COMMISSION OF THE EUROPEAN COMMUNITIES

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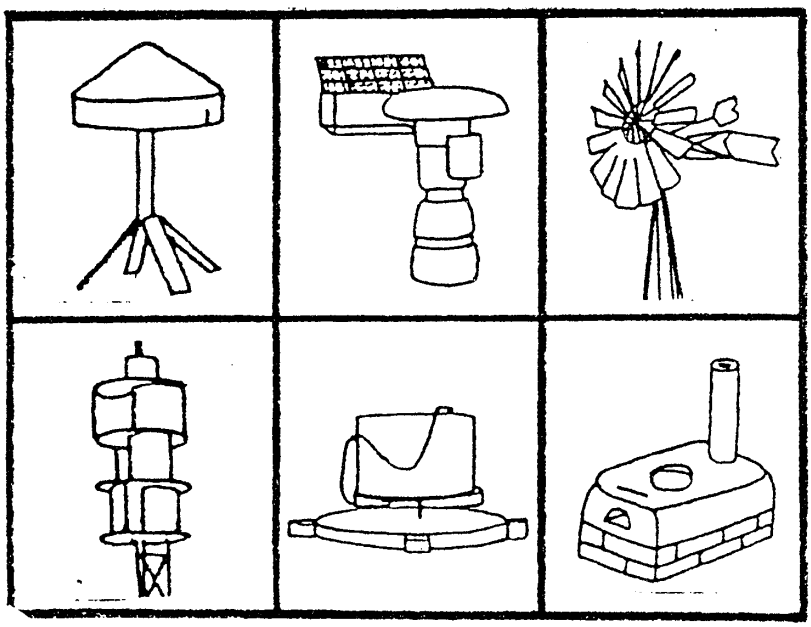
RENEWABLE ENERGY SOURCES

EVALUATION OF PROJECTS IN THE DEVELOPING COUNTRIES



DIRECTORATE-GENERAL FOR DEVELOPMENT

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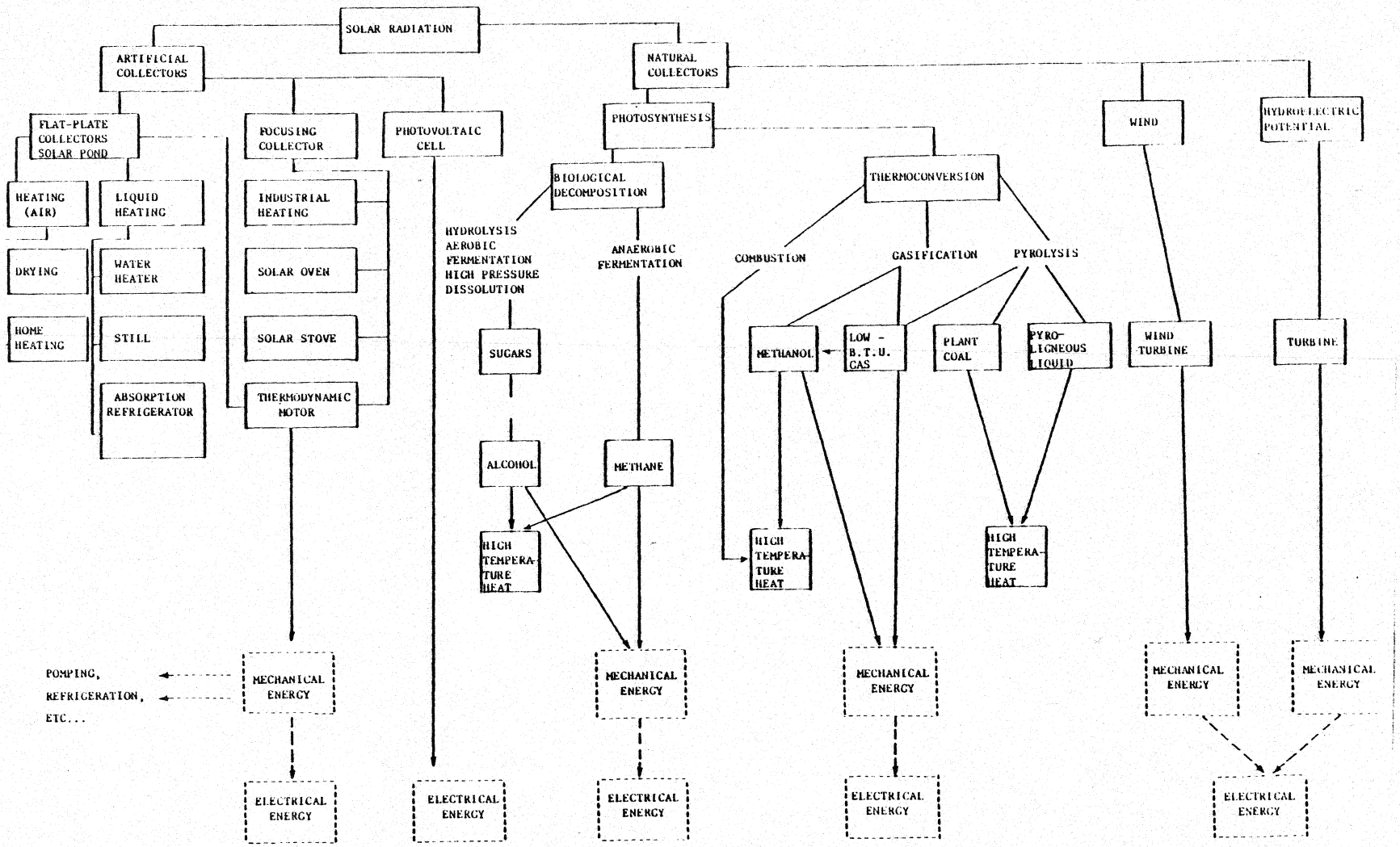
RENEWABLE ENERGY SOURCES AND DEVELOPMENT

Renewable sources of energy - principal pathways of utilization



RENEWABLE ENERGY SOURCES AND DEVELOPMENT

1. Technological advances in renewable energy sources

Renewable energy sources exist in a wide variety of forms. Solar energy, for instance, can be utilized in numerous ways, as shown on the following chart. The oldest and most common utilization of solar energy is, of course, the burning of wood.

Other branches have been developed over the past few decades, and each has reached a different stage of technological maturity.

- The most widespread appliction is the solar water heater for drinking water and home heating (there are literally millions of this type of water heater in the United States, Japan, and Europe).

- The other widely distributed technologies are:

  . multiple-blade wind pumps (Australia, Europe, United States)
  . micro-hydroelectric stations (China, Latin America),
  . geothermal energy for home heating (Iceland, France, Italy, United States),
  . biogas (China, India),
  . ethanol production from biomass (Brazil, Paraguay).

- Other branches exist in limited or single applications (aerogenerators, thermodynamic applications of solar energy, improved stoves, solar dryers).

- Photovoltaic energy shows great promise, although its applications are still very limited. The world market for photovoltaic energy is estimated at 4 MW, an insignificant figure, and for 1985, only 25 to 50 MW of power is expected to be installed.

- All other branches are in the experimental stage or undergoing preliminary study.

The following charts summarize the development stage and probable date of first commercial applications of the different types of renewable energy equipment.

Development stage of the various technologies

Technology/ Application	Development Stage			Date when large-scale marketing will probably begin[1]		
	Research	Pilot-stage	Commercially available	before 1985	1985-1990	after 1990
SOLAR HEATING						
A. Systems						
- Solar water heaters			x	x		
- Industrial heating LT[2]		x		x		
- Steam generator		x			x	
- Still			x	x		
- Desalination unit		x		x[3]	x[4]	
- Solar dryer		x		x	x	
- Refrigerator		x			x	
- Air conditioner		x			x	
- Solar pump 10 kW			x	x		
- Solar pump (+ motor) 10 kW		x			x	
- Power stations						
-- 100 kW		x			x	
-- 100 - 1,000 kW		x			x	
-- 1 MW		x				x
- Solar stove		x			x	
- Solar oven HT[2]		x				x
- Solar pond		x			x	
B. Collectors						
- Normal flat-plate			x	x		
- Selective flat-plate			x	x		
- Cylindrical-parabolic concentration			x	x	x	
- Parabolic concentration		x	(x)		x	
PHOTOVOLTAIC SOLAR ENERGY						
A. Systems						
- Solar pumps						
-- Water pumps (village supply)			x	x		
-- Water pumps (livestock supply)			x	x		
-- Microirrigation			x	x		
-- Irrigation 10 kW			x	x		
-- Irrigation 10 kW		x			x	
- Telecommunications (all individual applications)			x	x		
- Signals			x	x		
- Refrigeration			x	(x)	x	
- Ventilation and small motor systems			x	x		
- Air conditioning by water vaporization		x			x	
- Individual lighting			x	x		
- Transportation (automobiles, etc.)	x				x	
- Power stations						
10 kW			x	x	x[5]	
100 kW		x				x
- Battery chargers			x	x		
- Rechargeable battery chargers		x		x		
- Power for television			x	x		
B. Collectors						
- Flat-plate modules			x	x		
- Concentration modules		x			x	

1) On condition, of course, that the technology proves competitive with respect to other, "competing" solutions.
2) LT = Low temperature; HT = High temperature
3) Up to 5 m³/day
4) Over 5 m³/day
5) Adaptations to extremes in climate

Technology/ Application	Development Stage			Date when large-scale marketing will probably begin[1]		
	Research	Pilot-stage	Commercially available	before 1985	1985-1990	after 1990
WIND ENERGY						
A. Systems						
- Wind pump (mechanical) 5 m³/hr			x	x		
- Wind pump (electric) 5 m³/hr			x	x		
- Aerogenerator						
-- 30 kW			x	x		
-- 30 - 100 kW			x	x		
-- 100 - 2,000 kW		x			x	
-- 2 MW	x				(x)	x
B. "Collectors"						
- Sail rotors			x	x		
- Multiple-blade rotors			x	x		
- Savonius rotors		x		x		
- Darrieus rotors		x			x	
- Rapid propellers 100 kW			x	x		
- Rapid propellers 100 kW		x			x	
HYDROELECTRIC ENERGY						
- Micro-hydroelectric station 10 kW			x	x		
- Mini-hydroelectric station						
-- 10 - 100 kW			x	x		
-- 100 - 1,000 kW			x	x		
GEOTHERMIC ENERGY			x	x		
OCEAN THERMAL ENERGY						
- Thermal gradient	x					x
- Wave energy	x					x
- Tidal energy			x		x	
BIOGAS[6]						
- Substrate: manure						
-- Small scale 20 m³		x		x		
-- Medium scale 1,000 m³			x	x		
- Substrate: agricultural ewfuaw + manure						
-- Small scale		x		x		
-- Medium scale		x			x	
- Unconventional substrate:						
-- Slaughterhouse refuse		x			x	
-- Cannery refuse		x			x	
-- Algae		x				x
-- Water hyacinth		x			x	
-- Coffee husks and other substrates	x				x	
GASIFICATION[7]						
- Small unit 50 kW			x	x		
- Medium-sized unit 50-500 kW		x	x	x		
- Large unit 500 kW		x		x	x	

Technology/ Application	Development Stage			Date when large-scale marketing will probably begin[1]		
	Research	Pilot-stage	Commercially available	before 1985	1985-1990	after 1990
PYROLYSIS						
(plant coal + oils + gas)						
- Small unit		x	(x)	(x)	x	
- Medium-sized unit		x			(x)	x
- Large unit		x	(x)	(x)	x	
BRIQUETTES FROM PLANT-MATTER REFUSE[1]						
- Straw		x			x	
- Rice husks			x	x		
- Groundnut shells			x	x		
- Sawdust			x	x		
- Others	x				x	
COMBUSTION						
- Improved stoves						
-- Heating wood			x	x		
-- Charcoal		(x)	x	x		
- Industrial boilers, plant-matter refuse			x	x		
ETHANOL[8]						
- Discontinuous system						
-- 1 m³/day		x			x	
-- 10 m³/day			x	x		
-- 750 m³/day			x	x		
- Continuous system			x	x		
- Using cane sugar juice		(x)	x	x	(x)	
- Using molasses			x	x		
- Using cassava		x	(x)	(x)	x	
- Using sweet sorghum and other cereals	x				x	(x)
- Using wood refuse	x					x
METHANOL[9]						
- From wood		x			x	
- From other plant matter	x					x
OTHER						
- Energy-producing plants						
-- Wood		x	(x)	x		
-- Other		x			x	
- Vegetable oils	x					x

2. The contribution of renewable energy sources to development

As can be seen, a certain number of applications are first becoming operational. The continuous price increases for crude oil have rendered them competitive, despite their ususally high investment costs, with respect to conventional energy sources. Mostly, it is their decentralized nature that makes it possible to plan a great number of renewable energy solutions, particularly in rural and isolated locations, in order to satisfy sparse needs. Extremely varied, renewable energy solutions are thus capable of making significant contributions in all spheres of development.

2.1 - Rural development

By their very nature, renewable energy sources are well suited to rural development. Numerous applications are thus possible:

Energy needs	Possible renewable energy solutions
Cooking	- Improved stoves - Reforestation (biomass + solar collector) - Anaerobic fermentation of plant waste - Solar cooking
Village water supply	- Photovoltaic pumps - Wind turbine and aerogenerator
Livestock water supply and irrigation	- Dual-fuel engines powered by low-BTU gas (gasification of waste, straw, etc.) - Photovoltaic and thermodynamic pumps - Multiple-blade wind turbines and aerogenerators
Lighting	- Photovoltaic lighting - Anaerobic fermentation
Drying food products	- Solar dryers
Refrigeration of food products	- Solar cold rooms
Rural electrification	- Micro-hydroelectric stations - Aerogenerators - Dual-fuel diesel engines (gasification of plant waste) - Thermodynamic and photovoltaic solar power stations
Cottage industries	- Solar water heaters - Solar ovens - Motors powered by solar arrays
Forests, fire monitoring	- Radio relay sensors powered by photocells

2.2 Health:

The health sector stands to benefit greatly from the contribution made by renewable energy sources:

Energy need	Possible renewable energy solutions
Villages: supply of drinking water	- Installing solar pumps on bore-holes requiring motorization - Wind turbine and aerogenerator
Infirmaries, hospitals, maternity wards: . drinking water . lighting . ventilation . medicine refrigerator . medical appliances . sterilization . hot water . distilled water . air conditioning	 - Photovoltaic or wind pump - Solar array or aerogenerator - Solar water heater - Solar still - Passive or active air conditioning (depending on building)

2.3 Equipment and transportation:

This technical field includes a great number of divisions: construction, public works, electricity, transportation, ports and navigable waterways, meteorology, etc. Among some of the numerous possibilities for renewable energy applications:

Sector	Energy need	Possible renewable energy solutions
Construction	Air conditioning Hot water	- Passive air conditioning, mostly - Active air conditioning in other cases (see corresponding chapter) - Solar water heater
Electricity	Rural electrification	- Dual-fuel diesel power station operating on plant waste - Micro-hydroelectric stations - Aerogenerators - Solar power stations
Road transport	Fuel for engines	- Ethanol (or methanol) mixed with petroleum products
Railroads	Power for signals, switches, radio-telephones, etc.	- Solar arrays

2.3 Equipment and transportation (continued)

Sector	Energy needs	Possible renewable energy solutions
Air transport	Power for radio beacons, VOR, etc, obstruction lighting	- Solar arrays - Aerogenerators
Sea transport	Power for signaling equipment; radio communication with offshore platforms	- Solar arrays - Aerogenerators
Meteorology	Powering telemetry equipment Radio data transmission connections, etc.	- Solar arrays - Aerogenerators

2.4 Telecommunications and information:

Renewable energy equipment (solar arrays and aerogenerators) offer considerable advantages when powering equipment in isolated locations (autonomy, low recurring charges compared to competing energy sources, simplicity, and reliability). These renewable energy sources, already competitive, are likely to find very many applications, as can be seen in the following chart:

Sector	Energy need	Possible renewable energy solutions
Telecommunications	Powering radio relays, VHF and UHF relay transmitters, rural telephone exchanges. Radiotelephones, emergency telephones, amplifying relays over coaxial cables, transmitter/receivers, VHF and UHF radio, etc.	- Solar arrays - Aerogenerators (windy regions)
Information	TV transmitters and relay transmitters. Radio relay transmitters, community radio, etc.	- Solar arrays - Aerogenerators (windy regions)

2.5 Education and research:

National educational and research departments can also benefit from certain renewable energy applications.

Energy needs	Possible renewable energy solutions
Transmitters, relay transmitters, scholastic television. Scholastic television sets. Scholastic radio receivers.	Solar arrays, mostly.
Air conditioning for school buildings	Passive and active air conditioning
Hot water for dormitories, cafeterias	Solar water heaters
Water pumping for schools	Photovoltaic pumps, wind pumps, aerogenerators
Data transmission for research in: . meteorology . hydrology . pollution . independent measurement stations	Solar arrays Aerogenerators (windy regions)

2.6 Industry

At last, renewable energy equipment is capable of providing economic solutions to part of industry's energy needs:

Sector	Energy needs	Possible renewable energy solutions
Agricultural industries: . rice mills . oil mills . sugar refineries . decortication mills . canneries etc.	. mechanical energy . electricity . high- and low-temperature heating	. Extraction of energy from plant waste by: - gasification (diesel engine dual fuel), - combustion (steam turbines) . Solar collectors
Food industries: . dairies . breweries . soda factories . slaughterhouses	. industrial heating	. Use of focusing collectors for the production of industrial heat.

2.6 Industry (continued)

Sector	Energy needs	Possible renewable energy solutions
Other industries: . tannery . textiles	. industrial heating	. Use of flat plate or focusing collectors for the production of industrial heat.
Woodworking industries: . sawing . unrolling . cutting . joinery	. electricity . steam	. Extraction of energy from wood scraps by gasification or combustion.

3. Renewable energy sources in Western Africa

Western Africa has now carried out its first experiment in integrating renewable energy equipment, as shown in the following list, summarizing completed projects:

Technology	Country	Localisation	Use	Installation Date	Basic Specifications
Solar Water Heater	Ivory Coast	Yamoussoukro	Hotel	1981	180 m² collectors
	Upper Volta	Fada	8 projects	1978	
	Niger	Niamey and environs	49 administrative villas 39 private villas 8 hospitals and maternity wards + more recent projects	1976 to 1978	
	Senegal	Sali Portudal	Hotel	1981	500 m²
		Dakar	Veterinary school	1981	60 m²
		Saint Louis	Hotel	1978	36 m²
		Thiès	Clinic	1979	16 m²
		Dakar and environs	Industrial water heating	1977/ 1979	25 m²
Solar Still	Mauritania	Iwik-Bank d'Arguin	Ornithological Research Center	1980	120 m² 400 l/day
	Niger	Niamey and environs	Laboratories, garages (15 units)	1976 1978	25 l/day each

Technology	Country	Localisation	Use	Installation Date	Basic Specifications
Thermodynamic Pumping	Upper Volta	Ouagadougou	Training demonstration	1971	0.4 kW peak
		Djibo	Village water supply	1976	1 kW peak
		Taparko	Livestock water supply	1978	1 kW peak
		Djibasso	Village water supply	1979	1 kW peak
		Po	Livestock water supply	1979	1 kW peak
		Demnouo	Livestock water supply	1979	1 kW peak
		Gangaol	Livestock water supply	1979	1 kW peak
	Cape Verde Islands	San Domingos	Village water supply	1979	1 kW peak
	Mali	Dioila	Village water supply	1975	1 kW peak
		Katibougou	Irrigation	1977	1.3 kW peak
		Diré	Irrigation and electricity production	1979	75 kW peak
	Mauritania	Chinguetti	Village and livestock water supply	1973	1 kW peak
		N'gorel Guidal	Irrigation and refrigeration	1978	10 kW peak

Technology	Country	Localisation	Use	Installation Date	Basic specifications
Thermodynamic Pumping	Niger	Bossey Bangou	Village and livestock water supply	1973	1.3 kW peak
		Karma	Irrigation	1978	10 kW peak
		Tabalak	Irrigation	1980	5 kW peak
	Senegal	Dakar IPM	Pilot plant	1968	1.2 kW peak
		Dakar ONUDI	Evaluation plant	1975	1 kW peak
		Medina Dakhar	Village water supply	1976	1 kW peak
		Niakhene	Village water supply	1977	1 kW peak
		Méouane	Village water supply	1977	1 kW peak
		Diaglé	Livestock water supply	1977	1 kW peak
		Dakar IUT	Demonstration - training	1977	1 kW peak
		Bondie Samb	Livestock water supply	1981	10 kW peak
	Chad	Karal	Livestock water supply	1976	1 kW peak
		Ati	Livestock water supply	1977	1 kW peak
		N'Gouri	Village water supply	1977	1 kW peak
		N'Djamena	Water, electricity and refrigeration	1980	5 kW peak
Thermodynamic Electricity	Upper Volta	Koupela	Refrigeration	1975	1 kW peak
	Senegal	Diakhao	Sub-Prefecture	1981	25 kW peak

Technology	Country	Localisation	Use	Installation Date	Basic specification
Photo-voltaic Pumping	Ivory Coast	Yamoussoukro	Engineering School (2 pumps)	1980	2 kW peak
	Upper Volta	Mogtedo	Village water supply	1979	0.9 kW peak
		Kamboinsé	Village water supply	1979	0.9 kW peak
		Bané	Village water supply	1980	0.5 kW peak
		Tangaye	Village water supply and mill	1979	1.8 kW peak
		Ziniaré	Village water supply	1979	0.6 kW peak
		Markoye	Livestock water supply	1980	0.9 kW peak
	Mali	Koni 1	Village water supply	1977	0.9 kW peak
		Nabasso		1977	0.9 kW peak
		Tominian		1978	1.3 kW peak
		Yangasso 1		1978	1.3 kW peak
		San		1979	1 kW peak
		Yangasso 2		1979	1.3 kW peak
		Djenna		1979	1.3 kW peak
		Safolo		1980	1.3 kW peak
		Kimparana		1980	1.3 kW peak
		Bé		1980	
		Wassasso		1980	0.9 kW peak
		Tion		1980	1.2 kW peak
		Bossoni		1980	1.3 kW peak
		Koni 2		1980	0.9 kW peak
		Koro 1		1980	1.3 kW peak
		Koro 2		1980	
		Nworo		1980	5 kW peak
		Ben Markala		1980	1.3 kW peak
		Kanssara		1981	1.3 kW peak
		Tene		1981	0.9 kW peak

Technology	Country	Localisation	Use	Installation Date	Basic specification
Photo-voltaic Pumping	Mali	Samanko	Village water supply	1980	1.2 kW peak
		Bourem			0.9 kW peak
		Diré			1.3 kW peak
		Bankass		to	5.2 kW peak
		Mopti			1.3 kW peak
		Camp Modibo			2.6 kW peak
		Diaware		1981	1.8 kW peak
		Meninka		1981	1.3 kW peak
		Mopti Sevaré		1981	2.6 kW peak
		Mieg Mopti		1981	5.2 kW peak
	Mauritania	Garak	Irrigation	1980	3.9 kW peak
		Nrakat	Village water supply	1980	0.9 kW peak
	Senegal	Babak	Village water supply	1978	1.3 kW peak
		Bambey		1978	0.9 kW peak
		Haere Lao		1979	0.9 kW peak
		Affiniam		1980	0.6 kW peak
		Saname		1980	2.6 kW peak
		Ndioudouf		1980	2.6 kW peak
		Gourou		1980	2.6 kW peak
		Montrolland		1979	0.5 kW peak
		Medina Dakhar		1980	1.5 kW peak

Technology	Country	Localisation	Use	Installation Date	Basic specification
Photovoltaic Electricity	Ivory Coast	Railroad line	Railroad signaling 29 stations equipped	1981	25 kW peak (total)
	Mali	San	Electric power for hospital	1979	8.5 kW peak
		Kolokani	Electric power for infirmary (focusing photovoltaic cells)	1981	5 kW peak
		Bla	School lighting	1980	0.15 kW peak
		Kimparane	School lighting	1980	0.16 kW peak
	Niger	Villages	822 television sets, schools and communities	1980	30 kW peak (total)
		Tillabery	T.V. retransmitter	1977	0.12 kW peak
	Senegal	Dakar	Experimentation	1979	0.6 kW peak
Aerogenerator	Cape Verde Islands	San Nicolau	Pumping	1980	4100 W
		San Vicente	2 beacons	1980	300 W 150 W
		Praia	3 wind potential measurement stations	1981	250 W
	Mauritania	Iwik	Pumping - electricity production	1981	4100 W
	Senegal	Dakar IUT	Training - demonstration	1979	1100 W
		Louly Bentegné	Village water supply	1981	1100 W

Technology	Country	Localisation	Use	Installation Date	Basic specification
Multi-blade Wind Turbine	Upper Volta	Ouagadougou Bobo Dioulasso Villages	15 wind pumps (hospitals, missions, etc.)	1974 1981	
	Cape Verde Islands	Sao Vicente	60 wind pumps for irrigation	1977 1980	
	Mali	Bandiagara	1 wind pump 1 wind pump	1964 1980	
	Senegal		17 wind pumps	1948 to 1980	
Savonius Wind Turbine	Upper Volta	Dori Ouagadougou Toesse	Village water supply Experimentation (2 wind pumps) Village water supply	1978 1978 1981	3 troughs
	Senegal	Dakar IUT Diaglé Keur Bakar	Experimentation Village water supply Village water supply	1975 1978 1979	2 troughs 4 troughs 4 troughs
Savonius Wind Turbine	Senegal	Mbiriem Mouride Mbodiene Dakar IUT Dakar IUT	Village water supply Village water supply Experimentation Experimentation	1979 1979 1980 1981	4 troughs 4 troughs 2 troughs 2 troughs + Darrieus rotor

Technology	Country	Localisation	Use	Installation Date	Basic specification
Biogas	Upper Volta	Kongoussi (hospital)	Sterilisation	1978	Discontinuous
			Refrigeration, pumping, medical analyses	1979 1979	Semi-discontinuous
		Tanghin	Horticultural school kitchen	1981	
		Kongoussi	Irrigation	1981	
		Kougsabia	Cooking, refrigeration	1981	
		Saria			
	Mali	Bamako	Solar energy laboratory, experimentation	1979	
	Niger	Lossa	Cooking, lighting	1980	
	Senegal	Diour Fissel	Cooking, lighting	1980	Continuous
		Bambey		1979	
		Nianing	Cooking	1980	
Improved stoves	Upper Volta	Urban and rural areas	≃ 1200 completed	1980 to 1981	
	Niger	Urban and rural areas	≃ 400 completed	1980 to 1981	
	Senegal	Urban and rural areas	≃ 2000 completed	1980 to 1981	

This experience has created a vital force in Africa, whose countries are now defining their own renewable energy policies with technical and financial assistance from the international community, preparing wide-range distribution programs, and above all, implementing their own policies and programs. Proof of this can be found in the research centers, training centers, renewable energy equipment production units, and solar energy engineering firms they have founded.

In this key period of transition, from the experimentation stage to that of mass distribution, this experience is of immense value. It is thus essential to evaluate the completed projects, or at least the most representative ones, that are likely to be reproduced on a large scale:

- in order to comprehend the technical successes of and people's feelings about the completed projects, to analyze the reasons for each success or the causes of problems encountered, and to draw conclusions concerning the appropriateness of certain techniques with respect to the needs they are supposed to satisfy;

- to highlight the success factors for upcoming projects and programs.

4. Project evaluation

For reasons of maturity of the techniques used, as well as the interest in and the prospects for their development, seven renewable energy branches have been grouped together in one evaluation:

- solar drying
- thermodynamic solar pumping
- photovoltaic solar pumping
- photovoltaic electrical applications
- wind pumps
- anaerobic fermentation
- improved stoves.

Five assignments were conducted on location:

- Upper Volta (12 - 24 May 1980, 2 - 6 March 1981)
- Senegal (28 September - 11 October 1980)
- Mali (16 - 25 October 1980, 14 - 23 June 1981)
- Niger (27 -30 October 1980)
- Cameroon (24 - 31 January 1981).

The first part of this report comprises a series of detailed evaluations based on inspections made while on assignment. Various documents concerning the promoters and manufacturers have been added for certain applications. Keeping in mind the diversity of situations encountered and the interest of first-hand information, it was deemed worthwhile to present much of what was learned through interviews. Very often, these evaluations do not go beyond relating the facts; their interpretation is thus very brief. More detailed analysis of the appraisals of these evaluations is presented in the second part of this report, which offers numerous suggestions for facilitating the creation and proliferation of renewable energy projects in the future. The first part may seem a bit long, nevertheless, it is advisable to read it in order to gain a full understanding of the difficulty of each achievement, to recognize the successes and shortcomings, and to approach the summary in the second part with a background helpful in appreciating our conclusions.

PART 1

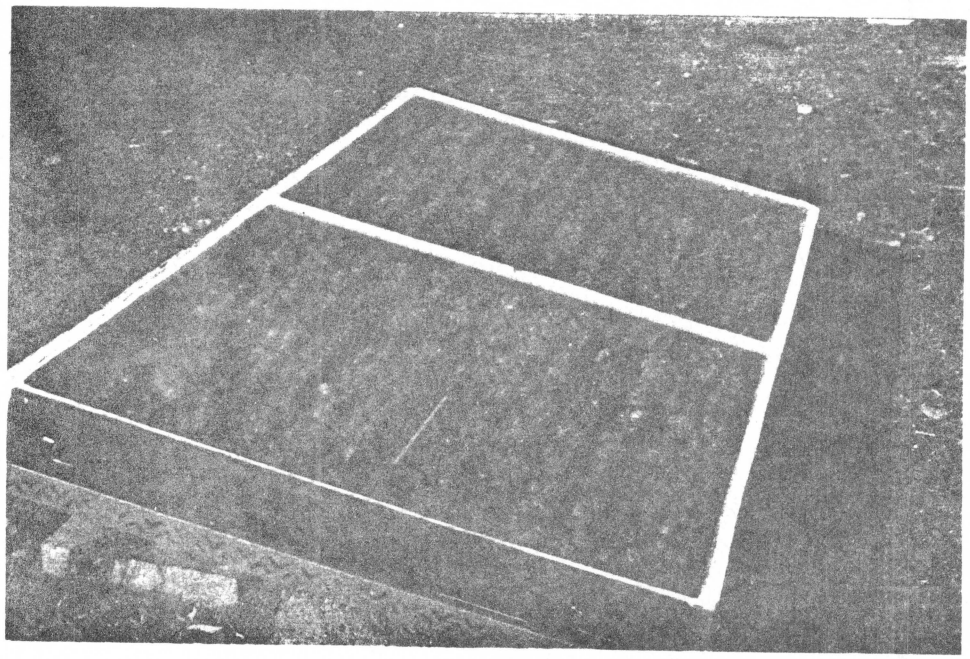
ON-SITE EVALUATION

A. SOLAR DRYERS

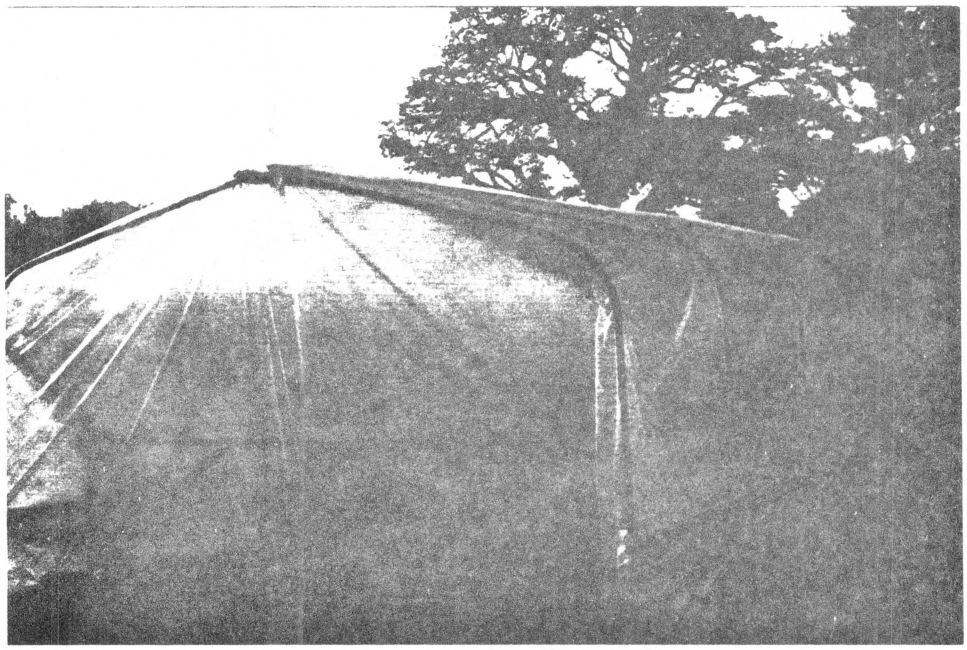
A. SOLAR DRYERS

Example 1: Sesol solar dryer (CERER, Senegal) pg. 34

Example 2: Solar dryers at Koumbidia (Senegal) pg. 40



. Drying karite nuts



. Solar tent

Although little emphasis has been put on solar dryers until now, they satisfy a real and important need for:

- Preserving food:

Preserving perishables by means of open air drying is a tradition in the Sahel. However, this method has proven inadequate (long and irregular drying time, need for pest control) and output is limited. Superior processes can be used to preserve surplus food (fruits, vegetables, fish) and reduce the risk of food shortages when supplies are low, a problem far from solved.

