.8	509.0	21.78	5.92	294.2	473.5	0.59	3.55	156
Meru	23.4	12.6	18.0	7.5	384.0	16.83	4.46	64.1	103.2	0.45	2.68	118
Mombasa	30.2	22.4	26.3	8.1	462.0	19.77	5.27	148.8	239.5	0.54	3.22	142
Moyale	27.2	17.5	22.4	7.2	381.0	16.30	4.43	155.1	249.6	0.44	2.66	117
Nairobi	23.4	11.9	17.7	6.9	455.0	19.47	5.29	83.6	134.5	0.53	3.17	140
Nakuru	25.4	9.5	17.5	7.1	511.0	21.87	5.94	70.7	113.8	0.59	3.56	157
Narok	24.6	8.4	16.5	7.5	476.0	20.37	5.53	105.9	170.4	0.55	3.32	146
Nyeri	23.2	12.2	17.7	6.1	351.0	15.02	4.08	81.6	131.3	0.41	2.45	108
Thika	25.5	13.1	19.3	6.8	441.0	18.87	5.13	126.8	204.1	0.51	3.08	135
Voi	30.6	19.3	25.0	7.2	445.0	19.04	5.17	129.0	207.6	0.52	3.10	136
Wajir	33.7	22.2	28.0	8.0				236.1	380.0			

Source: Kenya Meterological Depertmant

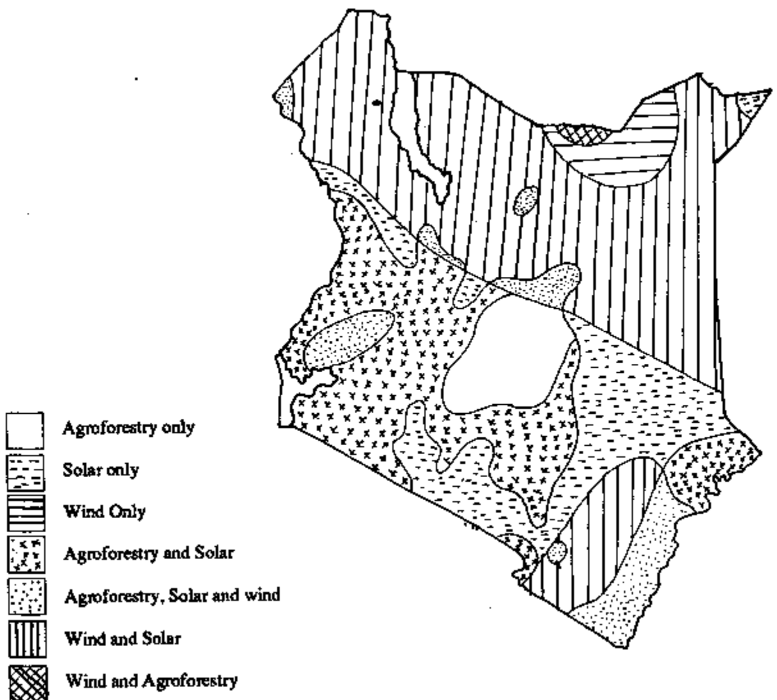
3.0 ANALYSIS AND DISCUSSION

The threshold conversion factors adopted in this study are based on general limits of operational energy converters. For example, the 10% adopted for solar electricity converters is within the 10-15% range for photovoltaic cells.

The conversion of solar energy to heat is more efficient and the 60% percent adopted here is a very modest absorption factor. Both the 10% and 60% of the incident solar radiation are shown in Table 1. This shows that nearly all regions in the country have a potential of generating electric energy above 0.4kW-hr per day for every square meter of exposed collection surface.

These figures are plotted on the Kenyan map and show that apart from the Central highlands and regions around Moyale, the rest of country can generate above 0.5kW-hr on a daily basis. The region around Lodwar can generate above 0.6kW-hr daily. The solar energy converted into heat can be used best for heating water. Going by the above assumption the solar energy available for heating, ranges between 2.45kW-hr and 3.78kW per day for every square meter of collecting surface.

Figure 2: Composite map showing regions where different forms of energy can be viably exploited.



(Source: Meteorological Department)

Wind energy can be used to generate electricity and pump water. For water pumping, the output depends on the speed of wind, the depth or head at which pumping is carried out and the dimensions of the windmill. The average daily wind run, which is as low as 200km, can effectively be used to pump water.

Electricity generation from wind energy requires wind speeds higher than 5m/s which approximates to a daily windrun of above 400km. While wind energy can be used for water pumping over most of the country, electricity generation is limited to a few regions in the northern part of the country.

The rainfall patterns over the country indicate that much of the country receives less than 500mm of rainfall annually. The regions that receive over 500mm of rainfall are the high potential areas with high population density. According to the FAO mapping of the fuelwood situation in developing countries, the northern and north eastern regions of the country are classified as desert or semi-desert. These areas have very few resources and a low population.

The rest of the country suffers fuelwood shortages, obliging the population to over-exploit the tree resource. In this region, agroforestry could counter deforestation problems that are associated with population pressure. In particular, agroforestry should be stressed among the rural agricultural communities whose requirements for fuel are mainly met by the existing fuel wood resources.

In areas where rainfall is below 500mm the environment is prone to degradation due to variable weather patterns. Agroforestry should be practised to deter environmental degradation. At the same time, these low potential areas are becoming more populated, with movement of people from the high potential areas necessitating agroforestry.

Hydro-power is also dependent on rivers which in Kenya are dependent on rainfall. The Tana River, the largest river in the country, has mostly been used for hydro-power. Most of the other rivers are not so amenable to large scale damming for power production. However, tidal waves along our coastline need to be explored in order to develop it.

4.0 RESULTS AND CONCLUSION

From the foregoing discussion, it is clear that solar and wind energy can be used over much of the country to supplement the conventional sources of energy.

By using the Kijito water pumps, the regions with an average daily windrun exceeding 200km can pump water using wind energy. The northern and coastal areas of the country provide this form of energy. These are also the low potential areas where the stream flow does not favour overland water supply. The main source of water in these regions is primarily wells and bore holes. These regions could therefore use wind energy to pump water. Effective electric power generation is confined to areas around Marsabit where the mean daily windrun exceeds 400km.

Solar radiation is readily available for water heating. Apart from the Moyale and the Central highlands, most of the rest of the country receives enough energy to heat 130 litres of water by 20 degrees celsius daily.

Electricity production from solar radiation is viable as long as the energy needs are below 1kW-hr daily. Therefore, solar radiation for the generation of electricity is recommended for small consumers only or as a stand-by source.

In conclusion, this paper presents a composite map showing different areas and their energy potentials using the thresholds mentioned above (see Fig.2.). The areas receiving above 500mm of rainfall are taken to be viable for agroforestry development. Where 10% of the daily radiation exceeds 0.5kW-hr, solar electricity generation is viable. Those with a daily windrun in excess of 200km can generate wind energy. The potential for hydro-electric power is not indicated in this composite map.

From this composite map, it is evident that most regions can exploit at least two of the forms of energy highlighted. However, the central highlands can accommodate agroforestry while using energy derived from other sources.

From this study, wind energy seems to hold a lot of promise for the Northern Kenya to pump water. In the same region, the generation of electricity by wind and solar radiation can be done at the urban centres and its environs, as well as institutions and hospitals. Kenya's rural population would benefit from agroforestry practices as it halts forest depletion.

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SOLAR COOKING TECHNOLOGY: THE EXPERIENCE OF TRANS WORLD RADIO

By
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Trans World Radio

1.0 SUMMARY

People in the developing countries rely on wood for over 50 percent of their energy needs and their forests are getting smaller as their populations rise. Solar power, wind power, and other alternative energy sources seem to be the obvious solutions to the problem, but they have rarely been put to test. With Kenya's fast growing population, the solar energy could address most energy needs. The best way to support developing countries is to recognize and promote the riches they already offer including solar energy.

This paper gives a profile of the solar Cooker project at Trans World Radio and suggests that while solar cooking has a positive socio-economic impact on the recipient community, its acceptance is difficult.

2.0 INTRODUCTION

The type and model of solar cooker constructed and distributed by Trans World Radio was originally designed and developed by a German, Werner Merz. He then gave Trans World Radio the authorization to make and distribute the solar cookers in March 1992. However, it was not until June 1992 that the first cooker was given out. Meanwhile a survey was being carried out through a questionnaire between April and June of the same year.

According to the survey, 75% of Kenyans use firewood for cooking and just a small fraction use paraffin. Charcoal is the second most used fuel. In fact, to feed and warm itself, the world has largely relied on forests as a source of fuel.

Statistics show that closed forests are disappearing at the rate of 7.5 million hectares per year and open forests 3.8 million hectares per year. Yet, these forests constitute the only means of livelihood for Africa's rural population.

It is a paradox that while the village woman, on whom the burden is greatest continues to suffer, natural resources dwindle at an alarming rate. Africa's abundant sunshine can be an alternative source of energy. But how can this vast energy resource be used more effectively and how can it be diversified to include cooking, heating water and other energy consuming household activities?

During the survey, the fuel needs of different families were assessed. For example, families, average 8 persons, in Amagoro village, Busia, Kenya have the following average household fuel requirements:

i) Firewood - 3 head loads per week;
ii) paraffin - 5 litres per week at Kshs. 60/= or 16 soda bottles at Kshs. 6/= each; and,
iii) charcoal - 1/2 gunny bag at Kshs. 70/=.

3.0 THE SOLAR COOKER

The versatile solar box cookers can be made from many different low cost materials that, do not impact negatively the on environment, and that require few tools and little skills.

The cooker utilises energy from the sun to obtain temperatures between 1500C and 200°C depending on the weather and time of the day. Investing in a solar box cooker is a worthwhile investment because the cooker:

- saves on cooking fuel costs and dependency;
- utilises a principle that is easy to understand;
- is easy to manufacture; and,
- is effective in accomplishing cooking tasks.

Parts of the Cooker

The Glass Panel framework

This comprises a wooden framework that supports two glass panels sufficiently spaced at a distance of slightly over one inch. The glass panels have a thickness of about 3mm.

The glass should be at least 50x50cm [20"x20"] to gather enough sunlight for cooking a family meal.

It should rest tightly on the inner box to retain heat and should always be kept clean.

The Cooking Cavity

Should be at least 45x45cm [18"x18"] and just a bit taller than the tallest dark cooking pot.

Must stand temperatures of upto 2000C without melting or giving off fumes

Must be moisture-proof so that the steam from food does not get into the insulation and drain off heat.

