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INVOLVEMENT OF NGOS IN THE DEVELOPMENT OF RENEWABLE SOURCES OF ENERGY IN AFRICA **

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* Organized jointly by UNIDO and the Association of African Development Finance Institutions (AADFI).

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INTRODUCTION

In implementing the resolutions of the Fourth General Conference of UNIDO, held in Vienna (Austria) from 2 to 19 August 1984, inviting the international community and particularly non-governmental organizations (NGOs) to increase their co-operation with African countries in implementing priority measures under the programme of the International Development Decade for Africa (IDDA), UNIDO, in co-operation with the Association of African Development Finance Institutions (AADFI), decided to organize a forum devoted to the participation of NGOs in the implementation of the IDDA programme, at Abidjan (Ivory Coast) from 27 to 30 August 1985.

Five themes will be the subject of discussion during the meetings of th Abidjan Forum:

(1) food and agro-food industries;

(2) agricultural mechanization;

(3) building and construction materials industries;

(4) energy;

(5) financial aspects of industrial development.

This working document is intended to serve as an introduction to the discussions on theme No. 4 which might be entitled:

"The role of NGOs in the development of renewable energy sources in Africa".

Taking as an example the case of solar energy, one cannot speak of "a new source of energy". It is just that certain technologies are relatively recent. In the text of the report we have adopted the expression "renewable energy".

In the absence of surveys among African states and NGOs, only the experience in Mali and the Sahelian countries is set out in this document. In order to fill this gap, the Forum should invite representatives of NGOs to present their experience in the field of applications of renewable sources of energy.

GLOSSARY 1/

To avoid divergences of interpretation or confusion, the World Bank has given the following definitions to a number of expressions used to designate the various types of energy.

CLASSIC TYPE ENERGY OR CONVENTIONAL ENERGY

Forms of energy which, at the present time, are by far the most common in modern industrial economies: coal (including lignite and peat); petroleum (comprising fuel oil, petrol, kerosene, diesel oil, natural gas and liquid petroleum gas), and electricity produced by the combustion of one of these fuels or by hydro or nuclear energy. Wood is not included in this category, although it was widely used in the past for industrial purposes and to a certain extent still is.

COMMERCIAL ENERGY

Any form of energy sold by a commercial enterprise or public service. This expression is virtually synonymous with "classic type energy" or "conventional energy". Wood and other traditional fuels (see below) are not included in this category although they are frequently the subject of sale transactions.

PRIMARY ENERGY

A form of energy whose use is not preceded by a chemical transformation. This notion is of particular interest in connection with electricity generation, hydroelectric energy being considered as primary energy and thermal electric energy as secondary. Nuclear energy is currently included in primary energy, although, strictly speaking, this classification is incorrect.

RENEWABLE ENERGY

Forms of energy partially or totally regenerated in the course of the annual solar cycle. It is considered, for example, that solar and wind energy, hydro energy and that from fuels of vegetable origin are renewable, while mineral fuels and nuclear energy are not.

FUELS FROM BIOMASS

These are combustible and/or fermentable materials of vegetable origin such as wood, charcoal, maize cobs, cotton stalks, rice chaff, manure compounds.

TRADITIONAL ENERGY

Covers types of energy generally used in "traditional" or pre-industrial societies. These are mainly fuels originating from biomass and this expression is most often considered as excluding mineral fuels and hydro energy, although the use of water mills dates back more than a thousand years.

SOLAR ENERGY

Technologies using solar radiation to supply heat which can be converted into mechanical or electrical power or which can produce electricity directly (photovoltaic cells).

1/ Extract from "L'énergie dans les Pays en développement". (World Bank, August 1980).

1. INTRODUCTION AND HISTORICAL BACKGROUND

Energy is one of the key factors if not the driving force in the development of a country. Energy consumption per head of the population is often used as a criterion for classification into industrialized or developing countries.

The African continent, which is known for its significant potential in agricultural and mineral raw materials, includes only a few oil-exporting countries and a large majority of oil-importing countries, almost all of which have a low income. Energy in Africa is largely imported, and it is therefore a factor in dependence on developed countries which possess the technology and control markets and prices.

Before the first "oil shock" and in the aftermath of independence, African countries had all given priority to agriculture in their economic and social development plans. A number of them, poorly informed of their energy potential and lacking the large capital resources required to exploit local sources of energy, remained dependent on the import of petroleum products to satisfy their energy needs, which were to a large extent created by equipment and technologies themselves imported from industrialized countries.

A few African countries, in an attempt to develop an energy policy based on the use of national energy resources, directed their attention to the exploitation of certain renewable energy resources: energy from rivers (the so-called "white coal"), solar energy and wind power. Such countries include Mali and Senegal in West Africa, which took part in the first world conference on new sources of energy held in Rome.

This initial phase in the history of renewable energy resources was characterized by research, development and laboratory testing of the first prototypes of solar water heaters and cookers, coinciding with the establishment of co-operation between African countries and certain industrialized countries. The pioneers of this period were all researchers, including notably Professors Trombe (France), Masson (University of Dakar, Senegal) and Moumouni (Niger).

The energy crisis, provoked by the savage increase in the price of oil, weighed heavily on the balance of payments and compromised the economic growth of the developing countries. It made authorities in Africa aware of the importance of energy in development and led them to seek alternative solutions based on the exploitation of national resources in order to satisfy energy needs. The renewal of interest by nearly all the African countries in alternative local energy sources, that is renewable energy sources, is due to the major resources of biomass and solar energy.

The serious and continuing drought which has affected the countries of the Sahel since 1972 has given rise to a firewood shortage.

New technologies appeared: photovoltaic cells, improved stoves, etc. while at the same time vast campaigns were organized to involve and inform the populations concerned. Finally, the United Nations Conference on New and Renewable Sources of Energy held in Nairobi (Kenya) made it possible to make international opinion aware of the importance of renewable energy sources. The African Member States of WAEC (West African Economic Community) and ICDCS (Permanent Inter-State Committee on Drought Control in the Sahel) decided to cement their common will for co-operation in the field of renewable energy by forming and setting up the Regional Solar Energy Centre (CRES) whose seat is at Bamako (Mali).