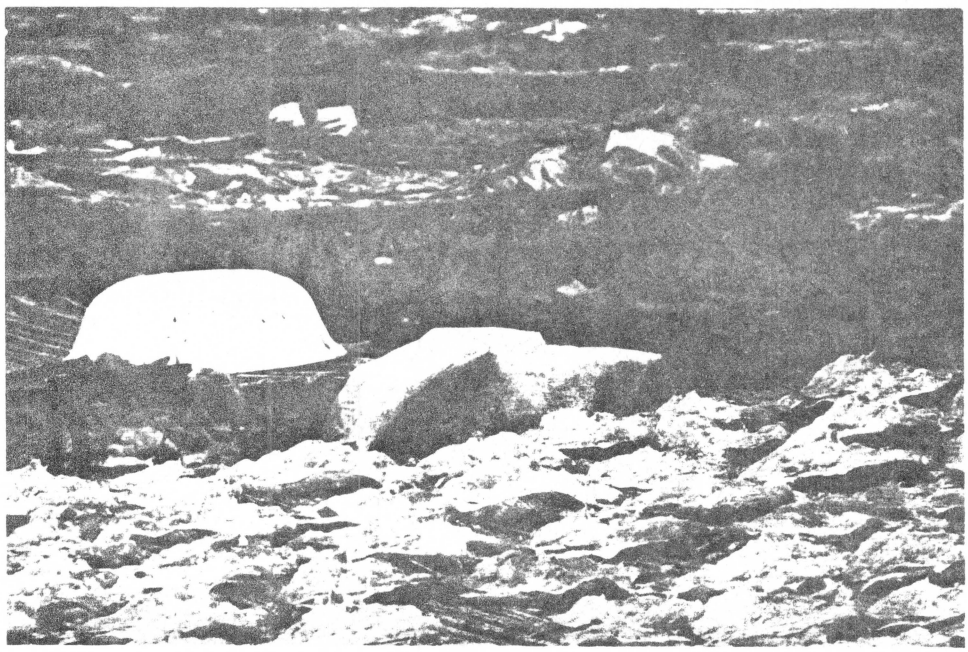
- Preserving the harvest:

A large percentage of the food that is damaged due to inadequate preservation (spoilage, parasites) could be saved through the use of appropriate drying techniques in order to:

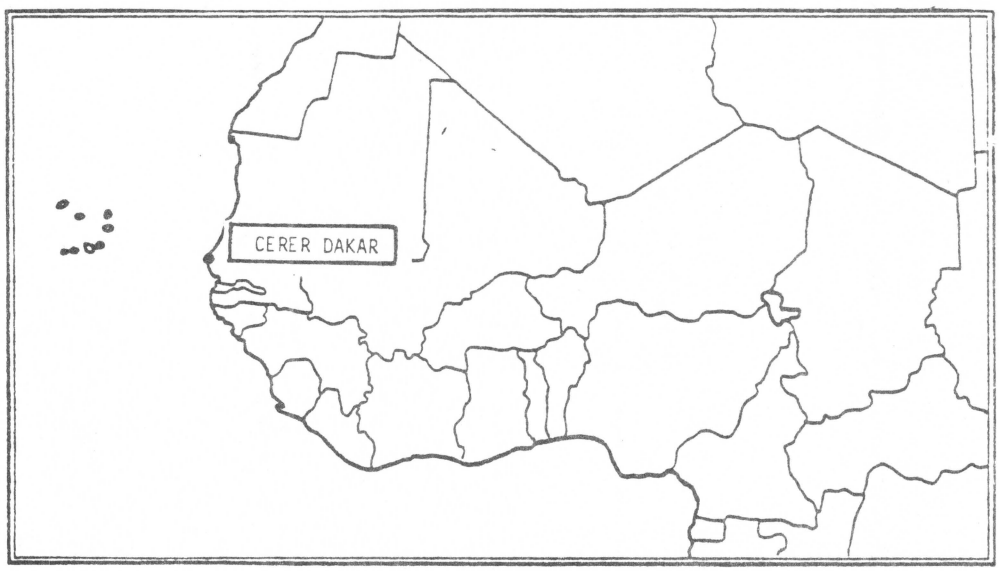
- preserve the products before storage and sales,
- make year-round marketing possible.

- Preserving forage:

It also seems essential to create ample forage reserves during the rainy season in order to meet the needs of sedentary animals during periods of low supply and in order to avoid overgrazing. Available fodder resources are wasted every year while appropriate drying techniques have been developed.



. Traditional fish drying



EXAMPLE 1	SOLAR DRYER SESOL 1.20 C E R E R / SENEGAL
Documentation source: C E R E R	

1. Technology selected

The traditional process of drying fish on grids by direct exposure to sunlight entails considerable losses (40 - 60%) mainly due to infestation by insects. CERER has developed several prototypes of solar dryers aimed at improving product quality in order to increase its conservation and productivity, and improve hygienic conditions compared to the traditional method.

Experiments on these prototypes made it possible to test:

- different solar collector structures for hot air production
- different designs for drying locations (tunnels, chambers)
- different types of grids
- various construction materials (wood, cement) and insulating materials (glass wool, groundnut shells, polyurethane)
- natural ventilation (simple, using a solar chimney) and forced ventilation

and to make certain technical choices. At present, two types of technology have been selected:

a)- drying tents, easily hand crafted and low in price, designed for individual fishermen and small fishing villages;

b)- semi-industrial dryers equipped with flat plate solar collectors for the production of hot air, described below, designed for fishing cooperatives with:
  - some financial means
  - a management/maintenance organization
  - a distribution network.

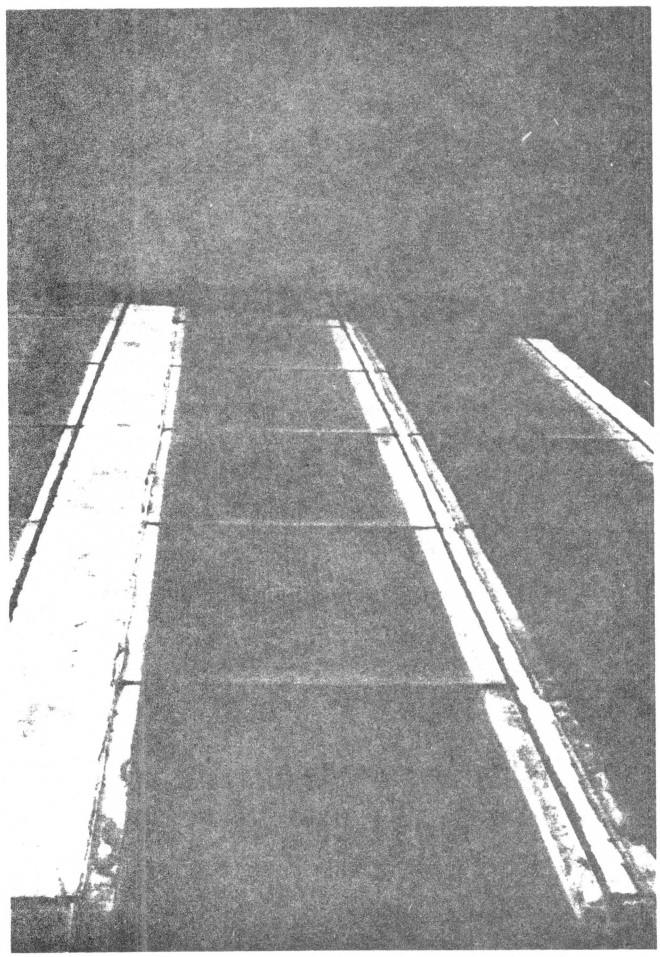
2. The Sesol 1.20 solar dryer

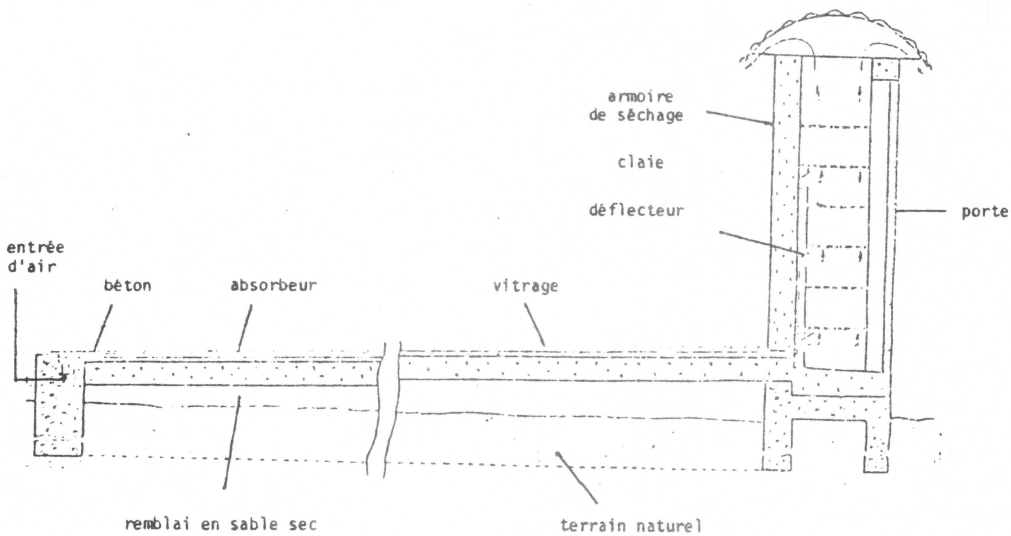
The CERER research team concentrated its efforts on:

- perfecting a simple, inexpensive construction process,
- modular design for eventual expansion or the development of a larger dryer,
- using locally available materials or those exploited locally.

The result is a compromise between performance and the restrictions imposed by local fabrication. The Sesol 1.20 dryer, whose structure and absorber are shown in figures 1 to 3, has the following specifications:

. drying chamber capacity for fresh fish = 250 Kg
. working surface of the flat plate collectors = 20 m^2, divided into four rows of 0.76 x 6.5 m^2 each
. forced air ventilation -- air output = approximately 1,200 m^3/hr.
. hot air circulation inside the drying chamber using a system of deflectors
. cost of the prototype = approximately 2,000,000 CFA Francs.





Séchoir solaire SESOL 1.20

(Source : CERER)

3. Economic interest of the solar dryer for fish

In rural areas, the fish used in drying is often that which is left over from the sales of fresh fish. Its price varies throughout the year depending on the quantities caught. Nevertheless, the average can be estimated at 50 CFA Francs/Kg of fresh fish.

In drying, the fish loses close to two-thirds of its original weight. When fresh, it contains between 70 and 80% water. To prevent the spread of micro-organisms in the dried fish, maximum advisable water content is 25% (source: Institut de Technologie Alimentaire, Dakar). The official limit set by the Office des Pêches du Sénégal is 35% maximum water content for dried fish.

Consequently:

1 Kg of fresh fish produces 1/3 Kg of dried fish.

The use of a solar dryer, which can dry all the fresh fish it treats, affords an increase in productivity, compared to the traditional method (entailing 40% loss), of:

(0.40 x 1/3 Kg) of dried fish / Kg of fresh fish.

The dried fish is sold for approximately 250 CFA Francs/Kg in Senegal (and as much as 900 CFA Francs on certain export markets). The profit made from the use of a solar dryer is:

33.33 CFA Francs / Kg of fresh fish.

The cost of a 100 m^2 solar dryer, of the same type as the one built by CERER is evaluated at 8,000,000 CFA Francs. Its minimal drying capacity is estimated at 750 Kg of fresh fish in two days. The profit made equals:

33.33 x 750 = 25,000 CFA Francs / two days,

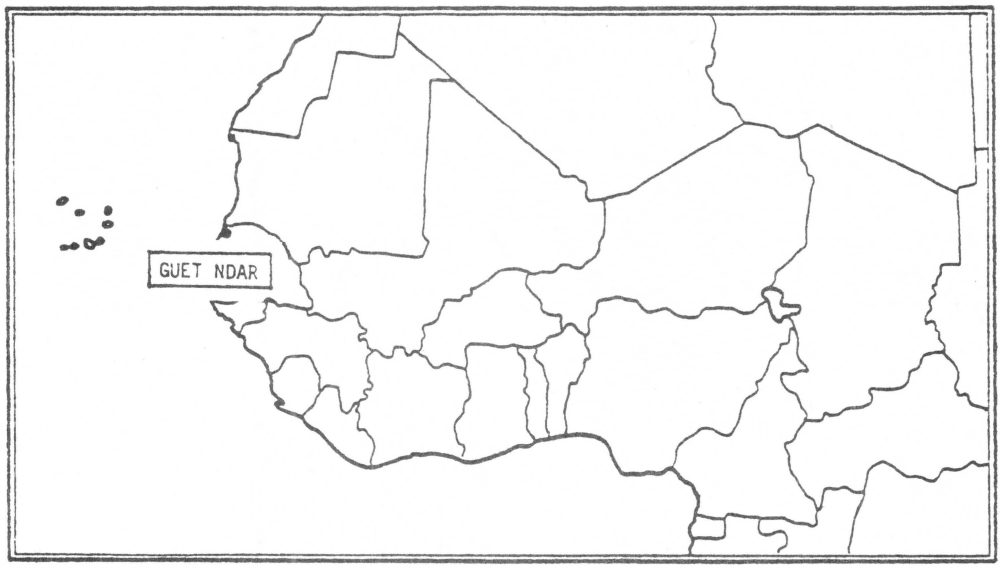
or, for a 300-day fishing season: 3,790,000 CFA Francs. This sort of equipment can be paid off in two years.

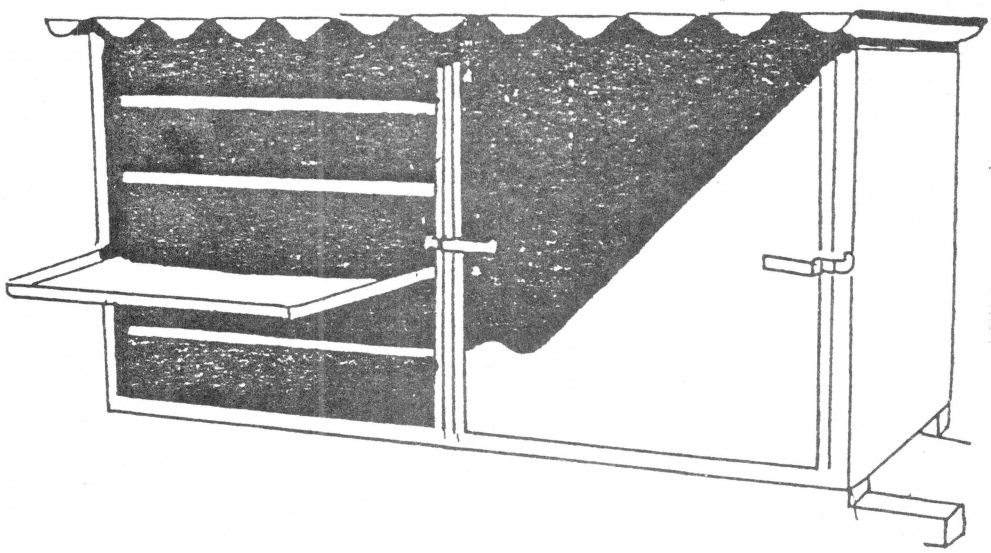
4. The Sesol 1.100 solar dryer

Taking best advantage of its experience, CERER is currently producing a solar dryer for fish designed for the Guet Ndar neighborhood of Saint-Louis. The lebon inhabitants of Guet Ndar make their livelihood fishing, a considerable part of which (about 30%) is done locally.

The Sesol 1.100 dryer can dry 750 Kg of fresh fish in two days. Its modular design comprises three parts:

- eight thermally insulated drying chambers where the fish is loaded (overall capacity is close to one ton)
- a battery of flat plate solar collectors (approx. 100 m^2) for hot air production, arranged in eight rows
- an electric forced air ventilation unit (6,000 m^3/hr.) designed to accelerate the drying process.



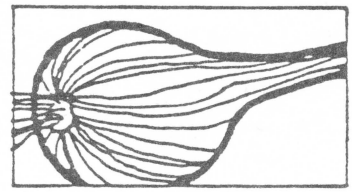


. Drying chamber
of the Sesol 1.1000 dryer

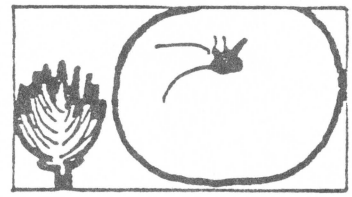
A CERER-trained operator, employed by the Service Régional des Pêches Maritimes is in charge of operating the dryer. Each woman brings a load of prepared fish which the operator places in the different compartments of the drying chamber and removes once dried. In addition, the operator is responsible for cleaning the dryer as well as providing minor servicing.

CERER will carry out a two-year measurement program in order to monitor the dryer's operation and determine its effectiveness under actual conditions. A series of special instruments has been designed for this purpose, to be used in conjunction with a microprocessor-based measurement station created by the Ecole Nationale Supérieure Universitaire de Technologie de Dakar (solar radiation, air flow, humidity levels).

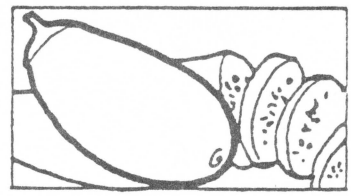
onions



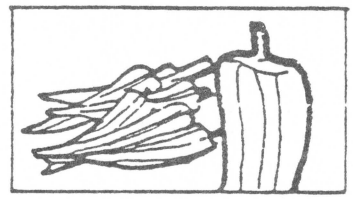
bissap
tomatoes



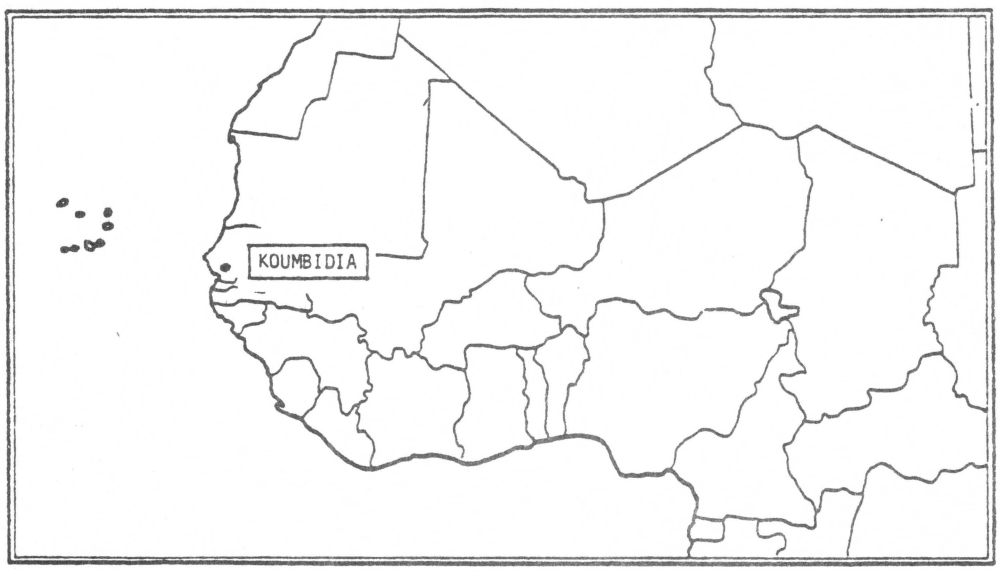
eggplant



gumbo



(Source : G.R.E.T.)



EXAMPLE 2	SOLAR DRYERS AT KOUMBIDIA / SENEGAL
From GRET/ISPA/ CERER report March 1982	

1. Location

Koumbidia, located in the region of Sine Saloum, is one of the truck farming stations under the direction of the Institut Sénégalais de Recherche Agronomique. Truck farming, introduced a decade ago, has significantly altered the eating habits of villagers. It has also become a profitable operation for women, who sell their vegetables at the market at Koungheul, a stopping-off point 10 km from Koumbidia.

2. Drying

Drying is an old tradition. Long before truck farming began, part of every harvest was set aside for drying. Now the traditional herbs, leaves, and berries are being supplanted by vegetables:

- onions (crushed, rolled, and dried, or left to dry in the ground)
- tomatoes and bissap (ground to a salty paste)
- 'dia katous' (a sort of bitter eggplant, crushed and dried)
- gumbo (reduced to a powder after drying; also sold at the Koungheul market).

Generally speaking, the quantity of food dried is very small, and the products that are dried are used as condiments in making sauces. The number of products dried is also limited compared to the diversity of varieties cultivated.

Vegetable drying seems to be doubly profitable:

- it reduces harvest losses and provides vegetables for out-of-season consumption, such as eggplant, tomatoes, white onions (especially), that are the necessary ingredients in local dishes;

- it brings women an appreciable income, as dried products sell for proportionately more money than fresh produce.

3. Solar drying

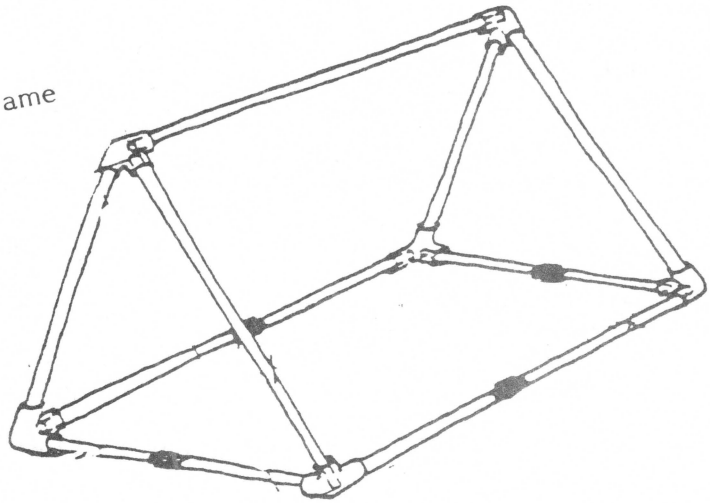
Solar drying, an intermediate stage between natural drying (the traditional process) and artificial drying (using fuel) seems well suited to local needs:

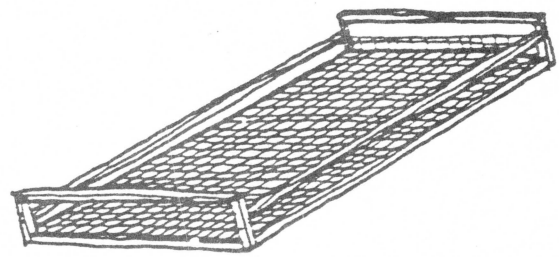
- it utilizes many of the same processes and customs that come from drying things under the sun;

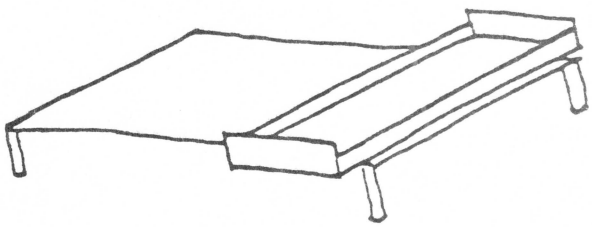
- it offers assurances of dessication and hygiene far superior to that of traditional methods.

Since 1981, various solar drying techniques have been brought to Koumbidia. Each one requires an increasing amount of villager participation.

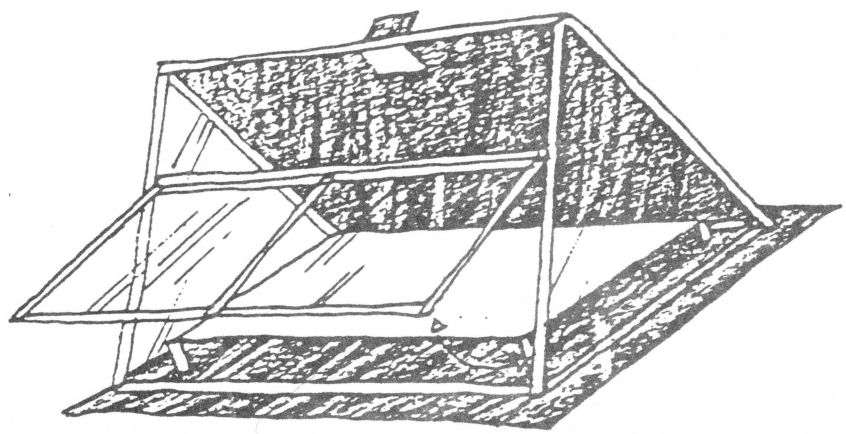
The frame







The tray support and the screens



(Source: GRET)

The solar tent

4. Solar tents

In 1980, three solar tents, prefabricated by CERER in Dakar, were left with groups of women in Koumbidia. These easy-to-build tents are made up of a wooden frame and a polyethylene cover. They are transparent on the sides facing south, east, and west, and blackened on the front and floor. The vegetables are arranged on a support frame, which is attached to the framework at a height a few centimeters off the ground.

The women had mixed feelings about these tents. Only one of the tents seems to have been truly 'adopted' by the users. Nevertheless, this first experimental phase provides an insight into the women's reactions and guidelines for setting up solar dryers at Koumbidia.

- Usage of the tents is disorderly, non-conducive to proper drying, and the cause of disputes between the women. Individual dryers should be preferred to collective dryers.

- The women dry many different types of products at the same time and frequently manipulate the dryer. Inasmuch as possible, the dryer should be indirect or semi-indirect, impervious to dust and drafts, and equipped with a drying grid, divided into compartments, that is separate from the dryer itself.

- Faced with the risks of depredation, both by rodents and livestock, the dryer should be raised and portable.

For these reasons, solar tents were abandoned in favor of other techniques.

5. Box dryers

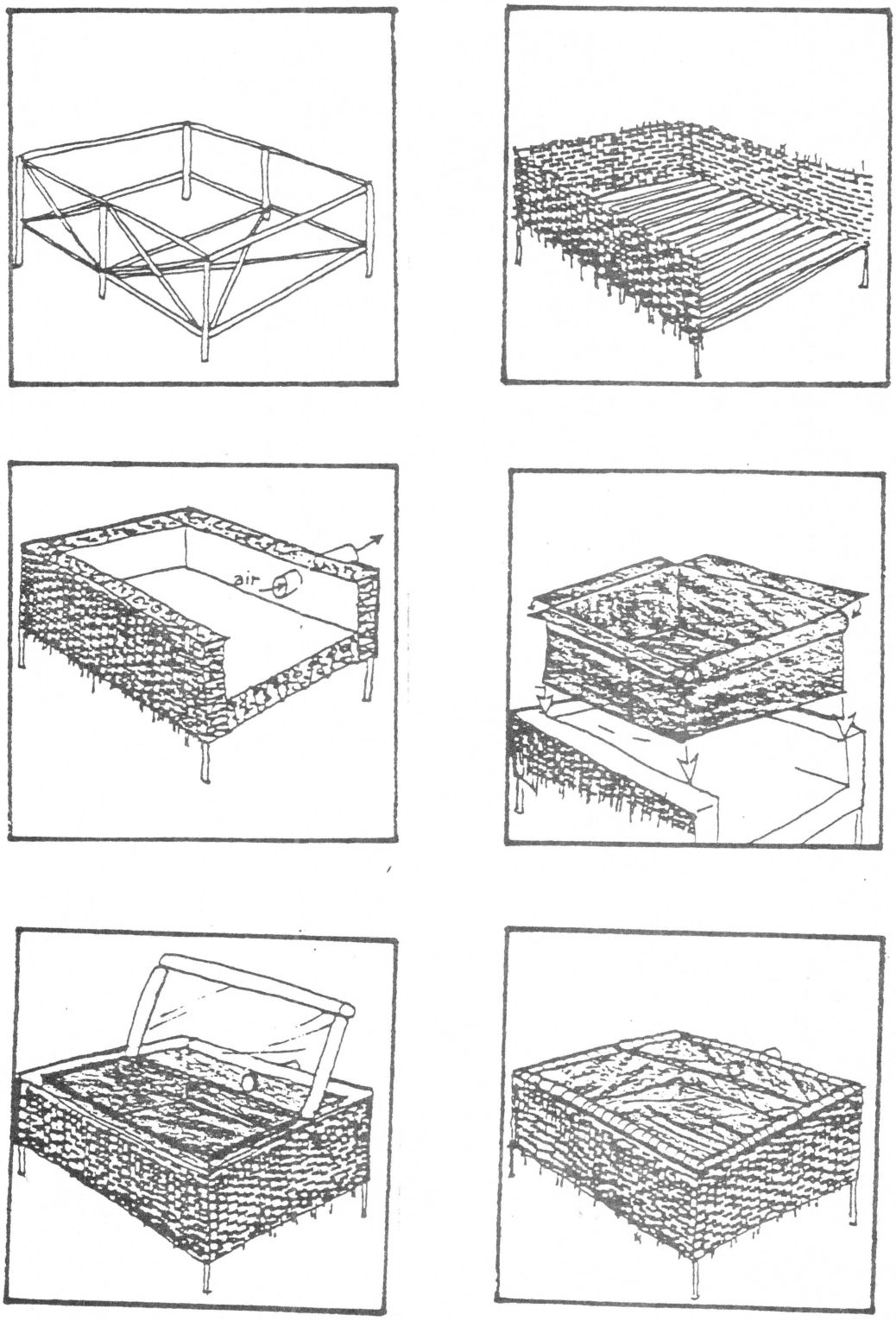
The promoters of this project suggested the villagers create a new dryer. This model offers the two-fold advantage of:

- possibility of being built with locally available materials (wood frame, cover of thatched bamboo, insulation using groundnut shells, absorber and transparent cover made from used fertilizer and urea bags) at low cost;

- fabrication carried out entirely by the villagers who themselves suggested construction techniques.

This box dryer has provided unusual results when tested -- a temperature rise of over 30°C -- and has since been used satisfactorily. It proved that villagers are capable of producing solar dryers locally and at low cost. Unfortunately, the box dryer did not withstand the bad weather of the wintering season, and was abandoned afterwards.

Following these experiments, and despite the unsatisfactory results, the women of Koumbidia showed a real interest in pursuing drying operations. This was the first year they were able to preserve their dried products for so long a period of time as well as incorporate reconstituted vegetables in their cooking until well into the wintering season. Over half of them offered financial contributions toward a dryer built by themselves, providing it was to be more sturdy and more easily transportable than the prototype box dryer.



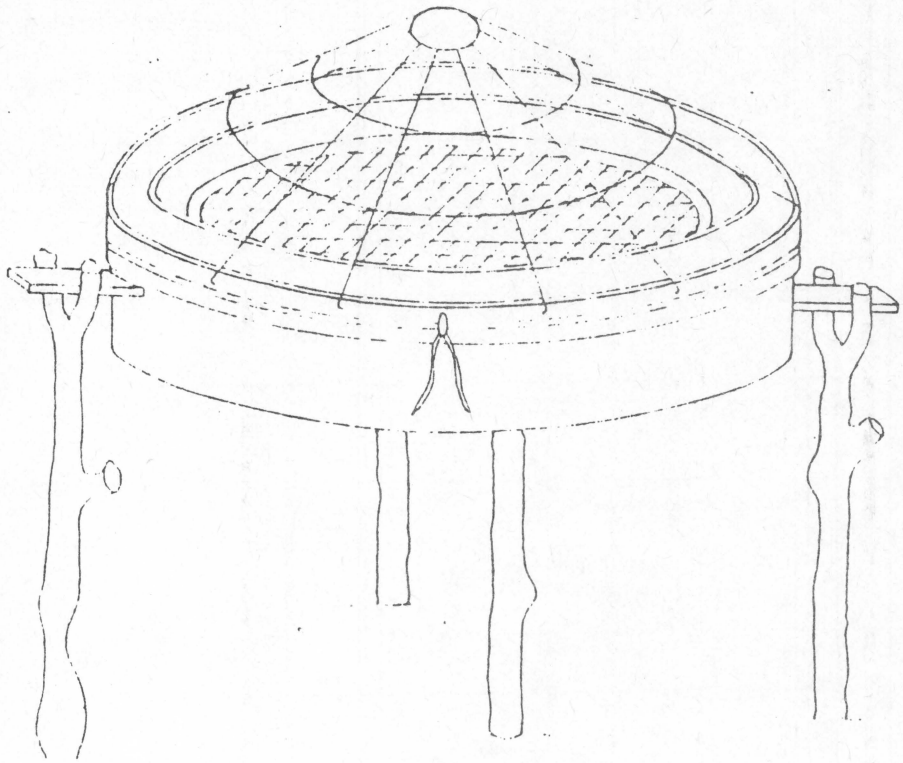
Construction of a box dryer

(Source: GRET)

COMPONENTS	ORIGIN	QUANTITY	COST
Wooden frames			
Thatched fiber walls	local fabrication	6 m^2	village fabrication
Absorber chest	black polyethylene (fertilizer bags)	5 bags	salvaged in village
Insulation	groundnut shells	2 50-Kg bags	recycling
Transparent cover	white polyethylene (urea bags)	3 bags	salvaged in village
Air circulation ducts	fabric rolls	2 m of tubing	salvaged from Koungheul market
Paint, nails, string, etc.	Koungheul hardware store		1,200 CFA Francs
Screens for grids	Koungheul market	1.5 m^2	2,000 CFA Francs
Labor	tailor, for stitching the polyethylene		
T O T A L			3,200 CFA Francs

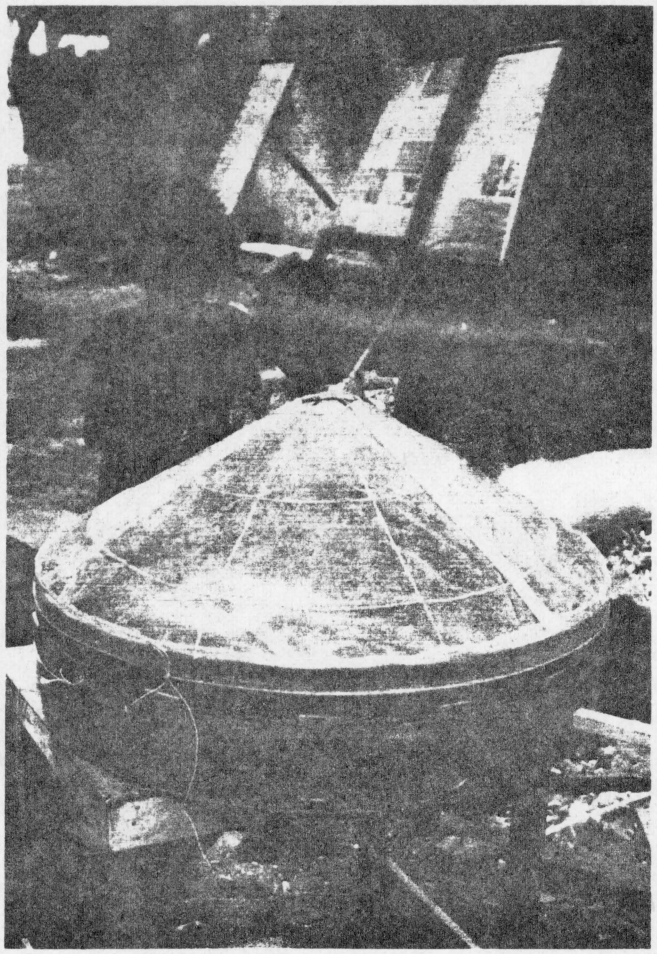
6. Hut dryers

A new model dryer was built within a week's time, in collaboration with the craftsmen from the market at Koungheul. Its shape resembles the traditional hut, but it is actually more sophisticated than the previous one, in that it uses more costly materials -- plywood (immersed in water, then shaped around a template), plastic film (black and transparent), a bicycle rim (for the frame and drying grid). Overall, it is more expensive (costing about 7,000 CFA Francs), but also sturdier and easier to move around than the box dryer. About twenty of these dryers are to be built and distributed among the women of Koumbidia in exchange for a contribution of 1,500 francs.