The walls should be thin because they soak up little heat. They should be shiny to reflect heat back to pots and bottom tray. A thin aluminium sheet is better than a heavy duty one.

Insulation

Must stay dry and must withstand high temperatures.

Outer Box

Can be made of just about anything, so long as it holds insulation and keeps dry.

Reflector

Shiny to reflect more sunlight into the cooker, especially when the sun is lower in the sky - early and late in the day.

Adjust it so that it reflects extra light into the box.

4.0 THE PRINCIPLE OF OPERATION

The Solar Cooker functions according to the greenhouse effect. Light rays (not heat-rays) from the sun penetrate the window and are absorbed by the dark surfaces in the inside and changed into heat. Since the cooking cavity is tight and the glass largely impermeable to heat radiation, the temperature inside rises until the loss by reflection equals the energy that falls in. To reduce the losses of heat on the one hand, the window consists of two glass panels separated by an air space. On the other hand, the cooking cavity is well insulated all round. As a result temperatures of over 1000C are obtained, enough for cooking and baking.

The simplicity of this cooker both in operation and in manufacture, makes it a particularly attractive investment, especially for people in the countryside. It is hoped that the technology, will find wide acceptance and usefulness around Africa and beyond.

5.0 IMPORTANT TIPS

The average cooking and baking times are 2 to 4 hours, respectively, depending on the meal, the quantity and the radiation intensity of the sunlight. As the food does not come to the boil in the cooker, it may be left inside for a longer period than the normal cooking time without any problem.

The amount of water used is approximately one third of what one would normally use, because there is no evaporation. The cooker is also good for stewing meat and baking bread or cakes. Other possible uses are nut roasting, boiling of water and sterilizing of medical equipment.

For good thermal efficiency, pots, crockery and baking-moulds should be dark on the outside - dull black is best. To attain short cooking-times use thin-walled aluminium pots and distribute the food to be cooked to several smaller pots. For better heat-exchange do not put the pots directly on the floor but on a grate, or simply on two wooden bars about 2 cm high. This allows hot air to circulate under the pot and heat it from below.

In order to minimize on heat loss, keep the number of times the cooker is opened to a minimum. If the cooker has to be opened for stirring, for example, do this quickly and briefly. It is best to add all the seasoning at the beginning except salt which should be added after cooking. Stirring is unnecessary as nothing burns or boils over.

Except for cleaning of the glass panes, hardly any upkeep of the cooker is needed. Even if it is fitted with a weather-protection, the cooker should be protected from getting wet.

With good care the cooker will provide useful service over several years.

Only by trying out the various dishes will solar cooking be successful, and the more you succeed, the more enjoyable the cooking and baking.

6.0 COMMUNITY INVOLVEMENT

According to the survey carried out by Trans World Radio, the respondents who included teachers, community workers, pastors, farmers and agricultural extension officers gave good ideas on how to disseminate solar cookers as well as tips on their proper use.

Educators in the rural areas can help train the target group on how to prepare indigenous food using the cookers. As an introduction to the solar cooker and training exercise, Trans World Radio intends to hold nutrition workshops. During the workshops, solar cookers will be used to prepare different meals by women from different parts of the country. All the participants will receive complimentary cookers.

7.0 CONCLUSION

When energy is freely available in a community, it leads to improved living standards and encourages various other activities. Above all, conservation of forests is enhanced.

However, the provision of solar cookers is a difficult exercise. It requires patience, understanding and resources. Until everyone who wants a solar cooker is able to afford, accept and use one, the use of solar energy in the rural areas will remain a distant dream.

WIND ENERGY TECHNOLOGY: THE CASE OF KENYA

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SUMMARY

Wind as a primary source of energy has been known and exploited by many countries for well over a century, mainly for sailing, milling and water pumping. As a resource, wind is quite variable in both time and space and therefore the technology is best suited in applications where the energy end-use is: relatively independent of time (e.g. irrigation and water pumping); utilized with some form of storage facilities (e.g. Batteries or water tanks); or interconnected with other power plants such as diesel or large utility grids.

The tropical winds are generally low, in particular, those close to the Equator. They are comparable to those in extra-tropical regions that are very strong and can persist over a long period, making them potentially useful for large wind energy conversion machines. However, there are many regions in the tropics where wind energy technology is feasible. It is necessary to carefully locate potential sites by understanding the wind distribution patterns and match, them with the characteristics of the wind machine.

A number of countries in Sub-Saharan Africa started viewing wind energy as a potential source of energy for rural populations, remote villages and islands, where costs of transporting fossil fuels are un-affordable.

Countries that are considering the use of wind energy as an energy source include Ethiopia, Kenya, Zambia, Zimbabwe and, to some extent, Tanzania and Uganda. Kenya, however, is better placed to use wind energy than any of the other countries. This is because of the existence of two very successful wind pump manufacturers who supply over 70% of all the windpumps in the country.

This paper highlights some developments on wind energy utilization and the available technology, with reference to Kenya. Problems with the technology are also briefly mentioned.

1.0 INTRODUCTION

The energy crises of 1970 and the 80's forced many countries to address the possibility of improving the reliability of energy supply, and the gradual replacement of fossil fuels with alternative sources of energy. This would ideally preserve the environment from pollution and degradation. Furthermore, studies have indicated that fossil fuels (coal, gas and oil) might not last beyond the year 2030 and that all fossil and fissionable fuels may be depleted by the year 2350 (Quarachi, 1984).

Many developed countries are putting substantial funds into the research and development on renewable energy technologies, in particular, wind and solar energy. These include Sweden, Denmark, Germany, the United States, The Netherlands, Norway and the United Kingdom.

In Africa, as well as in other developing countries the situation is different. Majority of the people are situated in the rural areas that are either arid/semi-arid and dry-lands where drought and water shortages are a common feature. Fuelwood, cattle dung and agricultural wastes are the energy sources available in these areas, with fuelwood constituting the highest demand.

This poses serious environmental threats such as forest depletion, vegetative cover loss and soil erosion. Consequently, many countries are faced with a scarcity of energy. This is aggravated by increasing population, industrial growth and problems of balance of payments associated with the import of fossil-based fuels. These countries are now searching for other cheaper alternative sources of energy to supplement the expensive fossil-based fuels.

Despite the fact that winds are generally low within the tropics, there are however many potential sites within mountainous areas, coastal strips and other well exposed windy sites. In most of these locations the mean wind speeds can range from 2.5ms-1 to 7ms-1. This range of wind speed is appropriate for either wind pumps or small wind generator installations, particularly, in remote villages and isolated islands.

Technology for harnessing wind energy varies considerably from country to country and may be constructed from a wide variety of materials and technological levels. It may range from cheap individual craftsmanship using local materials to higher levels, of advanced technology for high speed systems.

In Sub-Saharan Africa, not many individuals have the technology to design, install and maintain facilities for harnessing wind energy. The major cause for most wind machine failures in the region has been poor extension services from the manufacturers with respect to maintenance and repair.

2.0 THE WIND ENERGY RESOURCE

The winds that blow over the tropics are mainly the Northeast and Southeast Monsoons that result from differential solar heating between land and sea surfaces. The complex topographical features coupled with the nature of the surface induce local wind circulations such as land/sea breezes or mountain/valley winds that may be strong at certain times of the day.

Areas with regional topographical features such as ridges, mountains, gorges, passes, valleys and cliffs have a lot of influence on prevailing wind patterns, by channelling and significantly accelerating the winds. Such features are indicative of potential sites for machine installations.

Available Wind Energy and the Extractable Power

The available wind energy is proportional to the wind speed cubed, the air density and the area as given by the formula:

$P_a = 1/2\ p.A.V^3$ (W)

Where P = air density (Kg/m^3)

A = Rotor Swept area (m^2)

V = Wind velocity (ms^{-1})

The available wind energy per unit area as well as the energy pattern factor (Ke) on the mean available wind energy in KwH/m^2 are all suitable in characterizing the available wind energy at the various sites.

The amount of energy that can be extracted by a wind machine is given by

$P_e = 1/2.C_p.\ \rho\ \Gamma\ A.V^3$ (W)

Where C_p is the power coefficient and ρ is the total

efficiency of the machine.

For cases where the analytical wind distribution, such as the Weibull distribution, is known, the available wind power and that which can be extracted by a wind machine are given by

$P_a = 1/2.\ \rho.\ A.C^3.\Gamma\ (1+3/k)$ (W)

and $P_a = 1/2\ \rho\ .C_p.\ \rho\ A.C^3.\ \Gamma\ (1+3/k)$ (W) where $V^3 = C^3 . \rho \Gamma (1+ 3/k)$

C = Scale factor of the Weibull distribution

K = Shape factor of the Weibull distribution

Γ = the Gamma function

The Weibull distribution is given by

$f(v) = (k/c) . (v/c)^{k-1} \exp(-(v/c)^k)$

and is the most widely used distribution for characterizing observed wind speed frequencies (Hannessey, 1977).

In wind resource assessment studies, the following main investigations must be carried out:

(i) determination of the amount and type of power required;

(ii) selection of sites that seem to possess high wind potentials;

(iii) studies of wind characteristics at each of the sites to determine the availability and consistency of the power;

(iv) selection of the best site based on consistency; and,

(v) determination of a wind machine size and type that matches the available wind characteristics.

It is important to note that improper siting of wind machines is a major cause of dissatisfaction by those using wind driven machines. Proper site selection tends to minimize maintenance costs and damage risks and are thus economical. By knowing the wind characteristics of a site, the available power, the wind speed and machine efficiencies one can determine the size of required wind machine for a site from the wind power equation, and thus determine the rotor area.

If a wind machine is to be installed at a great height (10 m) above ground, then the varying speed of the wind with height must be considered. In this case, either the power law equation or the logarithm profile law equation may be used to determine the wind speeds at heights above the standard 10 m. (Doran & Verholek, 1978)

3.0 WIND ENERGY TECHNOLOGY IN KENYA

Kenya has a good information network, and a considerable amount of wind data covering much of the country can be obtained from the following sources:

- Kenya Meteorological Department;
- Ministry of Energy;
- Kijito Windpump Monitoring Programme ; and,
- Agricultural Research stations, etc.