Thanks to laboratory research, field experiments, the spread of new technologies and their adaptation to the socio-cultural environment, the results achieved by several African countries - particularly those of the Sahel - in the development of applications of renewable energy are encouraging, although certain difficulties must be overcome.

CRES developed a regional programme for renewable energy and lent its support to Member States of WAEC in the preparation of national programmes. The national programme of Mali emphasizes applications of solar energy from photovoltaic sources: solar pumping station for the supply of water and the development of vegetable growing, microelectrification of dispensaries and rural health centres and telecommunications among others.

The aim of this report is to analyze the renewable energy potential, briefly set out the various technological branches, analyze the "state of the art" of the various applications, specify the principal constraints which retard their development and the role played or which could be played by non-governmental organizations in the renewable energy sources sector. Given that energy is a single entity, the analysis of the situation with regard to renewable energy resources must take account of the overall context of energy in Africa and in developing countries.

2. GENERAL REMARKS ON ENERGY IN AFRICA AND IN DEVELOPING COUNTRIES

The level of energy consumption in developing countries, and in Africa in particular, is low in comparison with world consumption. This situation is characteristic of their state of underdevelopment. According to the World Bank, oil-importing developing countries consume only 12 to 15 per cent of world commercial energy. Moreover this energy consumed is almost entirely imported from oil-exporting countries whose ranks include very few African countries.

It is the towns which consume most of the commercial energy, while the countryside and the urban poor use kerosene for cooking and lighting, and above all firewood for the former.

However for a number of reasons, particularly the use of energy equipment and installations imported from developed countries such as transport facilities, electricity generating stations, factories and so on, the growth of energy demand in developing countries exceeds that of their gross national product (GNP).

These countries have significant potential energy resources with regard to traditional and renewable energy resources and a scarcity of commercial resources of energy. Being low income countries, they do not have the major capital necessary to exploit their own local sources of energy.

In these circumstances, in order to satisfy runaway growth in energy demand, developing countries are forced to manage demand more effectively by a rigorous selection of priorities, and by economy and conservation measures, while stimulating and encouraging alternative energy solutions based on local resources.

The energy crisis unleashed by the savage increases in oil prices stimulated the interest of governments in developing countries in developing renewable energy as an alternative source of power.

3. CURRENT RESOURCE SITUATION AND STATE OF THE ART IN APPLICATIONS OF RENEWABLE ENERGY SOURCES

In Africa, 70 to 90 per cent of the energy used in rural areas and poor urban districts is supplied by traditional energy sources, mainly renewable, such as firewood, charcoal, agricultural residues and animal wastes.

Commercial energy is almost entirely a matter of urban consumption, 60 per cent of this energy being consumed by about 20 per cent of the population in the highest income bracket.

Renewable energy sources offer several advantages for developing countries and this is why they are of increasing interest to the authorities there.

As far as potential is concerned, renewable energy sources are the most abundant in developing countries, particularly biomass resources and above all solar and wind power. The Sahelian countries of Africa lie in a geographical region which is particularly favoured with regard to solar radiation. In addition, biomass is also abundant in a few countries which also have an adequate rainfall.

Unfortunately, mainly because of a lack of finance, these renewable energy resources and particularly biomass have been little or poorly evaluated, the available data being clearly inadequate and often fragmentary.

The relatively high cost of commercial energy means that the use of certain types of renewable energy to satisfy the small-scale and decentralized energy needs of scattered populations in rural areas of developing countries is an alternative economically viable solution. Thus the economical use of water, notably for fruit and vegetable irrigation, may make the relatively large investment in a photovoltaic solar pumping station, whose operating and maintenance charges are incidentally negligible, a profitable undertaking.

Although they have very great potential for satisfying their energy needs, developing countries are not mastering renewable energy technologies for lack of capital and experts. Renewable energy can play an important role in attenuating effects of the energy crisis, particularly in rural areas. Governments, for whom rural development is the first priority, have expressed their interest and their wish to develop applications of renewable energy sources and have decided on the launching either of specific projects or programmes on a national scale.

3.1. Potential renewable energy sources

The renewed interest in renewable energy sources has appeared during the last decade as a result of the energy crisis. Basic data on renewable energy sources are either non-existent or inadequate. For lack of an inventory of these resources, one is limited to an arbitrary estimate extrapolated from the available fragmentary data.

Despite this gap, the countries of West Africa have attempted to evaluate the potential of the subregion.

3.1.1. The energy situation in the countries of West Africa

The energy situation in the countries of West Africa is marked by the following predominant features:

- An almost total lack of fossil fuel deposits (coal and oil, except in Nigeria and Ivory Coast), the energy sources which made the prodigious technical and industrial development of Europe and North America in the space of two centuries possible.

- The predominant use of firewood and charcoal to satisfy household energy needs, and at such an intense rate of forest exploitation and using such rudimentary techniques that the ecological future of the zone is seriously compromised (deforestation, even desertification).

- The existence of a large potential in terms of renewable energy sources (solar power, wind power, hydroelectricity, recovered biomass and so on), sources which are still hardly exploited.

The key role of energy in all modern production processes and trade (agriculture, industry, transport, communications, etc.) together with the continued and growing scarcity of classic energy sources is forcing West African countries aiming at development:

- on the one hand, to preserve their forest heritage by improving the mode of exploiting their timber resources (reafforestation, substitution of improved ovens and stoves for those at present used, exploitation of by-products and plant and animal wastes by gasification, pyrolysis or methane fermentation, etc.).

- on the other hand, to promote the spread of renewable energy equipment such as solar collectors and generators, wind motors, hydroelectric generating stations and so on.

3.1.2 Renewable energy resources in West Africa

The picture of the various renewable energy resources for West Africa is currently as follows:

3.1.2.1. Animal and vegetable biomass energy

3.1.2.1.1. Firewood and charcoal

These still provide 80 to 90 per cent of energy used in West Africa, particularly for domestic needs (cooking, heating water) and crafts (forging, brickmaking, pottery).