. Construction of hut dryers

(Source: GRET)



(Source: GRET)

B. THERMODYNAMIC SOLAR PUMPING

B. THERMODYNAMIC SOLAR PUMPING

1. Village water supply:

Example 1: Thermodynamic solar pump at Merina Dakhar (Senegal) pg. 53

Example 2: Thermodynamic solar pump at Makari (Cameroon) pg. 65

Example 3: Thermodynamic solar pump at Djibo (Upper Volta) pg. 71

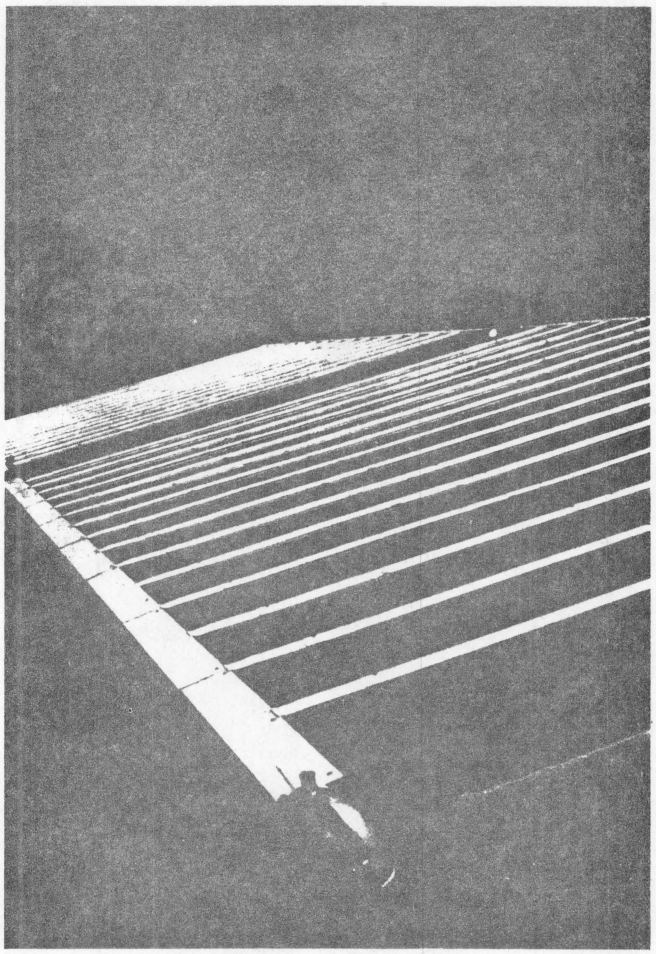
2. Livestock water supply:

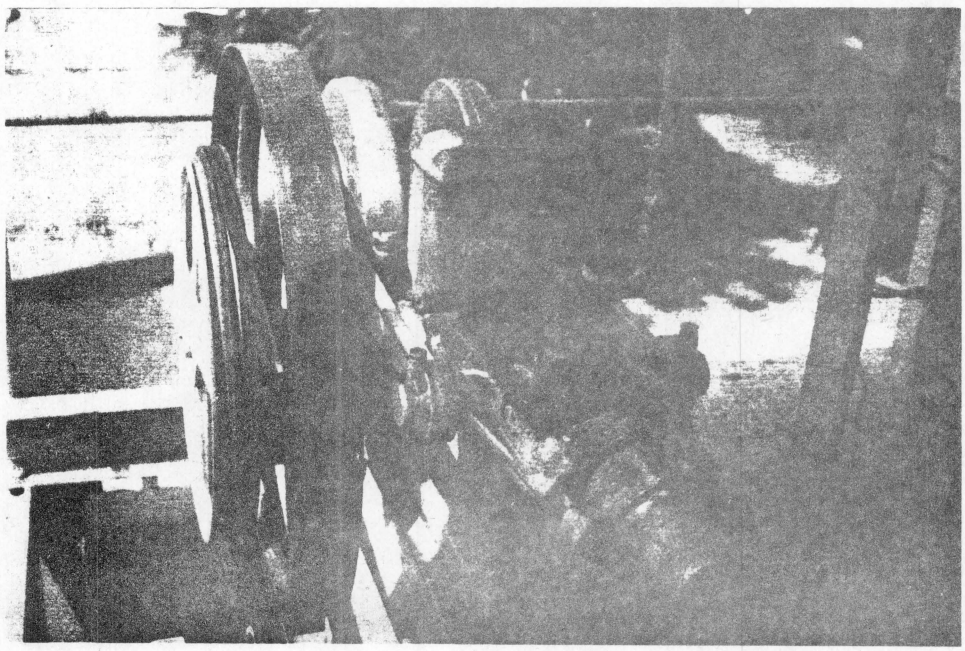
Example 4: Thermodynamic solar pump at Bondie Samb (Senegal) pg. 77

3. Irrigation:

Example 5: Thermodynamic solar power plant at Dire (Mali) pg. 84

Example 6: Thermodynamic solar pump at Karma (Niger) pg. 92





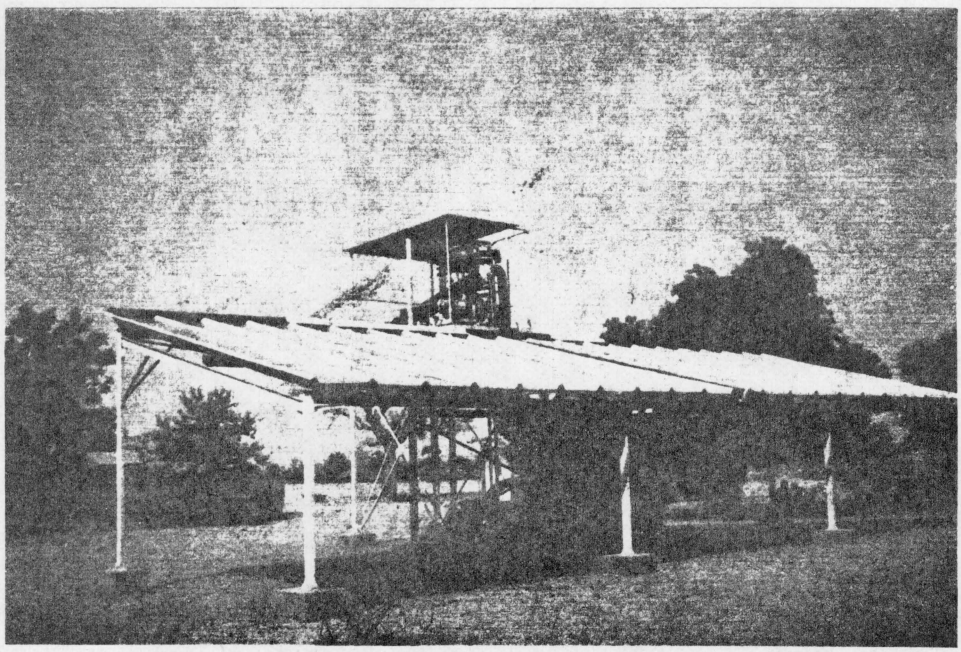
THERMODYNAMIC SOLAR PUMPING

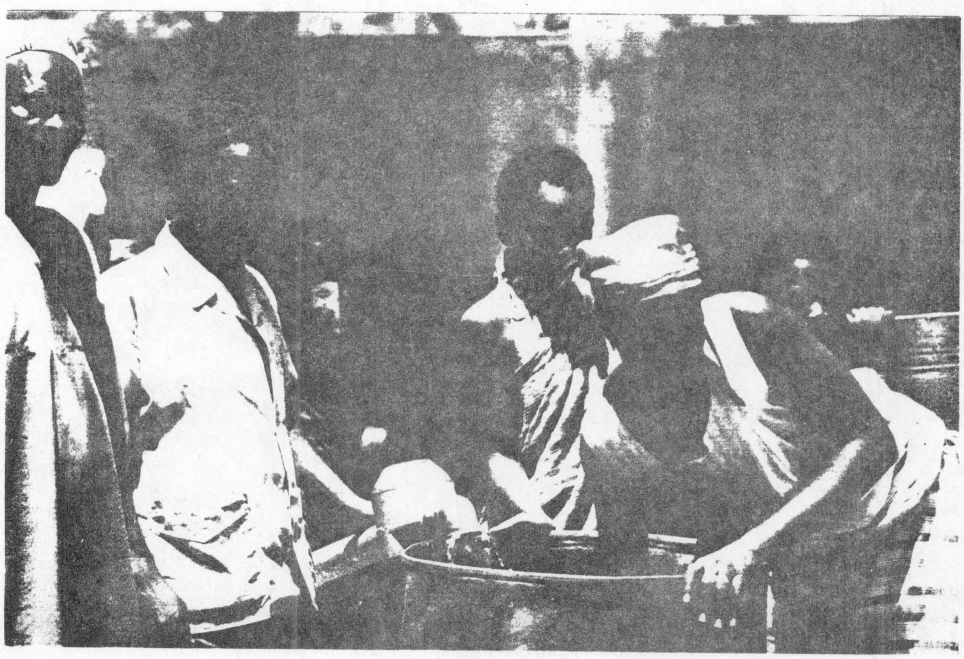
SOFRETES thermodynamic solar pumps were ther first to be installed on-site. They were highly instrumental in bringing the possible contributions of solar energy to rural development schemes to the attention of the international community.

On-site results from the first pumps were varied, depending on the local environment, receiving organizations, etc. The following evaluations make it possible to form an objective opinion (we believe) of the results of this already outdated first generation of pumps. Prudence should be exercised when extrapolating, because new projects, now starting up, are based on significantly different technology. It would be advisable to evaluate them eventually in order to measure their progress.

An honest comparison between thermdynamic solar pumps and photovoltaic pumps assumes that equipment of the same age and in comparable environments will be compared. In our opinion, the results would not be to the discredit of SOFRETES. Thermodynamic solar pumps are used for:

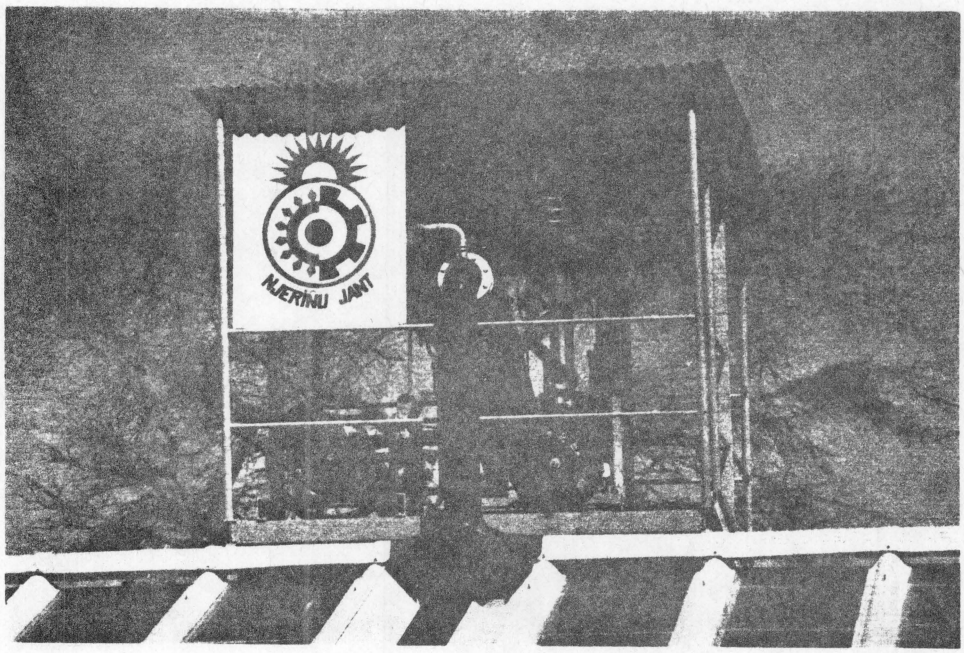
- village water supply
- livestock water supply
- irrigation.





1. Pumps for village water supply programs

In some villages, surface and well water can be tapped by means of human energy (simple tapping), sometimes assisted by pumping systems (hand pumps, foot pumps), or using animal energy. In many cases, however, access to sufficient quantities of drinking water requires boring deeper holes, and thus the use of mechanical pumping techniques.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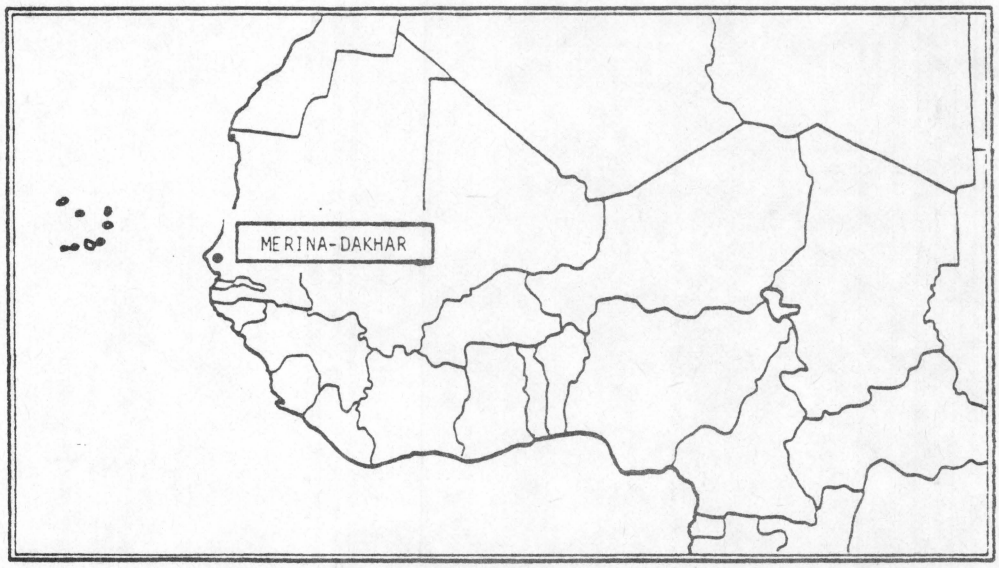

MERINA-DAKHAR

EXAMPLE 1	THERMODYNAMIC SOLAR PUMP AT MERINA DAKHAR / SENEGAL VILLAGE WATER SUPPLY
Inspection report: 5 October 1980	

1. Location

Approximately 100 km from Dakar, north of Thies, sub-prefecture easily reached by paved roads. No public electricity network; existence of private electric generators (for the sub-prefecture, youth center, etc.).

2. Rated specifications

The SOFRETES contract planned on: Q = 15 m^3/day
MH = 39 m
T cold water = 29°C

3. Start-up date: Beginning of 1976.

4. Pump performance

- The pump was in working order and operating the day of our visit (start-up time -- approx. 11:00 AM). Daily operation lasts 4 to 5 hours.
- Actual flow rate is quite noticeably lower than rated (by about 50%). We measured a flow rate of approximately 2 m^3/hr for an insolation of 850 W/m^2.
- The pump suffered a relatively high number of minor breakdowns which were easily repaired within a reasonable amount of time (location easy to reach) by a qualified representative of Sinaes who represents SOFRETES in Dakar.

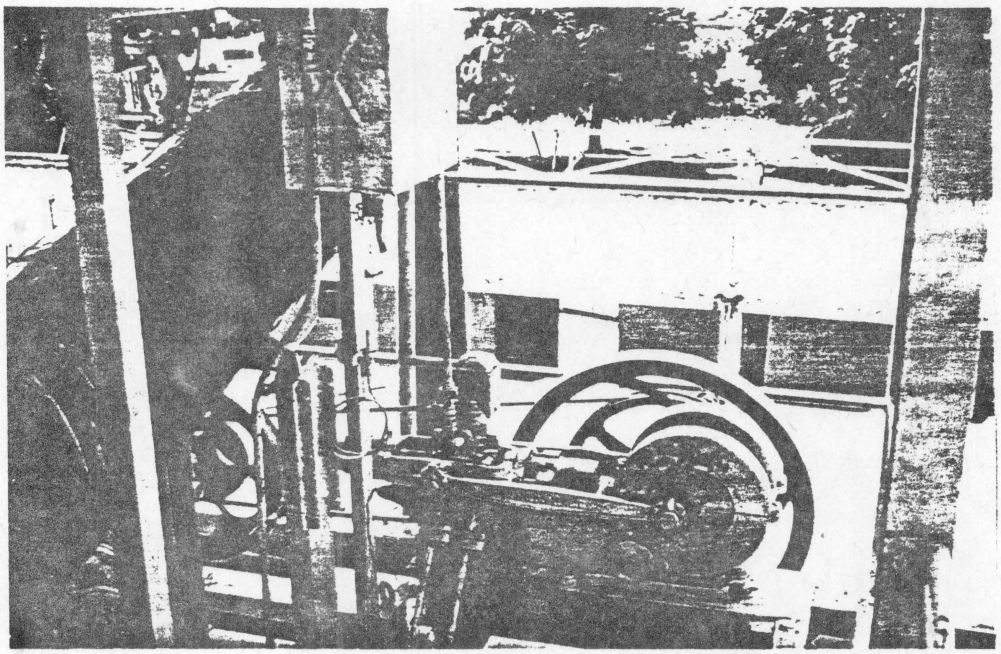
5. Pump conditions

- The pump is apparently in good condition, as regards the collectors as well as the circulation loop and hydraulic press.
- On the other hand, lubrication seems inadequate. The caretaker had no oil pump.

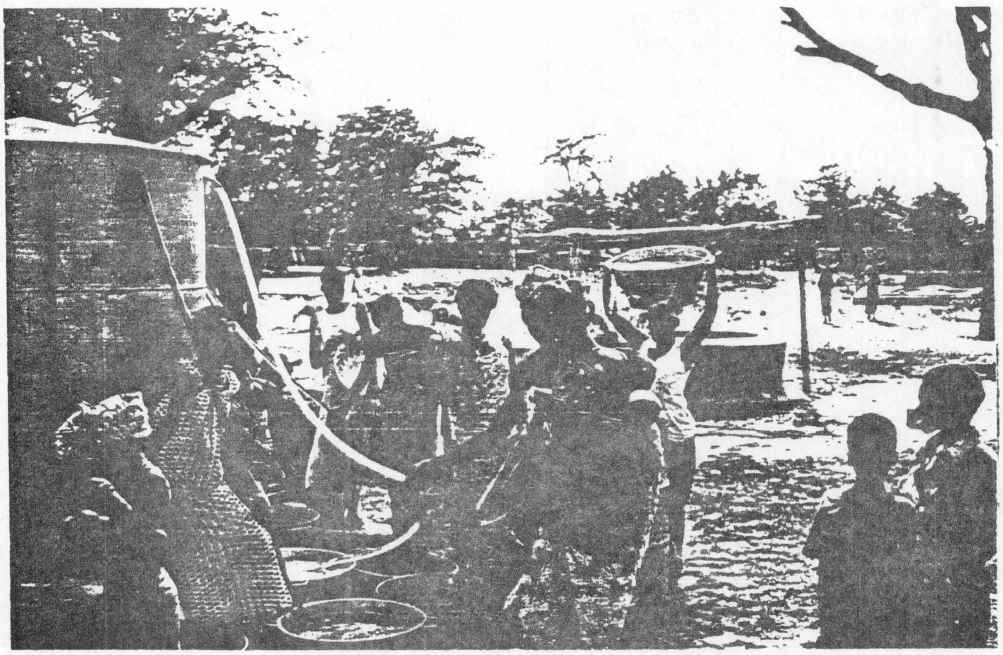
6. Problems with the caretaker (see notes concerning the caretaker's point of view)

The caretaker of the pump has received no remuneration over the past years, which he considers unfair. His livelihood was thus drawn exclusively from his agricultural income. He has two assistants to replace him when he is absent. Since September 1980, a village committee exists which is in charge of managing the pump (maintenance and partial remuneration for the caretaker). The first collection of 110 FF was distributed as follows: 50 francs for the caretaker, 15 francs for each assistant. According to the caretaker, this sum is pathetic. He had hoped to receive an income of around 200 francs per month.

Note: The sub-prefect has planned to raise individual contributions after the harvest. Moreover, the caretaker could receive some gratuities by offering priority water deliveries to certain persons in the village.



. Moteur thermodynamique



. Distribution d'eau à la borne siphoïde

7. User satisfaction

Users enjoy the solar pump but complain that its output is quite insufficient compared to the growing needs (population migrations towards sources of water) and its daily service too limited (water is pumped for only about two hours per day). The introduction of hydrants would seem to be a good solution (no waste, numerous connection points, no fragile taps) for widespread use.

8. The point of view of Mr. Amsata-Sall, Sub-Prefect of Merina Dakhar

The district comprises 44,000 inhabitants over a surface area of 622 km² (69 inhabitants per km²). This is dense considering the poorness of the soil. The population can be divided up as follows:

- rural community of Merina Dakhar: 18,000 inhabitants
- rural community of Koul: 15,000 inhabitants
- rural community of Pekesse: 11,000 inhabitants

The village of Merina Dakhar itself has a population of 700. It is surrounded by two hamlets, with a population of 850 and only a well, located 1 km and 1.5 km from the center.

There is thus a need to install three new hydrants, one in each of the two hamlets and one near the youth center in order to "give young people the incentive to remain on the land" through truck farming. It is hoped that the photovoltaic pump currently being installed near the existing pump will make it possible to connect additional hydrants.

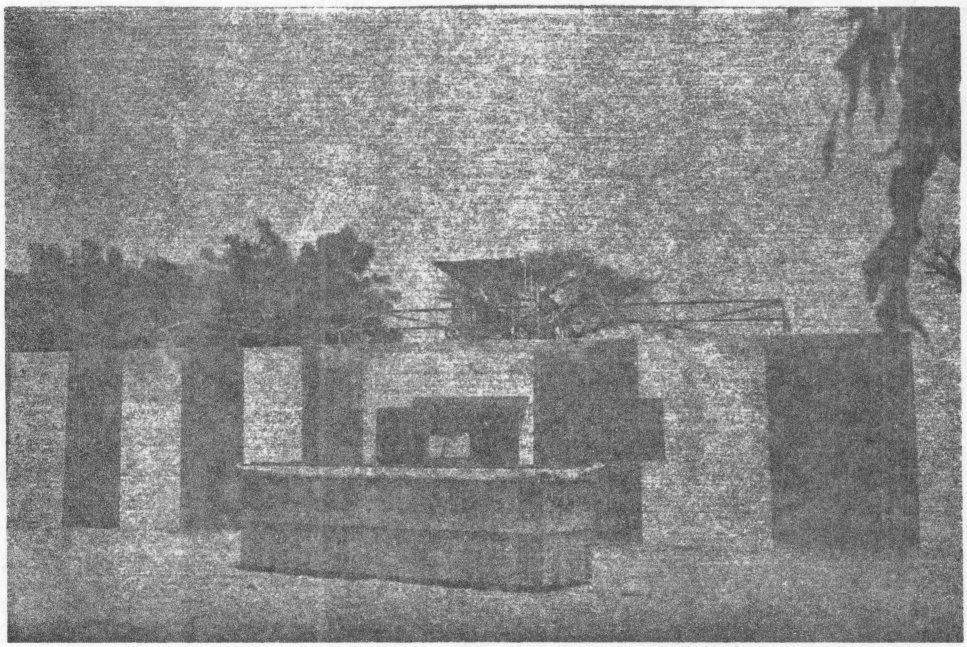
The present thermodynamic pump has been functioning well despite some breakdowns. Nevertheless, its capacity is inadequate. There seems to be a preference for diesel pumps, which are more powerful and operate for longer periods of time. Reference was made to the village of Pekesse where there is a big diesel pump for which the villagers finance the purchase of diesel fuel.

The sub-prefect recalls the constant increase in population around the large villages of Merina, Koul, and Pekesse. Migrants move closer to the route in search of better living conditions (water, schools, health, etc.). In his opinion, the solar pump experiment was positive despite its inadequacies. The experience at Niakhene, however, was a total failure, and its inhabitants were greatly disappointed.

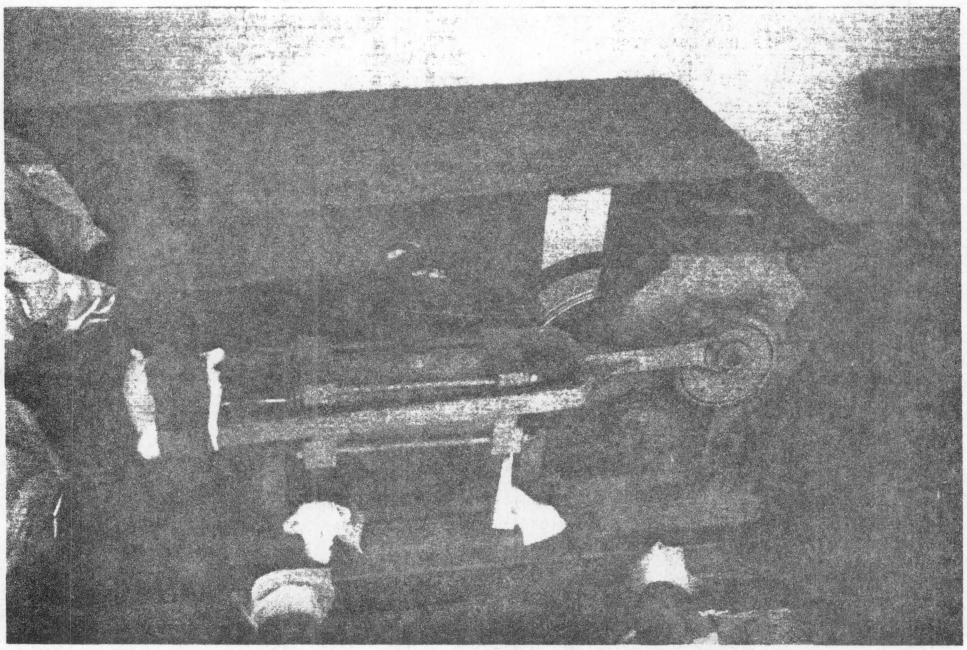
At present, the village has two schools and five classes. There is a youth center with its own electric generating unit that works correctly. Village pharmacies are planned and a nurse is expected to arrive.

The food situation is very poor. Two hundred forty tons of cereals provided as aid were distributed in May. The prospects for 1980/1981 are still disturbing (extreme lack of rainfall).

The sub-prefect has no information concerning the origins of financing for the initial solar pump nor for the new photovoltaic pump in the process of being installed. He has received no information concerning the type of work, expected daily flow rate, etc.



. Arrival of the photovoltaic extension
Installing the panels on the roof



. DC motor and new pump. The second wheel will be connected to the thermodynamic motor by means of a belt.

9. Expansion of the present pump at Merina Dakhar by the addition of a photovoltaic pump

9.1 Nature of the project: The project involves increasing the capacity of the present thermodynamic pump ($10m^3$/day over 4 to 5 hours) using the following photovoltaic system connected to the same bore-hole pump:

- solar array
- batteries
- control panel with programmer
- DC motor
- hydraulic press

Electrical energy produced during the day is stored in the batteries in order for the pump to be able to operate at other times than the present hours of operation (11:30 AM to 4:30 PM) and thus increase total output.

9.2 Project specifications:

- BP X 47 C solar array, 48 x 33 W = 1,584 peak watts
- flow rate = 18 - 20 m^3/day
- manometric head = 40 m

9.3 Project progress report:

At the time of our visit, the equipment was on location but not installed. Only the module supports were in place on the roof of the building constructed in front of the present thermodynamic pump. Today the project should be operational (April 1981).

PROCES VERBAL D'ESSAI

POMPE SOLAIRE : SOFRETES 1 kW — Localisation : SENEGAL, MEDINA DAHAR — Date d'essai : 5/10/80

Caractéristiques nominales : 15 m3/jour sous 39 m H.M.T. — Réalisé par : B. MEUNIER/B. EMSELLEM

Météorologie : ciel clair avec léger voile

Heure GMT	Ensoleillement W/m2 G (1)	Ensoleillement W/m2 D %	MOTEUR V_v	MOTEUR I_A	MOTEUR P	MOTEUR AR.	DEBIT (2) 1 AR/mn ≃ 0,09 m3/h. Index compteur	DEBIT Volume (1)	DEBIT Débit horaire m3/h.	Niveau DYN (m)	Hauteur REF (m)	H. MT (m)	OBSERVATIONS
11h35	780	-				24,3			2,19	-10 m	+1,5	12 m	. Utilisation directe sortie pompe.
11h40	790	-				22,7			2,04		(+10m)		. Refoulement sur chateau d'eau.
11h50	810	-				22,2			2,00				
11h55	825	40%				22,4			2,02				
12h00	825	-				21,8			1,96				. Temps eau chaude 70°C
12h22	850	41%				22,4			2,02				. Température au soleil 47°C
13h00	880	-				23,5			2,12				. Température ambiante 33°C
													. Température eau sortie pompe ≃ 10°C
			(1) perpendiculairement aux capteurs plans										

(2) selon SOFRETES, sous réserve que le circuit hydraulique soit bien purgé.

REPUBLIQUE DU SENEGAL
REGION DE THIES
DEPARTEMENT DE TIVAOUANE
ARRONDISSEMENT MERINA-DAKHAR

DECISION : N° 000016 /AMD portant création d'un comité chargé de la gestion de la pompe solaire de Mérina-Dakhar.

Le Sous-Préfet de l'Arrondissement de Mérina-Dakhar,

VU la Constitution, notamment en ses articles 37 et 65 ;
VU la loi 72-02 du 1er Février 1972 relative à l'organisation de l'Administration territoriale ;
VU le décret 72-636 du 29 Mai 1972 relatif aux attributions des Chefs de circonscriptions administratives et des chefs de village ;
VU le décret 80-760 du 27 Juillet 1980 portant nomination du Sous-Préfet de l'Arrondissement de Mérina-Dakhar ;
VU l'avis favorable de l'assemblée populaire villageoise tenue le 23 Août 1980 à Mérina-Dakhar,

- D E C I D E -

Article premier: Il est créé à Mérina-Dakhar, un comité chargé de gérer la pompe solaire de ladite localité.

Article deux : Ce comité est composé comme suit :

MM:	Assane Ndoye, chef de village de Ndoyène ...	Président
	Talla Maram Diop, chef de village de Mérina-Diasse	Vice-Président
	Ibra Ndoye, chef de village de Mérina-Dakhar	Trésorier
	Macoumba Tine, notable	" Adjt.
	Ada Marème Ndoye, notable	Commissaire aux Cptes
	Moussa Ndoye, mécanicien préposé à la pompe	Membre
	Macoumba Guèye, assistant préposé à la pompe	-"-
	Modou Diagne, assistant au préposé à la pompe	-"-

Article trois : Les charges d'entretien de la pompe solaire seront supportées par les populations concernées, les fonctionnaires et agents de l'Etat basés à Mérina-Dakhar, à raison d'une participation financière mensuelle fixée à :

- 100 Frs. pour les non salariés : paysans et pasteurs,
- 300 Frs. pour les fonctionnaires et agents de l'Etat

Article quatre : Le comité de gestion se réunira le 8 de chaque mois sur convocation de son président, pour faire le point de la situation et prendre toutes mesures utiles.

Il sera obligatoirement réuni si la moitié des membres en fait la demande au président.

Article cinq : La présente décision sera enregistrée, publiée et communiquée partout où besoin sera./.-

Mérina-Dakhar, le 11 SEP. 1980

Le Sous-Préfet.

AMPLIATIONS :
- MIET/DA GAT
- Secrétariat d'Etat à la Recherche Scientifique et Technique
- Gouverneur Région Thiès
- Préfet Dpt. Tivaouane
- Membres comité de gestion
- Chrono
- Archives

Points of view of the caretaker of the pump at Merina Dakhar
expressed during a detailed interview, 5 October 1980
Comments by SEMA

1. Familiarity with the pump

- The caretaker was present for the assembling of the four pumps installed in the region, as well as during numerous maintenance visits. He believes he is familiar with the operation and major malfunctions of these pumps.

- His explanations of the difficulties encountered at Niakhene (SOFRETES pump in a neighboring village), shows that he truly understands the system well.

Comments: All too often, the intellectual and technical capabilities of caretakers has been underestimated. They are essential to the correct operation of the installations. Initial training should be reexamined.

2. Tools, spare parts, lubricants

- The caretaker had virtually nothing to correct even the most basic malfunctions (leaking pipe, belts needing replacement, etc.).

- The caretaker had no grease and no grease pump. The pump is lubricated, but only on rare occasions, and probably by SINAES.

3. Caretaker's interest in maintenance

- The caretaker is visibly interested in maintenance problems and feels he is capable of making repairs (he learned from watching the SINAES repairman). Nevertheless, he does not feel this is his job, since it was never assigned to him and he receives no payment for it.

Comments: The caretaker, if given a short supplementary training course, could handle maintenance and ordinary repairs for his pump and the three neighboring pumps. This would be a more efficacious solution than sending in teams from Dakar.

4. Management of the pumped water

The caretaker starts up the pump at about 11:30 AM, then:

- he brings water to the important persons in the village,
- he partially fills the water tower,
- he opens the hydrants at around 3:30 - 4:00 PM,
- he shuts the pump off at about 5:00 PM.

5. Condition of the distribution network

- The caretaker points out that the water tower must be very dirty (access is impossible because there is no ladder). It is quite small, cubic in shape, made of steel, and appears to be in good condition (volume = 10 m^3 probably).

- The caretaker mentioned that several valves are out of service and leak constantly. Water will not remain in the tower due to the numerous valve leakages. The tower is used only intermittently, never for overnight storage. This is unfortunate considering the need for a sure, regular water supply.

- The hydrants, widely appreciated, appear to be in good condition.

Comments: The success of a hydraulic project, and particularly of a solar pump, greatly depends on the quality of the hydraulic network (valves, taps, pipes, water tower). As we have seen, defective maintenance of these networks considerably impedes the proper utilization of these expensive solar pumps. It is necessary to train the caretaker to service the network and provide him from the outset with a reasonable supply of valves and taps. These parts wear out much more quickly than in Europe (due to very intensive utilization, sand abrasion, etc.).

6. Remuneration for the caretaker

This subject has been raised elsewhere. The means of providing for the caretaker and the pump represents a vital point in the project's durability. Thoughts along these lines have already been expressed at Merina Dakhar (see note from the Sub-Prefect), albeit somewhat late. Two approaches are possible; one is community responsibility (as in Merina Dakhar), the other is direct water sales by the caretaker, a practice much more acceptable than one would tend to think. Merina seems to have implemented both approaches, that is, the community provides some financial support, and the caretaker profits from the sale of water.

7. Caretaker's point of view concerning the new thermodynamic solar pump

The caretaker is apparently little informed about the specifications of the solar array now being assembled as well as on the consequences it will have on:

- village life (changes in water distribution),
- his functions (work hours, services to be provided).

Comments: Extremely little information has been given to the caretaker, the village, and the Sub-Prefect. We feel that informing those persons concerned is a key element in project acceptance, as it is a sign of respect.

8. Assurance of water supply

The solar pump has been operating quite regularly since 1976. Breakdowns and shutdowns due to the climate have not exceeded a few days per month. (The advantage is in the proximity of Dakar and the existence of SINAES). The village has two wells; neither is dry, both are in good condition. They are located near the village, and thus the villagers are spared the disastrous consequences of pump breakdowns, despite the enormous inconvenience caused.

Comments: Solar pumps should not be installed if there is no emergency water supply in the vicinity (a permanent well in good condition, hand pump, etc.). The risk of a total water shortage is unacceptable.

9. Caretaker's feelings about the solar pump

The caretaker has a positive attitude towards the pump; he has no complaints concerning technical choices, and it offers him a sense of power over the villagers. Since he alone is the provider of pure water, the villagers have total confidence in him.

Comments: The job of caretaker of the solar pump is one in which the villagers place their confidence. The village chief is responsible for selecting the caretaker, who often turns out to be the chief's son (we have seen this on several occasions).