There have been numerous wind pump design projects in Kenya since 1975 including the following:

(i) Bob Harries Engineering Ltd., initiated by Intermediate Technology Development Group (ITDG) in 1975, who are the manufactures of Kijito Windmills;

(ii) Pwani Fabricators, part of a large engineering firm in the coastal region, is producing a copy of the Climax multi-bladed wind pump of South Africa;

(iii) UNIDO/Kenya Industrial Estates (KIE) project started in Kisumu in 1976 and funded by UNIDO. Wind pumps best suited for water pumping around Lake Victoria (The 12 PV 500 wind pump) were manufactured;

(iv) Kenya Industrial Estates (KIE)/United Nations Development Programme (UNDP) project - this was later discontinued;

(v) University of Nairobi project - 1970-1978; and,

(vi) National Council of Churches of Kenya (NCCK)/Christian Industrial Training Centre (CITC) project - 1976-1978.

Only the first two manufacturers have progressed to a stage of viable commercialization. Kenya, therefore, is in a good position to use wind pumps, since good quality machines suitable for local conditions are manufactured in the country. This reduces the foreign exchange requirements for the purchase of machines and spare parts that would otherwise have been necessary. To date, over 70% of all the windpumps operating in Kenya are locally manufactured. Many of these windpumps were installed through aid funded water supply projects, or private large-scale cattle ranchers.

The Ministry of Water Development (MOWD) has shown great interest in windmill water projects although there are no known Government wind pump projects in the country.

Institutional Aspects

There is a general lack of interest and expertise in many institutions regarding all aspects of wind pumps, with the exception of Nairobi and Moi Universities, where courses in renewable energy are being taught. The Ministry of Energy's staff are also being trained in aspects of wind energy.

Training is certainly necessary for wind pump selection, site evaluation, installation, operation and maintenance. The Kenya Industrial Estates and the Agricultural Finance Cooperation usually can make arrangements for credit to individuals and groups who wish to instal windpumps in their areas.

The Special Energy Programme (SEP), Kenya

This was started in May 1979 by the government of the Federal Republic of Germany, and is coordinated by GTZ in cooperation with the Ministry of Energy. The programme has a number of features, one of which is to promote the introduction of relevant renewable technologies to satisfy basic needs and to conserve expensive fossil fuels. In Kenya, a number of wind and solar measurement programmes were started in 1983, with data collecting centres located at the Kenya Meteorological station sites.

Windpumps and Wind Generation in Kenya

The Kijito wind pump production project is the most successful wind pumping project in Kenya. The wind pumps are manufactured in sizes of 12', 16', 20' and 24' rotor diameters. Currently, there are over 200 wind pumps installed in Kenya. Most wind pumps are used for domestic and livestock water supply, with a few for irrigation. The prices of Kijito windpumps put them beyond the reach of individual small scale farmers. The total cost of the Kijito wind pump is between US $3,000 and US $12,000, depending on the rotor size, pump size, depth, and distance of site from the factory.

Other windpump types which have been in operation in Kenya include the Pwani Windmill, the UNIDO/ KIE prototype in Kisumu (12 PU 500) used in small scale irrigation, the University of Nairobi/NCCK wind pump and the Mbita mission wind pump. Most of these last wind pumps, however, are not in operation at present.

These numerous projects have failed for a variety of reasons including:

(i) the use of inferior technology, and the premature installation of unproven designs;

(ii) short term duration of expatriate contracts, leading to a lack of project continuity,

(iii) under-estimation of the complexity of wind pumping technology;

(iv) poor extension services to wind pump users in maintenance, repair and agricultural practices;

(v) lack of assessment of project viability with respect to the requirements of the potential wind pump users; and,

(vi) lack of adequate long term project financing.

Apart from the wind pumps, there are also a number of wind chargers and generators at a number of sites in Kenya. These range between 0.5 kW through 200 kW. The 200 kW wind generator is located near Marsabit and is connected to the grid. Most of the wind generators are used for supplying electricity to hospitals, dispensaries, radio and TV (transmission) and receivers.

5.0 CONSTRAINTS IN THE DEVELOPMENT AND UTILIZATION OF WIND ENERGY TECHNOLOGY

These include:

- the lack of rural infrastructure to promote the development of wind pumping and autonomous wind electric power;
- the lack of wind energy specialists in: Data collection, interpretation and site prospecting; Systems design, engineering and management; Systems operation and maintenance;
- insufficient detailed wind resource data;
- absence of wind energy courses in universities and technical schools;
- inadequate funds for financing institutions, technical services and training in most African countries; and,
- high initial costs, compared to fossil fuels.

6.0 CONCLUSIONS

Many Sub-Saharan Africa countries are experiencing levels of energy demand in excess of the limited available supplies, manifested by a depletion of their foreign exchange reserves.

This has forced many countries to search for alternative sources of energy, such as wind and solar energy. Harnessing these energy alternatives using various levels of technology can help solve social, economic and environmental problems. They can curb deforestation, soil erosion and pollution, and save the country an enormous amount of foreign exchange currently spent in importing expensive fossil fuels.

These countries need to undertake preliminary wind resource inventories to establish their wind energy prospects. They should also designate national focal points for wind energy policy making, planning and implementation within the appropriate Government department.

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DISCUSSION

The following are some issues that arose after the presentation:

- costs of installation per kW of wind powered generators are high which in turn limits the affordability of wind powered technologies.

SUDAN

SOLAR THERMAL TECHNOLOGY: THE CASE OF SUDAN

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1.0 INTRODUCTION

Sudan is the largest country in Africa. It has an area of about 2.5 million Km^2 and a population of 20.5 million. The growth rate is 2.7% and the population density is less than 10 persons per square kilometre. Sudan's per capita income is less than US $400. Agriculture is the major source of income. The climatic conditions vary from desert, with no rainfall, in the North, to a typical equatorial type climate in the South. The area in between varies from semi-desert, savanna to rich savanna climate.

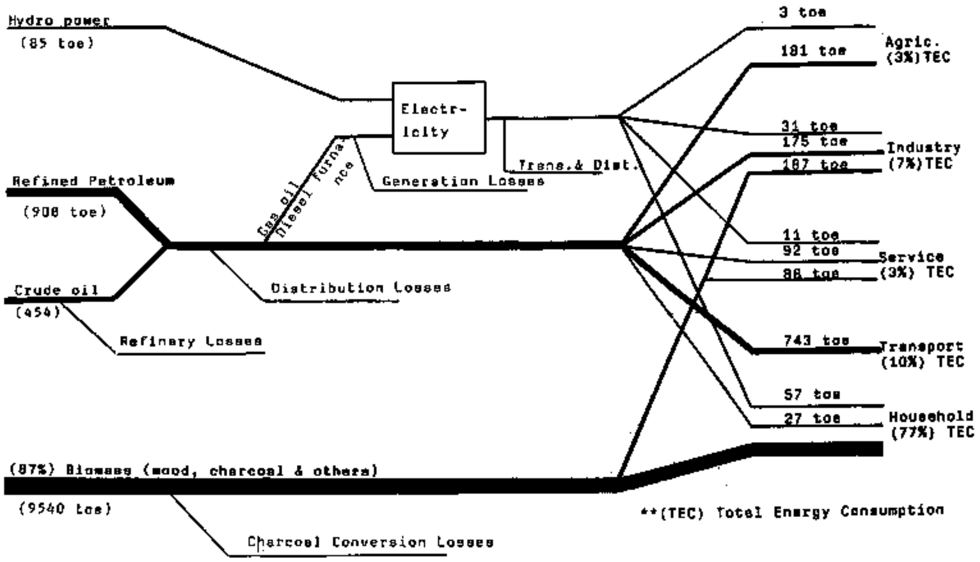
During the last two decades, the economy suffered major structural imbalances between imports and exports, and expenditure and revenue. This effect is reflected in the resulting energy problems and environmental destruction.

2.0 THE SUPPLY DEMAND PATTERNS

The total energy supply of Sudan is approximately 10.9 x 106 Toe. Biomass is the major source of energy. Its share accounts for 87% of which wood makes up 89%. The rural population relies more on wood while the urban dwellers use charcoal. This indicates a heavy exploitation of forestry resources.

The household sector accounts for 77% of the total energy consumption (TEC). 7% of the TEC used by the industrial sector comes from petroleum, biomass and electricity. The transportation sector takes 10% of the TEC. This sector takes almost 60% of the total petroleum consumption. The agricultural and service sectors consume 3% of the TEC each. Figure 1 shows Sudan's energy balance for the year 1991.

Fig. 1: Sudan's energy balance for the year 1991



Sudan suffers critical energy problems, especially in the remote areas where there are relatively high population densities. The uncontrolled exploitation of forest resources has resulted in deforestation with a subsequent loss of vegetative cover eventually leading to serious desertification. The rate of desertification is estimated to be 10 km annually. Thus, in 1985, the country suffered drought and hunger in most of the rural and nomadic areas, resulting in starvation of both human beings and their animals. High rural to urban migration has increased in the region over the last few decades.

The energy balance of the Sudan shows heavy biomass consumption, particularly in the household sector. In order to cope, energy conservation programmes such as the improved charcoal stoves have been introduced. Electricity conservation is also addressed through the promotion of energy saving activities in the industrial sector and the reduction of consumption through tariffs in the residential areas. Another conservation measure is the planting of trees and the promotion of sustainable energy programmes.

The Solar Energy Potential

Solar energy represents a vast energy source that is available in many areas where conventional energy supply is extremely expensive. The large scale contribution of solar energy to the economy of the Sudan is expected to be in medium and low temperature applications.

High levels of solar radiation have been recorded all over the country, where the duration of sun-shine ranges between 10 and 12 hours daily with an average solar radiation of 20 to 25 MJ/M2/day. Climatic data in 70 stations have been recorded since 1957. Among the recorded data are hourly total direct and diffuse solar radiation on a horizontal surface.

Rising sand and sand storms are major causes of the diffused radiation. Despite this, Sudan has a considerable potential for solar energy, 7 to 9GJ/m2/year, on the horizontal surface.

3.0 SOLAR THERMAL APPLICATIONS

High Temperature Application: Solar Water Boiler

In Sudan, the national electric grid extension extends to the central region where there is a high population density. Due to the vastness of the country, it is difficult to supply remote regions with electric energy. Solar energy seems the appropriate solution. A solar water boiler is designed to supply sterilized water at remote medical stations.

Principle of Operation

The functional components of the system are shown below. Water flows from the storage tank [A] and passes through a solar collector [B] to the outlet pipe [C] which has an additional height [H] over the water level in the storage tank. When boiling, water vapour causes an overflow of boiling water which then collects in a suitable vessel [D].

In order to achieve a temperature of approximately 1000C, the boiler's tubular vacuum collector with a selective absorber coating is used. In addition, booster mirrors concentrate the direct beam radiation by a factor of four. The booster mirrors are non-tracking, and require adjustment to the sun's elevation every 2 to 3 weeks.