The evaluation of regional consumption is difficult because of the scarcity of statistics and discrepancies between the various information sources. Some countries, which are members of CRES (Regional Solar Energy Centre), have estimated consumption as follows:

COUNTRY	CONSUMPTION OF WOOD AND CHARCOAL	REFERENCE YEAR	PERCENTAGE OF NATIONAL ENERGY CONSUMPTION
	(tpe/year)		(%)
GAMBIA	170 000	1981	not available
SENEGAL	1 400 000	1981	63.7
MALI	1 050 000	1977	86.7
BURKINA FASO	740 000	1980	84
IVORY COAST	1 165 000	1980	46.1
NIGER	680 000	1982	80.5

Table 1: Consumption of wood and charcoal in the six countries belonging to CRES.

Wastes of animal origin and household wastes

The energetic exploitation of these resources is possible using several techniques:

- direct combustion in small-scale or industrial ovens or boilers;
- methane fermentation in bio-digesters.

Although livestock rearing is widely practised in the Sahelian countries of West Africa, the recovery of animal wastes is confronted by serious obstacles:

- There is a significant cattle population throughout the Sahel but the collection of cow dung is difficult because of the nomadic lifestyle of many herdsmen. Mali, for example, with five million cattle and 12 million sheep and goats could in theory produce 200,000 tpe in the form of biogas; but only a small fraction of this potential is easily recoverable, in practice 20,000 tpe from the 20,000 plough oxen kept in sheds.
- Abattoirs could supply an appreciable contribution of bio-energy.
- Urban waste (household rubbish, brewery draff, etc.) can be exploited by combustion or fermentation in small thermal power stations.

Agricultural by-products and wastes

Arising from forestry and farming, these represent an enormous potential which is still unexploited or poorly exploited for lack of a system for collecting this biomass and the appropriate equipment (gas generators and "dual-fuel" engines, biodigesters).

COUNTRY	NATIONAL POTENTIAL IN TPE/YEAR	YEAR	SOURCES OF ESTIMATE
GAMBIA	Not available		
SENEGAL	Not available		
MALI	1 320 000	1984	TRANS-ENERGY Study
BURKINA FASO	670 000	1984	CRES Report
IVORY COAST	6 000 000	1982	" "
NIGER	1 610 000	1982	" "
MAURITANIA	Not available		
CAPE VERDE	Not available		

Table 2: Energy potential of vegetable residues in Member States of CRES.

Except in Ivory Coast (where 4 million tpe are producible through the exploitation of forests), this energy potential comes mainly from food crops (millet, sorghum, maize, rice) and industrial crops (cotton, ground-nuts).

It should however be noted that one of the common alternative uses of agricultural by-products is as animal fodder (cereal straw, ground nut and cotton-seed cake, etc. ...) which somewhat limits the availability of these resources for energy purposes.

Solar energy

As a result of its situation within the tropics, West Africa enjoys excellent insolation (4.5 to 6.5 kwh/m^2/day, i.e. an annual mean of 5.5 kwh/m^2/day) which in theory would be sufficient amply to cover its total energy needs.

Indeed, it is possible, for example, to make an approximate estimate of consumption in the six principal countries of the zone as follows:

COUNTRY	AREA km^2	OVERALL ENERGY CONSUMPTION (domestic + industrial + transport) tpe estimate for 1985
GAMBIA	10 000	200 000
SENEGAL	200 000	2 200 000
MALI	1 204 000	1 400 000
BURKINA FASO	274 000	900 000
IVORY COAST	320 000	2 600 000
NIGER	1 270 000	800 000

Table 3: Overall national energy consumption, representing a total of 8,100,000 tpe consumed over an area of approximately 3,400,000 km^2.

If one assumes a conversion yield of only 5 per cent for collected solar radiation and an equivalence of 4,000 kwh/per 1 tpe, it can be seen that solar generators (photovoltaic cells for example) with a surface area of:

$$\frac{8\ 100\ 000 \times 4\ 000}{0.05 \times 5.5 \times 365} = 323 \times 10^6\ m^2 = 323\ km^2$$

would be sufficient to produce all the energy currently required by the economies of the six countries, in other words less than 1/10,000th of their total area.

Wind energy

The exploitation of wind energy is a promising alternative for certain water needs in the country (market gardening, animal watering) and for the development of other income-generating artisanal activities (e.g. flour milling, river shipping etc.).

Zones with a high wind potential are:

- Cape Verde and certain other coastal fringes;
- The Sahel Strip, which is a cattle raising area.

Hydroelectricity

The hydroelectric potential in the region is considerable, being linked with the major hydrographic network of the big rivers and their tributaries: Niger, Senegal, Gambia, the Voltas, Cavally, Sassandra, Bandama, Comoé, etc.

By way of example,

- Mali has a capacity of 1,050 MW (1981 estimate);
- Ivory Coast could generate 7,100 GWh for a total capacity of 3,800 MW (1984 estimate).

On these figures, the dams built to date provide the following contributions:

COUNTRY	SITE	DATE OF ENTRY INTO OPERATION	WATERWAY	CAPACITY MW	GENERATION GWh/year
MALI	Félou		Senegal		2.7
	Manantali	1988 *	Bafing (Senegal)	150	
	Sotuba	1966	Niger	5.40	35
	Sélingué	1980	Sankarani (Niger)	45	180
IVORY COAST	Ayamé 1	1959	Bia		
	Ayamé 2	1965	Bia	50	200
	Kossou	1972	Bandama	174	500
	Taabo	1979	Bandama	210	1 000
	Buyo	1980	Sassandra	150	850

* Forecast.

Table 5: Current production of hydroelectric energy in Mali and Ivory Coast.

The poor supply of water experienced by the West African region for 15 years, far from hindering, has stimulated numerous studies aimed at better exploiting this hydroelectric potential, particularly in the form of micro and mini-generating stations on tributaries of major rivers and in mountainous regions with high rainfall (for example the Keniéba power station in Mali).

Other Renewable Energy Sources

(a) Animal traction: is already used to a limited extent in the transport of goods and people, agricultural traction (ploughing teams) and pastoral irrigation (donkey and camel wheels), and could be further exploited in stock-rearing zones. It could effectively replace human muscular energy which unfortunately remains the principal form of energy available to many farmers throughout West Africa.

The tasks of drawing water and carrying loads, which are often performed exclusively by women and children, should as a matter of priority be dealt with in this context.

(b) Geothermal energy: Geothermal potential is very little known in West Africa and is probably of insignificant volume.