10. Impact of the solar pump on village development

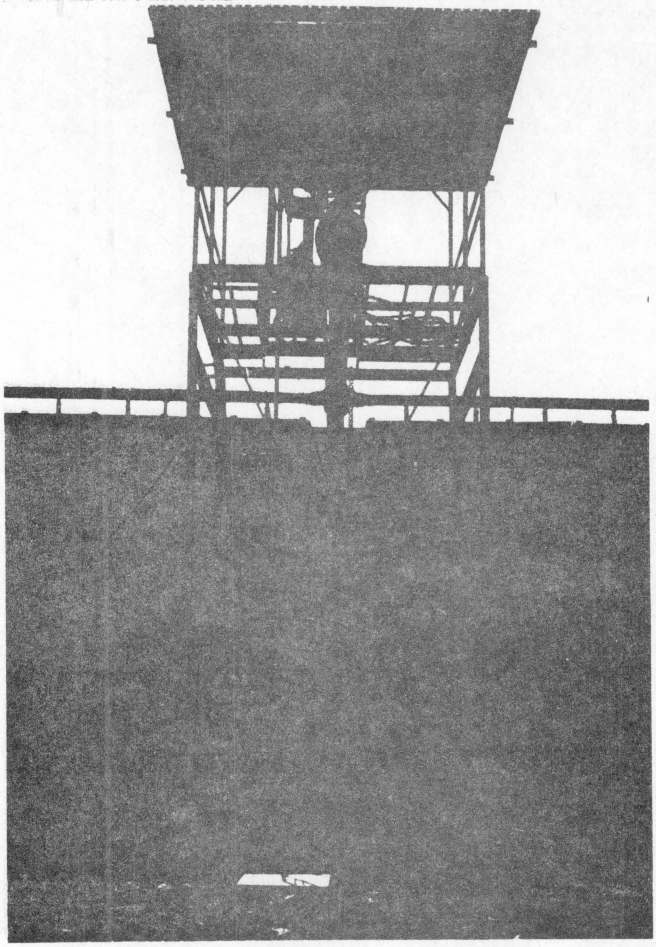
According to the caretaker, "the pump has aided village development", "the women save much time getting their water and can thus sell things and bring money into the village". Since the pump's installation, "the village has grown considerably". Many rural dwellers have permanently relocated in order to be closer to the perennial source of water, schools, maternity services, etc.

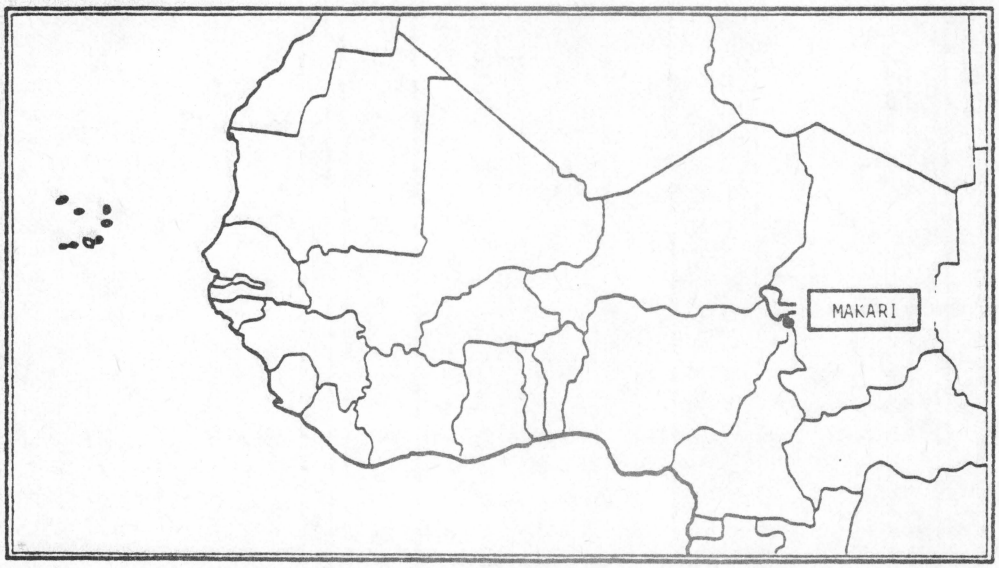
Comments: In our opinion, the greatest contribution of this solar pump is the self-confidence it has promoted in the village. The villagers' pride in their pump is evident, and the village now gives the impression of a certain affluence despite its situation in a very poor region (afflicted by perpetual drought). Its impact on health, in terms of the pumping of pure water, while difficult to measure, seems to be felt very deeply.

Unfortunately, the service provided is quite insufficient. Water is pumped only two to three hours per day, enough to supply only a small part of the village population (the hamlets are not connected). The hydraulic network absolutely must be extended by adding a solar array which would at least double the daily flow rate. This has not been planned.

11. Concluding statement

As far as the caretaker and the villagers are concerned, the solar pump project has been highly positive despite all its shortcomings. Its success is explained, to a large extent, by the existence of a maintenance organization (SINAES).




MAKARI

EXAMPLE 2	THERMODYNAMIC SOLAR PUMP AT MAKARI / CAMEROON
Inspection report: 29 January 1981	

1. Location

330 km north of Maroua; 260 km of the route is paved road, the other 70 km is a passable sand trail. Inaccessible during the rainy season.

2. Rated specifications

- collector surface = 70 m^3
- delivery rate = 3 m^3/hr.
- manometric head (MH) = 20 m
- operating time = 6 hours
- pump = BRIAU AFRICA type, belt driven
- bore-hole = 4", depth = 70 m
- tank height = 8 m
- static level = 12 m

3. Start-up date

December 1975

4. Measured performance

None (pump was not in working order).

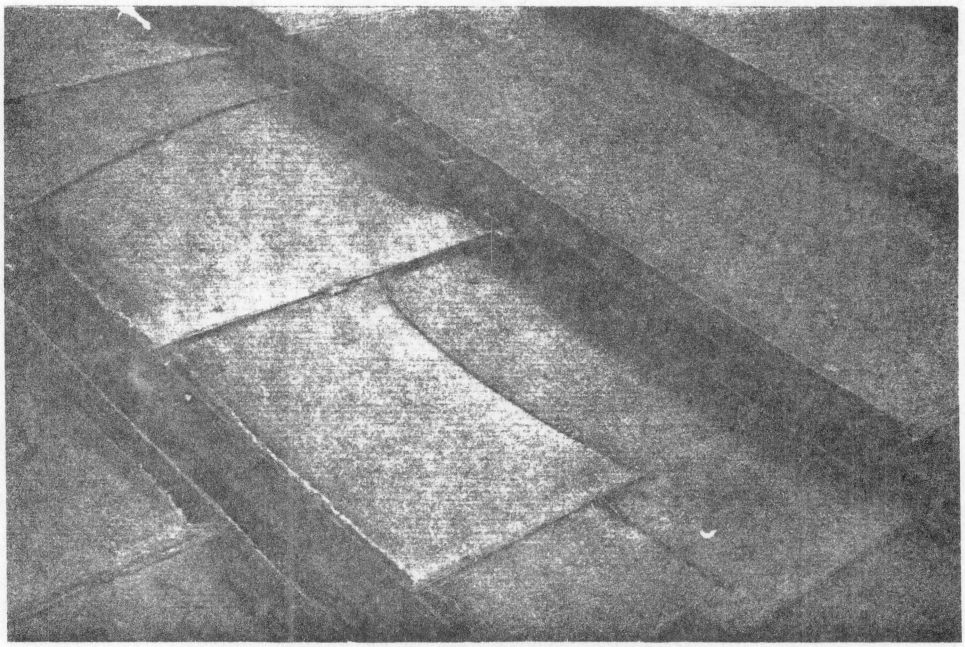
5. Condition of equipment

Collectors: The collectors are installed on the roof of the building that serves as the veterinarian's office. Two of the absorptive surfaces (in aluminum) are punctured. The water in the collector circuit leaks constantly (the caretaker fills the expansion tank with water at 8 AM when he wants to run the pump; the pump is then operated from 10:30 AM to 3:30 PM).

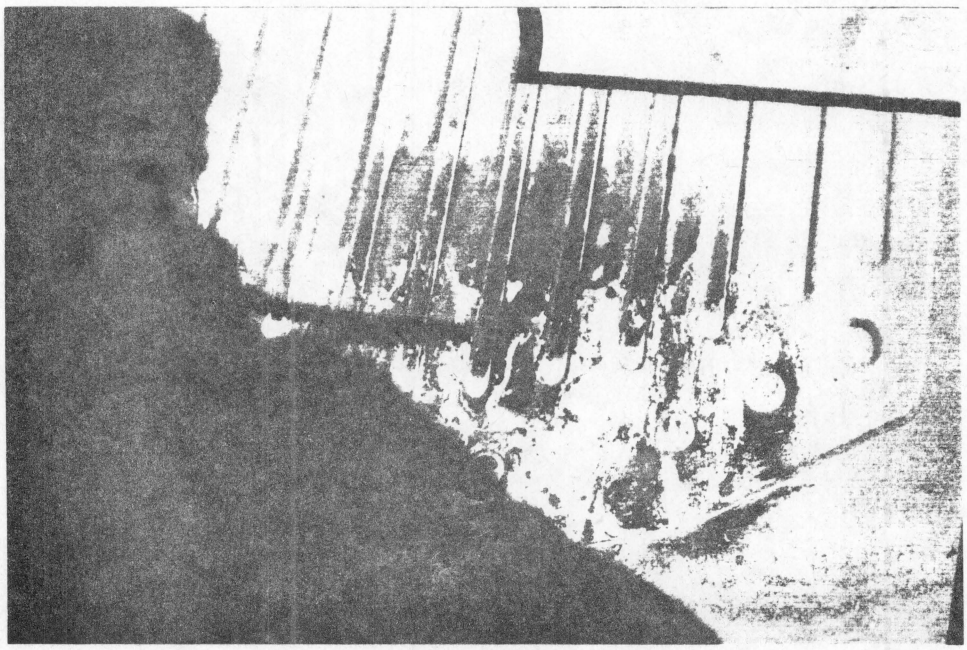
The lack of an argon welding set in northern Cameroon makes it impossible to repair the absorptive surfaces (however, a repair job using 'araldite' glue might do the trick). The lack of valves above and below the inoperative collectors makes it impossible to isolate them from the rest of the circuit, leaving the pump out of order (or, when it does operate, the daily flow rate does not exceed 4 m^3).

Moreover, several glass panes are shattered and the joints are sealed with putty. The harmattan, which constantly raises dust clouds from the ground, causes the absorptive surfaces in certain collectors to be covered with a fine layer of sand. Everywhere else, the exterior glass panels are opaque since the caretaker can only wash the panels with a water spray (there is no solid ground between the rows of collectors). In trying to wash the collectors, he had to step on some of them and thus broke the glass panels (see photographs).

Heat insulation: The heat insulation split and came unglued in numerous places around the pipes.



. Broken glass, collectors full of sand.



. Punctured absorber

Thermodynamic circulation loop: the pistons are not completely impervious. The caretaker drained the butane circuit once a week when the pump was working.

Tank: in good condition, capacity exceeds 20 m^3.

Current pumping system: submersible motor pump powered by an ONAN 20 HP electric generating unit (there are three units of this type at the center).

6. History

According to the caretaker, the pump operated correctly until January 1980, at which time the absorbers were punctured. At present, the pump is not used. The caretaker starts it up when visitors arrive -- he fills the expansion tank to 200 liters at 8 AM and the pump is started at around 11 AM when the butane pressure reaches 10 bars. The day we visited the installation, he filled the circuit at 11 AM. At 12:15 PM the pressure had not passed 7 bars. At our request he started up the motor, then stopped it immediately (when no pumping takes place the water condenser is not powered). The motor started up correctly and seems to function normally.

7. Receiving organizations

The Commission for the Lake Chad Basin is an intergovernmental organization (comprising Niger, Nigeria, Cameroon, Chad), whose headquarters, formerly located in Ndjamena, have been moved to Maroua. The Commission's Assale Serbequel project, developed in Makari, on the banks of the Serbequel River, includes:

- the cultivation of saplings (margosa, acacia for reforestation),
- a livestock vaccination campaign, currently inoperative (the vaccine was prepared in Chad).

The commission's heavily financed center (permanent buildings, three 20 HP electric generating units, several light and heavy vehicles -- generally out of order) gives the impression the money was underutilized.

8. Caretaker's status

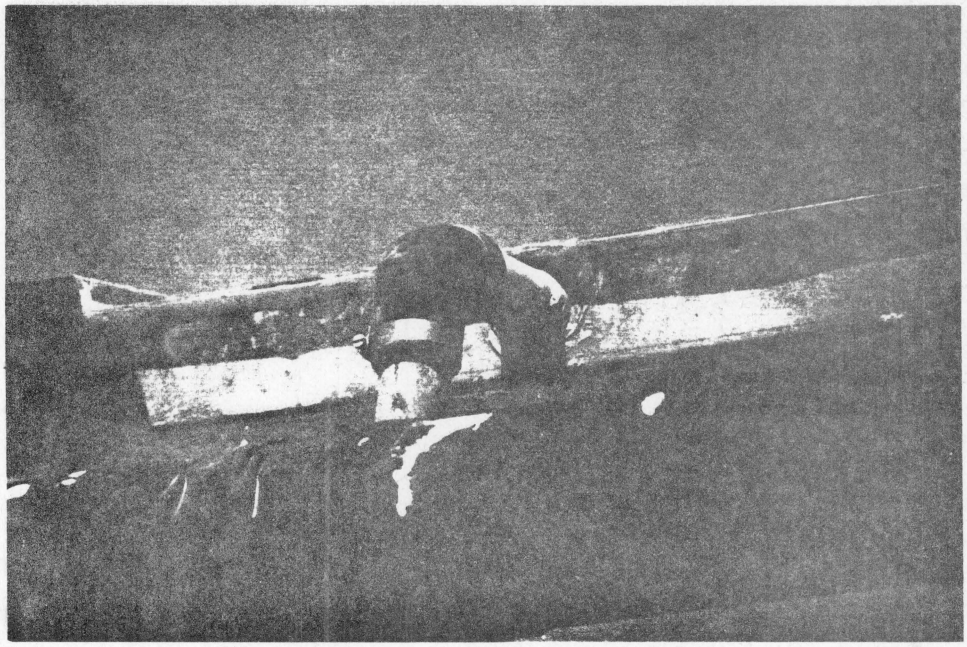
The caretaker is paid by the Commission. He was previously assigned full time to the solar pump; now he is warehouseman and is only partly concerned with the pump (starting it up for visitors). Maintenance is limited to:

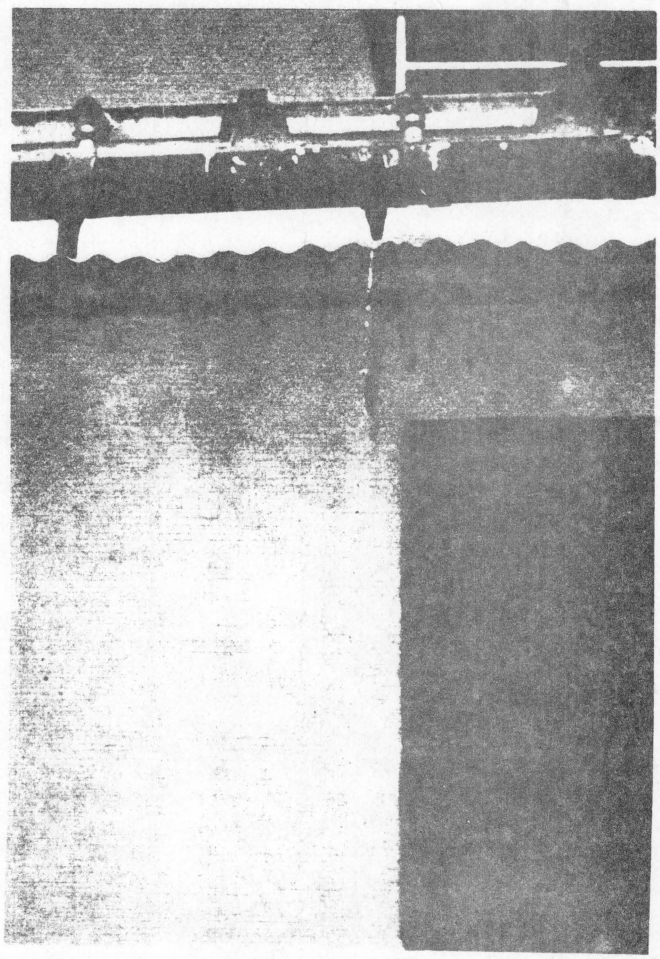
- lubricating the Briau pump,
- draining the butane and filling the circuit,
- washing the collectors (with a water spray),
- filling the water circuit before starting up.

The caretaker seems to be motivated by the pump which confers on him a particular status. The rest of the center seems generally indifferent.

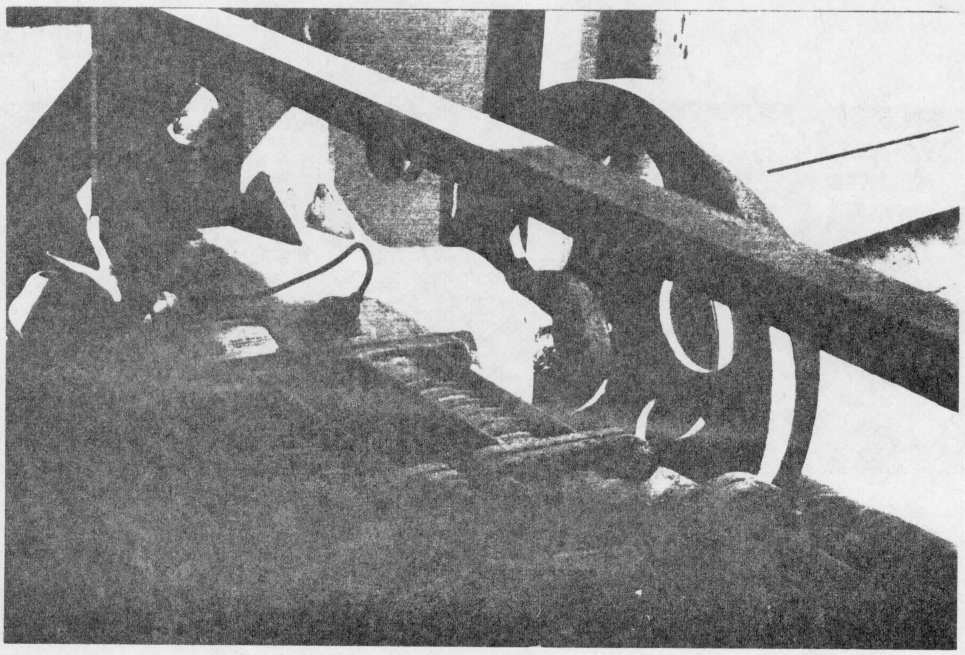
9. Conclusion

This pump could be repaired easily (absorbers, broken glass panels), otherwise, it is useless. Due to its out-of-the-way location, it does not interest the directors of the Maroua-based Commission.

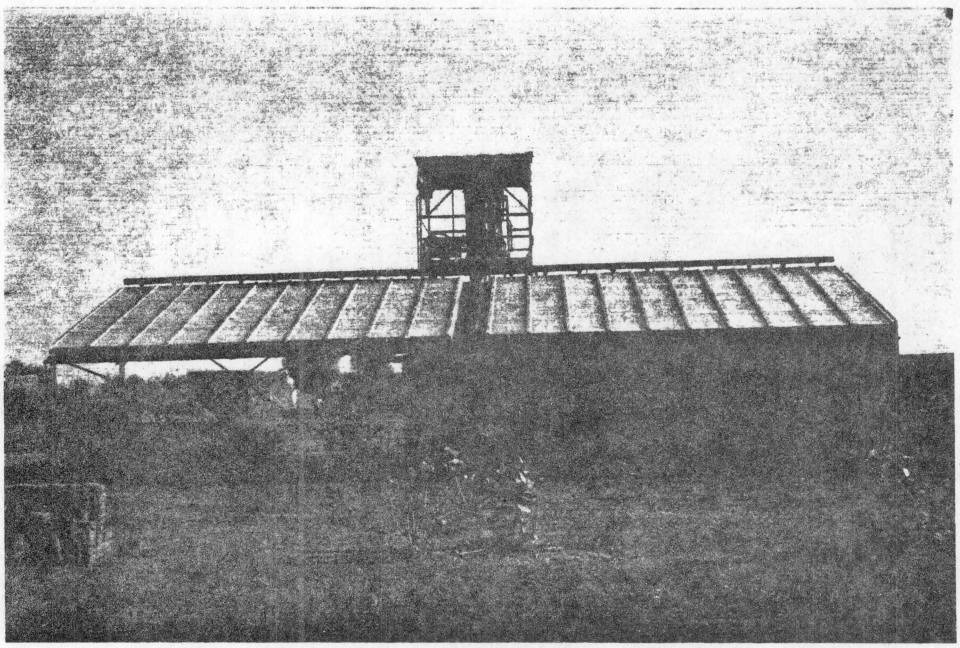


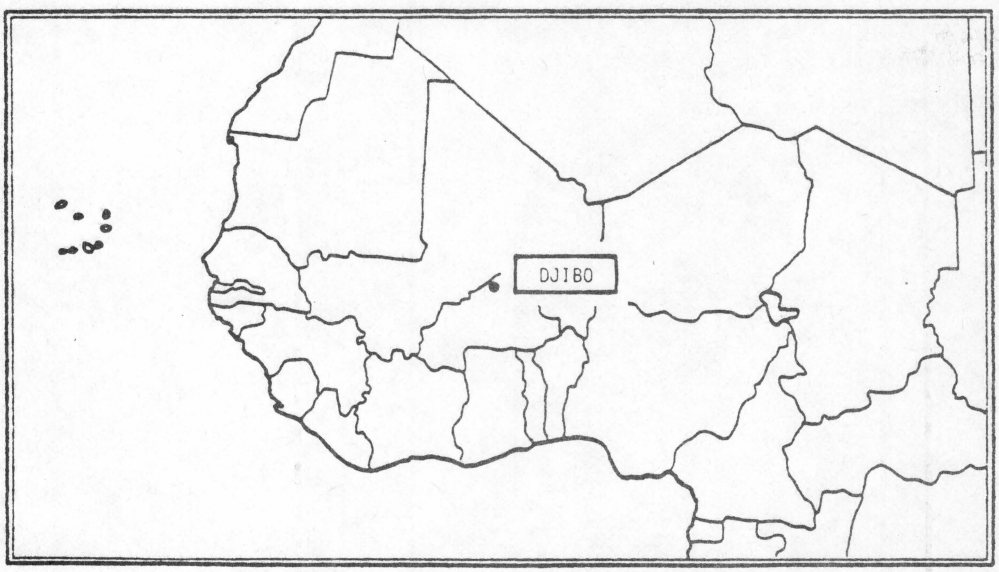


. Water flowing from the bottom of the collector with a broken absorber



. Double-piston thermodynamic pump




DJIBO

EXAMPLE 3	THERMODYNAMIC SOLAR PUMP AT DJIBO / UPPER VOLTA VILLAGE WATER SUPPLY
Inspection report: 22 May 1980	

1. Location

150 km northwest of Ouagadougou, prefecture of approximately 10,000 inhabitants, available water source located at the market.

2. Start-up date

1976?

3. Financing

Non-governmental organizations

4. Prefect's point of view

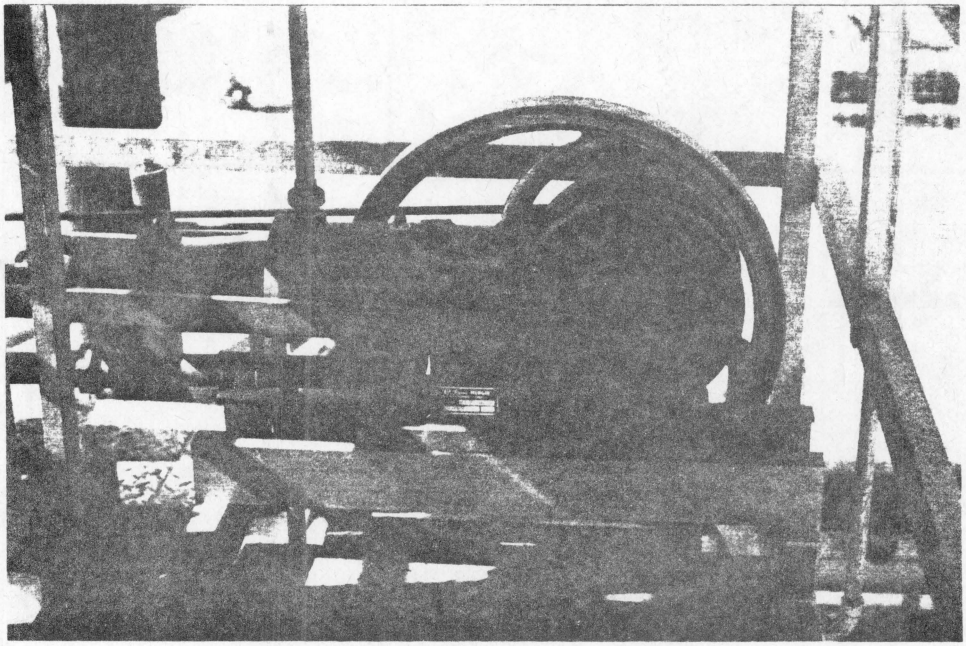
The Prefect, Mr. Gaston Ouedraogo, considers this pump inadequate with respect to the needs of the population (only 10% of their needs). He expressed dismay over the frequent breakdowns and the long waits for servicing which, at times, reached several months. Mr. Ouedraogo indicated that the caretaker supports himself on the sale of water. The administration receives no percentage of the money the caretaker makes. During the wintering season the pump functions poorly. Water does not rise as far as the water tower and the valves clog. The town has good wells that never dry up and there is a dam nearby.

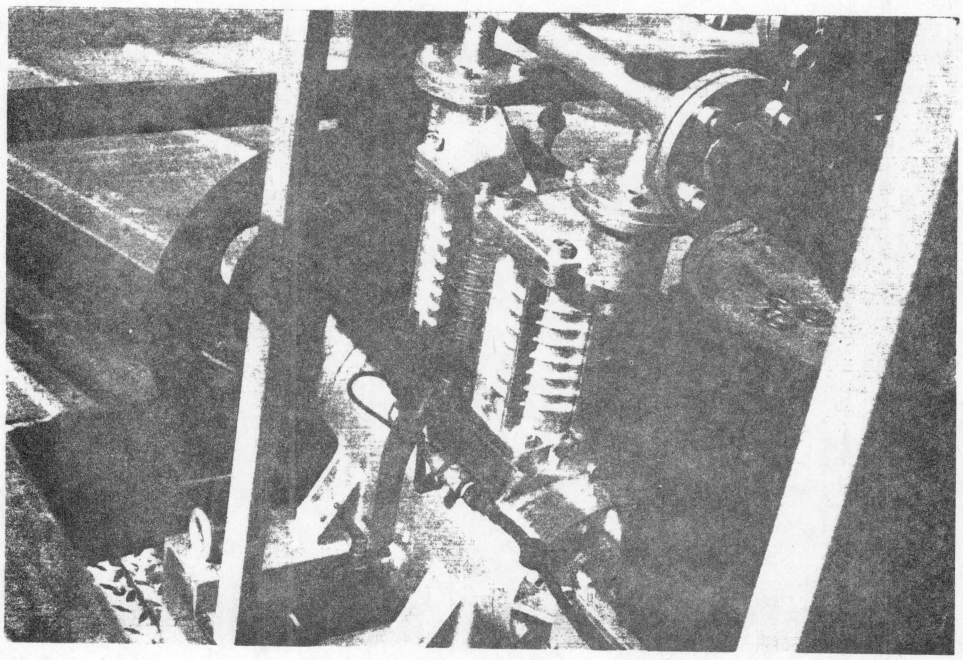
5. Condition of the equipment

The equipment appears in good condition; the equipment seems to have been very carefully maintained by the caretaker.

Performance measured on 22 May 1980 -- Djibo

G M T	Overall radiation (solar panels)	Filling time for 220-liter cask	Delivery rate	Dynamic level
10:45 AM	780 W/m²	---	---	4.9 m SL
11:00 AM start-up	800 W/m²	---	---	---
11:17 AM	818 W/m²	7'08	1.85 m³/hr	6.4 m
11:25 AM	---	6'34	2.01 m³/hr	6.4 m
11:30 AM	827 W/m²	6'38	2.00 m³/hr	6.4 m
11:40 AM	832 W/m²	6'28	2.04 m³/hr	6.4 m
12:15 AM	860 W/m²	---	---	---





. temperature of water leaving collectors 70°C
. temperature of pumped water leaving loop 41°C
. discharge = approx. 1 km; delivery head unknown, probably a few meters

6. Performance noted in recent years

Mr. Belem Malek's (caretaker's) notebook includes the following indications:
- in 1978 the pump operated for 216 days, the rest of the time insolation was insufficient or the pump was not in working order;
- in 1979 the pump operated for 142 days. It was shut down for 163 days for insufficient insolation and was inoperative for 60 days.
- sales of water reached a high of 248 (220-liter) casks and 1,304 (20-liter) buckets for a total of 80.6 m^3 for the month of April 1979 alone.
Note: this figure seems low and is perhaps inaccurate.
- There is no displacement meter.

7. Solar pump's reliability -- maintenance

- At the outset a BRIAU positive-displacement pump was used to draw water. It broke down on several occasions, and we came to repair it three times.
- Since then, the pump and press have been replaced (February 1980), and a VERGNET pump was installed which has a lower delivery rate than the previous one.
- The belt was replaced once in February 1980.
- Some of the glass panels have been replaced.
- Some of the flanges leaked and all the catches had to be replaced.
- There were also leaks in the circulation loop which had to be repaired (evaporator).
- The caretaker adds butane every six months.
- The caretaker has already repaired various leaks himself and replaced one of the press's connecting rod bearings.

8. Caretaker's attitude -- remuneration

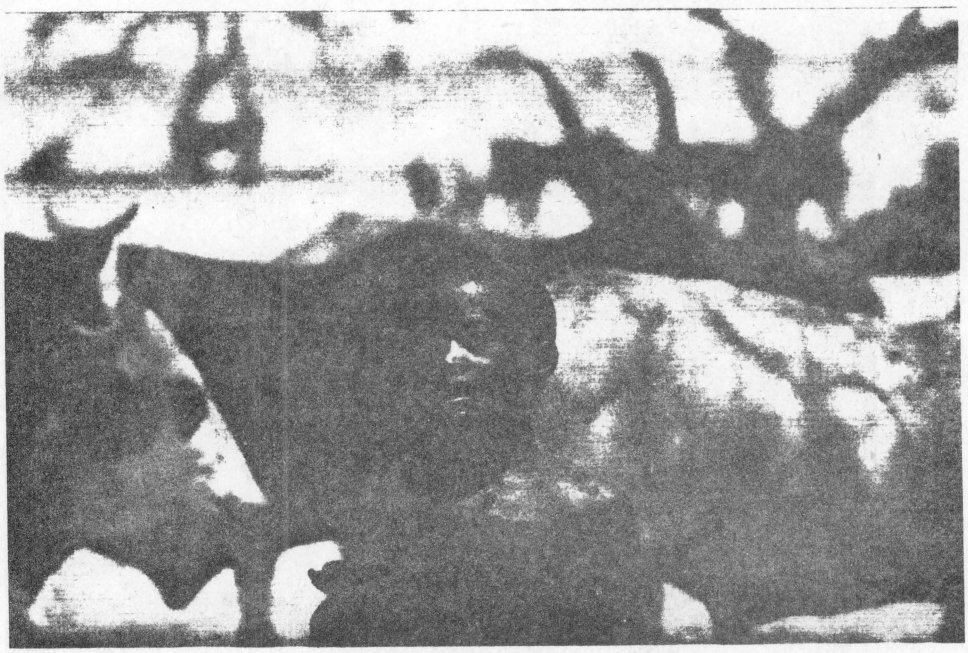
The caretaker receives his remuneration through the sale of water, at the rate of 5 CFA Francs per 20-liter bucket and 35 CFA Francs per 220-liter cask. He also receives from 10 to 15,000 CFA Francs per month enabling him to support his family (one wife plus one child), living under the pump, and pay for the pump's operating expenses (lubricant, bolts, bearings, etc.). The caretaker, with only a primary school education, is motivated by his remuneration and has a positive and responsible attitude towards the equipment. He is relatively independent and has been able to maintain the pump in working order despite the technical difficulties.

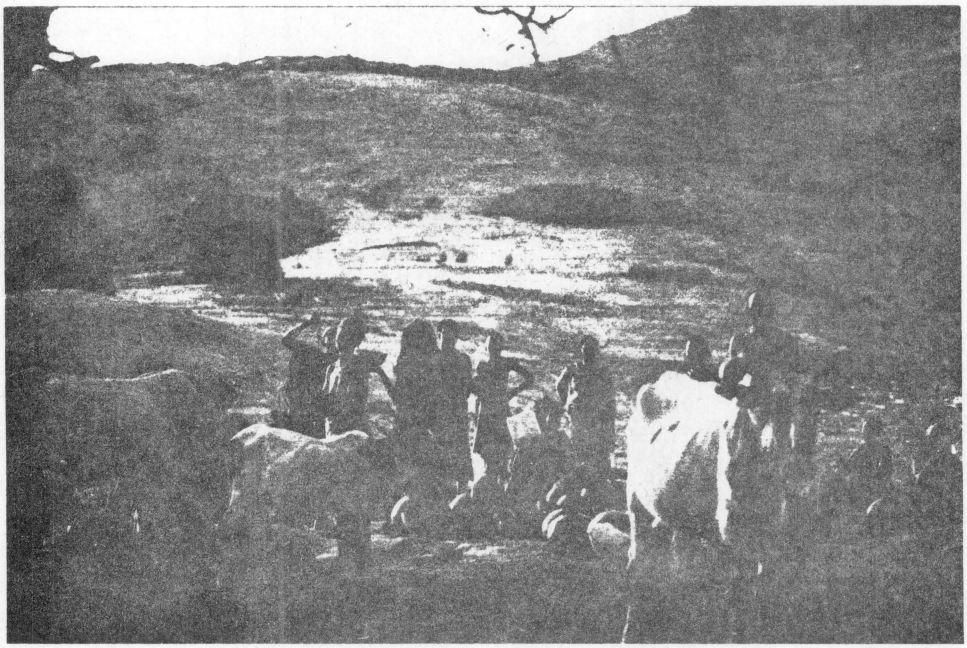
9. Spare parts

The caretaker is in possession of a small supply of spare parts and tools (contrary to other installations).