During testing, the following parameters were measured:

- Hourly integrated values of the global and diffused solar radiation;
- ambient air temperature;
- wind speed; and,
- amount of collected boiled water per hour.

When the atmospheric temperature was between 27 °C and 37 °C, the amount of boiled water collected was 41.7 litres. The performance in the afternoon was significantly higher than in the morning.

Long Term Performance

The system has been in operation for 7 months. The output dropped significantly after 2 months due to the deposition of minerals in the boiling duct of the collector. After cleaning, its performance improved. The system performance could be increased by using a heat exchanger between the boiling water and the collector inlet or by pre-heating the incoming water using, for example, a flat plate collector.

ERI recently developed and tested a solar system with a concentrator mirror. This system is proposed for use in small industries such as the soap, soft drinks and milk processing industries. The aim is to supply hot water needed for thermal processes of up to 80°C.

Low Temperature Application: Solar Water Heaters

In Sudan, different methods have been used to heat water. The main types of heaters are:

(a) electrical heaters;

(b) fossil fuel heaters; and,

(c) biomass fuel heaters which use fire wood, charcoal, residues and animal waste.

The extent to which these heaters are used in the rural household depends on the availability of the fuel and its cost. However, the rural household relies mainly on biomass and animal waste, both of which are getting scarce and more costly. Hence the need to emphasize the use of solar water heating systems for the provision of hot water. At the same time, solar water heaters seem to be appropriate for public services and community centres, where hot water is desired e.g. hotels, hospitals, laundries etc.

Technical Package

Different system designs were developed, tested and evaluated. Usually the following assumptions were made:

- a steady state exists;
- the supply tank provides a uniform flow to the tubes;
- there is a one dimensional heat flow through the covers and back insulation;
- the temperature gradient around the tube can be neglected;
- the effect of dust and dirt on the collector are negligible; and,
- the heat capacity of the glass cover is not considered.

System Design

The main components could be summarised as follows:

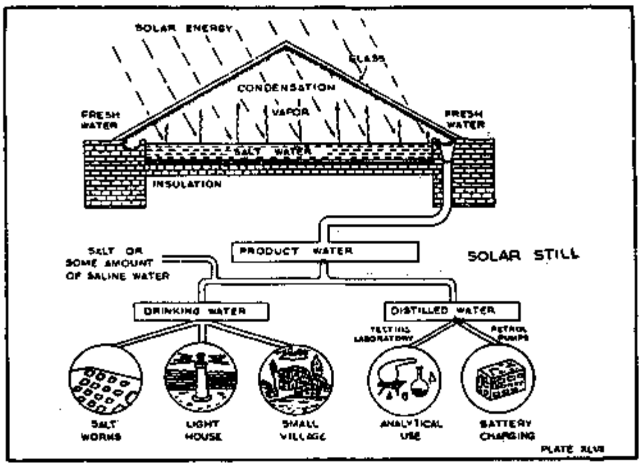
- galvanized steel tubes;
- flat and corrugated galvanized plates;
- galvanized pipe connections and fittings;
- sawdust, fibre glass, white polythene and glass wood for insulation; and,
- a 2mm glass cover.

All these components are available in the local market, which is an advantage, given the unavailability of hard currency.

Solar Distillation and Desalination

Various simple designs of solar distillation and desalination systems were developed using locally available materials. Among these are: a wooden frame with a glass cover, which is usually for small scale size production; or easy construction made out of bricks for relatively large scale use.

Figure 2: Solar Still



The following parameters have been considered in the designs:

- the availability of local materials instead of imported ones;
- available skills among the local crafts people and the technology development level of our local industries; and,
- techno-economic factors such as the durability of materials; performance of the still; operation and maintenance problems; and the simplicity in construction of the various designs was carefully considered and analyzed.

Distilled water is needed for industry, for instance in the making of perfumes and accumulator batteries. It is suitable in regions where clean drinking water is not available such as the coastal areas.

Solar Cookers

Different types and sizes of solar cookers have been developed, tested and disseminated by the ERI. Both household family size cookers as well as community type solar cookers for use in hospitals, camps, prisons or schools were designed and tested.

A box type solar cooker, as shown below, consists of a wooden box that is perfectly insulated. A galvanized iron sheet painted black was used as an absorber. Double glass was used, but sometimes single glazing was used. The glass panes were fixed to the wooden frame with flexible adhesives to avoid breakage during expansion.

To increase the amount of solar radiation falling on the collector plate, a reflector was used. The optimum reflector angle was calculated using a standard formula. The optimum tilt angle of the reflector was found to be 82 degrees. Results of a water boiling test with the solar box cooker are presented in Table 1 below.

Figure 3: Box-type Solar cooker

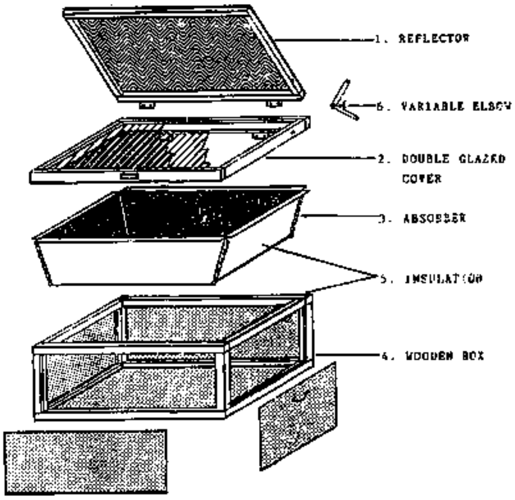


Table 1: Water Boiling Test with Solar Cooker

Time (a.m)	Air Temp. °C	Late Temp. °C	Pot temp. °C	Total(watt/m) radiation
9:30	24	44	22	676
10:00	25	133	49	697
10:30	27	147	80	881
11:00	28	156	102	881
11:30	31	160	102	882
12:00	31	167	102	861

As mentioned previously, the ERI disseminated this technology, but there are still some constraints in household preference. The solar cooker has to be adjusted regularly and the cost of the wooden box is relatively high. More recently, a hard cardboard (carton) solar cooker has been developed and tested. In addition, both single and double glazing types were tested and compared with the wooden type. The techno-economical analysis showed promising results. However, the life-time of the glazed type is expected to be less than that of the wooden box.

Solar Driven Cold Store: System Description

The main components of the system are:

Solar Collector Field

A solar collector field of 80 m^2 was constructed. It consisted of four parallel groups of solar collection. In each group, the 9 solar collector modules were connected in series, each with 18 tubes. No reflectors were used.

Refrigerator

A single-state, ammonia-water absorption refrigerator was used. It consists of a condenser, absorber, rectifier, solutions pump and under cooler. An integrated generator/solar array was used instead of a conventional generator.

The evaporator is integrated with the cold buffer. The rich ammonia-water mixture from the absorber is fed into the headers of the solar collector modules. Ammonia evaporates in these headers and is collected and directed to the rectifier. A wanner hydrocele membrane pump is used to pump the ammonia-water mixture from the absorber to the integrated generator collector.

The cold room was constructed from pre-fabricated panels with polyurethane, 8 cm thick, as insulation material. The dimensions are 5x5x5m. Ten parallel evaporator plates, each surrounded by a metal reservoir, and containing approximately 500 litres of water, provide the system's cooling power and act as a cold buffer. Provision is made for the ammonia to be fed into an air cooler instead of the evaporator/cold buffer configuration.

Cooling Water System

The cooling water system mainly consists of an evaporative water cooling tower fitted with a fan and cooling water pump. The cooling water is fed in parallel to the condenser, the absorber and the rectifier. The water in the system is regularly replenished from a water tower at the Soda test site. This water is pumped from a well (30m depth) to the water tower with a water pump driven by photovoltaic cells.

Data Collection

A 48-channel data collection system has been installed in a dust-free-room. The temperature, pressure, solar radiation level and flow sensors are connected to an AD convertor. Data is collected by computer and regularly analyzed and printed. This enables the operator to get a quick overview of the status of the system. The heat flow to the different components can also be calculated from the data.

Results

The following items were taken into account:

- the total system efficiency and the daily cold production under various conditions were determined;
- the heat flow through the walls of the cold room and the minimum cold room temperature; and,
- the behaviour of the system when the cold room is loaded with agricultural products.

Total System Performance

After carrying out the test, data related to the total system performance was obtained. The system attained 3kW (24 hour average) and 13kW (peak) cooling power under existing climatic conditions in March.

The total system efficiency is 13% which is lower than the anticipated 18%. The system efficiency decreases with decreasing area, which can be explained by the relatively higher heat losses at the lower area. Similarly, the cooling water temperature strongly influences the system efficiency. The water flow to the absorber and condenser has to be maintained for good system efficiency.

One can conclude that the lower than expected total system efficiency is due to the unexpected flow patterns in the collector field and is caused by an equal distribution of parallel flows.

Cold Room Behaviour

Tests were carried out to determine the behaviour of the cold room, that is, the minimum room temperature and the insulation losses.

The following conclusions were drawn:

- the minimum temperature achieved in the cold room was 7°C when the store was unloaded, while the buffer had a temperature of 0°C. This is higher than the design value of 3°C and is due to the relative low heat transfer to the evaporator. It can be improved by:
- introducing a fan to increase air velocity;
- introducing more evaporator area; or,
- improving the insolation value of the walls (K=0.26 W/m² K).

Solar Crop Drying

Traditional drying is the most common process in food preservation in Sudan. Drying is carried out by spreading the product on paved ground in thin layers. It is turned occasionally to ensure uniform drying or hung by chords suspended between poles and exposed to direct sun and wind. When there is rain or a storm, the product on the ground is piled and covered with an impervious material. These methods are unsatisfactory for a number of reasons, namely:

- the lack of, or little control over the drying period;
- the inability to ensure uniform drying; and,
- the possibility of loss through contamination by dust, rain and attacks by birds and animals.

Solar energy, under relatively controlled temperature and humidity, is a promising alternative to traditional drying practices. The ERI developed and tested solar crop dryers which were simple, affordable and from locally available materials.

4.0 COMMERCIALIZATION AND DISSEMINATION

The dissemination of the renewable energy technologies depends on the type of the technology to be disseminated and the target group. The different types of solar thermal energy applications require different approaches. Therefore, it is not possible to give an ideal method. However, except for solar cookers, the dissemination of solar thermal technologies in particular, is based on subsidies.

The problem with research in renewable energy is that budget allocations are usually low and insufficient. This is mainly due to government policies.

Therefore, foreign funding forms the bulk of funding for renewable energy projects. One of the problems with external funding is that it comes with conditions which may not fall within the country's research priorities.