3.2. State of technologies and applications of renewable energy

Taking each area of application in turn, we shall examine the most advanced technologies able to satisfy the energy needs of developing countries. There is a wide range of prototypes and equipment at the experimental stage. We shall place particular emphasis on the most reliable of these which are ready for wide utilization.

3.2.1. Energy techniques for the exploitation of biomass

Energy resources from biomass can be divided into:

- wood and charcoal
- liquid and gaseous fuels

3.2.1.1. Wood and charcoal

Nearly all energy consumed in rural areas and in the poor quarters of African towns for domestic purposes and cooking is supplied by wood. Unfortunately, forest reserves are being used up more rapidly than they are being replaced. That is why most large African towns, particularly in the Sahelian zone, are experiencing a real firewood shortage. In the countryside, villagers go further and further in search of wood, often requiring half a day's or a whole day's journey on foot.

The effort to combat desertification involves:

- a vast reafforestation campaign, particularly through village plantations
- more efficient use of wood as a source of energy.

In Africa it would be necessary to replant several million hectares in order to satisfy the demand for firewood. This is a long-term, but essential, enterprise. Several forestry projects are in progress or being launched.

In the short and medium term, simple technologies to make more efficient use of the available firewood resources must be developed.

(a) Improved stoves

For cooking food and domestic uses, the traditional open hearth with three stones is used almost everywhere in African country areas and in the populous districts of towns. This type of hearth only uses a very small part of the energy of the wood which is burned. By burning the wood in an enclosed space and by controlling the circulation of air entering and leaving by use of a chimney, it is possible to "improve" to a massive extent the performance of the traditional hearth, which is then called "improved stove".

Depending on the type of material used for their construction, the various types of improved stoves can be divided into two categories:

- fixed stoves, in masonry, whether clay or a mixture of sand and clay to reduce cracking. The construction technique can be mastered by local craftsmen through short practical training courses. Particular attention must be paid to the design of the stove; "tomb"-shaped forms are rejected by some superstitious peoples, the height of the stove will be adjusted according to the standing or squatting position of the housewife, and so on. Clay stoves are cheap but lack strength.

- portable stoves, either metal or ceramic. The construction of these is easy for local craftsmen, particularly manufacturers of metal furnaces and potters. The case of moving them inside or outside the kitchen and their low cost are major advantages.

Having been told that a firewood saving of up to 50% could be achieved, several women's organizations launched campaigns for building improved stoves. Experience subsequently showed that this saving had been somewhat over-estimated, but the operation nevertheless resulted in a saving of money for the urban housewife and a saving in time for the countrywoman. Further efforts are required to achieve a greater distribution of improved stoves.

Despite the absence of precise statistical data, it can be stated that several thousand improved stoves are in operation.

It appears that the enthusiasm which dominated the publicity campaigns for the use of improved stoves has subsequently flagged for a variety of reasons; for example, the real saving is probably less than 50%, there are numerous models and the choice between them is not easy for the uninformed user, difficulties connected with the use of local materials make it necessary to rely on inexperienced workmen whose remuneration may be beyond the means of a low-income household and the saving is of time but not of money in the country. There is evidence of a fairly clear preference for portable improved stoves, preferably metal, manufactured by local artisans. These portable stoves will certainly become more widespread, particularly in urban zones.

(b) <u>Charcoal ovens</u>:

The transformation of wood into charcoal involves a significant loss of energy. With a modern oven it is possible to obtain one ton of charcoal from 6 m^3 of wood, and only half this amount with a traditional oven.

There are several possibilities for improving charcoal manufacturing techniques. It is in urban zones particularly that households use charcoal, thanks to portable metal stoves currently manufactured by local artisans.

3.2.1.2. <u>Liquid and gaseous fuels from biomass</u>

(a) <u>Motor spirit</u>

Ethanol or ethyl alcohol, produced by the fermentation and distillation of molasses from sugar cane or sugar beet is used as a motor spirit either in its pure state or mixed with petrol. In Brazil the majority of vehicles use this mixture which is called gasohol and contains up to 20% alcohol. In Mali, a country which is landlocked and an importer of oil, the implementation of a project for mixing petrol with 3% alcohol is economically justified by the existence of two sugar refineries and the lack of a market for the alcohol produced by the two distilleries. Experiments have been carried out in Mali on the direct use of the alcohol produced by these distilleries in agricultural tractor engines.

In order to avoid major modifications to the engine, some experts consider that the alcohol petrol ratio should not exceed 15 to 20 per cent alcohol.

The distillation of wood produces methanol or methyl alcohol which presents problems when mixed with petrol and can therefore not be used as motor fuel.

(b) Biogas

Anaerobic decomposition of animal, vegetable and human wastes produces a gaseous mixture containing 55 to 65 per cent methane which can be used as a motor fuel. The mixture of water and organic substances is done in a digester. The gas produced is collected in the upper part of the digester and extracted through a pipe to power a refrigerator, lights, gas cooker, the motor of a cereal mill, etc. according to the capacity of the digester. In addition, the residual materials from the digester are recovered and used as soil fertilizer.

China and India are the two great pioneers of biogas techniques and have developed large-scale programmes: there are more than 10 million family-sized digesters in China.

There are a number of conditions and difficulties affecting the wider use of digesters: permanent availability of water and particularly animal or human wastes in sufficient quantity, the skills required in the construction of the digester, care in the handling of the gas, factors such as bacteria, temperature, acidity and others influencing the chemical reaction, the presence in the gas of small quantities of hydrogen sulphide which attack the metal components etc. For these various reasons bio-digester technique is still at the experimental stage in most African countries.

Direct combustion of solid biomass such as wood, bagasse, rice chaff, ground-nut shells and so on provides a gas of low calorific power which can be burned in the boilers of small power stations. When residues exist, plants can use them to produce steam and/or electricity for their own needs. In Mali, some rice plantations of the Niger Office are supplied with electricity by a low-grade gas generating plant of 300 KW.

3.2.2. Technologies making direct use of solar, wind and water power

Techniques making direct use of solar, wind and water energy are really very old; drying fish, windmills and watermills etc. Thanks to research efforts in specialized laboratories and institutes in industrialized and developing countries, new and more suitable equipment with better performance has been developed and tested on site.