10. Cooperation with the personnel from SOFRETES

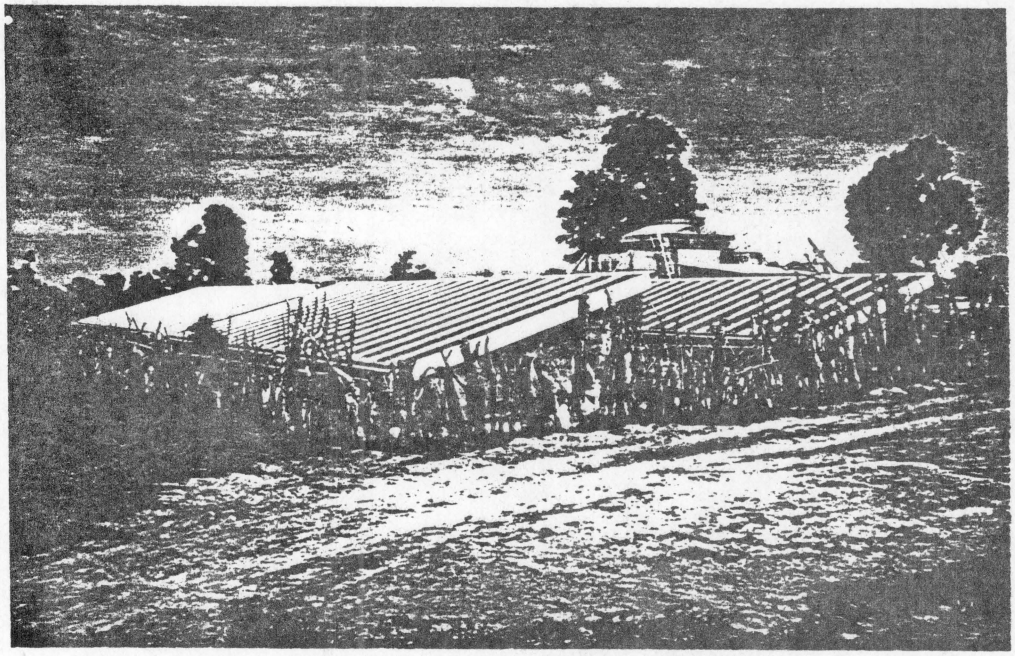
The caretaker is satisfied with the contacts between himself and the SOFRETES personnel in charge of training him.

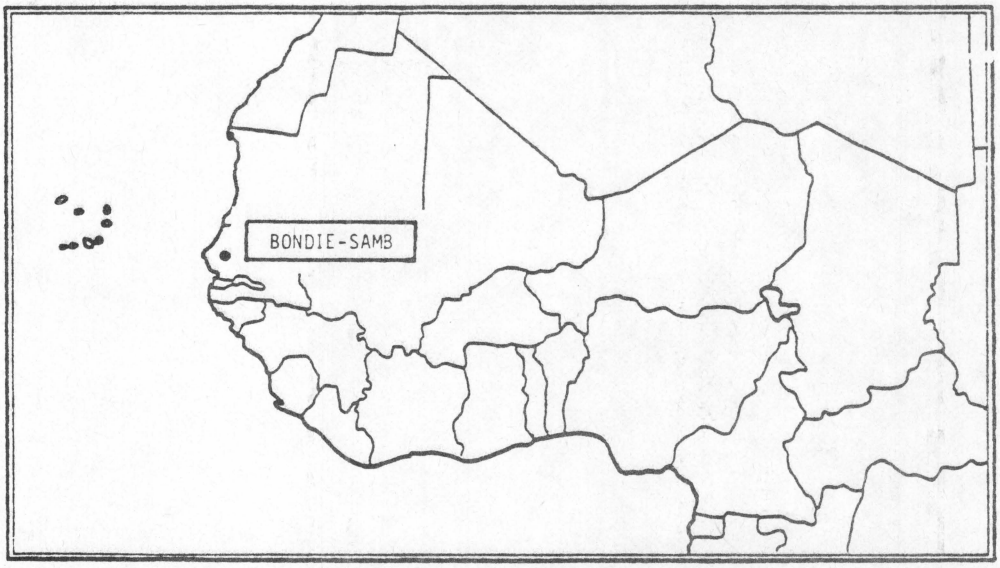




2. Pumps for livestock water supply

The increase in the number of bore-holes for livestock water supply along the paths used by cattle is one of the conditions for the survival of the livestock of the Sahel. For lack of water, the herds are too often decimated during the dry seasons. The bore-holes are generally deep and pumping the water out requires a great amount of energy. Mechanization is thus necessary.




BONDIE-SAMB

EXAMPLE 4	THERMODYNAMIC SOLAR PUMP AT BONDIE SAMB / SENEGAL LIVESTOCK WATER SUPPLY
From SOFRETES file: 8 April 1981	

1. Location

Bondie Samb is a village located 6 km northwest of Diourbel, in the area of Sine Saloum.

2. Rated specifications

- power = 10 KW
- delivery rate = 30 m^3/hr
- manometric head (MH) = 60 m
- total operating time = 6 hours
- surface of the double-glass selective collectors = 320 m^2
- temperature of the water pumped = 40°C
- evaporating condenser -- lowers the temperature by 20°C
- fully automatic operation

3. Start-up date

15 March 1981

4. Financing

French government

5. Utilization, receiving organizations

- village water supply
- water supply for the herds

This station will be managed by the Société de Développement et de Vulgarisation de l'Agriculture (SODEVA).

6. Companies participating in project organization and maintenance

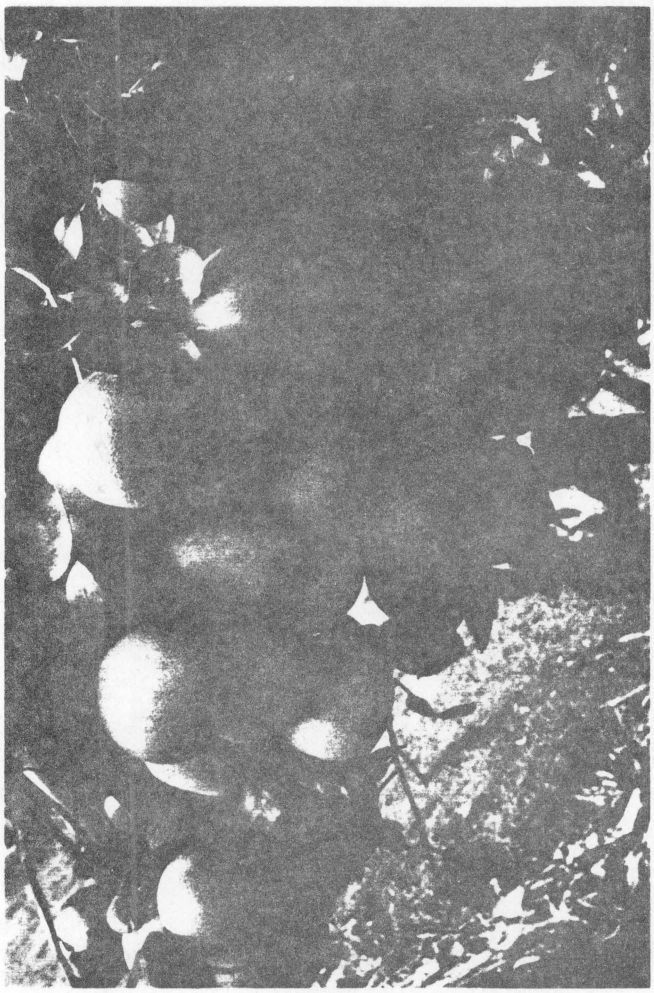
- civil engineering: SINAES
- assembly and installation of the selective collectors: SINAES
- construction of the troughs: SODEVA
- construction of the tank (200 m^3): ISRA
- general maintenance: SINAES

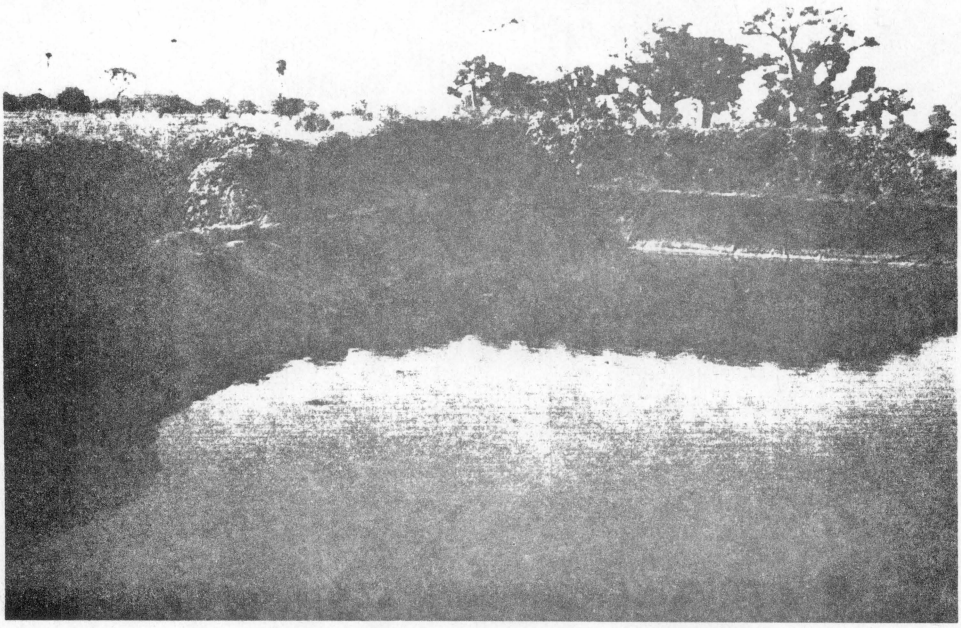
7. Performance observed

According to SOFRETES, the initial results are very encouraging and correspond to specifications. The evaporating condenser in particular performed extremely well. It should be noted that the expected rated output is still quite low (1.5%).

8. Comments

As this project is new and based on technology that is significantly different from that of the first generation of equipment from SOFRETES, it seems absolutely necessary to ensure a very careful follow-up program in order to monitor performance and be able to evaluate any progress made. It would also be worthwhile to ensure that the station's management by the receiving organizations (the village and SODEVA) be carried out properly (mainly, the caretaker should be paid) and a maintenance budget should be planned.

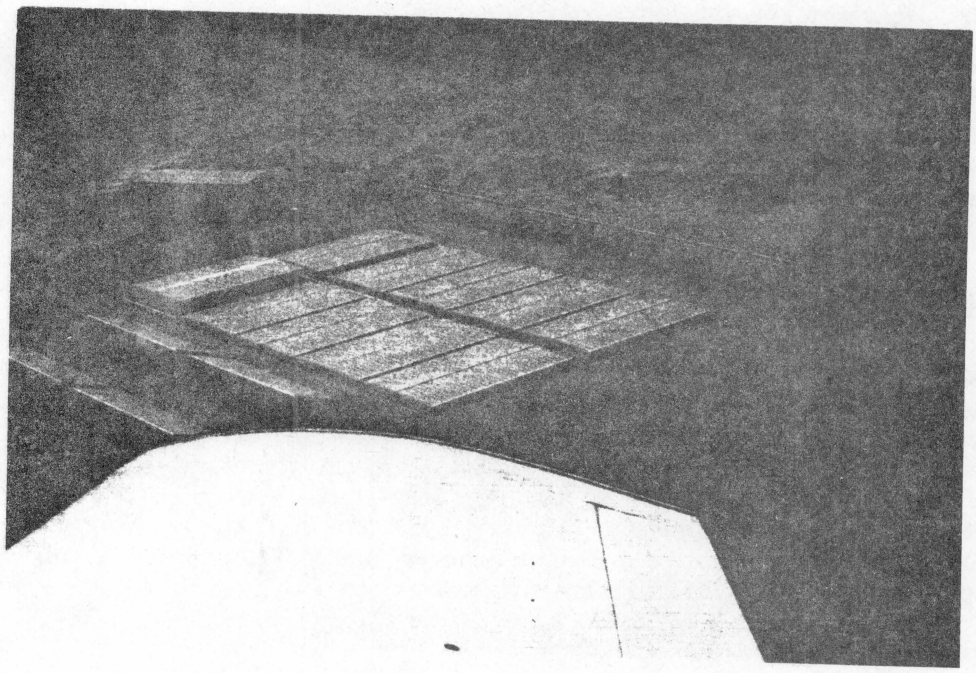


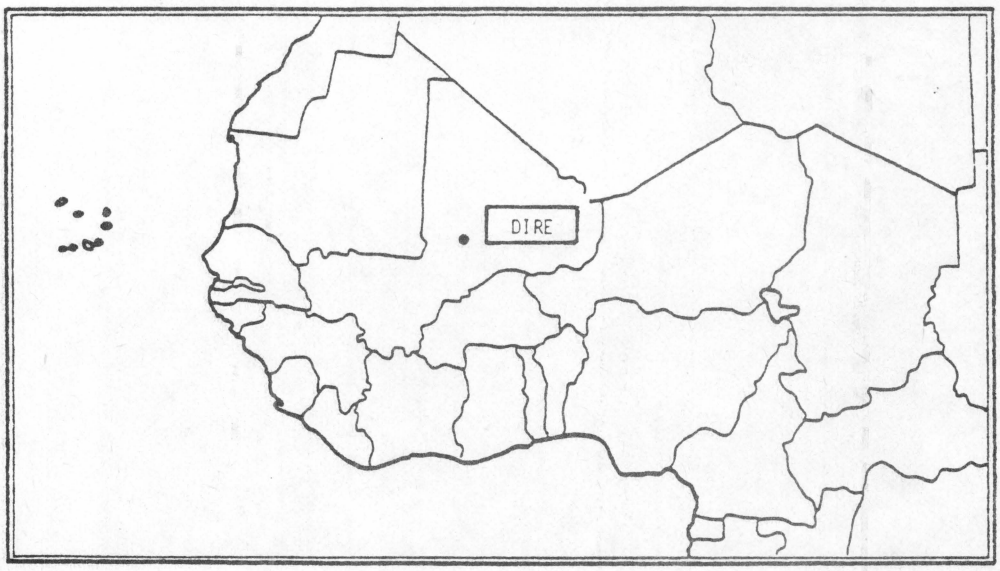


3. Irrigation pumps

Irregular precipitation is one of the principal factors limiting agricultural development in the region. It is certainly one of the causes of the region's growing deficit of food crops and one of the causes of the stagnation in cash crops. In order to remedy the situation, the countries of the Sahel have set up important crop irrigation development programs. However, implementation of these programs has not been rapid, the total irrigated surface area has hardly increased in recent years, and production cannot keep pace with demand.

The cost of energy is a factor in this state of affairs. The possibilities of irrigation by gravity are limited in this region. Generally speaking, dams can stabilize water flow, but the water must be pumped from rivers to irrigated areas. It is the cost of pumping using conventional energy sources that is a serious handicap to the profitability of irrigated cultivation. This is all the more so concerning underground water, which is abundant in certain parts of the region. Using this water for irrigation has been ruled out due to the extremely high cost of pumping using conventional energy sources. Thus, solar energy appears to be the reliable and economical solution, capable of guaranteeing the success of irrigated cultivation programs.




DIRE

The project at Dire, financed by the French government and executed by SOFRETES, is a particularly interesting one to examine because of its originality:

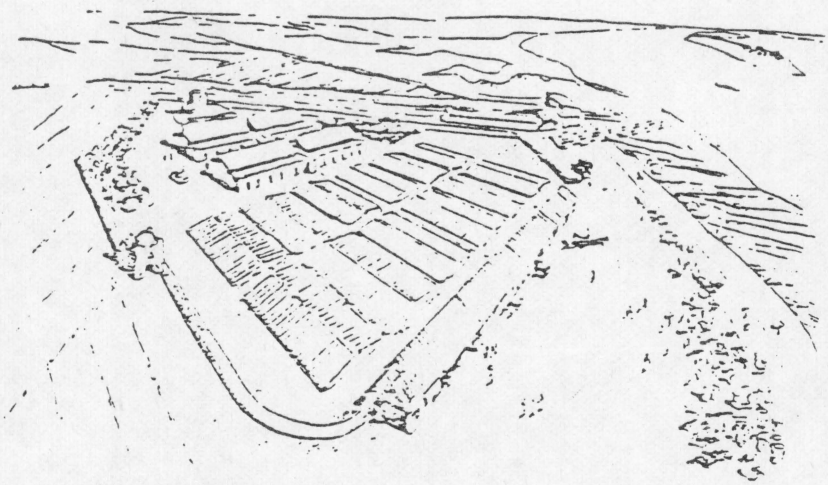
- it is probably the largest operational thermodynamic solar power station in the world;

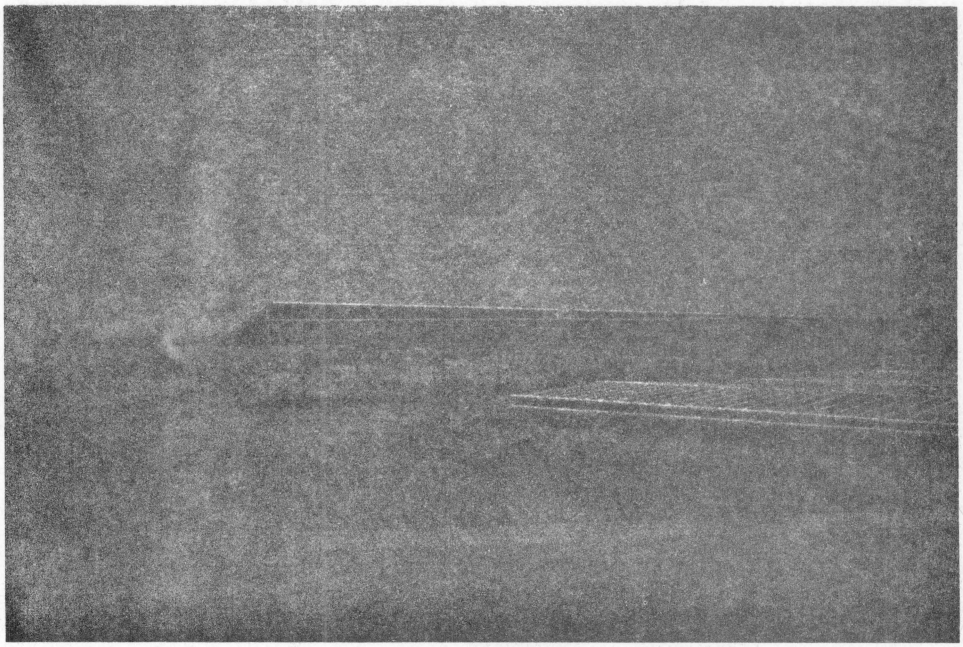
- it is located in a particularly harsh environment:
  . great distance from cities,
  . lack of local infrastructures (roads, equipped receiving location, qualified personnel, etc.),
  . very severe climate (due to its location on the edge of the Sahara);

- it incorporates innovative techniques including heat storage;

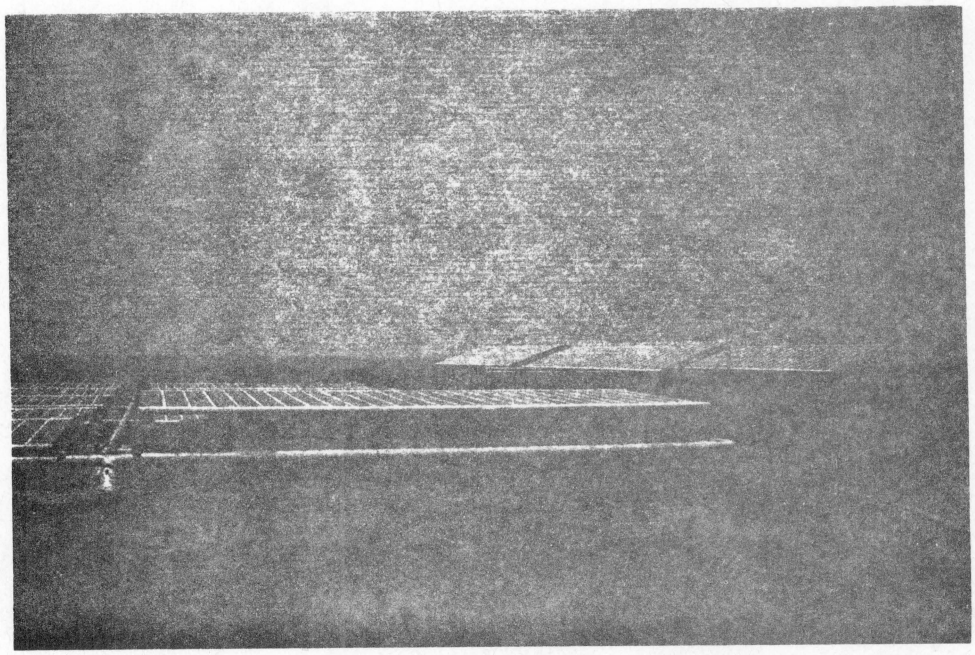
- it was built using a great degree of local participation (collector construction, for example).

As this project is nearing completion, we will attempt to provide a partial series of results.





. Ground-level and roof-mounted collectors



. Collectors installed over storage area (foreground)

EXAMPLE 5	THERMODYNAMIC SOLAR POWER PLANT AT DIRE / MALI IRRIGATION
Inspection report:	

1. Location

Dire is located on the banks of the Niger River near Timbuktu, over 1,000 km from Bamako and over 2,500 km from the coast. It is very difficult to reach either by road or river.

2. Utilization of the solar power plant

The solar power plant was built to:

- irrigate the existing plantation (approx. 150 ha), replacing the diesel pumping units which are often shut down for lack of fuel or spare parts;
- supply the town of Dire with drinking water by means of a bore-hole whose electric pump is powered by a solar power station;
- refrigerate certain hard-to-preserve agricultural products;
- supply a small tourist center with water, electricity, and refrigeration.

3. The project's technical specifications

"The thermodynamic solar conversion unit at Dire, built by SOFRETES, was designed to provide the following services:

- pumping water from the Niger River with an average daily flow rate of 8,500 m^3 for irrigation, except for three months out of the year;
- pumping drinking water from a well, with an average daily output of 600 m^3;
- powering a refrigeration unit whose specifications are: temperature = + 4°C and an average daily production of 30,000 frigories, except for three months out of the year;
- producing electricity at the end of the day for lighting, with an average power of 5 KWh.

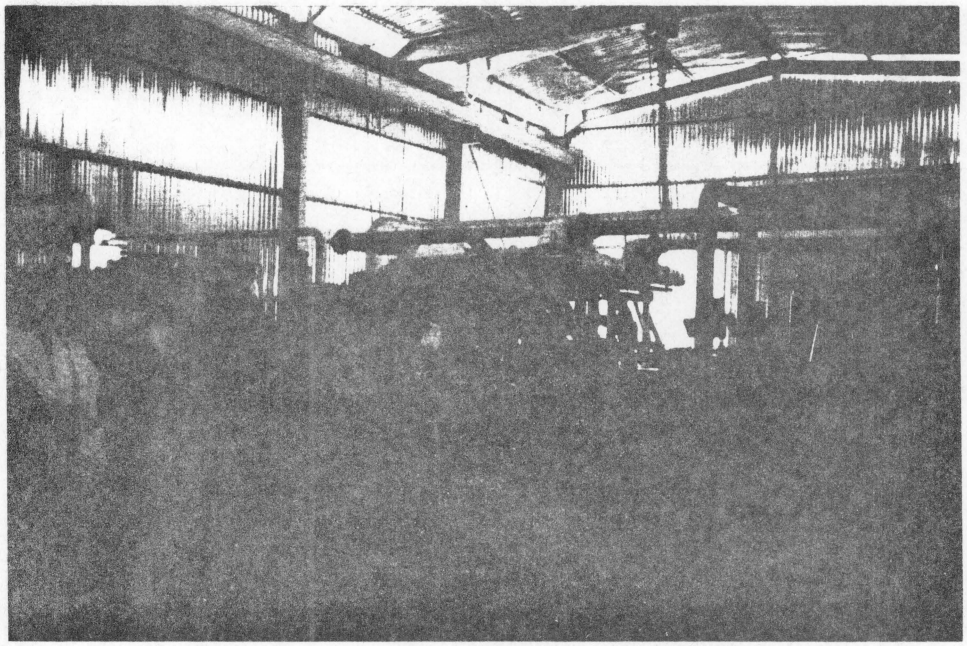
The SOFRETES equipment for converting solar energy into easily transportable energy is characterized by:

- collecting solar energy and transforming it into heat energy by means of networks of flat plate collectors. This energy is transferred to water, which is used to transport the energy;
- the transformation of this heat into primary mechanical energy by means of Rankine cycle rotating engines, with freon 11 as the thermodynamic fluid.

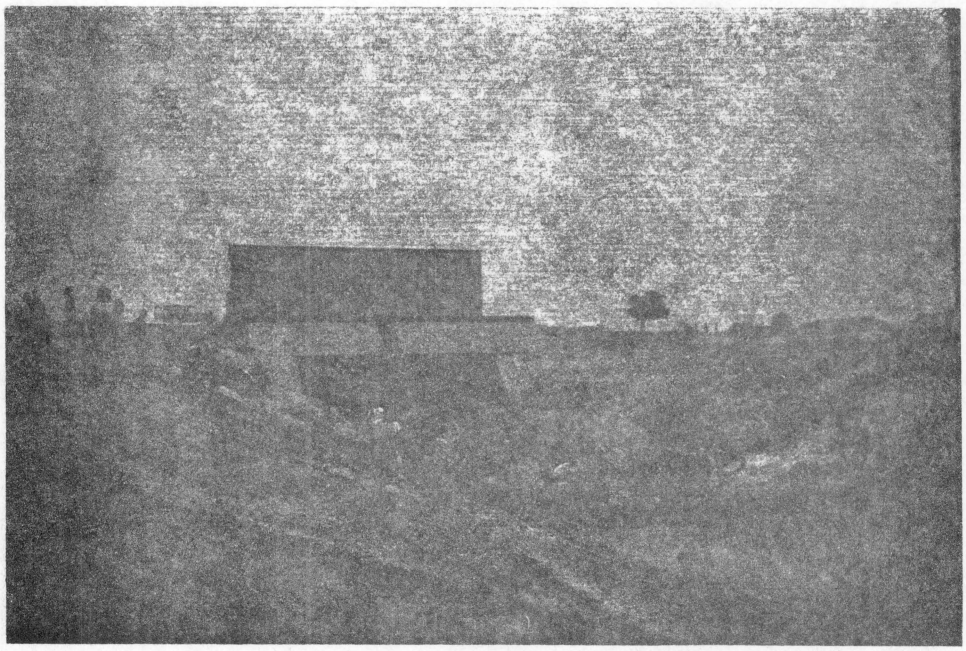
The power station includes:

- a network of interconnected collectors, using water, to which a corrosion-inhibiting agent has been added, as the heat-transfer fluid;
- a heat storage unit connected in parallel to the collecting network; the storage element is the heat transmitting fluid whose sensible heat is utilized.

Storage is used as a 'buffer' during the day. Thus, it regulates collection and evaporator entry temperatures according to a set level, providing a higher usable output of the incident solar energy. Moreover, it makes possible the recuperation of 'low calories' in the morning and evening as well as the 'high calories' during the day. Lastly, it powers the electric generating unit from 5 to 10 PM.



. Thermodynamic circulation loops and alternator (middle and background)



. Water intake channel and station

Two motor pump units with a reinjection pump, a condenser circulation pump, and an evaporator circulation pump are coupled to the shaft. These two units provide 90% of the pumping of the Niger River. After passing through a dissipation tank, the water is channeled to the area to be irrigated.

One motor/alternator unit with reinjection pump and condenser circulation pump coupled to the shaft provides electrical power for the following units:

- an AC/DC converter operating off a group of batteries;
- the regulation and control panel for the entire station;
- the heat-transfer fluid circulation pump and motor for this unit;
- the motor pump unit submerged in the well;
- the refrigeration unit;
- evening lighting;
- the heat storage water circulation pump motor."

The station is equipped with 3,200 m^2 of double-glass active collectors powering three thermal power systems with a total power of 80 mechanical KW. Daily production was planned at between 400 and 450 KWh/day in mechanical (irrigation pumps) and electrical form (alternator for lighting, auxiliary units, well pump, etc.).

4. Cost of the project

Approximately 7 million French Francs; this budget basically covers: part of the cost of research and engineering, equipment, civil engineering, shipment (very expensive), assembly, start-up, etc. This cost is relatively insignificant considering that this is a pilot plant in a unique situation. In addition, it seems that real costs noted were significantly higher.

5. Project progress report

The project has been operational since July 1979 and has been providing service, more or less as expected, despite construction difficulties that can be summarized as follows:

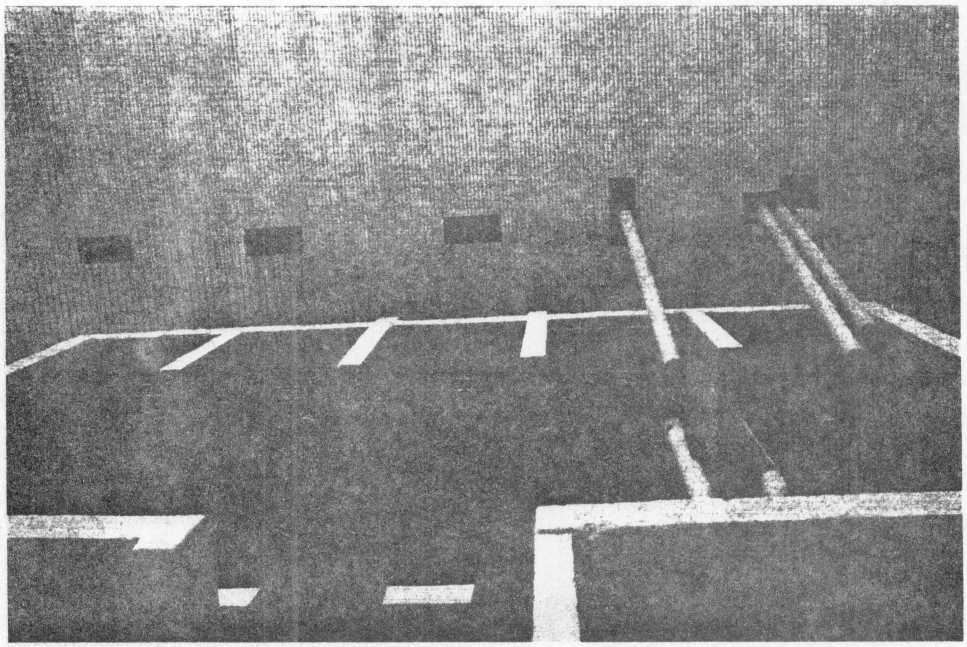
- Collectors: Insulation for the collectors was subject to deterioration (degassing) necessitating the replacement of the insulation in most of the collectors. At present, this work is nearly completed and has not impeded the operation of the rest of the station, thanks to the isolation possibilities offered by the rows of collectors (secondary valves).
- Heat storage: Completed, but not yet put into service due to problems with the collectors. Although inoperative, this did not prove to be a hindrance, because the areas to be irrigated turned out to be smaller than expected for reasons unrelated to the project. It is thus impossible to ascertain their performance at the present time or to compare them to their expected performance levels.

6. Measured performance

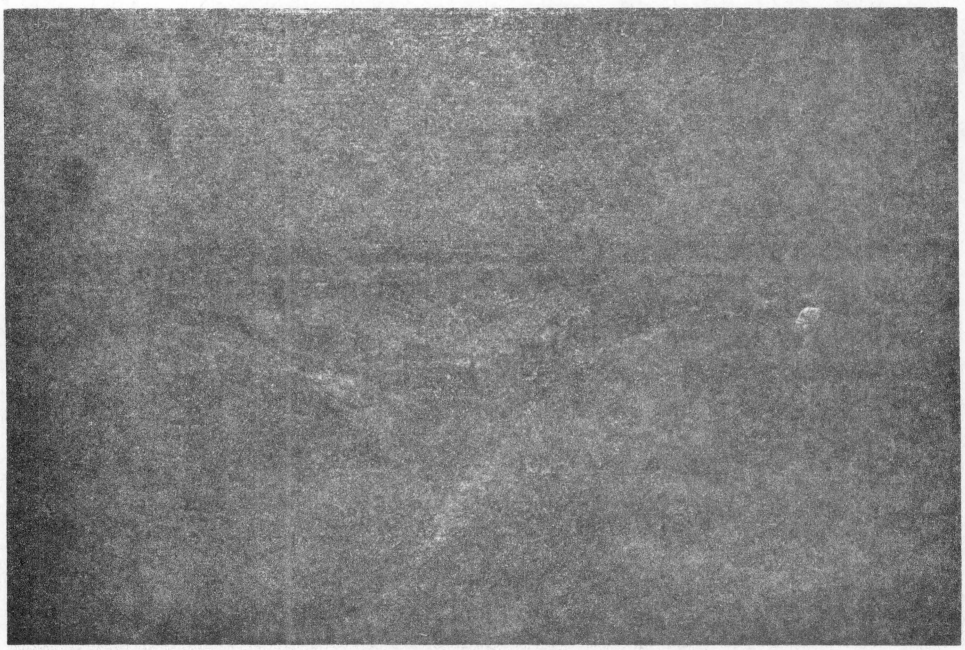
The performance measured provides incomplete and approximate information to the extent that:

- heat storage was not put into service;
- the measuring equipment available on location is very limited (no instruments, for example, for measuring power, speed, or output).

The readings taken were encouraging, however, despite their limitations.



. Discharge



. Rebuilding the channel

In February 1980 the station operated for a total of 135 hours 55 minutes, or an average of 4.7 hours per day (without storage). Maximum hourly flow rate is 1,400 m^3/hr which probably corresponds to a daily flow rate on the order of 6,000 m^3/day. It is unlikely that, with the introduction of storage, which would allow for a significant prolongation of the operating time, the level of 8,500 m^3/day announced could be reached (for 6.5 KWh/m^2/day), all the more so, since February is only a moderately sunny month (sun located quite low, atmospheric turbidity due to the sand whipped up by the harmattan).

In April 1980 the station operated up to 8 hours per day, according to SOFRETES. In February 1981 operating statistics were as follows:

- Dire 1: average operation = 5 hours per day
- Dire 2: average operation = 5 hours 40 minutes - 6 hours per day
- Dire 3: operation = 3 hours per day (for lack of sufficient demand).

7. Quality of service provided

The solar power station at Dire, despite the fact that some of its equipment was unfinished, provided extremely important services:

Irrigation:

- In 1979/80, 47 hectares of wheat were cultivated with an average yield of 1.5 T/ha. According to officials at the Agriculture Ministry and the agricultural engineering department, the solar power station made it possible to save the harvest at a time when the diesel pumps were not fueled.
- In 1980/81 all the irrigation in the area (wheat, sorghum, tomatoes) was accomplished by the solar station without using any diesel engines (they happened to be idle due to constant diesel fuel shortages).

Certain services planned at the outset could not, however, be provided:

- Water for the town of Dire: The submersible electric pump provides 60 - 70 m^3/hr. while the station is operating. For lack of a conduit leading towards the town, where a system is being installed, this drinking water could not be put to best use (used for irrigation while waiting).
- Refrigeration: The refrigeration unit remained in its crate; the cooperative and the tourist center, initially planned, do not yet exist.
- Electricity: No use has yet been found for the surplus that will be available once heat storage is put into service (until 10 PM).