On solar thermal energy, the work done has been confined to technology development and demonstration. No real dissemination has been carried out until now.

The fact that renewable energies are capital-intensive especially when they are imported, is in itself a constraint to its commercialization and dissemination. Locally manufactured solar thermal technologies might perform better, especially in the long term. Low cost and reliable solar thermal technology should be made available, for successful commercialization and dissemination.

Sustainability

To encourage the dissemination of solar thermal applications in the country there should be no subsidies. Producers and end-users should be able to sell and purchase their products at market prices. Sustainability does not refer only to the sustainability of one production company or possibly other manufacturers or importers. It refers to the achievement of the long term objective - the wide dissemination of the technology.

The idea is to both sustain what was implemented and also initiate a process of sustained development in the production and availability of solar thermal technology. This implies the involvement of not only the producers but also those organizations which determine the social environment within which the producers operate. Thus, in order to sustain renewable energy technologies, participation by the Sudanese government, the manufacturers, the end-users and other relevant organisations is a fundamental requirement.

4.0 THE ROLE OF INSTITUTIONS

The main institutions dealing with energy are the Energy Research Institute (ERI), the University of Khartoum (Faculty of Engineering) and the National Energy Administration (NEA). Although the institutions are few and their mandates clear, coordination between them is lacking, resulting in duplication of work.

The Energy Research Institute (ERI)

This institute is part of the National Council for Research in Sudan. It is responsible for research and development in the field of renewable energy. It also promotes the commercialization and dissemination of these technologies. Most of the work presented in this paper was done by ERI.

University of Khartoum

Research in the field of energy is done mainly by the Faculty of Engineering. Although carried out mainly for academic purposes, their work is recognised as a considerable effort in the promotion of research in renewable energy.

The National Energy Administration [NEA]

In 1980, NEA was created under the Ministry of Energy and Mining. The NEA is responsible for developing strategies for the energy sector and overall sectoral planning. Commercialization and dissemination are part of its activities. The work of the NEA is complemented by that of the other research-orientated agencies mainly, the ERI and the University of Khartoum.

5.0 CONCLUSION

The limited exhaustible energy resource, and the heavy dependence on traditionally available fuel, biomass, which resulted in fuel shortages and high prices, will pave the way for the wider application of solar energy in Sudan.

There is a large potential for solar thermal technology application in Sudan. The sun shines almost all day long in almost all parts of the country, except during the very short rainy seasons. The technology is available and the need for this technology is felt widely.

The use of local materials, whenever possible, should be emphasized in order to make solar thermal equipments available since limited funds are the main constraint to the commercialization and dissemination of the technologies. Low cost designs as well as reliable equipment have to be provided. The demonstration and dissemination of solar thermal technology need to be emphasized through thoroughly prepared projects so as to popularize the technology all over the country.

The full participation of the government, donor organizations, producer and end-users is required, in order to realize solar thermal applications in Sudan.

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DISCUSSION

The following are some of the issues that arose from the presentation:

- The lack of ongoing investigations on the utilization of local material. For instance, glass covers, and the selective performance of paints, because of lack of proper laboratory equipment.
- The need for co-operation with other countries in the region for the purposes of networking.
- The ongoing civil war in Sudan has had a negative impact upon RETs research programmes.

TANZANIA

BIOLATRINE TECHNOLOGY: THE CASE OF TANZANIA

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CAMARTEC

and Anna Ingwe
SEP/CAMARTEC

SUMMARY

One of the key needs for improved standards of living for people of the developing countries is energy for basic services, like food preparation and lighting. In addition, as society expands, sanitation is also an important area to monitor. In renewable energy technologies, biogas technology can be employed in localities endowed with biomass for the supply of energy while improving and maintaining good sanitation.

Within the Biogas Extension Unit of CAMARTEC, biolatrines have been developed for the safe disposal of human waste and energy recovery. After the initial positive results of the units which have been field tested since 1989, it has become necessary to carry out further research in the techniques, cultural aspects and the socio-economic environment, for future use.

This presentation will provide brief technical information on biolatrines and the research and development work undertaken by CAMARTEC, Tanzania.

1.0 INTRODUCTION

Biogas plants operate in anaerobic conditions. Biological and chemical actions eradicate most of the pathogens found in human wastes. A long residence of the pathogens in the digester means more elimination but not of the methane bacteria.

There are advantages accrued from biogas technology which include:

- the treatment of human wastes for sanitary disposal in the environment eliminates human pathogens and the unstable organic substances are reduced to a more stable form;
- the provision of biomass energy for lighting and heating purpose; and,
- the provision of a safe organic fertilizer as moisture and assimilable nitrogen compounds can limit crop production during certain periods of the year and in many soils.

Biolatrine plants have been designed and developed to improve environmental sanitation through the safe disposal of human wastes. Biolatrines supply energy from biogas whose effluent is a safe organic fertilizer for poor soils.

When organic wastes decompose, the chemically unstable substances are reduced to simpler stable forms. The heat released during this process would otherwise burn plant roots if the organic wastes were applied on farms without such treatment.

Medical laboratory tests have shown that biolatrine effluent is free from pathogens and can therefore be used as a fertilizer. Despite scientific proof, however, this organic fertilizer has been accepted by few farmers for cultural reasons. In many societies, working on human wastes is looked down upon. However, it is still important to put up demonstration units where people can learn alternative ways of disposing human wastes through treatment and at the same time produce energy.

In order to sustain the existing positive image of the biolatrine, biolatrine systems have to be planned and installed carefully by competent persons who employ the latest technical know-how.

2.0 BIOLATRINE TECHNOLOGY

A biolatrine is a unit of the biogas plants which use animal waste and once ventilated improves pit latrines (VIP latrines). Like the fixed dome biogas plants, they are constructed from locally available building materials like sand, cement, lime, brick and piping materials.

Biolatrines units serve primarily for sanitation to achieve environmental hygienic standards. In addition, biogas for lighting, supporting bunsen burners in laboratories and cooking is obtained.

At the household level, toilet provision can be incorporated into the agricultural biogas units, in which case the latrines are taken care of on a permanent basis.

For schools and colleges, the impact of biolatrines is more pronounced. In some cases, institutions have opted for biolatrines where there are problems with existing toilet systems like frequent digging in a limited area and unreliable water supply.

To maximize the benefits of biolatrine technology the effluent is utilized as a fertilizer. However, prior to this, it has to be proved safe and acceptable to the user. This is an important research and development area for the increased use of biogas technology.

Standardization of Biolatrines

Biolatrine digesters may be in the range of 8, 12, 16, 30 and 50m³ in singles or combined, depending on the size of the population and their settlements. In the digester, temperatures range between 20-25°C. Most human pathogens are eliminated within 100 days of retention time.

The amount of adult human wastes may be: 300 - 500 grams of faeces and 1-3 litres of urine per day. The estimated volume available for the biolatrine is therefore about 3.5 litres per person per day.

Mathematical Formula

$$\text{Wastes retention time in the digester [RT]} = \frac{\text{Digester capacity [vd]}}{\text{Daily feed volume [vf]}}$$

$$\text{that is RT} = \frac{vd}{vf}$$

By using this formula, the following results are obtained:

vd (m³)	vf (1)	RT (days)	No. of People	Biogas Volume (m³)2*
8	80	100	1 - 20 *1	3
12	120	160	1 - 30 *1	4
16	160	100	1 - 30 *1	6
30	300	100	40 - 80	12
50	500	100	80 - 140	120

1* Digesters in the of range 8-16m³ have been indicatedpossible. Even for one person, where resources are available due to insignificant final cost, differences show in the construction and gas piping of the digester.

2* Biogas production has been estimated on the following conditions:

- 22-25°C;
- Total solid contents - TSC 10%; and,
- Simple non-stirred digesters.

Values for vf and RT are based on non-flush toilets whereas the addition of water to urine is from anal cleaning only.

Should biolatrine digesters be fed from flush toilets, the following estimation path should be used:

- 300-500 grams of faeces per day;
- 3 litres of urine per day; and,

5 litres flush water per day.

Total: 8.5 litres of waste

from the formula RT = vd/vf and

safe value for RT = 100

then 100 = vd/V

from 40 persons, the suitable digester capacity is;

Vd x 100 x Vf = 100 x 8.5 l x 40 = 34000l = 34m³

This indicates that a digester that is 16m³ is no longer appropriate but 34m³ for the same effluent is. Such a digester will cost more money which may be justified depending on the case. In practice a 30m³ would be built.

An Estimate of Number of Cabins

- On average a person would require 5 minutes in the toilet;
- In 1 hour, about 10 persons may visit one toilet cabin.

This different categories use toilets differently:

- In offices, schools, colleges and hospitals, the use of the toilets would be frequent providing the toilets are close by; and,
- Army soldiers, polices and prisoners, may at times be working far away from their residences a situation which may necessitate a discipline to attend toilets only at specified times. Such a situation leads to a peak times when most of the people rush into the toilets.

Too few people will produce little biogas. The increased use ensures a presence of pathogens in the effluent due to a reduced retention time (RT).

In all institutions, sufficient care must be taken to find out in advance, the annual distribution of residents.

Planning for a Biolatrine

Biolatrines should be easily accessible for the people at any time of the day, all year round.

Biolatrines should be located on the leeward side of the offices or residences in order to minimize odour. It is important to have land area for effluent disposal, either by vehicle if the disposal area is far or if nearby, by physically carrying and applying it on the farm.

Only fairly upland and, non-water logged places should be chosen to handle biolatrine effluent. Like other biogas plants, the construction of the biolatrines during heavy rainy seasons should be discouraged.

Assuming that at anytime peak hours would be between 1 hour and 2 hours, the number of cabins will be shown on the table below:

Vd (m3)	RT (days)	No. of Persons attendants	No. of Cabins
8	100	20	2
12	10	30	4
16	100	40	4
30	100	140	8

Since people living as communities pose a relatively bigger problem in environmental sanitation, owing to their unsafe wastes disposal systems, and that we need wastes of 6 persons to generate energy sufficient for 1 person per day, it is safe to conclude that biolatrines are more suitable for institutions such as:

- schools and colleges;
- army camps, police and prison barracks; and,
- office, factories and industries.

Biolatrines will not work as expected in places where the number of attending persons fluctuates beyond the design figure.

3.0 PROMOTION

This technology is advertised through demonstration units and published materials. Training courses depend on demand. It is advisable that training teams be composed of technicians/engineers and artisans. Only properly qualified teams should be issued with certificates and allowed to undertake construction.