3.2.2.1. Applications of solar energy

3.2.2.1.1 Heliothermal applications

(a) Solar water heaters

Water heating by solar energy retained by collector panels is probably the first application in developing countries, including West Africa. The technology of these water heaters is now sufficiently well mastered and there are manufacturing plants in Senegal (SINAES), Niger (ONERSOL) and Mali (Solar Energy Laboratory). The water heater is a product that is both technically mature and economically and commercially ready for distribution. The manufacture of water heaters is still low in volume (some hundreds of units produced to date).

However it appears that in countries enjoying good insolation the heating of water is not regarded as a priority need. The cost of heating water is generally a minor part of the household budget. The use of water heaters therefore is likely to be limited to urban zones because of the cost. The marketing of the product is confronted with cost and technical quality problems.

(b) Solar stills

Solar stills are used to produce distilled water for use for example in hospitals and motor electrics workshops (battery electrolyte). There is a considerable potential market for the still, hence the interest shown by several countries in West Africa, including Mali, Mauritania, Niger and Senegal.

(c) Solar driers and cookers

The use of solar energy for drying, preferably in an enclosed space rather than in the open air, of fruit, vegetables, cereal, tobacco, fish and so on is common in several African countries with an agricultural base. Drying is a good method of preservation but can change the taste of the commodity, as in the case of fish. The lack of a means of regulating the temperature is one of the difficulties encountered. Solar drying can nevertheless be of interest for an agricultural or fishing co-operative.

With regard to solar cookers, it is difficult to adapt them to the habits of housewives who prefer improved stoves for cooking food. Like solar dryers, this is a technology at the experimental stage.

3.2.2.1.2. Photovoltaic applications

Solar energy is converted into electricity by means of silicon-based photovoltaic cells. Photovoltaic solar energy is particularly competitive in supplying small-scale power needs in isolated sites, particularly the pumping of water in rural zones, telecommunications relay, navigation beacons and buoys, electricity supply to rural dispensaries and so on.

The relatively high investment cost of photovoltaic solar generators is offset by zero operating charges and negligible maintenance.

In the medium term and if the cost of cells falls, the photovoltaic solar generator will play a predominant role in small-scale power applications at isolated sites.

(a) Photovoltaic solar pumps

In the context of village and pastoral water supply programmes, a substantial number of photovoltaic pumping stations have been installed in Mali (about 70 units), Senegal, Burkina Faso (about 15) and Niger, and in general the equipment is reliable and satisfactory in operation.

Moreover the Member States of WAEC, in their national renewable energy equipment programmes, envisage more or less intensive progress in installing new photovoltaic pumping stations ranging from 0.5 to 5 KWc power rating. The CRES regional programme gives the following picture:

COUNTRY	FORECAST INSTALLATION OF PHOTOVOLTAIC PUMPS NUMBER	AGGREGATE POWER IN KWc *
Gambia	Not available	Not available
Cape Verde	Not available	Not available
Senegal	30	115
Mali	260	716
Burkina Faso	41	150
Ivory Coast	239	422
Niger	Not available	Not available
Total	738 pumps	1 403 KWc *

* KWc=kilowatt-photovoltaic peak.

Table 4: CRES regional programme for installation of photovoltaic pumps over 5 years.

It should finally be noted that in Mali the tendency is to install photovoltaic pumps at certain large flow developing market gardening in order to obtain a profitable return on the investment.

(b) Various microelectrifications

Photovoltaic cells have effectively replaced classical electrical generators (diesel or petrol sets, dry batteries, etc.) in numerous low-grade power installations (a few watts to a few thousand watts) for the following applications:

- Lighting, refrigeration and ventilation of public establishments such as, in Mali, the hospitals at San and Kolokani and schools at Kimparan, Somo, etc.
- Telecommunications and radio
- Rail and air transport signalling.

In the latter two applications in particular, the reliability and quality of service make photovoltaic energy much to be preferred.

3.2.2.2. Wind Energy

For a very long time wind power has been used in countries enjoying regular and strong winds for pumping water and milling of cereals.

There are various types of windmill, varying in height, diameter and number of blades. The multiblade windmill which turns at a wind speed of 3 m/sec or above is the most widespread model in rural areas.

Windmill output depends on the characteristics of the prevailing wind but the available data on sites are insufficient and not very reliable. The components of high power windmills are imported from developed countries and assembled on site. Small multiblade windmills can be manufactured on site with locally recycled materials. An interesting experiment is that carried out at the Training Centre for Rural Artisans at Segou, Mali. Father Plasteig, Director of the Centre, takes in young peasants, gives them the necessary training and assists them in building their own windpumps of the Sahores type with components of bamboo, rubber and recycled parts. At the end of the training, the trainee returns to his village taking a complete windpump in kit form, which he can easily assemble over a well and then maintain. Some 50 windpumps have been built in this manner to date. The main application of the windmill is the pumping of water in pastoral areas. In about 1950, Mali installed some 30 windmills (Came and Aermotor types) in the north and eastern regions. All these windmills are now out of action owing to lack of maintenance.

In West Africa, Cape Verde, which enjoys a very favourable situation with regard to winds, is developing a major national programme for the installation of windmills. Some windmill installations are anticipated in Senegal, Burkina Faso and Mali.

More recently, prototype windgenerators for converting wind energy into electrical energy have made their appearance on the market. Apart from the high cost, a number of problems remain to be resolved.

The power output of the windgenerator should not be less than 15 KW.

3.2.2.3. Waterpowered microgenerating stations

Like the windmill, the waterwheel has long been used for grinding grain and raising water. If there is an appropriate site, it is still a simple and robust technology which can be used to produce energy.

The water turbine has a much better performance than the waterwheel.

Water-powered microgenerating stations are electricity generators (turbine-alternator) whose power varies in general between 5 and 50 KW. Several thousand water-powered microgenerating stations are operational in China.

The water-powered microgenerating station solution should be considered if the following conditions are present:

- the site has suitable characteristics, notably the availability of a permanent flow and adequate fall, and a minimum investment cost in terms of civil engineering.

- proximity to consumption centre in order to avoid the high cost and power loss on a long transmission line.