8. Problems encountered while carrying out the project

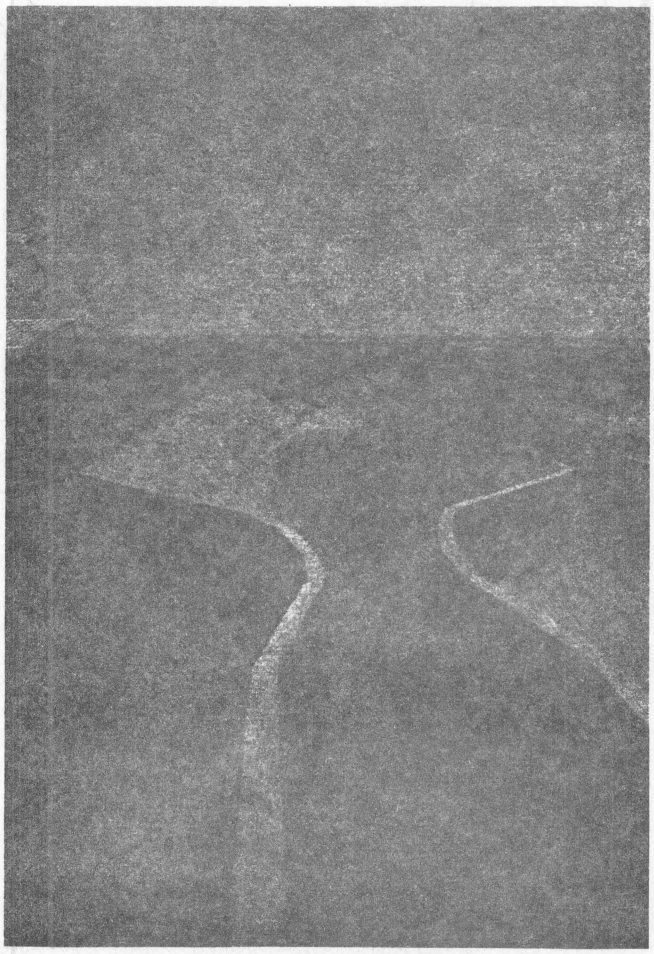
The project was very difficult to carry out considering the highly unusual circumstances. Solutions were found for most of the problems despite the very uncommon technical hazards, such as degassing of the insulating material which led to a complete overhaul of the collectors. Management for the project was difficult due to a tight budget, insufficient numbers of qualified personnel, the pilot nature of the project, and difficulty of access. It should be noted, however, that there was very close collaboration between the local population, the agricultural engineering services, the solar energy laboratory at Bamako, which lent a technician, and the personnel from SOFRETES.

9. The future -- problems to solve

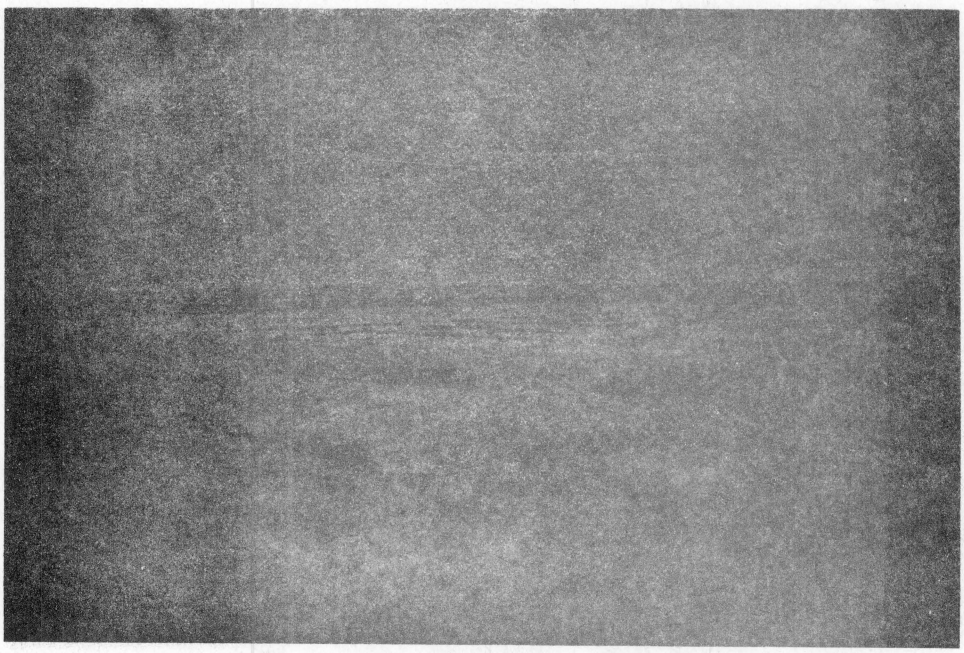
The future of this interesting and undoubtedly useful project must be ensured at all costs. This involves:

- maintaining and even increasing the manpower and financial assistance associated with the area currently being irrigated (assistance from the Fonds d'Aide et de Coopération);

. Irrigation channel



. Irrigated zones



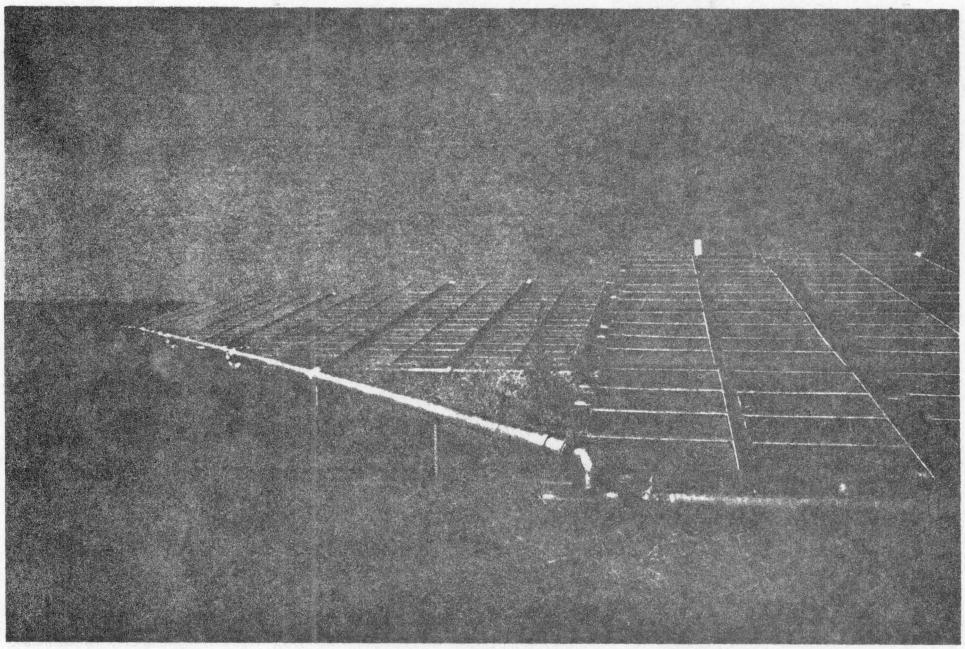
- additional financial means should be placed at the disposal of SOFRETES in order to guarantee the completion and maintenance of the equipment. This money could be provided according to the terms of a contract describing, in detail, all the services to be provided by the company;

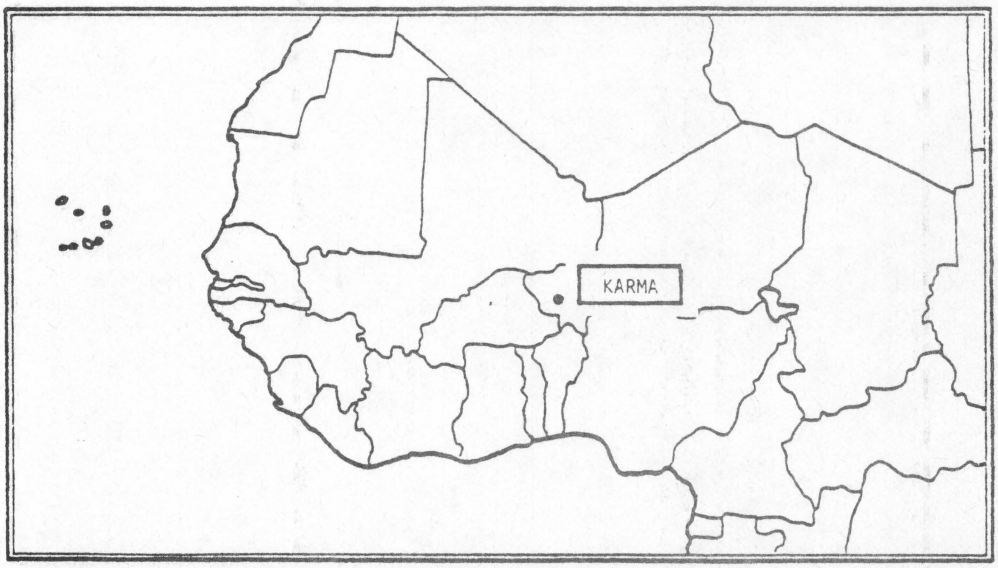
- keeping the technician from the solar energy laboratory at Bamako.

In our opinion, unless a new, more detailed analysis is performed on site, it will be absolutely necessary to:

- complete the project so that it may provide all the services originally planned (irrigation, drinking water for Dire, refrigeration, electricity). It would be unfortunate if for lack of investments, which are modest compared to the initial outlay, the project was underutilized. Aside from the technical completion of the station itself, it is necessary to finish:
  - the connection of the electric bore-hole pump to the Dire network,
  - the construction of a tourist campsite that would be provided with free drinking water, electricity, and a refrigeration unit, and would provide Dire with some resources and jobs.

It is also necessary to furnish the station with a greater supply of spare parts and install a minimum of measuring equipment in order to make best use of all the information to be gained form this first experience.




KARMA

EXAMPLE 6	THERMODYNAMIC SOLAR PUMP AT KARMA / NIGER IRRIGATION
Inspection report: 28 - 29 October 1980	

Aside from the visits to Karma on 28 and 29 October 1980, the present report relies heavily on the very exhaustive reports drawn up by the delegation of the EDF in the Republic of Niger and by ONERSOL in November 1979 and June 1980.

1. Preliminary remarks

The solar energy project at Karma was conceived as an experimental station and a prototype. This is justifiable because it is the first solar pumping station of its size built in Niger (the pump at Bossey-Bangou, built in 1968 is one-tenth as powerful), because it provides ONERSOL laboratories with possibilities for experimentation (as well as the means for testing the collectors produced by their manufacturing division), and because it utilizes the solar thermodynamic branch which is still relatively new (despite the fact that similar equipment has been set up in other countries by SOFRETES, mainly in Senegal, Mali, and Upper Volta).

Purpose of the experiments

Experimentation with a pilot plant such as the one at Karma should lead to:

- improving the thermodynamic motor and the system as a whole in such a way as to increase performance and reliability under conditions usually encountered in Niger;

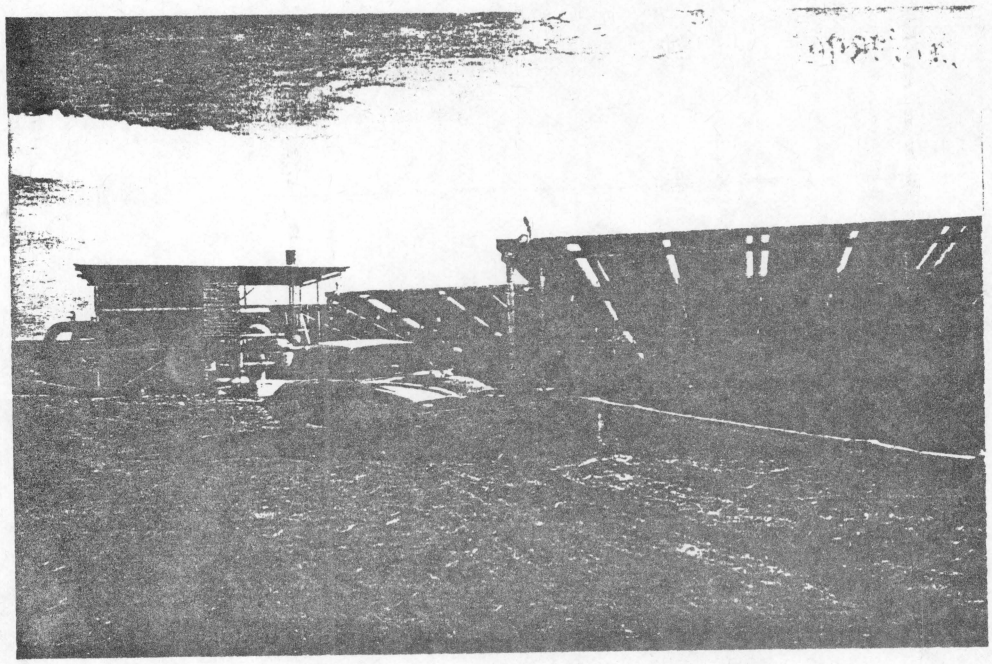
- determining the most appropriate mode of operation for similar solar pumping stations to be built in the future: more or less advanced automation, qualifications of the personnel in charge of starting up and maintaining the equipment, organization of the more complex repair and maintenance operations. The goal here is to find optimal profitability for future stations to prevent the advantages of solar energy from being outweighed by the disadvantages of costly operation and energy-consuming maintenance (maintenance crew visits, etc.).

Means of experimentation

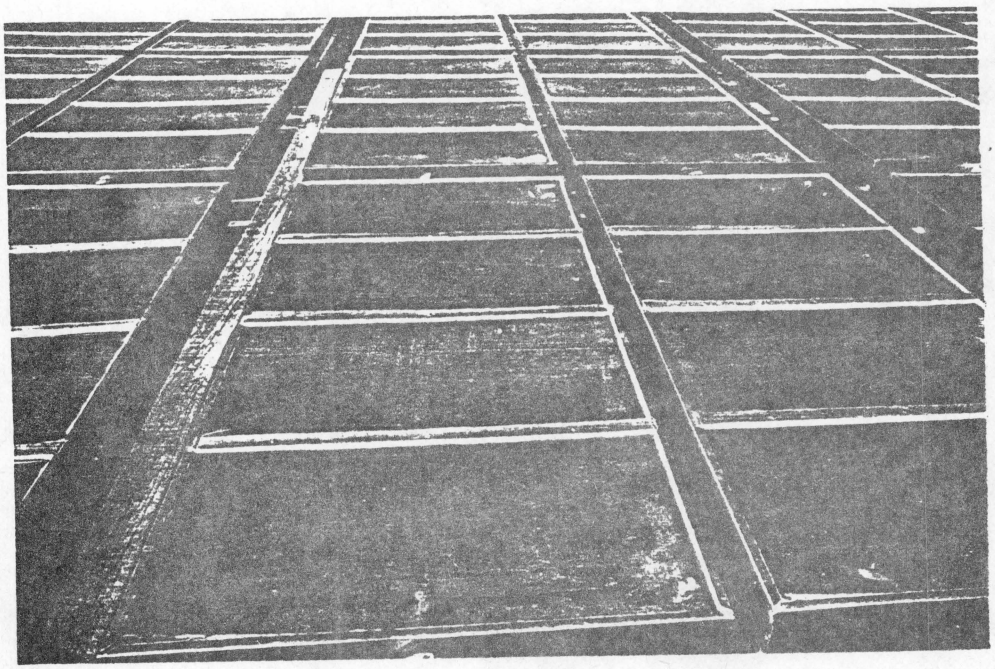
Present conditions for experimentation can be termed satisfactory:

- the pump at Karma is located 50 km from Niamey, where ONERSOL has at its disposal sufficient means for processing the measurement data collected, diagnosing flaws, and intervening in the event of breakdowns;

- an engineer from ONERSOL (from the French technical assistance team) makes the round trip Niamey-Karma on a daily basis in order to start up the equipment;



. Boucle thermique et capteurs



. Capteurs ONERSOL

- the mechanic, assigned by the UNCC (the pump's user) for the maintenance of the diesel pumps connected in parallel with the solar pump, is currently being trained to operate the pump by the French technician in charge of the pump;

- the tools stored on location (hoisting and welding equipment, etc.) make it possible to do a good portion of the repair work on the spot.

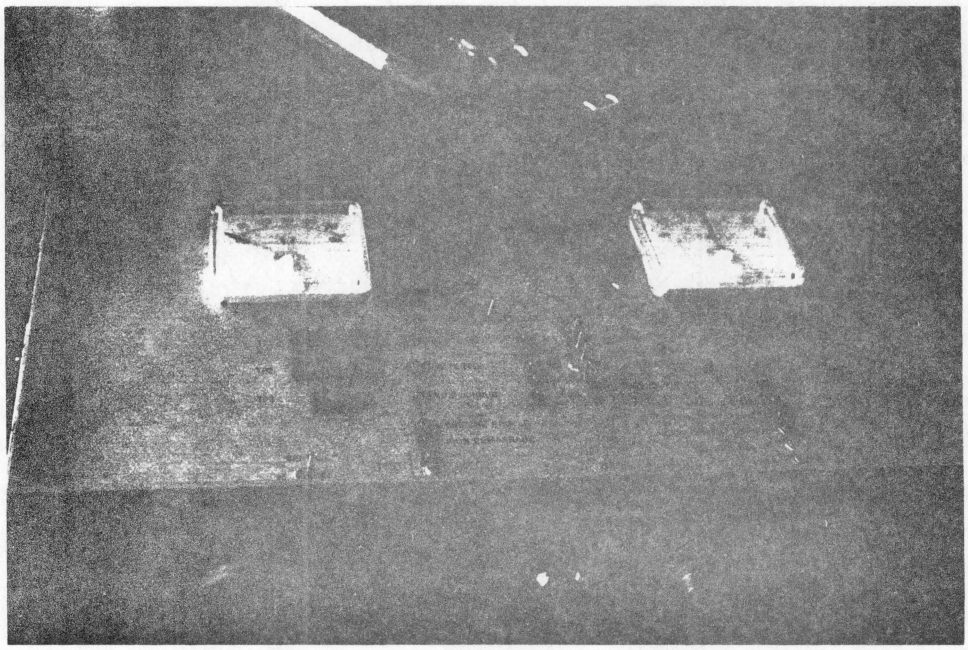
The system is lacking in certain equipment, mostly measurement instruments, that would make it easier to discern the condition of the system in the event of malfunction or breakdown. Although measurement programs enabled accurate evaluation of the pump's performance under normal operating conditions (readings taken using instruments brought to the site), the operator is less prepared to analyze the cause of breakdowns, since only the freon pressure gauge is located on the pump itself. The reports written by the technician in charge of monitoring the pump, therefore, can only be qualitative. The manufacturer will have to do without certain information necessary to make a precise diagnosis of the malfunctions affecting the prototype, to decide on the modifications to carry out, and to design future equipment based on the same model.

2. Assessment of performance

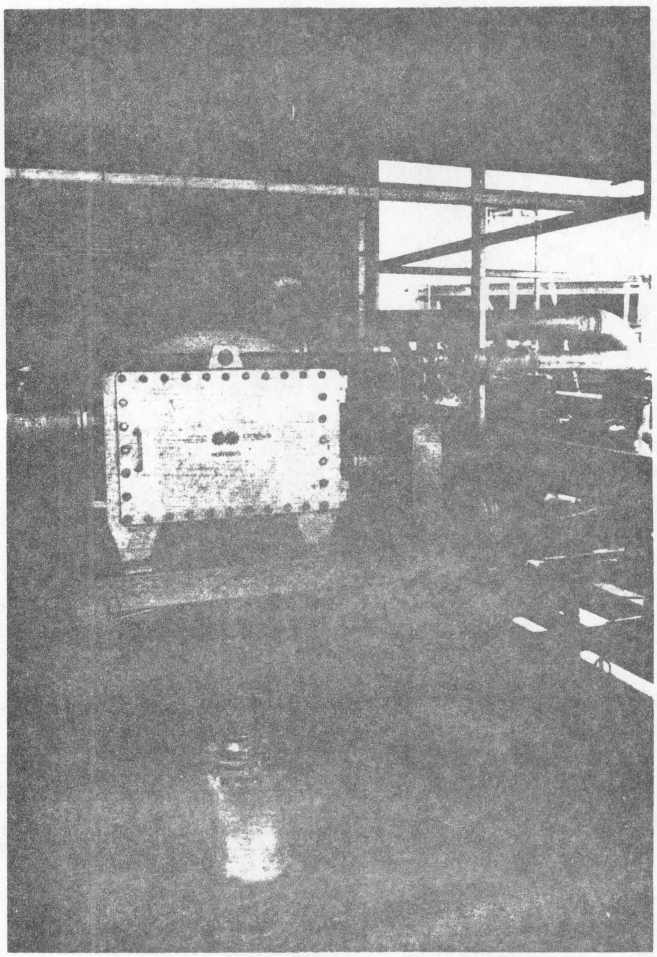
The pump's performance is defined by the readings taken in October, November, and December 1979, as well as in January 1980, as listed in the reports of the delegation of the EDF in Niger. The average hourly delivery rate per month from September 1979 to March 1980 was higher than the 400 m^3/hr. rated. The manometric head was generally lower than the 5.9 m rated (2.7 to 4.5 depending on the month). We have no statistics for September 1979 nor for the months after April 1980.

It is possible to estimate the variation in output as a function of the manometric head by using the pump's characteristic curves A (see appendix 1). For purposes of comparison, we can take the results of the day for 18 November 1979 (appendix 1), where the average hourly delivery rate was 470 m^3, close to the average delivery rate for the month of November (450 m^3/hr.). This particular day was sunny (average = 765 W/m^2). The average delivery rate for the day was reached by 3:30 PM with a speed of 1,300 RPM and a manometric head of 3 m, giving us a point (131 liters/sec., 1,300 RPM, 3 m) on curve A. A manometric head of 5.9 m on the same curve gives a delivery rate of 104 liters/sec., or 375 m^3/hr., only slightly different from that rated. Nevertheless, this is only very approximative. In order to be more precise, it would be necessary to reconstitute an entire standard day, however, it is preferable to wait for the statistics from July and August 1980.

The number of hours of operation never exceeds 6 hours per day, giving an average daily delivery rate varying between 2,300 and 3,100 m^3, depending on the month (see appendix 6). Comparative tests made on 21 and 22 November 1979 show that the optimal time for opening the freon valve, at that point, was 10:50 AM (see appendices 1 and 2). The pump is normally shut down at about 4:30 PM.



. Control panel



.Circulation loop:
condenser,
evaporator

Under existing conditions, daily output cannot be increased by starting up the pump earlier. The only solution would consist of adding a heat transfer storage fluid to the system (undergoing tests at Dire, Mali) making it possible to maintain the temperature of the water in the collectors at a level 1 - 2°C lower than the temperature at the end of the preceding day.

Output:

If we take the day of 21 November 1979, average power provided at various hours, according to the pump's characteristic curves (A), is as follows:

11 AM - 12 noon	=	4 KW
12 noon - 1 PM	=	7.4 KW
1 - 2 PM	=	8.6 KW
2 - 3 PM	=	7.8 KW
3 - 4 PM	=	4 KW
4 - 4:15 PM	=	3 KW

giving a total energy of 35.5 KWh for the day. If reducer output is 90%, the energy supplied to the motor shaft is 39.4 KWh.

Average insolation for 21 November 1979, between 10:35 AM and 4:17 PM was 700 W/m², or 4.1 KWh/m² for 5 hours 52 minutes. However, pumping energy is to be compared to the total daily incident radiation, for a period of about 8.5 hours, giving approximately 5.5 KWh/m² less; for 700 m² of collectors, that gives 3,580 KWh, for an overall daily output (power to the motor shaft with respect to the incident energy) of 0.92%. The actual energy of the water pumped is, given 460 m³/hr. on the average for the day and an average manometric head of 3.2 m:

$$460{,}000 \text{ liters} \times 5.87 \text{ hours} \times 9.81 \times 3.2 = 84.67 \times 10^6 \text{ joules} = 23.5 \text{ KWh.}$$

$$\text{Total output } \frac{\text{energy of pumped water}}{\text{incident solar radiation}} \text{ is therefore } \frac{23.5}{3{,}850} = 0.6\%$$

This output could clearly be increased (over 1%) by using a storage system.

Collector output -- calculations made using the readings from 22 January 1980 lead to an evaluation varying from 22.6% at 2:30 PM to 28.7% at 5 PM (see appendix 5); the value 36.8% at 5:30 PM is due to the fact that the energy extracted remains relatively constant while the incident energy becomes much weaker. It is not representative of the rate in the middle of the day.

3. Ease of start-up

The June 1980 note from the EDF and appendices 2 and 5 provide an accurate description of what happens when the pump is started up, particularly regarding the transient rate and the accidents that can take place. The readings taken and the observations noted on the cards show that optimal start-up time can vary considerably (up to about 30 minutes) from one day to the next. The comparative tests of 21 and 22 November show that early start-up (at 10:35 AM on the 21st instead of at 10:53 AM as on the 22nd) can entail a significant rate drop which in turn could lead to a total shutdown.

POMPE SOLAIRE DE KARIA (MOYENNES MENSUELLES)

Mois	HMT moyenne m	Nbre d'heures de fonctionnement	qté eau pompée /mois	heure de démarrage	heure d'arrêt	temps de fonct.	débit maxi m3/h	débit mini. m3/h	débit moyen m3/h	débit journalier m3/jour	ARRETS
Août 79	6	45	non mesurée	-	-	-	-	-	-	-	mise en route le 8/8/79
Sept 79	4,5	63	32 000	10 h 30	16 h 30	6 h	600	300	500	3 100	20/9 au 30/9
Oct 79	4	179	92 500	10 h 30	16 h 30	6 h	600	300	500	3 100	1j (mauvais temps)
Nov. 79	3,5	148	66 700	10 h 50	16 h 30	5 h 40	550	360	450	2 550	3j (mauvais temps)
Déc. 79	2,7	74	34 000	11 h 30	16 h 30	5 h	520	390	460	2 300	20/12 au 31/12
Janv. 80	2,9	87	38 000	12 h	17 h 15	5 h 15	510	340	440	2 300	1/1 au 13/1
Fév. 80	3,8	29	non mesurée	-	-	-	-	-	-	-	Révision de 500 heures
Mars 80	4,0	123	55 300	11 h 15	17 h 15	6 h	505	300	450	2 700	27/3 au 31/3
Avril 80	4,2	26	9 600	11 h 15	17 h	5 h 45	450	200	370	2 100	8/4 au 27/4
Mai 80	4,4	16	non mesurée	11 h 30	15 h	3 h 30	-	-	-	-	1/5 au 9/5 11/5 au 15/5
Total au 26/5/80 mesuré		784	328 100								

Total extrapolé environ 210 000 m3 campagne précédente
360 000 m3 dont 150 000 m3 campagne en cours

REMARQUES : bien que le mois de Décembre corresponde à une H.M.T. minimale, l'ensoleillement pendant cette période correspond au minimum annuel. Ceci explique la chute du temps moyen de fonctionnement et des débits journaliers.

Source : FED-ONERSOL

Automatic, timer-controlled operation, as initially designed by SOFRETES, can only be planned if insolation is perfectly consistent on a day to day basis. In any case, an operator's presence is occasionally required in order to regulate the timers according to the seasons and in the event of heavy cloud cover.

It does not yet seem possible to consider employing an inexperienced operator. The experiment is currently being run at Karma using a qualified diesel mechanic who is now in charge of the diesel pumps on the site. The experiment shows that the thermodynamic solar pump is sufficiently complex as to require the absolute mastery of all modes of operation, and this can only be acquired through a training period of several months' duration. Basically, the operator must learn a certain number of processes, such as:

- utilization of the circulation pump before start-up
- pressure to be attained before start-up
- optimal charge level for the batteries and charge time
- draining the collectors and filling the water circuit
- reinjection of freon in the event of pump shutdown during the day
- keeping a measurement log for noting minor accidents.

4. Reliability

Appendix 6 to the EDF-Niger memo mentioned above reviews the breakdowns that occurred from August 1979 to May 1980, as well as the total number of hours of operation from September 1979 to April 1980. An availability rate has been computed based on the ratio of the actual number to the theoretical number of hours of operation. This came out to 60% (a respectable result considering the experimental nature of this unit). Breakdowns were due mostly to gas leaks, oil leaks, and corrosion problems.

5. Assessment of utilization

The solar energy experience at Karma does not include the use of water, because the water provided by the solar pump represents only part of the water needed for the UNCC's irrigation of the area. The water provided by the solar pump should correspond to the irrigation of 20 fictitious hectares. This goal was reached, since 2,300 to 3,100 m^3/day are adequate for this surface area.

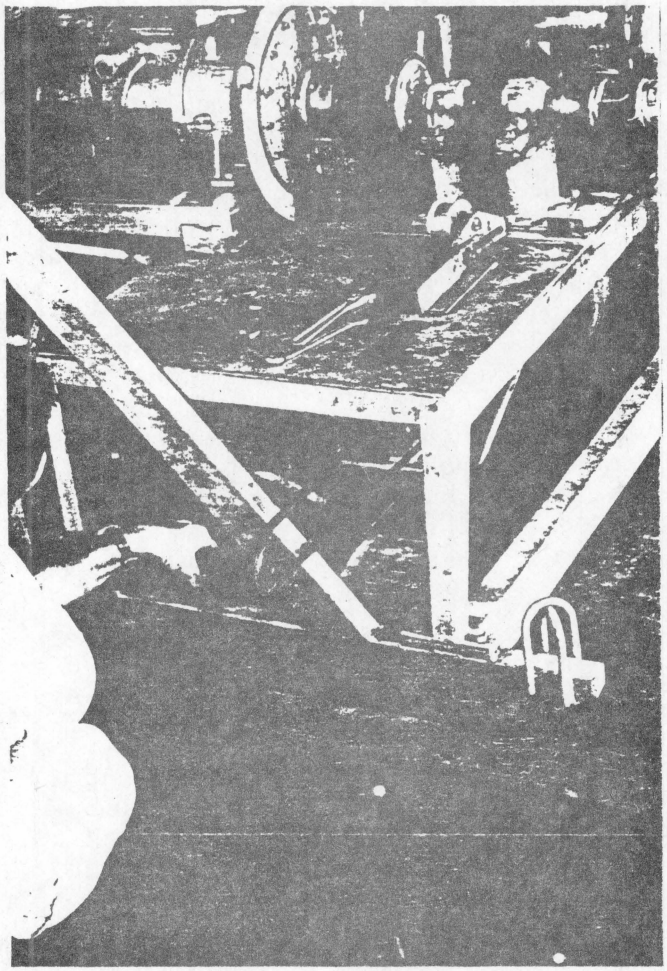
Distribution of the volume pumped over the period of time is not, however, perfectly suited to farmers' needs:

- pumping hours (11 AM to 4:30 PM) do not correspond to the best times for water utilization (mostly in the morning), and this requires an eventual regulation of the irrigation system;

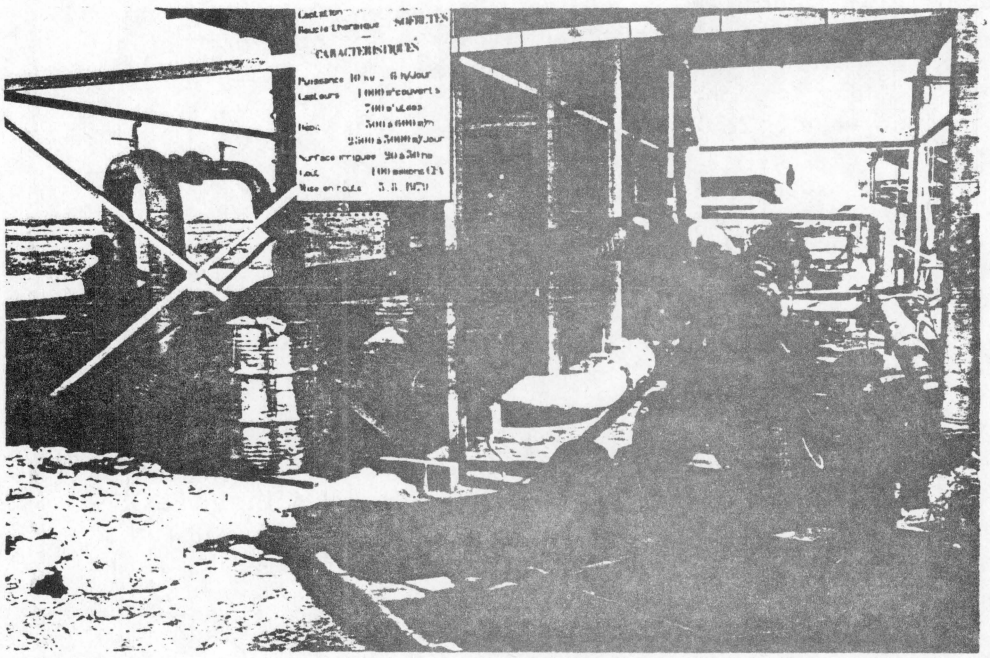
- the quantity of water pumped (excluding variations due to the manometric head and insolation, which vary with the seasons) is relatively consistent throughout the year, while the demand for water increases with successive cultivation operations. The equipment could therefore be used for other purposes at certain times of the year, for example, generating electricity to power agricultural machinery.

- Moteur et arbre (en haut)

  Réinjection artificielle de fréon à l'évaporateur (en bas)



- Pompes diesel installées en parallèle



6. Appraisal of the first year of the Karma experiment

The experiment was a success in the sense that it brought up situations on which the manufacturer had not originally counted:

- the consequences of the presence of water or air in the freon -- corrosion of the reinjection pump, loss in pump efficiency -- both occurrences causing short term equipment shutdowns;

- the ineffectiveness of certain repairs and the risks inherent in these repairs (see appendix 5 and the EDF-Niger memo);

- problems caused by water circulation:
  . non-homogeneous circulation through the rows of collectors,
  . localized overheating can cause steam to form, and consequently, cavitations of the circulation pump,
  . steam formation can be considerable when start-up is too late for the heat transfer fluid to circulate, and the pump stops operating (this happened on 28 October when a test was made to start the pump at 2:30 PM).

These two types of mishaps demonstrated the need to install a sufficient number of draw-off taps. True prototype development, however, would require more complete readings and a more detailed analysis of the events observed:

- readings should include the rate of water being pumped, in such a way as to obtain the pump's real characteristics (manometric head, output, delivery rate, power, rotation speed);

- the relatively low temperature drop at the evaporator (2 - 2.5°C, rather than the 3.5°C planned) as well as the output level of the collectors once they have been integrated into the equipment, which was clearly lower than that originally obtained in tests (on the average, 25% instead of 40%), could be better explained after true delivery rate readings of the heat transfer fluid;

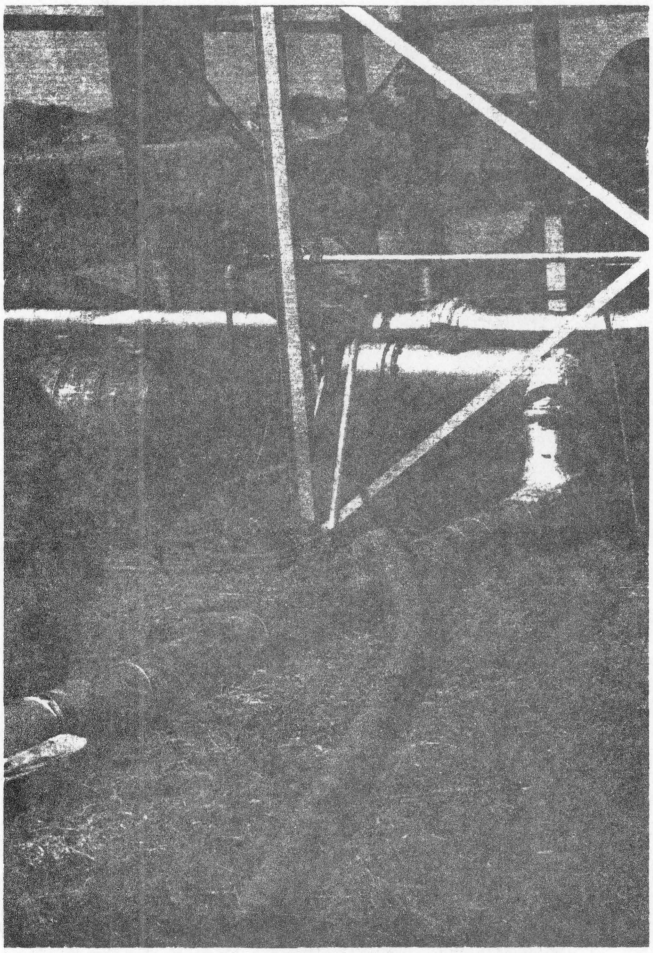
- the readings could be utilized more fully -- application of standard tests developped by the CEA, study of changes in performance with the passage of time, determination of the freon cycle.