In order to avoid biolatrine system failures which may lead to disease outbreak and epidemics, strong quality control measures are needed.

CAMARTEC has established communication with potential user groups such as schools, colleges and hospitals where biolatrines would be appropriate. However, close ties and joint activities are expected from related ministries: education, health, and environment, as well as interested development agencies. Biolatrine technology would benefit greatly from further research and development.

4.0 POTENTIAL RESEARCH AND DEVELOPMENT AREAS

- research on the daily maintenance of the unit at different locations and institutions;
- an analysis of the area and degree of pathogen concentration of the biolatrine system;
- an analysis of the manure value of the effluent on different crops/vegetables; and,
- research into the optimum retenion time for pathogen elimination and maximum gas production.

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DISCUSSION

The following are some of the issues resulting from the presentation:

- The lack of an integrated approah in biogas technology dissemination in developing countries.
- The lack of farmer motivation to invest in biogas plants due to the reduction in performance with time due to lack of proper maintenance
- The change in target group of biogas technology users. Initially the technology was meant for the poor but presently the technology is accessible only to farmers with high incomes.
- The improper way in which farmers and small butcheries dispose of waste containing fats.
- The incorporation of an integrated approach toward the technology in order to make it sustainable.
- Some disadvantages of biogas technology such as: maintenance is a time-intensive activity; and, insufficient energy for daily requirements. For instance, some traditional meals cannot be prepared by smaller ($10m^3$) plants.

EDUCATIONAL AND TRAINING INSTITUTIONS IN SOLAR TECHNOLOGY: THE CASE OF UGANDA

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ABSTRACT

Solar energy seems the most promising solution to the energy shortages, worldwide. Spurred by dwindling reserves, escalating costs and an uncertain future for fossil fuels, research and development in solar energy is proceeding fast. New break-throughs in theory and practice are occurring more frequently, bringing with them a new demand for trained technical and professional personnel. These demands will have to be met by universities, technical institutes and other organised educational programs on solar technology.

This paper therefore discusses strategies to be taken immediately, in order to adequately prepare for the increasing demand for development and the application of solar technology in the region.

1.0 INTRODUCTION

Uganda is a small land-locked country located in the eastern part of Africa. She occupies an area of about 236,000 km^2 and has a total population of approximately 17 million people. 90% of these live in the rural areas.

Uganda lies within the tropics and is cut in half by the equator. Thus, she experiences the equatorial climate (hot and wet seasons throughout the year). The country receives large quantities of solar radiation. The climate also encourages growth of thick forests and savanna-type vegetation.

Uganda is an agricultural country, producing coffee, cotton, tea and tobacco for export, and sugar cane, maize, beans, ground nuts, rice and peas for subsistence.

Energy Potential

Uganda's energy potential is high: hydroelectric, solar, biomass, wind, and small deposits of petroleum deposits are all available.

There are many rivers, with water falls all over the country, that can be used for hydroelectric power generation. It is estimated that the total hydroelectric power available is about 2500MW, most of which is concentrated along river Nile.

Being within the tropics and along the equator, the country receives large quantities of solar radiation with an average of 1.7KJ/cm^2/day almost anywhere in the country, and 6-8 hours of bright sunshine every day.

Wind power is available in very low quantities, and even then, it is very unreliable. The average wind speed is 2.0 m/s which is too low for the economical generation of electricity. However, it can be used for water pumping.

The climate encourages the growth of thick forests from which firewood and charcoal are obtained. However, the forest land is decreasing at an alarming rate as forests are cleared for agriculture and fuelwood.

As an agricultural country, Uganda has a lot of agro-wastes such as coffee husks, bagasse, cotton stalks and rice husks, all of which can be used to provide energy. Animal waste, especially cow dung, is available in sufficient quantities almost in every household in the rural areas. Biogas production is feasible in most parts of the country.

There exists deposits of petroleum in the western part of the country but quantities have not been determined for drilling to be done.

Present Level of Utilization

In the urban centres, most households, commercial and industrial sectors use electricity for their energy needs. In addition, firewood and charcoal are used for cooking while fossil fuels are used in the transport sector. In the rural areas, where 90% of the total population lives, firewood and charcoal are the major sources of energy for cooking while paraffin is used for lighting.

Women and children spend many hours each day, walking long distances in search of firewood. A lot of scattered trees have been cut and forests cleared leaving behind bare soils, resulting in severe soil erosion. In some regions of the country, households are now forced to spend their meagre incomes on firewood as free trees to cut hardly exist any more.

Solar energy, is still used for the drying of agricultural produce like coffee, groundnuts, maize, beans and tobacco. This is done by spreading the products on the ground and leaving them to dry.

A few solar cookers have been constructed and tested. Electricity from photovoltaics (PV) is currently used for powering communication equipment, refrigeration and lighting systems in remote areas. However, so far the use of PV is not widespread, partly due to the lack of awareness among the populace, but mainly due to the high cost.

However, energy from the sun accounts for the earth's largest energy resource. It has several advantages. Although it is not stored in a reserve where it can be drawn when required, solar energy is continuously being produced. It is inexhaustible, and the use of any amount of solar power, in no way diminishes tommorrow's supply. It does not have to be imported and neither does it have to be hauled or piped to the point of use. It is readily available at any location wherever the sun shines. It is non-polluting, has little, if any, adverse environmental impact, and leaves no residue or industrial waste.

2.0 CAREER DEVELOPMENT IN SOLAR ENGINEERING

Time is now ripe for students to take up careers in solar engineering. Opportunities will increase in numbers as the solar industry grows. Like other industries, the best jobs in the field will be held by these men and women who have prepared themselves with a solid background in theory and application. Preparation for this level of study requires one to have undertaken, at the minimum, undergraduate studies either in architecture or engineering. In addition, the studies should include or provide options for basic courses in environmental science.

Presently, those engaged in work on solar applications are either trained as engineering technologists or scientists through bachelor of engineering or science programmes. However, persons already possessing basic technician training or experience can avail themselves for short term training courses in solar technology.

3.0 CURRICULUM DESIGN

At present, no institutions exist in the region which train people in the field of renewable energies. Most of the experts in the field are trained abroad. Consequently, the numbers are still small. Therefore, there is need to train people locally to increase the numbers. This calls for the revision of the current curriculum in the universities and other technical institutes, or to set up regional centres for energy studies - like the Indian Institute of Technology, India , or the University of Oldenburg, Germany - which offer post-graduate training in renewable energy, or create appropriate technology centres like the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) in Tanzania.

The Makerere University's, Department of Electrical Engineering has taken the initiative to revise the curriculum to include the teaching of non-conventional sources of energy at the undergraduate level. Accordingly, our laboratories need to be updated to include simple experiments, for example, on the characteristics of solar cells, solar collectors, etc.

4.0 RESEARCH AND DEVELOPMENT (R&D)

There is a growing need for the experts to carry out R&D in the field of renewable energies, to enhance their application. This research should be done in collaboration with institutions of higher learning who have adequate laboratory and test facilities, and government bodies (e.g the Ministry of Energy). Collaboration with international bodies should be encouraged and where possible, joint research undertaken. This could lead to inter-regional consultancy and contracting. The results of research should be published in newsletters for the benefit of all those in the region since the problems faced are similar. Newsletters or journals for the region should be published to promote the activities of the experts in the field of solar energy in particular, and renewable energy in general.

5.0 CONCLUSION

Strategies to be adopted for the promotion of solar energy use in the region have been identified. The training of personnel in the field of solar technology has rated highest. However, for the successful implementation of these programs, a lot of funds are required. A special appeal is made to governments and other agencies to avail funds for research and development and if possible for the setting up of centres for the teaching and development of solar technology and other renewable energy technologies in the sub-region.

DISCUSSION

The following issues were discussed after the presentation:

- The need for a Sub-Saharan African Information Exchange Network on Renewable Energy.
- The role of institutions of higher learning in the education and training of RETs:
  - Polytechnic courses in the maintenance and operation of RETs; and,
  - Universities courses in the design and development of RETs.
- The need to incorporate the socio-economic aspects of RETs in the region.
- The appropriateness of the new syllabus at University of Makerere that incorporates basic training in renewable energy.
- The lack of follow-up in renewable energy projects - a key factor in the failure of such projects in the region.

PART FIVE: AN EVALUATION OF THE "RENEWABLE ENERGIES" COURSE

OPENING ADDRESS

By Ada-Samira Osinski, DAAD Regional Office-Nairobi

Distinguished Guests, DAAD Fellows, Ladies and Gentlemen,

On behalf of Mr. Helfer, the regional director of the German Academic Exchange Service, who is on mission in Germany, I would like to extend greetings and best wishes from the DAAD to you all as you embark on this important seminar. We especially thank KENGO for having taken the initiative and invested a lot of work to organize this seminar. We are also very grateful to the Kenya DAAD scholars Association for their participation in this function. It shows that the greater family of DAAD scholars takes much interest in fostering scientific co-operation between Germany and African countries.

We from DAAD are particularly glad that this seminar - though called on rather short notice - could be organized. It is an important step in our endeavour to bring together scientists from different African countries. Those who have undergone a particular DAAD scholarship scheme after they have returned from their postgraduate training in Germany, and have taken up professional work in their home countries, and bring them together with other African specialists in other fields, to exchange views and experiences.

We extend our very warm greetings to our German guests from the Universities of Oldenburg and Bremen who have accepted our invitation to participate in this seminar, and to share their experiences with their African colleagues.

The scholarship scheme under which these DAAD scholars got specialized postgraduate training at the University of Oldenburg was launched only a few years ago with financial assistance from the Germany Ministry of Economic Co-operation which is in-charge of German development aid. Its special aim is to encourage German Universities and Fachhochschulen to build up postgraduate courses with special relevance to developing countries. These courses should be open to German students and students from developing countries to initiate science-related interaction between them. The aim is to sensitize both groups on the need to enhance scientific co-operation in various fields between developing countries and developed countries like Germany.

The programme has picked up very well and presently about 20 German Universities and Fachhochschulen have joined the scheme with a wide range of specialized development related courses. The schemes seem to have become very popular with students of developing countries all over the world, although only few of these courses lead to a formal degree.

For the first time, we are able to sponsor a seminar with a regional outlook that brings together a group of African postgraduate students who underwent the same course in Germany two years ago, and who, since then, have been able to apply what they learnt to their professional work.

It is, for them, and also for their German lecturers, - some of whom we are glad to have with us today - and for DAAD, a unique opportunity to assess and evaluate the usefulness of the programme and, in particular, the course at the University of Oldenburg.