In order to advance knowledge on the potential for water-powered microgenerating stations, several African countries have undertaken study programmes and inventories of sites. These projects are in progress.

Countries lacking high relief and whose waterways are irregular in flow are little suited to the installation of water-powered microgenerators.

3.2.4. Investment cost and economic comparison with classic equipment

It is premature to draw definitive conclusions regarding the investment costs and economic viability of renewable energy projects because experience in the field of applications is quite recent and there are still few examples. As long as the equipment is not mass produced to satisfy the needs of a major market, its cost will remain relatively high.

As an example, an appreciable lowering of the cost of photovoltaic cells had been expected. Unfortunately prices have remained static or with only a slight downward trend.

In the annex, we offer case studies in Mali:

(1) Economic comparison of a solar water heater and an electric water heater at Bamako (Annex 1).

The solar water heater is twice as cheap as the electric water heater.

(2) Comparative cost per m^3 of diesel pumps and photovoltaic solar pumps (end 1983) (Annex 2).

(3) Estimated operating costs (costs of output achieved) by type (Annex 3).

The following conclusion can be drawn: for the four areas of application listed below renewable energy equipment is competitive:

- heat production: water heating
- pumping: photovoltaic solar energy or wind energy
- electric energy for isolated sites: photovoltaic generators up to 10 KWh/day approximately
- electricity generating stations of 50 KW and more: gas generators.

Finally, as a general rule, investment costs for renewable energy equipment are relatively high compared with equipment of the classic type but on the other hand recurring charges are markedly lower.

3.2.5. Possibilities for local manufacture of renewable energy equipment

The possibilities of local manufacture of components or complete renewable energy equipment depend:

- on the choice of the range of products capable of being manufactured on site,
- and to a great extent on the size of the market.

Before taking any decision on the local manufacture of particular equipment it is necessary to carry out a feasibility study on industrial production with a detailed and in-depth analysis of the market. The exiguity of the market in developing countries is quite common, particularly for new products such as renewable energy equipment. Regional or subregional co-operation is highly desirable in order to obtain a market of sufficient size. That is why CRES envisaged the creation of the UPS (System Production Unit) at Member State level.

It is also necessary to distinguish between equipment to be manufactured at national level and subregional level. At national level, industrial production must be based on existing units which are usually small- or medium-sized enterprises or artisanal workshops.

The market evaluation must be based on reliable data. It can be made easier if States have national short- and medium-term equipment programmes, as is the case with most of the Member States of CRES.

Taking account of certain criteria such as in particular the level of technological maturity, cost, priority accorded to the areas of application and acceptability to users, it is possible to base a programme of local manufacture in West African countries on the one hand on items selected by CRES and on the other on:

- assembly and encapsulation of photovoltaic cells in modules
- certain components of the windgenerator (blades, mast)
- assembly of components of photovoltaic generators.

An encapsulation unit is only viable at subregional levels.

A feasibility study in Mali on an industrial production unit for solar equipment carried out in December 1984 by UNIDO showed the interest of a unit with an annual production capacity of 185 water heaters, 70 windmills, 10 stills, 5 dryers and 25 supports, frames, etc. However, the economic and financial profitability would be low mainly because of the small size of the market in Mali.

That is why, for the West African subregion, an industrial infrastructure comprising a subregional industrial unit (such as the UPS of CRES) and small national artisanal units seems to us more realistic.

4. FACTORS AND CONSTRAINTS LIMITING THE DEVELOPMENT OF RENEWABLE ENERGY SOURCES

Despite the encouraging results obtained since the informing of international opinion by the United Nations Conference on new and renewable energy sources, numerous and varied constraints limit the development of applications of renewable sources of energy. Countries having potentially important and renewable energy resources must take the necessary measures to do away with these barriers and intensify their efforts to distribute and market products which are technically proven.

4.1. Technical constraints

The analysis of resources has shown the lack of available data and the absence of an inventory. This missing knowledge of resources explains why some governments in developing countries have not been in a position to define the role and place of renewable energy in their economic and social development plans.

Information on possible applications of renewable energy sources, the cost of various types of equipment, the advantages and drawbacks compared with conventional equipment is still scarce in some countries. This explains why there is a widespread view in these countries that such equipment is still experimental, sophisticated and high in investment cost.

With regard to technical maturity, some renewable energy equipment has become very reliable. This is particularly so in Mali with photovoltaic pumping installations: experience has shown pump faults but very few generator faults. The nine products selected by CRES are technically mature and viable. On the other hand, other equipment is at the experimental stage.

The absence of a technological environment is also a handicap in developing countries, limiting local replacement of faulty parts.

4.2. Financial constraints

The very low national incomes of developing countries prevent them from allocating the large financial resources required to implement equipment programmes. CRES for example estimates that its five-year regional programme (8 countries) will cost approximately 51 billion CFA francs of which 38.4 billion CFA francs are for equipment as such and 7.9 billion CFA francs for related work.

The involvement of foreign investors is essential to finance these investment programmes. The equipment investment costs are relatively high. Maintenance costs on the other hand are very low, which makes it easy for users in rural zones to accept them.

Investment in collective equipment is financed by the Government with the aid of investors. Recurrent maintenance costs are borne by users or local organizations. In rare cases (photovoltaic pumps installed in the region of San in Mali under the Mali Aqua Viva project directed by Father Vespieren), rural communities also make a contribution of 10 per cent to the investment cost.

4.3. Institutional constraints

At the institutional level the renewable energy sources sector is characterized in most developing countries by the multiplicity of the bodies involved and belonging to different supervising departments. The circulation of information is thus blocked and there is a lack of co-ordination and coherence in programmes of activities.

In some countries, it is essential and a matter of urgency to define an overall policy for energy including renewable energy sources. It is necessary to strengthen the bodies responsible for renewable energy planning. It is also necessary to specialize the fields of activity of existing bodies or set up, with specific areas of competence, research and development, engineering, installation and maintenance and industrial production departments. The creation of a co-ordinating centre or body is an absolute priority.

Finally, for community installations, a local structure with proper management responsible for the maintenance of the installations must be created at village level.

4.4. Weakness of human resources

The majority of developing countries do not have specialists in the various areas of renewable energy sources. There are few professionals in research, design and implementation. Where they are available, they are handicapped by lack of experience.