Modifications of the prototype:

The lessons learned form the first year of testing should form the basis for prototype modifications designed to improve performance and increase self-sufficiency. Karma, for example, would be the ideal location to test the utilization of heat transfer fluid storage.

Economic evaluation:

One year of operation is certainly insufficient for a realistic economic evaluation of this type of experiment. Moreover, we lack the economic elements concerning utilization (income from the irrigated zones, current cost of diesel operation to the UNCC) as well as ONERSOL's participation. It is certain, however, that the profitability of this type of station can only be guaranteed if it is truly self-sufficient, with reliable, automatic operation or start-up and monitoring by a caretaker with limited experience and occasional maintenance by qualified technicians.



. Artificial cooling of the condenser

C. PHOTOVOLTAIC SOLAR PUMPING

C. PHOTOVOLTAIC SOLAR PUMPING

Example 1: Photovoltaic solar pump at Samane (Senegal) pg. 110

Example 2: Photovoltaic solar pump at Guetale (Cameroon) pg. 118

Example 3: Photovoltaic solar pump at Yangasso 1 (Mali) pg. 134

Example 4: Photovoltaic solar pump at Yangasso 2 (Mali) pg. 140

Example 5: Photovoltaic solar pump at Tion (Mali) pg. 144

Example 6: Photovoltaic solar pump at Mogtedo (Upper Volta) pg. 146

Example 7: Photovoltaic solar pump at Markoye (Upper Volta) pg. 158

Stemming from the second generation of solar energy equipment, photovoltaic pumps began to appear in village water supply and small irrigation programs during the last decade. Their use is justifiable:

- when local hydrogeological conditions exclude the use of wells and when village needs are exceed a certain limit (up to which it is preferable to use non-motorized pumping methods, such as foot pumps);

- when the village is so isolated that regular pump maintenance (reliability with respect to conventional solutions) and fuel deliveries (profitability with respect to conventional solutions) cannot be guaranteed with absolute certainty;

- when the local population -- or often, the supervisory organization for the village -- has the means to purchase a motorized pump.

Measurements and observations made during the assignments in the area produced a precious source of information concerning the general condition of the existing installations. The fact that the duration of the inspections was very limited (one-half to one day per installation) should temper any interpretation of the findings. Several of those installations visited should be checked in much greater detail in order to produce definitive diagnostic analyses (detailed analyses of every part of every system). The difficulties we observed and judged worthy to published should not mask the very encouraging, one can even say excellent, results achieved at many installations located in particularly harsh environments.

Measurement methods used for on-site evaluations:

a)- Insolation measurements:

- Use of a Solarex calibrated high-precision reference scanner, producing 141 mV for 1,000 W/m²;
- Readings taken every 15 - 30 minutes in the same location as the panels;
- Total radiation is measured with precision; diffuse radiation is measured (narrow shadow cast on the test cell);
- The voltage produced by the test scanner is measured on a Beckmann high-precision digital multimeter (0.1%).

b)- Voltage measurements:

- Use of a digital multimeter.

c)- Current measurements:

- Use of an AOIP precision shunt + digital multimeter.

d)- Rotation speed measurements:

- Jaquet digital tachometer (error = $\pm$ 1 RPM)

e)- Dynamic level measurements:

- Use of an electric probe coupled to an ohmmeter.

f)- Temperature measurements:

- Two mercury thermometers (precision = 0.1°C), one placed on the surface of the modules, the other placed in the shade (ambient temperature).

g)- Flow rate measurements:

The methods used depend on the possibilities offered by the site:

- pre-calibrated displacement meter,
- variation in the level of a tank of even shape over a given period of time (chronometer),
- use of a calibrated 220-liter tank or 20-liter bucket; filling time measured with a chronometer.

Note: Electronic measurements are always made at the control panel input. In this way, the results are for the electric generator as a whole (including losses in the cables, diodes, etc.).

Peak and real electrical power observed

Manufacturers' power ratings are expressed in peak watts. In practice, measured power is significantly lower than rated power. This is not unusual, however, because:

- The peak watt rating of a module is the electric power produced by the module individually with an insolation of 1,000 W/m² perpendicular to the module at a supposed ambient temperature of 25°C. Manufacturers supply this value with an error of ± 10% compared to their specifications.

- In practice, the energy produced by a module inserted into a solar array is much lower, because:

  . the electric power produced by a module drops considerably with an increase in the ambient temperature; in Africa, an insolation of 1,000 W/m² almost always corresonds to a temperature well above 25°C;

  . as modules inside solar arrays are not all identical, electrical imbalances are always created between branches, thus causing power losses that can be great;

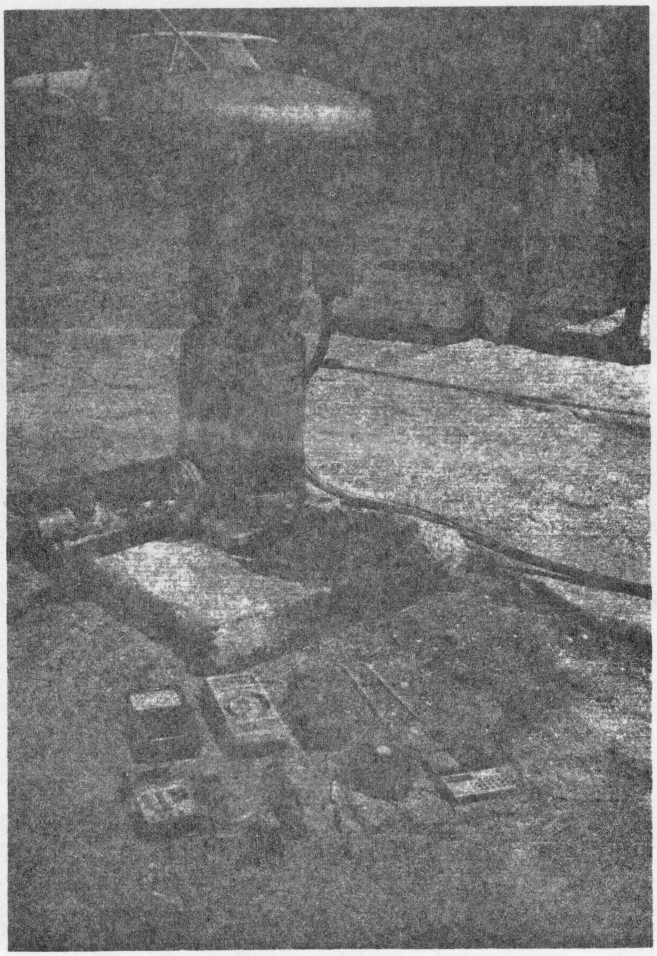
  . a module's maximum power is obtained only for a very narrow voltage range; in practice, however, optimal voltage cannot even be approximated, causing an additional loss of power, and causing the problem of choosing the right solar array for each load (motor + pump) that some manufacturers (Guinard, for example) have managed to overcome.

  . additional losses can occur at the solar array itself, due to the presence of protective diodes (connected in series) and resistance in the cables;

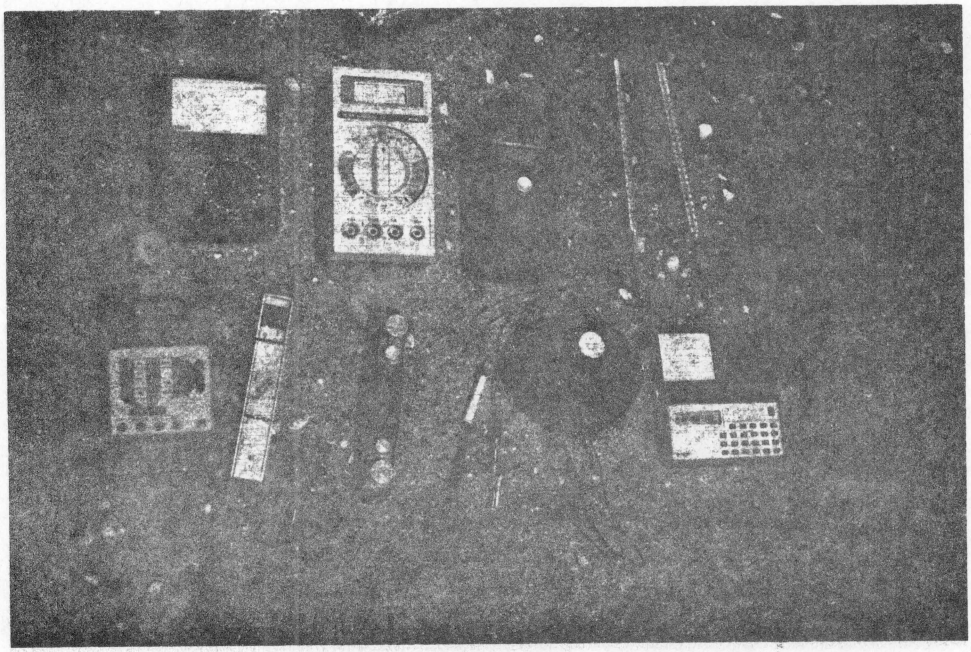
  . the actual power produced by the module is also affected by:

    - the percentage of diffuse radiation in the total radiation,
    - the transparency of the modules.

All these phenomena acting together explain why it is normal to obtain a measured electric power at the generator (all losses included) of about 20 - 30% lower than the theoretical rated power.



MEASUREMENT INSTRUMENTS FOR PHOTOVOLTAIC PUMPS



Shown:

- a Beckmann very-high-precision (0.1%) digital multimeter
- a Microconta 0.5% digital multimeter
- an ordinary multimeter used as ohmmeter for the probe (dynamic level)
- a Jaquet precision digital tachometer
- a Solarex calibrated precision test cell
- two precision thermometers
- a 5 VA AOIP precision shunt
- an electric probe (for measuring the dynamic level)
- a chronometer

PROCES VERBAL D'ESSAI

EXEMPLE

POMPE SOLAIRE :

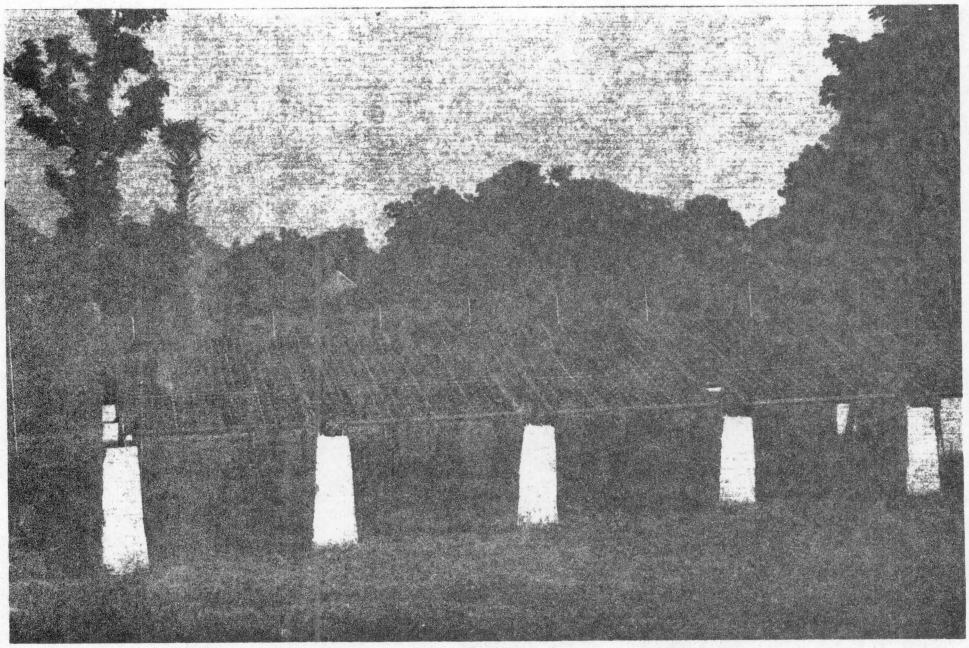
Caractéristiques nominales :

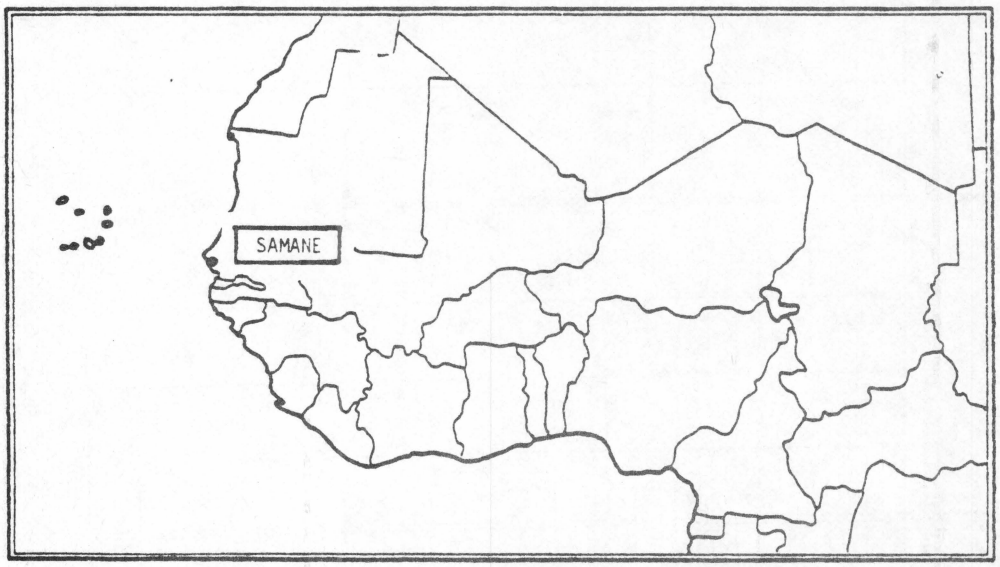
Localisation :

Date d'essai :
Réalisé par :
Météorologie :

Heure	Ensoleillement W/m2		MOTEUR				DEBIT			Niveau	Hauteur	H. MT	OBSERVATIONS
	G	D	V_v	I_A	P	Ntr/mm	Index compteur	Volume (l)	Débit horaire	DYN (m)	REF (m)	(m)	

115.




SAMANE

EXAMPLE 1	GUINARD PHOTOVOLTAIC SOLAR PUMP AT SAMANE / SENEGAL TRUCK FARMING
Inspection report: 7 October 1980	

1. Location

Approximately 150 km from Dakar, southeast of Mbour, easily accessible by paved road and 3 km of sand-covered trail; village of about 500 inhabitants.

2. Rated specifications (according to the Guinard offer)

- Generator = 2,600 peak watts -- France Photon FP 72 modules
- motor = 1,800 RPM
  U rated = 124 V
  I rated = 15 A
  motor efficiency = 86%
- 6-stage vertical-axis pump
  delivery rate = 17m³/hr = 125 m³/day
  manometric head (MH) = 25 m

3. Start-up date

April 1980

4. Measured performance

The enclosed tables show that:

- the actual manometric head (15 m) is much lower than the rated value (25 m), and the pump's output is thus lower;

- the pump's delivery rate is close to the rated value (17 m³/hr) although a slightly higher delivery rate could have been possible due to the lower manometric head (15 m instead of 25 m), even considering a decrease in pump efficiency (further from optimum);

- the solar array provides normal electrical power although slightly lower than planned (effects of temperature, losses in the diodes, cables, etc.);

- the output from the solar array and the motor pump unit is good in both cases (see appendix);

- the electrical operating points are well located on the photocells' characteristic curve (good adaptation of generator to load);

- the pump does not reach rated speed (1,800 RPM) despite insolation of close to 1 KW/m² (approx. 1,700 RPM), giving a lower delivery rate.

5. Equipment condition

- Solar array: equipment well cared for, few modifications in the appearance of the silicone-coated modules.

PROCES VERBAL D'ESSAI

Moteur Nm = 1800 tr/mn U = 124 V
P_{mec} = 1590 W I = 15 A
η_{mot} = 86%
Pompe FG-11-6 étages Qn = 17 m3/h à HMT : 25 m
115 m3/j.

POMPE SOLAIRE : SAMANE (CARITAS) Localisation : SENEGAL
Caractéristiques nominales : 2600 Wc (2080 W sous 800 W/m2) - U max = 124 V I max = 16,7 A

Date d'essai : 7.10.80
Réalisé par : B. MEUNIER/
Météorologie : I. CISSE

Heure	Ensoleillement W/m2		MOTEUR				DEBIT			Niveau	Hauteur	H. MT	s	a	OBSERVATIONS
	G	D %	V_v	I_A	P	Ntr/mm	cm^3/h	mn^t	Débit horaire m3/h	DYN (m)	REF (m)	(m)	(°C)	(°C)	
08h45	355	36	148	0	-	-	-	-	-	12,5	2	15	-	-	nuages { arrêt circuit ouvert
08h50	-	-	13	8	-	-	-	-	-				-	-	{ arrêt circuit fermé
09h00	-	-	67	6,5	436	1250	-	-	-				-	-	nuages légers
09h17	-	-	71	11,9	845	1260	-	-	-				39	33	ciel clair
09h30	590	28	82,2	12,0	986	1380	-	-	-				-	-	
09h45	710	35	86,9	13,0	1130	1430	32	15	11,2				39	34	ciel clair
10h00	715	30	92,5	14,0	1295	1460	39	15	13,7				39	34	" "
10h25	755	24	99,3	14,0	1390	1545	15	5	15,8				42	36	
10h50	830	24	102,8	14,5	1490	1600	17,5	5	18,4				42,5	36	
11h15	915	26	106,9	15,0	1605	1630	16,0	5	16,8				44	37	
11h37	910	20	107,6	15,3	1645	1645	15,0	5	15,8				47,5	37	passages nuageux
12h10	1000	25	112,7	15,3	1840	1670	16,5	5	17,3				45	37	" "
12h25	985	25	110,1	16,0	1760	1666	18,0	6	15,8				45	38	
12h35	990	31	110,3	16,3	1790	1678	28,0	8	18,4				-	-	" "
13h05	985	29	114,8	17,5	2010	1700	7,5	2	19,7				_	_	

Nota: les mesures ont été effectuées sur des intervalles de temps où le ciel était clair (rayonnement sensiblement constant).

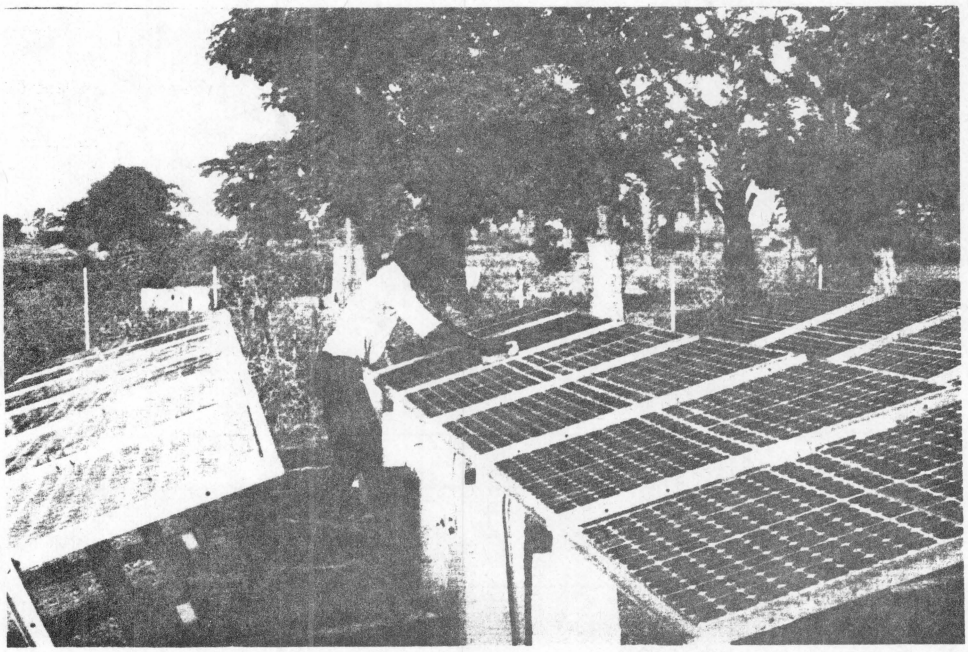
PROCES VERBAL D'ESSAI

POMPE SOLAIRE : SAMANE (suite)
Caractéristiques nominales :

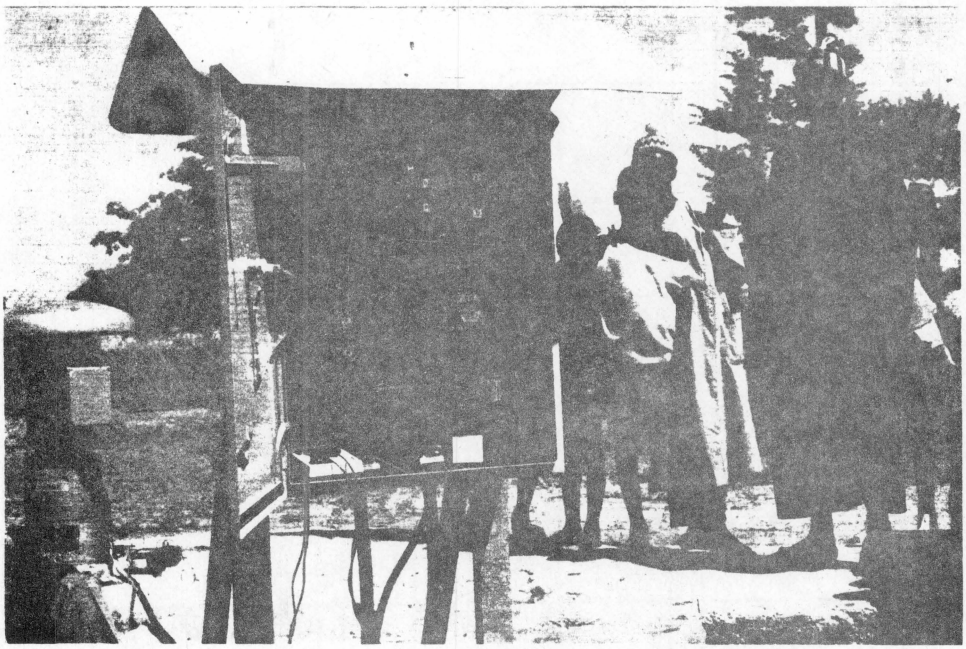
Localisation :

Date d'essai :
Réalisé par :
Météorologie :

Heure	Ensoleillement W/m2		MOTEUR				DEBIT			Niveau	Hauteur	H. MT			OBSERVATIONS
	G	D	V_v	I_A	P	Ntr/mm	h cm	t mn	Débit horaire m3/h	DYN (m)	REF (m)	(m)	s (°C)	a (°C)	
14h00	900	-	108,8	16,1	1750	1655	14,0	5	14,7				42	38	nuages intermittents
14h20	810/710	30	108,6	16,4	1780	1640	13,5	5	14,2	13	2	15,5	42	37	nuages, pluie intermittents
15h20	830	40	109,5	16,6	1820	-	2,4	43"	17,6				-	-	
															démarrage pour E $\geqslant$ 350 W/m2
															Vco : 145 V pour E = 830 W/m2



. Cleaning the panels



. Control panel

- Junction boxes: the main box containing all the modules was rusted, and its appearance was thus poor.

- Control panel: wires clean, the electronic overflow device had been disconnected.

- Motor + pump: nothing to report -- bearing regularly lubricated, silent operation.

- Tank: part of the original equipment, it is too small (approx. 10 m^3) and in poor condition (risk of collapse).

- Displacement meter: not installed.

- Dynamic level measurement: existence of an air line, electrical probe passes with difficulty.

6. Receiving organizations -- pump's caretaker

Guinard included the solar pump in the hydro-agricultural project led by Caritas (Senegal). This extremely well-managed project represents an excellent reception unit. The village of Samane was selected from among a large number of villages due to its extremely good agricultural results beforehand (irrigation using a hand pump). The village farmed four hectares of land in order to utilize the water from the new solar pump (utilization of a primary system feeding a dozen or so tanks for water recovery with sprinkler). The person in charge of the pump, conscientious and intelligent, is the son of the village chief; he received only basic instructions from Guinard.

7. Maintenance of the solar pump

This will be taken care of by the well-equipped Caritas maintenance center nearby and by the Guinard agent in Dakar. Spare parts must be shipped in from France.

8. Utilization of the water

The water from the solar pump will be used:

- for the local inhabitants,
- for the numerous animals (village and nomadic),
- lastly, and above all, for the irrigation of the truck farming zone of 4 ha (melons, tomatoes, peppers, etc.) that should bring the local population sufficient revenue.

9. Security of the water supply

The hand pump previously installed in the village was dismantled in order to install the solar pump. In addition, there is a well inside the village. A serious breakdown of the solar pump would, however, be severly felt by the villagers and would endanger the harvest of the truck farming crops. The villagers consider this risk unacceptable.

SAMANE (Sénégal) - Pompe GUINARD 2 600 Wc

Calculs complémentaires

1. Calculs des rendements :

Heure	$\frac{Pe}{4896} \times \frac{1}{S}$ $(\frac{W}{m2})$	E $(\frac{W}{m2})$	η générateur	η pompe + moteur	η global	Observations
9 h 30	53,6	590	9,1	-	-	2600 Wc = 4896 cellules
9 h 45	61,6	710	8,7	10,5	3,3	
10 h 00	70,7	715	9,9	43,2	4,3	Surface d'1 cellule $3,75.\ 10^{-3}$ m2
10 h 25	75,7	755	10,0	46,5	4,7	
10 h 50	81,1	830	9,8	50,5	4,9	
11 h 15	87,5	915	9,6	42,8	4,1	
11 h 37	89,6	910	9,8	39,2	3,8	
12 h 10	100,3	1000	10,0	38,5	3,9	
12 h 25	95,7	985	9,7	36,7	3,6	
12 h 35	97,6	990	9,9	42,1	4,2	
13 h 05	109,6	985	11,1	40,1	4,5	
14 h 00	95,2	900	10,6	34,3	3,6	
14 h 20	96,8	810	12,0	33,7	4,0	
15 h 20	99,2	830	12,0	40,8	4,9	

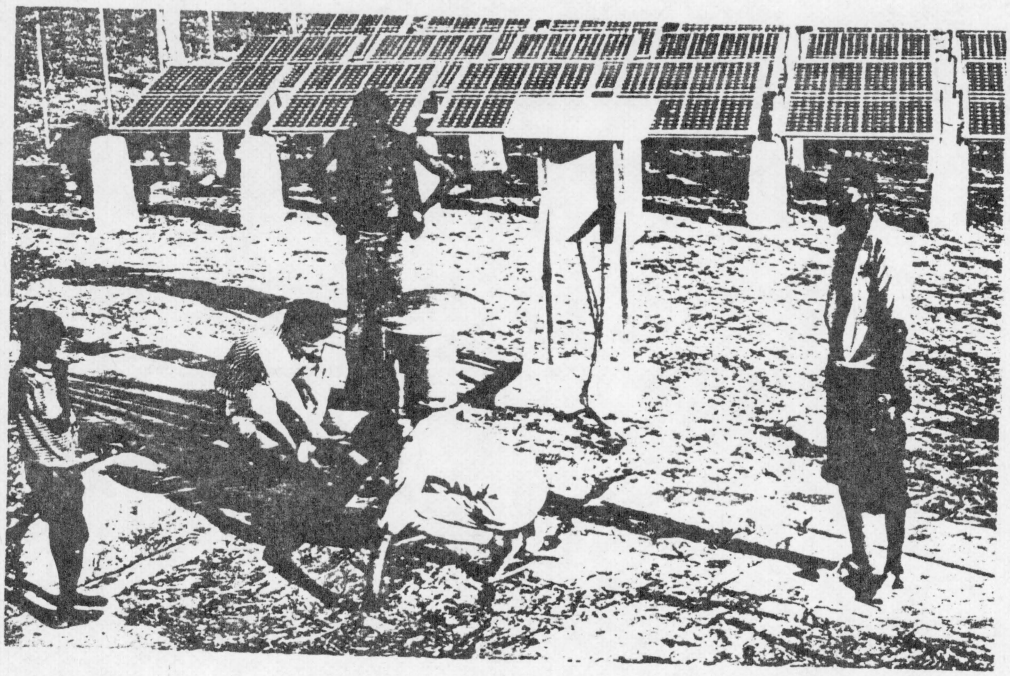
2. Caractéristiques I (V) - on ramène l'installation à 1 module FP 72 - branchement 24 V

68 modules (17 x 4) $\quad U_m = \frac{U}{4} \quad I_m = \frac{I}{17}$

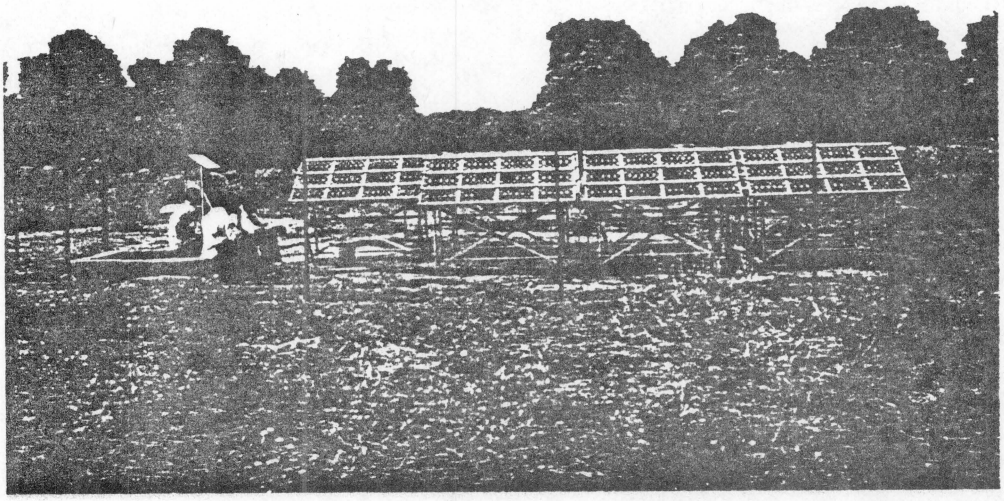
heure	U/4 v	I/17 A	W $\frac{w}{m2}$	$\frac{U}{N}$	Observations
9 h 30	20,1	0,71	590	16,8	Il faudrait ajouter la chute de tension des diodes de protection placées en série sur chaque branche (environ 0,7 V)
9 h 45	21,7	0,76	710	16,5	
10 h 00	23,1	0,82	715	15,8	
10 h 25	24,8	0,82	755	15,6	
10 h 50	25,7	0,85	830	15,6	
11 h 15	26,7	0,88	915	15,2	
11 h 37	26,9	0,90	910	15,3	
12 h 10	28,2	0,96	1000	14,8	
12 h 25	27,5	0,94	985	15,1	
12 h 35	27,6	0,96	990	15,2	
13 h 05	28,7	1,03	985	14,8	
14 h 00	27,2	0,94	900	15,2	
14 h 20	27,2	0,96	810	15,1	
15 h 20	27,4	0,98	830	-	

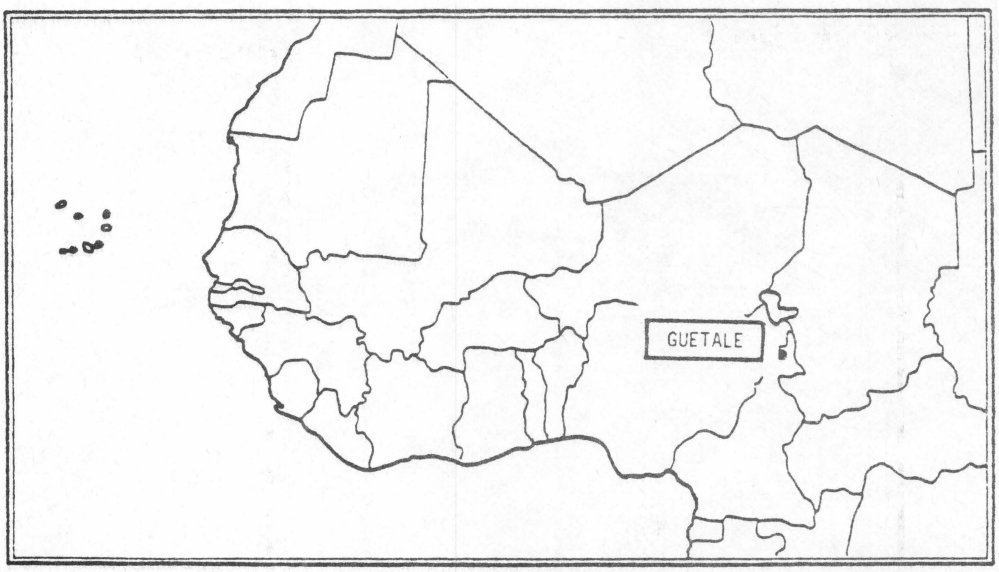
10. Local opinion of the solar pump

The solar pump was received quite well, although with some regrets. The villagers would have greatly preferred a diesel pump producing much more water (approximately five times more) and which would allow for the expansion of the truck farming activity, which is their most important source of income. The cost of the diesel fuel is not perceived as a handicap (profitability of the farming venture, expecially of melons, which growers sell for 3 French francs per kilogram.



. Mesures




GUETALE

EXAMPLE 2	GUINARD PHOTOVOLTAIC SOLAR PUMP AT GUETALE / CAMEROON TRUCK FARMING - VILLAGE WATER SUPPLY
Inspection report: 27 January 1981	

1. Location

About 100 km east of Maroua (60 km of paved road, 40 km of sand trails) at the Center for the Training of Young Farmers, near the sub-prefecture of Koza.

2. Specifications

- Generator: 7 groups of 12 RTC BP X 47 A panels; 924 peak watts

- Motor: type ACF 100 S2 -- 1,800 RPM
  rated power = 555 W
  U rated = 31 V
  I rated = 21 A
  rated efficiency = 85%

- Pump: type Alta X F4 100 D-20
  shafting = 16 m
  Q rated = 30 m^3/day
  MH = 20 m

3. Start-up date: October 1980

4. Financing: Ministère de la Coopération (France)

5. Results of the readings

a)- The manometric head measured was the same as rated -- 20 m.

b)- Generator output is very good -- an average of 10.3% for the entire day, with a peak during the afternoon.

c)- Operating points are well located, slightly below the characteristics.