The University of Oldenburg and especially the representative from the "Renewable Energy Course" deserve our special thanks, for their initiative and tireless work in assisting developing countries to train specialized personnel in the vital area of renewable energy.

We hope that a lot of new ideas and initiatives will come out of the deliberations of this seminar and that continued scientific cooperation between all the participants can be established and nurtured.

From DAAD's side we wish the seminar full success.

Thank you.

Hans M. Helfer; Regional Director; DAAD Regional Office-Nairobi

THE RENEWABLE ENERGY EDUCATION PROGRAMME IN OLDENBURG

By
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THE POSTGRADUATE COURSE

This one-year MSc. Course has been running since 1987. It is aimed at students with an academic education of at least four years in engineering or natural sciences who intend to apply their knowledge about Renewable Energies in their future occupational work.

From 1987 to 1993 a total of 72 engineers from all over the world had participated in the course. Figure 1 shows the distribution of students by origin and figure 2 their specialization during the undergraduate studies.

Figure 1: Regional Distribution of Students Origin

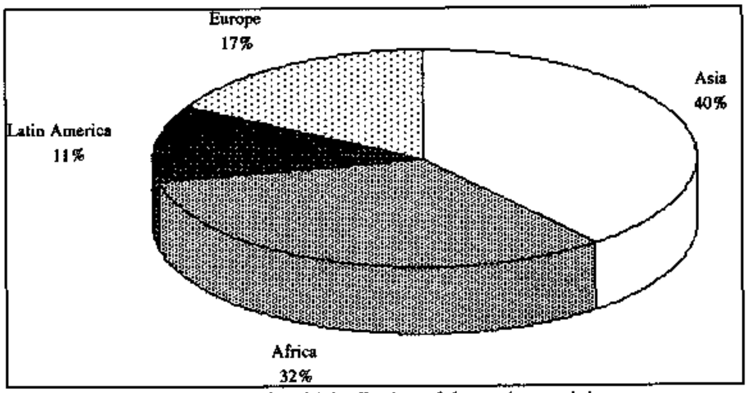

Figure 1: Regional Distribution of the students origin

Figure 2: Distribution of the Students Undergraduate Specialization

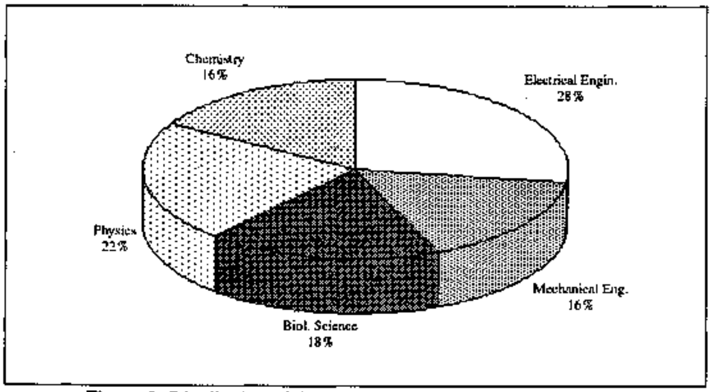

Figure 2: Distribution of the students undergraduate specialization

COURSE OBJECTIVES

- Scientific principle of renewable energies;
- technical feasibility of renewable energy systems;
- economic theory of energy resources;
- components of small-scale energy supply systems (Lab);
- analysis, simulation and design of energy systems;
- case studies;
- thesis on a subject related to the participants' future occupation; and,
- 8 weeks external practical training with enterprises and institutions concerned with energy systems.

TOPICS OF THE SYLLABUS

- Photovoltaics;
- solar thermal conversion;
- wind energy conversion;
- (Micro) hydro power;
- energy from biomass; and,
- storage components (electric and thermal).

The scientific level of the lectures, seminars and laboratory classes is such that the theoretical background is profound enough not only to apply but to understand renewable energy systems, their positive impacts and their limitations. On the other hand, the application of RETs should be matched by the practical problems in the field. Figure 3 gives a picture of the distribution of the different classes regarding lecture hours.

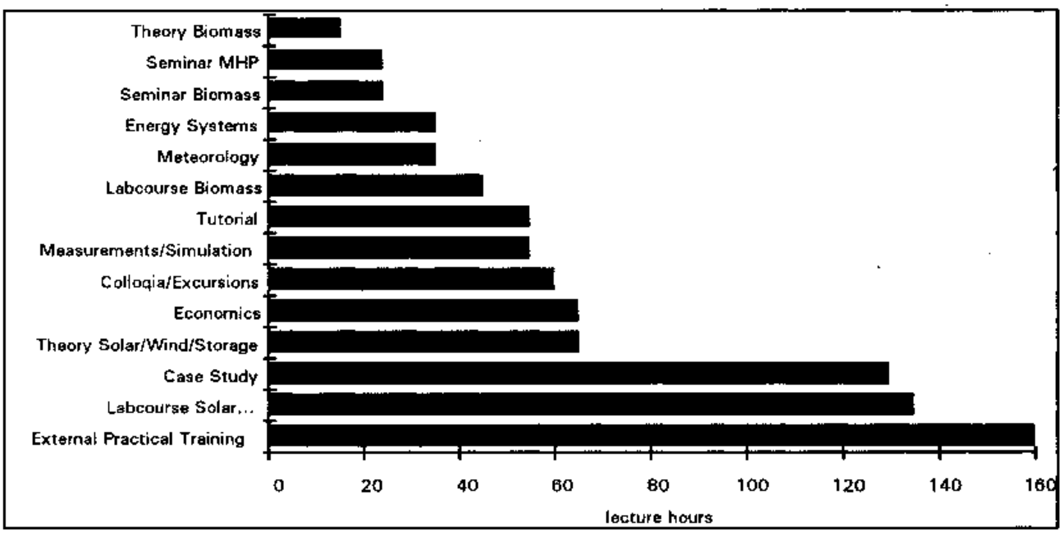

Figure 3: Distribution of Lecture Hours
(Total: ≈ 700 lecture hours + external practical training + thesis work)

Figure 4 shows the number of hours dedicated to the different RETs' Principles of Renewable Energies in the basic lectures. (Biomass use is not included in this lecture but studied separately).

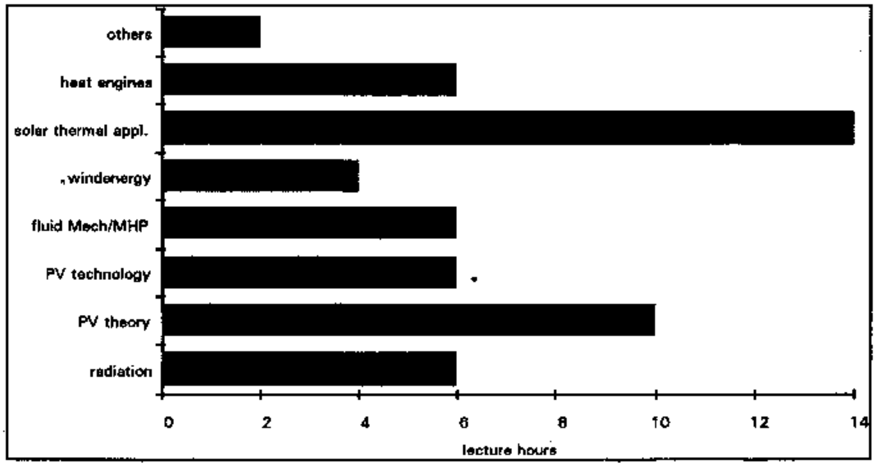

Figure 4:
Spectrum of the lecture principles of renewable energies (excluding biomass use)

After knowing the course structure - topics and time dedicated to them - it may be interesting to look at the student's decisions on the subjects of their final thesis. Thereafter, the course programme and interests of the participants can be compared (figure 5).

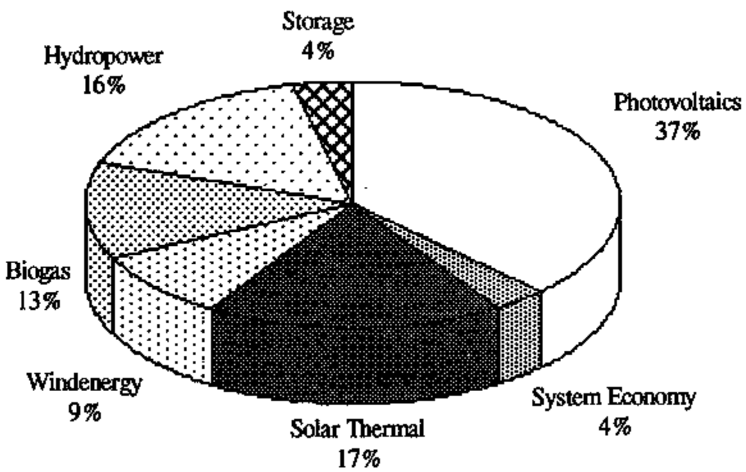

Figure 5: Subjects of thesis work
(The discussions of the Evaluation Workshop have been based on this information)

CURRICULUM GUIDELINES AND MATERIALS FOR PRE-UNIVERSITY EDUCATION

The five years experience on the Postgraduate Course in Renewable Energies was used to prepare curriculum guidelines and materials aimed at introducing RE into the undergraduate and postgraduate education of universities in developing countries. For this purpose, the Renewable Energy Group was contracted by GTZ in 1992, to develop curriculum guidelines within the frame of a Supra Regional Programme on New Energy Technologies of the German Ministry of Economic and Development Cooperation (BMZ). The materials will be available to all interested universities in June 1993.

To apply, evaluate and improve this approach, a corresponding project is to be launched at the University of Zimbabwe starting January 1994. Based on the materials developed in Oldenburg, a German expert will assist in creating a Renewable Energy Centre at the Faculty of Engineering, conducting RE education, research and dissemination in Zimbabwe.

SUMMER SCHOOLS ON SOLAR AND WIND TECHNOLOGIES CONDUCTED BY THE RENEWABLE ENERGY GROUP

Apart from the Postgraduate Course the Renewable Energy Group started a summer school programme in 1992. This is aimed at specialists from partner institutions working on Renewable Energy Dissemination Programmes of the German government in developing countries. Such programmes include the Photovoltaic Pumping Programme (PVP), Sonne 2 and Wind, which are part of the ELDORADO Programme funded by Germany's Ministry for Research and Technology. After focusing on PVP, the structure of the next summer schools are as shown in figure 6.