States will remain dependent on technical assistance for as long as they fail to take the urgent and vigorous measures required to train competent specialist professionals.

4.5. Sociological constraints

The acceptance of renewable energy equipment by the rural populations concerned is a priority target. The design and use of this equipment must not challenge cultural values and certain ancestral traditions.

Only a continuing process of information, promotion and the arousing of awareness regarding new technologies, with technical follow-up and management assistance, can lead progressively to a massive adoption by populations of renewable energy equipment. This is an essential condition for the success of any popularization programme.

5. ACTIVITIES AND ROLE OF NGOs IN THE DEVELOPMENT OF RENEWABLE ENERGY SOURCES

Renewable energy is aimed at satisfying small-scale decentralized energy needs in rural zones in Africa and the developing countries. As a result of its major potential and its growing competitiveness, particularly in isolated sites, it is destined to become a key factor in rural development in developing countries.

One of the targets of NGOs is to contribute to the development of rural zones with limited means and by using all local resources (human, agricultural, pastoral, water), including energy resources such as biomass, waste of agricultural and animal origin etc. which make up the major part of renewable energy.

Confronted with the numerous possibilities offered by the applications of renewable energy sources in the rural environment, some NGOs have directed their attention to simple technologies, cheap and preferably using local materials, which are within reach of the country dweller. Their attitude is more reserved when it is a question of imported technology with sophisticated equipment which is very expensive and virtually inaccessible to the world of the peasant.

It is for this reason that NGOs have been particularly active in the field of applications of biomass: improved stoves, digesters.

5.1. Summary of NGO activities

Without surveys among NGOs, it is difficult to draw up a balance sheet of their activities in the field of renewable energy sources. We will confine ourselves to mentioning a few achievements.

Despite the absence of precise statistical data, several NGOs have contributed to the construction and distribution of improved stoves with the support, in most cases, of women's organizations whose role is vital for propaganda and promotion. The development and testing of prototypes and the improvement of performance are generally carried out by laboratories or specialized institutes.

There is a fairly clear trend in favour of portable improved stoves, preferably made of metal and manufactured by local artisans; these are destined to become widely distributed.

In several countries, NGOs, thanks to their local knowledge and a precious store of experience, have helped research institutions to define and test prototypes better adapted to socio-cultural conditions.

5.1. Biogas

The use of agricultural, agro-industrial and animal wastes to produce gas in a digester is a technology which has been recently introduced in Africa thanks to the experience of certain developing countries, notably India and China. In several African countries, NGOs, alone or in collaboration with specialized institutions, have designed, built and tested digesters with a preference for sites where concentrated waste was available in sufficient quantity.

Experiments with digesters have shown up certain obstacles: the need for regular supplies of waste and of water, careful construction and sound engineering in particular, leak-tight digesters and gas piping, safety precautions in the handling of the gas etc.

In order to ensure widespread diffusion of digesters there is a need to intensify the information and awareness campaign among rural populations in Africa who, historically, have little experience in the use and handling of gas as a source of energy.

Action by NGOs can contribute to overcoming this obstacle, which is of a socio-cultural nature. It will then be possible to launch major programmes for the distribution of small family-size digesters, as in China.

5.1.2. Windpumps

Windpumps are generally wholly imported and rarely manufactured on site in most African countries. In Mali, Father Plasteig's Training Centre for Rural Artisans at Segou is probably the only NGO in the subregion which manufactures windpumps.

Although they are concerned with the problem of pumping water, NGOs are not very active in the field of windpumps except in regions where wind conditions are exceptionally favourable.

5.1.3. Solar equipment

Here again it is a matter of wholly imported equipment, with a high investment cost but negligible maintenance charges. This explains the lack of interest shown by NGOs with their limited financial resources.

The energy crisis and the rise in the price of oil have increased the competitiveness of solar energy in the case of isolated sites lacking any energy source. Thus in Mali, two NGOs are working in the solar energy sector: Mali Aqua Viva directed by the "dynamic" Father Vespieren who is boring wells and equipping them either with pumps relying on human power or solar pumps. In its zone of operations, MAV has installed nearly 30 solar pumping stations.

Another NGO, "Iles de Paix", is operating in the Tombouctou (Timbuctu) region of Mali and has installed one or two solar pumping stations for irrigation.

It is common to hear complaints from NGOs that solar equipment is sophisticated and not very reliable. The experience acquired in Mali for 10 years past suggests that the new generation of solar generators shows good qualities of reliability. Moreover, the solar generator is composed of wholly static components without any sophisticated system for control, regulation or other functions.

5.1.4. Solar water heaters

The solar water heater, which is a technology that is easy to implement, is destined for major development particularly in the towns, which limits NGO involvement.

5.2. Possible NGO contributions to the development of renewable energy sources

For the reasons already mentioned, NGOs have generally not been very active in the field of applications of renewable energy; however, the progress achieved by new technologies, the growing interest among rural populations, particularly in improved stoves and photovoltaic solar pumping stations, should stimulate NGOs to take greater interest in the sector of renewable energy sources.

5.2.1. Intensification of NGO activities in priority areas of application

NGOs are involved in several countries in the construction of water-related (wells, bore-holes) and sanitary (rural dispensaries and maternity clinics) infrastructures. They can assist those rural populations which are interested in completing these facilities by:

- Photovoltaic solar pumping equipment and the development of market gardening,

- Supply of solar electricity to dispensaries and maternity clinics.

In general terms NGOs could intensify the activities in which they are currently involved and expand them in line with new possibilities.

5.2.2. Involvement in the socio-cultural aspect

The socio-cultural aspect of renewable energy projects, including promotion and propaganda, is a particularly important task. NGOs can make an appreciable contribution here.

5.2.3. Assistance in training and maintenance of equipment

NGOs can also assist rural communities in training local artisans in the maintenance and repair of community equipment. They can contribute assistance in the management of such facilities.

5.2.4. Collaboration between NGOs and bodies responsible for the renewable energy sector

This collaboration is essential in order to achieve better co-ordination of the activities of NGOs and those of State bodies. It also covers exchange of information, agreement on the choice of the most suitable technologies, organization of awareness campaigns and so on.