5 days DEWI/PRE	common seminar	1. introduction * rural energy supply * solar and wind technology applications * ecological aspects * social aspects	
3 days DEWI	excursions	2. field trips to solar and wind energy systems	
5 days each PRE(solar)/DEWI(wind)	special seminars	3. solar energy * solar radiation * solar cells * storage components	4. wind energy
5 days each PRE(solar)/DEWI(wind)	special seminars	5. PV technology application * PV systems * system design and optimization * system performance	6. wind technology appl.
5 days Inst. Political Economy, CvO	common seminar	7. economical analysis of renewable energy systems	
5 days PRE	seminar	8. case study	9. visits to manufacturers
1 day PRE/DEWI	common final session	10. final discussion conclusions evaluation of the summer school	

Figure 6:
Structure of summer schools

This paper explains how a university research group is able to contribute to education, training and dissemination in the field of renewable energies. What is necessary to succeed in introducing RE to the national energy supply systems is cooperation of all RE experts wherever they are working. Regional alumni associations of the university courses such as the MSc. course on Renewable Energies may contribute to this by building networks of knowledge exchange and personal assistance.

For further information, please contact, The Course Director, Renewable Energies, University of Oldenburg, Postfach 25 03, D-W-2900 Oldenburg, Germany. Tel. +49 441 798 3544, Fax +49 441 798 3326, Telex 25 655 unol d

RENEWABLE ENERGY EDUCATION AND TRAINING: EVALUATION OF THE POSTGRADUATE COURSE "RENEWABLE ENERGIES"

By
Dr. Ekkehart Naumann
Renewable Energies Course
Oldenburg

The workshop took place on two different afternoon sessions. The basis for this workshop was the presentation made by Dr. E. Naumann. It included facts about the postgraduate course and gave a detailed overview of its structure, contents, etc.

The main objectives of the workshop were:

- A comprehensive questionnaire, prepared by the instructors of the Postgraduate Course in Oldenburg, to evaluate the curricular approach. The questionnaire was first evaluated and discussed with participants from East Africa. Then the improved questionnaire would be sent to all former students of the postgraduate course for feed back.
- The overall course content and structure would be discussed between officials from the University of Oldenburg and former students from eastern Sub-Saharan-Africa. It would address how to improve it so that it meets the needs and occupational realities of the course participants upon their return home.
- The results of the programme-evaluation would be used to develop the framework of the curriculum, currently on-going at the University of Oldenburg. These proposals would be used as a framework to introduce similar courses at universities in developing countries in order to meet the needs of future specialists on Renewable Energy Technologies in their respective regions.

The results of the questionnaire and the evaluation workshop were as follows:

- The course concept and the single lectures were assessed quite differently, which means that the whole scale (1 = strongly agree, 5 = strongly disagree) was used. Hence one can assume that the answers were genuine in spite of the presence of the officials from the University. The discussions were fruitful and gave valuable information to improve the course.
- The expectations concerning the course had been more or less fulfilled. Overall, most of the subjects taught during the course proved relevant in the field in their home countries.
- However, it was proposed that the course content relate more closely to real-life situations. The students from East Africa are mostly involved in the dissemination of Renewable Energy Technologies in rural areas. Thus, situations in the field were such that the theoretical knowledge acquired in the course was inadequate in solving all of the problems. The necessary knowledge relating to the socio-cultural economic situation, planning, marketing and experiences from the other projects were lacking.
- The Postgraduate Course at the University is an academic training programme with a final award of an MSc. degree. However, it was unrealistic to try and acquire both the course content and practical experience all within only one year.

- Practical work should be given more emphasis in all theory classes. The former students underlined the importance of block seminars that involve other experts, cover laboratory work, case studies and the external practical training.

There was consensus among the participants that follow-up activities should be intensified, especially through direct contact between the former participants ("Local Networking").

These are only highlights. Detailed results from the workshop, are available on request.

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THE IMPORTANCE OF EDUCATION AND TRAINING IN RENEWABLE ENERGY TECHNOLOGY DISSEMINATION

By
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STATEMENT 1

RENEWABLE ENERGY SYSTEMS NEED TO CONSIST OF RELIABLE AND COMFORTABLE TECHNOLOGIES

As an acceptable technology to be disseminated through commercial marketing Renewable Energy Systems (RES) should be able to compete with traditional technologies in respect of reliability, comfort and costs. Of course, competition has to been fair, which means at least subsidies on fossil energy should be stopped or comparable subsidies have to be provided for RES; social and environmental costs of the competing technologies have to be considered.

This is quite a common experience from a lot of RES dissemination projects in the developing countries as well as in industrialized countries.

STATEMENT 2

RENEWABLE ENERGY SYSTEMS NEED SOCIAL ACCEPTANCE AND PRESTIGE

For commercialization RES not only have to be reliable, comfortable and affordable but customers should be proud to own such systems.

People not only shift over to new technologies, because they are competitive and appropriate, but because they want to improve their social status as well. Hence it follows that RES should not only be reliable but look convincing and professional.

STATEMENT 3

RENEWABLE ENERGY SYSTEMS NEED TO BE THE SUBJECT OF ADVANCED SCIENTIFIC RESEARCH AND EDUCATION

To improve technical standards and manufacture of system components, scientific research and development is needed.

To increase quality as well as social acceptance and prestige of a new technology the scientific community should estimate the respective subjects worth dealing with, publishing about, and introducing and educating young scientists in.

From history it may be learnt that funding of new technologies and a high standard of quality largely depend on the esteem for the respective fields in the scientific community.

High regard of renewable energy subjects within the scientific community and funding of the respective research and development by the government makes this field an attractive one to young scientists and engineers. Combined with dissemination and commercialization programmes a new field of qualified occupational work may be created.

Scientific research should not be overestimated with respect to commercialization of a new technology, because it is focusing on scientifically interesting items more than on practical aspects. But on the other hand, if intellectual elites accept this technology as important and advanced, it will be considered by the decision-makers in politics and industry.

STATEMENT 4

MAN POWER DEVELOPMENT: ENERGY SYSTEMS SHOULD INCLUDE LONG TERM SCIENTIFIC EDUCATION

Short-term training measures for project staff members in the field of RES are necessary. However, such training is not sufficient to undertake dissemination of the technologies successfully.

To create stable expertise on RES among energy experts, engineers and scientists should learn as much about photovoltaic, solar thermal appliances, wind energy conversion, fermentation of biomass, etc. including the respective theoretical background to common energy technologies such as combustion engines, thermal power plants, etc.

Of course, qualified personnel are required immediately to start and run projects in the field of RES. Therefore, we cannot wait for a new generation of experts scientifically educated in this field. Short-term measures are needed to train project staff members.

For the reasons mentioned above, manpower development programme should include both long-term education as well as short-term training.

Scientific research, development, education and training in renewable energies with regard to application and dissemination should be combined.

DAAD REGIONAL OFFICE FOR AFRICA - NAIROBI

By
Hans M. Helfer,
Regional Director DAAD-Nairobi

DAAD, the German Academic Exchange Service, is an organization of all institutions of Higher Education in the Federal Republic of Germany, founded in 1925. DAAD aims at promoting international university relations through academic and scientific exchange between the Federal Republic of Germany and foreign countries. DAAD activities are funded mainly by the German Foreign Office, the Ministry of Education and Science and, as far as educational assistance in developing countries is concerned, by the Ministry of Economic Co-operation.

In 1973, DAAD established a Regional Office for Africa in Nairobi to serve countries south of the Sahara, excluding the Republic of South Africa. Until 1982, the office was financed by the German Agency for Technical Co-operation (GTZ). It has since been fully taken over by DAAD. The office also continues to operate on behalf of GTZ in the field of higher education and research promotion in Africa and also represents the German Rectors Conference (HRK), the German Research Association (DFG), the Max-Planek-Society (MPG), the Alexander-von Humboldt-Foundation (AvH) and other German institutions dealing with scientific co-operation. There is also close co-operation with the Centre for International Migration and Development (CIM) and the German Foundation for International Development (DSE).

The objective of the DAAD Regional Office in Nairobi, which since 1985 works under its own bilateral Kenya-German governmental agreement, is: to co-ordinate all DAAD scholarships, fellowships, university staff recruitment, exchange programmes; to identify new approaches in educational and scientific co-operation; to maintain contacts with the African universities and to assist them in liaising with universities, research institutes; and organization of educational and scientific aid in Germany.

DAAD scholarships and staff recruitment/exchange schemes in Africa aim primarily at supporting the African universities in their staff development in a variety of subject areas, predominantly in science and agriculture, but also in medicine, veterinary science, engineering, architecture, education, population studies and other development oriented fields.

Scholarship applicants for "In-country" scholarships are pre-selected by the universities on the basis of academic performance and staff requirements without interference from the sponsor. Emphasis is laid on postgraduate studies.

There are also approximately 70 "Third-country" scholarship holders sent for postgraduate studies to Kenya from other universities in Africa. In addition, DAAD provides a number of scholarships for postgraduate studies for African students in the framework of exchange programmes of the Association of Faculties of Agriculture in Africa (AFAA), the African Regional Postgraduate Programme in Insect Science (ARPIS/ICIPE), the Natural Products Research Network for Eastern and Central Africa (NAPREGA) and is involved in the scholarship programme of GTZ for the African Network of Scientific and Technological Institutions (ANSTI).

There is also a small number of scholarships available each year for postgraduate studies (after masters) at German universities, part of them to be used for Ph.D. studies under the joint supervision of a Kenyan and German supervisor (sandwich scholarships). A new programme has been established to provide scholarships, at German universities and Fachhoschulen, for various postgraduate courses with special relevance to developing countries. These are being administered jointly with DAAD at the Carl-Duisberg-Gesellschaft (CDG). For those invited for long term studies in Germany, language courses are included.

DAAD also runs a programme for African university teachers and former DAAD scholarship recipients for short-term study and research visits to German universities and research centres. On the other hand, DAAD provides scholarships for young German scientists to do studies and research in Kenya on various topics.

The DAAD academic teaching staff recruitment programme is the other academic exchange programme. However, it has decreased in respect of Kenya during the last years due to financial constraints. Within this programme DAAD recruits and sponsors German professors and lecturers, especially in development related fields, for long term - two and more years - and short-term - one to three months - assignments at the request of African universities. The aim is to bridge gaps mainly in postgraduate teaching programmes until qualified nationals are available.

It is the aim of the German Government's Educational and Scientific Aid Programme to improve the economic and social conditions of the developing countries through training. The experiences gained in co-operation with African universities, encourages DAAD to continue and improve its programmes with a view to help establish independent and self-reliant Institutions of Higher Learning and Research. At the same time, the programme hopes to assist them in their international academic relations, especially in the scientific and cultural exchanges with German Universities.

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