At the institutional level, NGOs should be represented in national co-ordination structures in the renewable energy sources sector.

5.2.5. NGO support to artisanal production units

NGOs can also assist local artisans in improving the technical and financial performance of renewable energy equipment. They can promote the setting up of small local artisanal units, particularly in the manufacture of metal or ceramic improved stoves, small charcoal ovens, etc.

5.2.6. Creation of specialized NGOs in the field of renewable energy sources

The growing interest in renewable energy sources may encourage specialization. Thus in several countries certain NGOs envisage specializing in certain priority applications of renewable energy. Similarly, the idea of setting up national NGOs for the development of certain forms of renewable energy has made considerable progress.

6. CONCLUSION

The energy crisis has given a new impetus to the development of renewable energy in developing countries, particularly those which have major biomass, solar energy and wind resources and which are importers of petroleum.

Renewable energy sources offer a variety of solutions which are technically and economically viable in satisfying small-scale, dispersed energy needs in rural zones.

Renewable energy technologies have achieved remarkable progress. Some products have attained a sufficient degree of reliability and maturity for their distribution to be envisaged on the basis of industrial or artisanal production.

NGOs can play and important role in the development of renewable energy if steps are taken to involve them in co-ordination and planning activities in the energy sector.

ANNEX 1

WATER HEATING

CASE STUDY: ECONOMIC COMPARISON OF A SOLAR WATER HEATER AND AN ELECTRIC WATER HEATER AT BAMAKO

(Source: SEMA/AFME - updated 1984)

Location: Bamako

Overall minimum solar insolation: 3.7 kWh/m^2 (overcast sky in January)

Hot water requirements at 50° C (family of six people): 6 x 30 = 180 l/day

Cold water temperature: 25° C

Daily calorific requirements:

Q = m. t = 180 x (50-25) = 4,500 kcal/day or 5.23 kWh/day

Collector surface required with an output of 0.5:

Calorific energy collected: 3.7 x 0.5 = 1.85 kWh/m^2 collector/day

The requirement is therefore 5.23/1.85 = 2.83 m^2 of plane collectors.

Cost comparison on an annual basis:

	Solar water heater	Electric water heater
Investment cost	600 000 FM	300 000 FM
Amortization 10 years 10%	98 000 FM	45 000 FM
Electricity at 100 FM/kWh (output 0.9 *)		212 000 FM
Total annual expenditure	98 000 FM	261 000 FM
Cost per m^3 of hot water **	1 500 FM/m^3	4 000 FM/m^3

* Number of annual electric kilowatt/hours = 5.23/0.9 x 365 = 2,120 kWh per year.

** The cost should be slightly increased in order to allow for maintenance.

N.B. 100 Malian francs (FM) = 1 French franc (FF) = 50 CFA francs

ANNEX 2

COMPARATIVE COST PER CUBIC METRE OF DIESEL PUMPS AND PHOTOVOLTAIC SOLAR PUMPS (END 1983)

(Source: SEMA ENERGY/AFME) Value in French francs

	Diesel generator set + electric immersion pump	Photovoltaic pump with 1300 W peak	
Head of water	30 m	30 m	
Nominal flow	7 m^3/h	32 m^3/day	
Annual operating hours	1 800 hours	1 800 hours	
Annual volume pumped	12 600 m^3	11 500 m^3	
Investments (in FF) generator + pump + pump house	125 000		
Photovoltaic pump		270 000	
Annual amortization (in FF)	Life of 4-10 years	Life 10 years	15 years
with interest rate at 10%	24 900	43 900	36 000
Annual operating costs diesel fuel *, oil, labour, maintenance	37 600		
Periodic maintenance		8 000	8 000
Total annual cost	62 500	51 900	44 000
Cost per m^3 pumped	4.95 F/m^3	4.50 F/m^3	3.80 F/m^3
(excluding structural work and distribution)	(i.e. 495 FM/m^3)	(450 FM/m^3)	(380 FM/m^3)
including operating costs of	3.00 F/m^3	0.70 F/m^3	0.70 F/m^3

* Diesel fuel: 16,200 FF/year based on 6 FF/l (including storage cost); a second table is annexed assuming a price of diesel fuel of 4 FF/l (400 FM, excluding distribution and storage).

N.B. 1 French franc = 50 CFA francs.

ANNEX 3

ESTIMATED OPERATING COSTS (COSTS OF OUTPUT ACHIEVED) BY TYPE

(Source: Energy Planning, Annex IV, Trans Energy, January 1985)

Type and field of application	Investment cost * (useful life)	Production or output achieved	Cost/output achieved (amortization + operation)
Solar water heater	600 000 FM (10 years)	180 l/day at 50° C	1 500 FM/m^3
Solar still (1 m^2)	150 000 FM (10 years)	3-4 l of distilled water/day	20 FM/l
Photovoltaic solar pump 1,300 W peak	27 000 000 FM (15 years)	32 m^3/day at 30 m	300-400 FM/m^3 (including 70 FM operating cost)
Wind generator for pumping (average wind speed 5 m/s)	14 800 000 FM (10 years)	40 m^3/day at 30 m	200 FM/m^3
"Sahores" type windpump, (Plasteig) (average wind speed 3 m/s)	450 000 FM (3 years)	6 m^3/day at 15 m (equivalent to 3 m^3/day at 30 m)	197 FM/m^3
Photovoltaic electricity generators (100 W peak or 10 W constant)	1 500 000 FM (15 years)	250 Wh/day	2.5 FM/Wh
Photovoltaic lighting kit (33 W peak - 4 fluorescent tubes)	600 000 FM (15 years)	4 x 3 h/day of lighting	230 FM/day
Photovoltaic refrigerator (60 + 15 l)	1 500 000 FM (15 years)	Conservation of food and/or pharmaceutical products	500 FM/day
Biogas digester (6 m^3, continuous operation)	450 000 FM (10 years)	3 m^3/day at 60% CH_4	100 FM/m^3
Gas generator and electricity generating set (300 kW)	100 000 000 FM** (10 years)	2 000 kWh/day	60 FM/kWh **

* Investment costs including equipment and installation.

** Data to be confirmed.

N.B. 100 Malian francs (FM) = 1 French franc = 50 CFA francs.