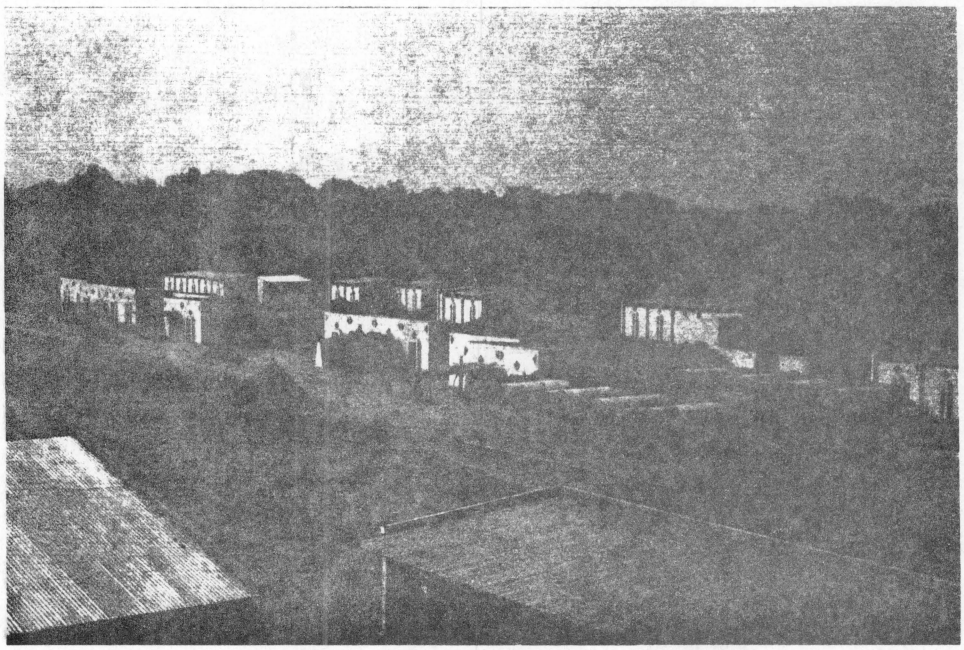
d)- The water delivery rate for the day was mediocre.

. This is only partially explained by insolation the day we visited the installation (see table).

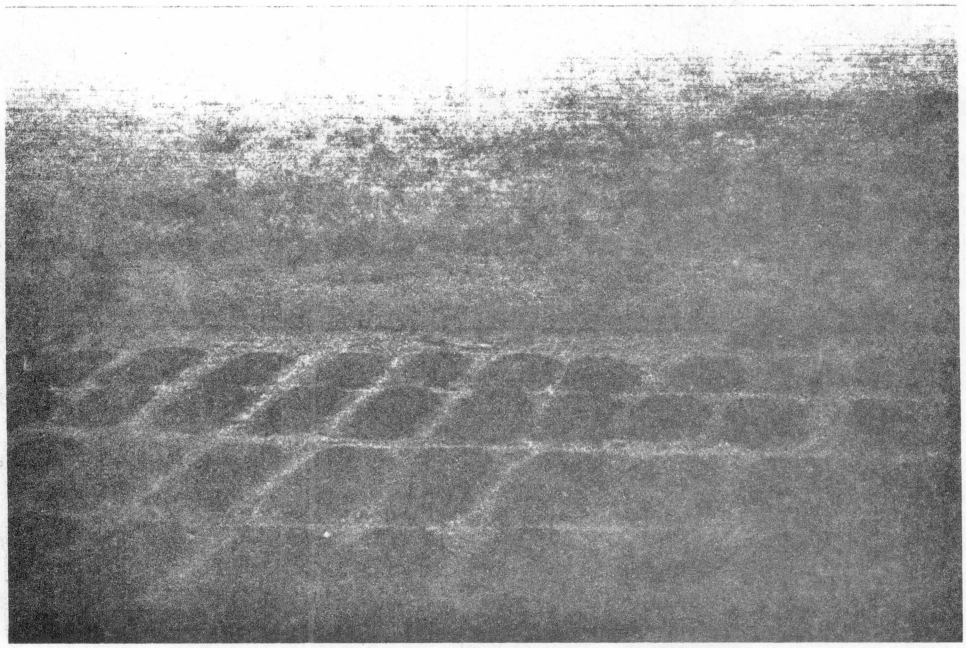
. The reason also seems to lie in the motor pump's inadequate output (1).

e)- The hourly delivery rate is practically constant from 10 AM to 3 PM.

(1) An outflow valve, partially closed, could be the reason for the poor hydraulic performance, but this possibility is improbable, based on an inspection by Mr. Jacquin, who installed the pump (25 February 1981).



. Center for the training of young farmers



. Truck farming zone

127.

REPUBLIQUE UNIE DU CAMEROUN

C.F.J.A. GUETALE

U.I.

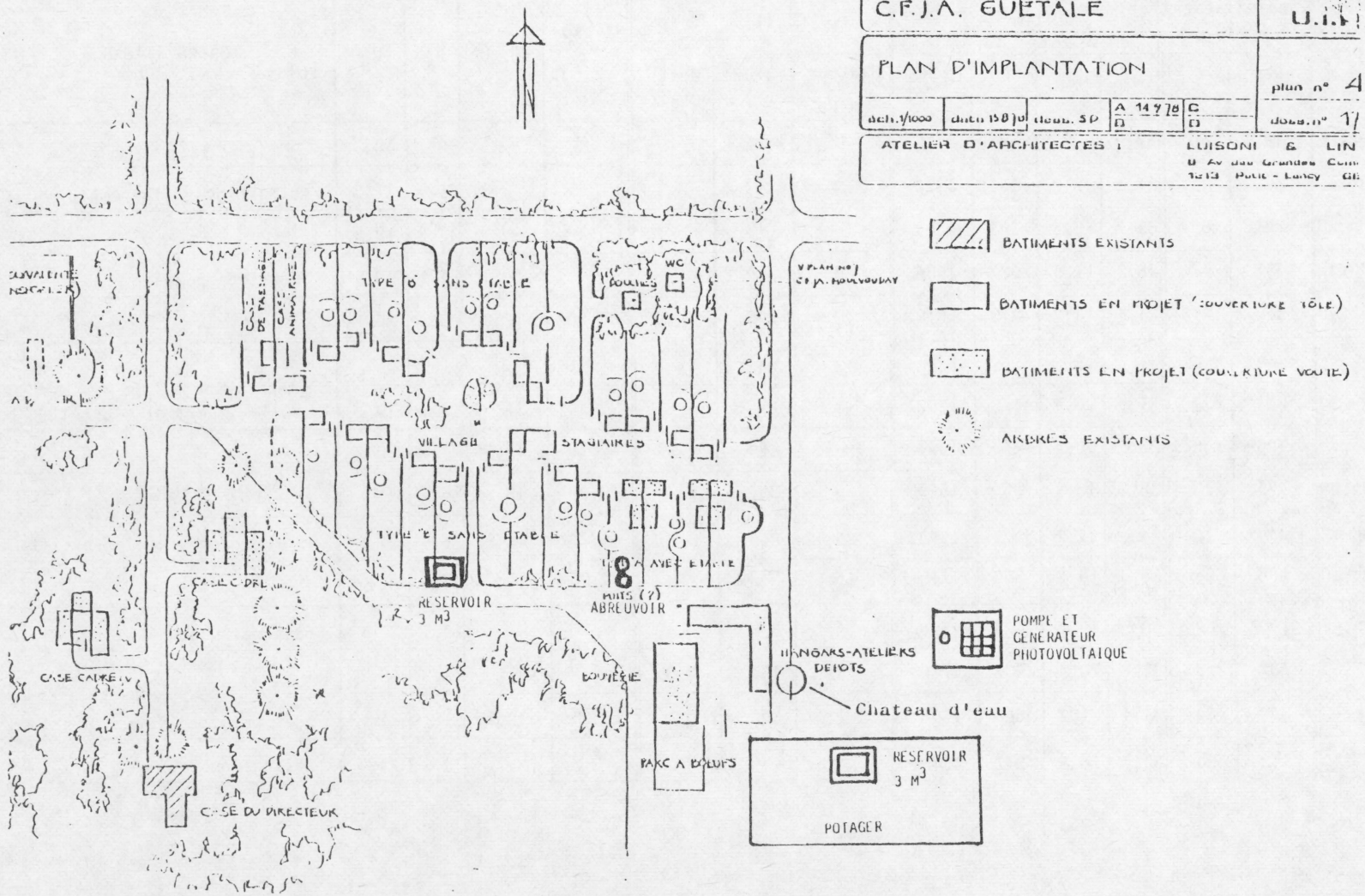
PLAN D'IMPLANTATION

plan n° 4

ech. 1/1000	date 15 8 78	dessin. SD	A 14 7 78 B C D		dossier n° 17

ATELIER D'ARCHITECTES : LUISONI & LIN

8 Av. des Grandes Com...
1213 Petit-Lancy GE



PROCES VERBAL D'ESSAI

POMPE SOLAIRE : ALTA X — Localisation : GUETALE — Date d'essai : 27.01.81

Caractéristiques nominales : 900 Wc - 19 m^3/jour à 22 m. — Réalisé par : A. HAENTJENS

Météorologie : temps brumeux

Heure	Ensoleillement W/m2		MOTEUR				DEBIT			Niveau DYN (m)	HMT (m)	θ_a	θ_b	OBSERVATIONS Volume = h x 9,89 m^2
	G	D %	V_v	I_A	P	Ntr/mm	Hauteur en cm.	Volume (l)	Débit horaire m3/h.					
08h.06	191	60	37,3	-	-	-						20	18,5	
08h.24	255	78	21,1	7,2	152	1190	-					21,5	17,5	démarrage de la pompe
08h.30	291	88	23,9	8,5	203	1385	-					23	18,5	
08h.45	397	77	28,2	11,6	327	1586	1	99				24,5	19,5	début de pompage
09h.00	440	79	28,4	13,2	375	1616	2	198	0,6	9,00	17,80	26,5	20	
09h.15	489	75	27,8	11,6	322	1560	2	198				25,5	20,5	
09h.30	284	73	21,3	8,4	179	1252	-	-		9,10	17,90	23	19	voile important - arrêt du pompage
09h.45	298	86	22,8	10,3*	235	1630	1	99		9,10	17,90	24,5	20	
10h.00	475	70	28,2	12,4	350	1641	3	297	0,6	9,20	18	26,5	21	
10h.15	645	70	29,8	17,7	527	1703	5	495		9,70	18,50	28,5	21,5	ciel dégagé - voile persistant
10h.30	688	65	29,9	18	538	1715	6	593		9,90	18,70	30,5	21,5	
10h.45	730	62	30	15,8	474	1640	4	396				29,5	22	passage nuageux
11h.00	787	70	31	20,4	632	1770	5	495	2,0			32	25,5	
11h.15	894	63	31,4	21,2	666	1799	7	692		10,60	19,40	34	24	
11h.30	816	64	30,7	18,8	577	1575	4,5	445				33,5	24,5	passage nuageux

128.

PROCES VERBAL D'ESSAI (suite)

POMPE SOLAIRE :
Caractéristiques nominales :

Localisation : GUETALE

Date d'essai : 27.01.81
Réalisé par :
Météorologie :

Heure	Ensoleillement W/m2		MOTEUR				DEBIT			Niveau DYN (m)	HMT (m)	θ_a	θ_b	OBSERVATIONS Volume = h x 9,89 m^2
	G	D %	V_v	I_A	P	Ntr/mn	Hauteur (cm)	Volume (l)	Débit horaire					
11h.45	830	35	30,3	19,6	594	1747	4,5	445		10,70	19,50	33	26	
12h.00	823	52	30,8	20,2	622	1791	5,5	544	2,15	11,00	19,80	37	25,5	
12h.15	908	57	31	19,9	617	1768	6	593		11,20	20	35	26,5	
12h.30	830	44	30,9	20,1	621	1784	5	495		11,30	20,10			
12h.45	823	52	30,7	19,8	608	1790	5	495		11,60	20,40	36,5	27,5	ciel dégagé, mais assez brumoux.
13h.00	794	47	30,4	18,9	575	1786	4	396	2,0	11,70	20,50	37	26,5	
13h.15	823	38	30,8	19,6	604	1795	6	593		11,90	20,70	37	28	
13h.30	759	43	30,4	18,9	575	1794	7	692		12,10	20,90	35	28	
13h.45	773	42	30,5	18,9	576	1793	6	593		12,20	21	35,5	27	
14h.00	716	49	30,4	18,4	559	1790	4	396	2,3			35	28,5	
14h.15	723	38	30,5	18,7	570	1785	6	593				35,5	28	
14h.30	688	38	30,3	18,3	554	1788	5	495		12,20	21	34,5	28	
14h.45	645	42	29,8	17,0	507	1770	4	396				35	29	
15h.00	582	49	29,1	15,5	451	1740	4	396	1,9	11,90	20,70	34,5	28	
15h.15	504	42	28,7	14,5	416	1722	2	198				33	27	

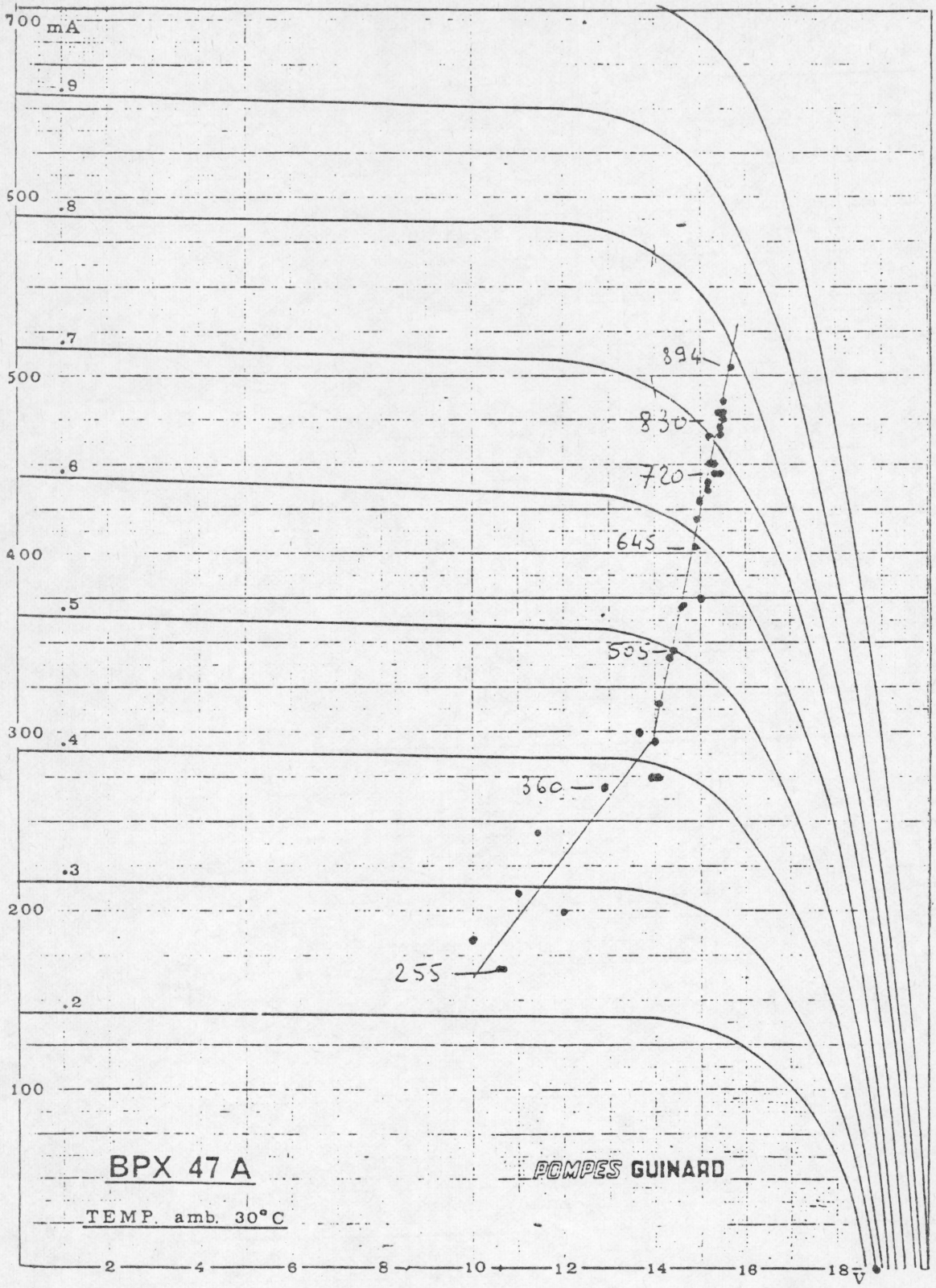
PROCES VERBAL D'ESSAI (suite)

POMPE SOLAIRE :
Caractéristiques nominales :

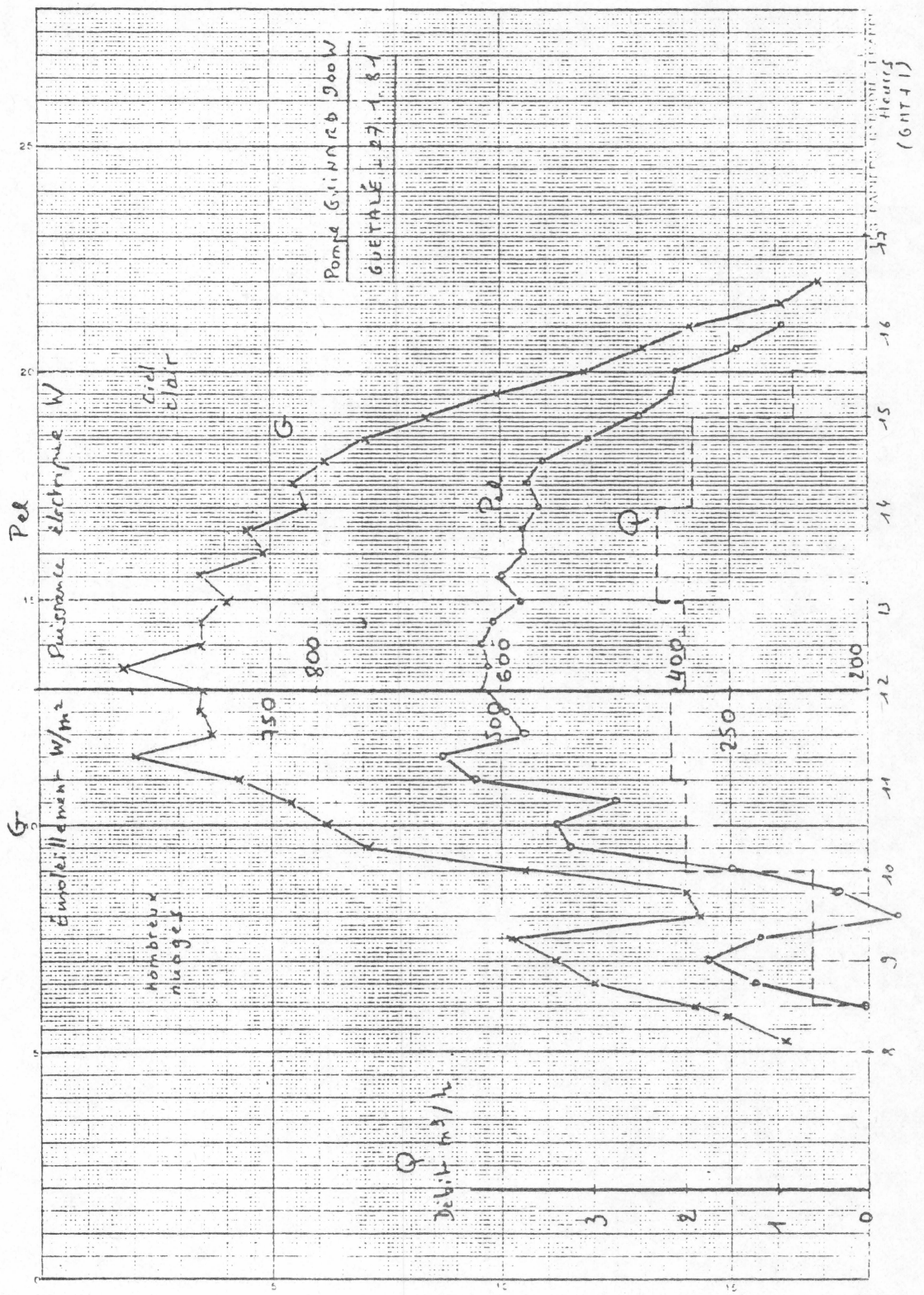
Localisation : GUETALE

Date d'essai : 27.01.81
Réalisé par :
Météorologie :

Heure	Ensoleillement W/m2		MOTEUR				DEBIT			Niveau DYN (m)	HMT (m)	θ_a	θ_b	OBSERVATIONS
	G	D %	V_v	I_A	P	Ntr/mm	Hauteur (cm)	Volume (l)	Débit horaire					
15h.30	482	44	28,5	14,4	410	1704	2	198	0,8	11,60	20,40	32,5	27,5	arrêt du pompage
15h.45	411	52	27,4	12,6	345	1650	-	-				33	27,5	
16h.00	362	51	25,8	11,4	294	1549	-	-		11,00	19,80	32	27	
16h.15	284	60	21,9	8,9	195	1315	-	-				30	27	
16h.30	255	61	19,9	7,7	153	1160	-	-		10,60	19,40	29	26	
17h.00							-	-						arrêt de la pompe
TOTAL									11,6				N.B.	La mesure directe de la hauteur d'eau dans le réservoir (la seule possible) est imprécise au quart d'heure près mais excellente pour le total pompé dans la journée (pas de cumul des erreurs de lecture).



GUETALE (27.I.1981)


Pompe G.INNARD 900W
GUETALÉ le 27.1.81
Pel
Puissance électrique W
Ciel clair
G
Ensoleillement W/m²
nombreux nuages
Q
Débit m³/h
Heures (GMT+1)

f)- The pump operates well only close to its rated speed. Below 1,600 RPM in the morning and 1,700 RPM in the evening (greater MH), the water delivery rate is zero.

g)- The delivery rate was measured by taking the difference between the upper edge of the water tower and the level of water in the tower. This reading is accurate for the day as a whole, acceptable for hourly readings, and debatable for fifteen-minute intervals (accuracy of 20% + fluctuations due to the whirlpool effect). Hourly delivery readings were thus preferred.

6. Equipment condition

Generator: very stable assembly, well adjusted. Metallic supports bolted to cemented breeze blocks. No trace of corrosion. Junction boxes in good condition. Slight traces of rust in the corners. Main connection box and wires in very good shape.

Modules: slight deterioration -- darkening of the glass in the corners, yellowing of the inside surfaces of the cells, and discoloration of the anti-reflection layer. No grids missing, no tightness problems.

Control box: locked shut (the head of the Center does not have the key). Good external appearance.

Pump: good external appearance. No unusual noises during operation.

Well: Constantly covered (with a movable metal cover).

Tank: Good condition, capacity = 21 m^3; usable capacity = 16 m^3. Automatic shut-off system when tank is full.

Displacement meter: not installed.

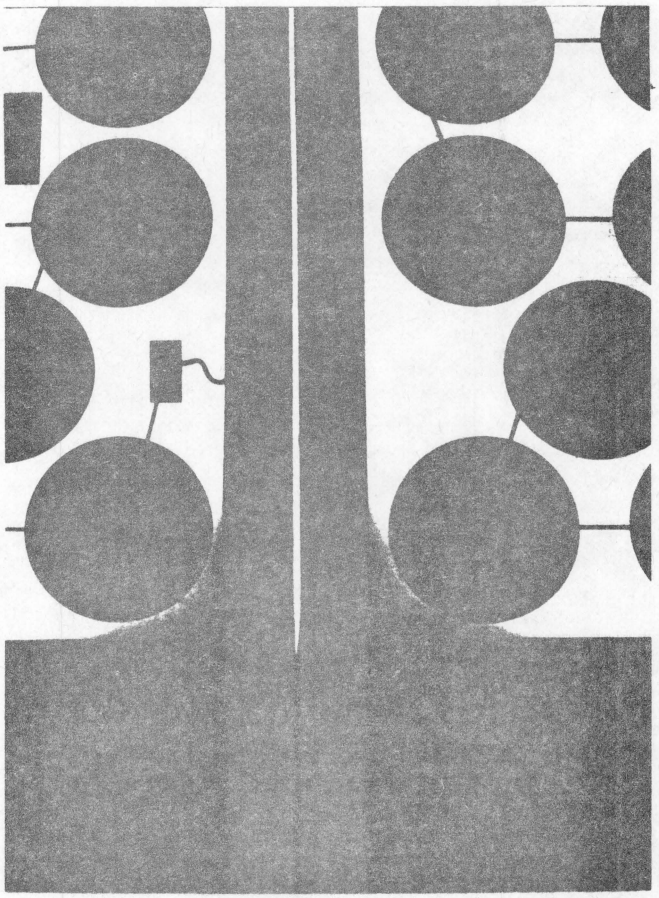
Pipes: 2", 43 m long, 3 pipe bends, 8 m difference in height (+ 16 m of shafting).

7. History of the pump

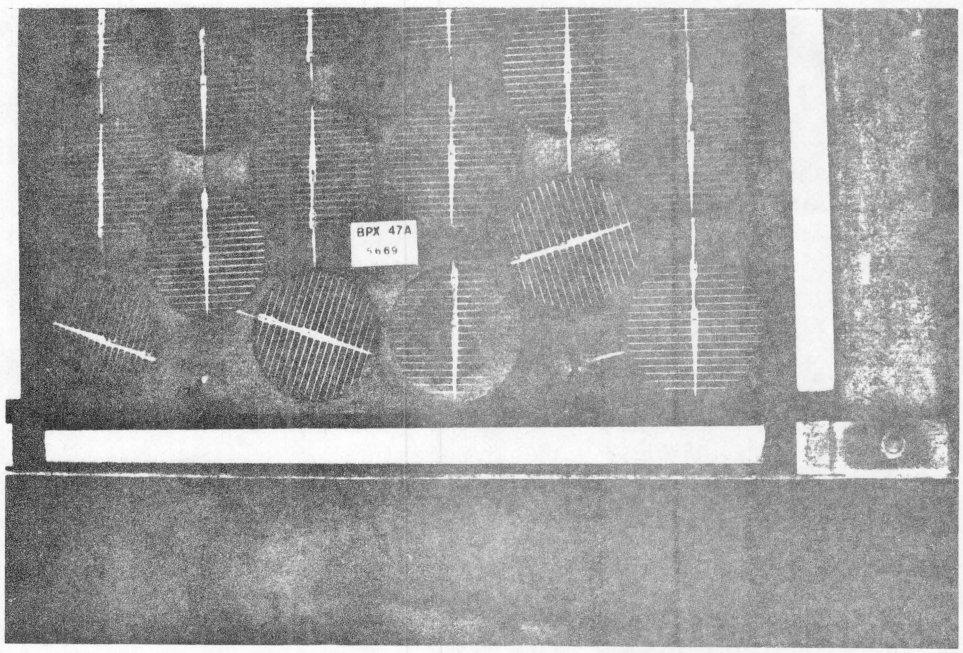
The three-year "Sahel Energies Nouvelles" (new energies) program of 1976 planned the installation of a 1,800 peak watt photovoltaic pump in the Wasa nature preserve. The location ultimately selected was that of an already existing pump site at Koza. Since the shaft was sealed and located on land belonging to the Center for the Training of Young Farmers at Guetale, it was decided in March 1979 to install two 900 peak watt pumps in two training centers -- one in Guetale, the other in Ngouma (in the extreme north of northern Cameroon).

The pump at Guetale was installed when the Center was opened (October 1979). The pump at Ngouma has not yet been installed and the Center has not yet been completed. (The 1,800 peak watt pump initially planned is still in storage in Guetale.) The pump installed in Guetale has been operating for 14 months without any technical difficulty and without maintenance (except for cleaning the panels).

. Panels: yellowing in the corners (gravity-free)



. Discoloration of the antireflection coating



8. Receiving organizations

The Centers are governmental organizations under the jurisdiction of the agricultural education authority. Their purpose is to train young farmers, living in the vicinity of the Centers and lodged for the duration of their studies (one year), in farming techniques (the cultivation of millet, cotton, corn, and groundnuts; husbandry, truck farming). The Center in Guetale consists of twenty-five trainee-couples and their children, and about ten executives, or in all, about one hundred persons.

The Centers are also directed by the International Union for Child Welfare (IUCW), a non-governmental organization whose headquarters are in Geneva, and which maintains five permanent workers in the region of Maroua. These workers are involved in designing and setting up the construction sites for the Centers being built, and in the management of existing Centers. There are five Centers at present in the region of Maroua plus one under construction (at Ngouma), (see report below). The IUCW subsidizes:

- the construction of the Centers,
- equipment for the Centers.

Operating expenses are financed by the government of Cameroon.

The fact that there are foreign permanent workers guarantees proper design of the Centers, correct finishing of the installations, and good management of the existing Centers. The educational branch is under the direction of the head of the African Center who is assisted by Mr. Faucher, pedagogical advisor delegated by the IUCW. In Maroua, the Centers are considered a highly positive achievement compared to other projects originally provided with much heavier funding.

9. Pump maintenance

Maintenance is practically nil (cleaning the panels). It is carried out by the Center's director, who alone has the key opening the key to the installation, although he does not have the key to the control box, nor does he have any tools or spare parts.

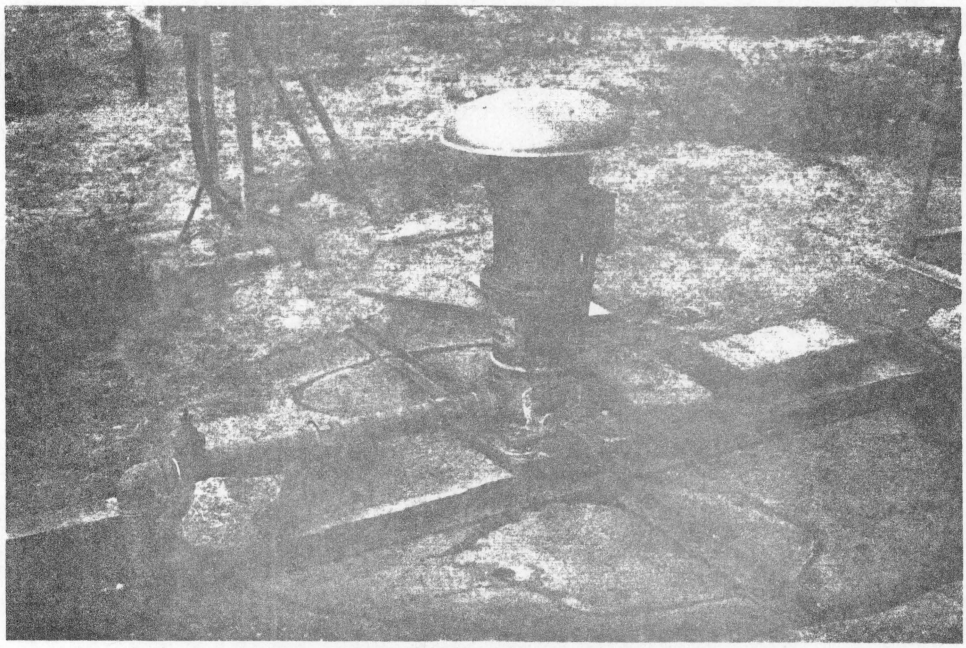
10. Utilization of the water

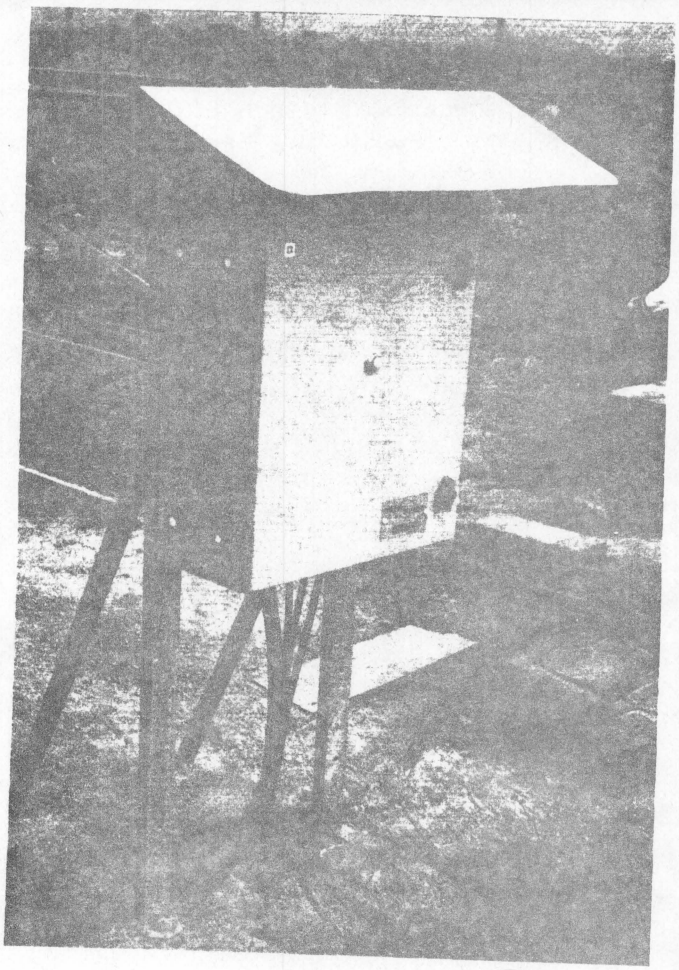
The water pump supplies a 16 m^3 tank, which in turn supplies:

. a small tank (3 m^3) for the vegetable garden
. a trough for the Center's fifty head of cattle
. a tank (3 m^3) and taps for the trainees
. the homes of the Center's director and executives
. the sub-prefecture.

11. Adapting the pump to demand

- During the rainy season (July - August) insolation is high after the storms and the demand for water is lower (essentially for drinking and washing). The pump always satisfies this demand.





- During the first part of the dry season (September - February) insolation is sometimes less than adequate (December - January). The sky is foggy and the sun is lower on the horizon. On the other hand, the demand for drinking water and water for washing decreases significantly in the absence of strong heat. The pump always satisfies demand.

- At the end of the dry season (March - June) high insolation causes higher delivery rates (over 16 m^3/day [?]) but demand increases sharply. On certain very hot days water rationing is necessary.

Overall, the pump satisfies demand quite well. A slight alteration in the diameter of the pipes makes it possible to regulate delivery rates and avoid wasting water.

12. Security of water supply

The pump, assembled over a well within a closed area, provides water of a quality equal to that from a pump installed over a bore-hole (hermetically sealed well). In the event of a breakdown, manual pumping can satisfy demand, although there is a risk of pollution.

13. How the Center's director views the pump

At the outset he was openly hostile to the idea because of the risk associated with a new product; he favored a submersible motor pump driven by a diesel unit. The director is now entirely satisfied with this pump that requires no maintenance and incurs no operating costs, all the more so, since the pump has enhanced his prestige (numerous foreign visitors, mostly Americans, and Cameroonian visitors). On the other hand, he objects to the total lack of training, although he seemed uninterested during installation.

14. The local population's view

The trainees are only concerned with the regularity of the water supply. The pump, which is not centrally located, does not, or no longer makes them curious, even when a technician comes to take readings. Nevertheless, the 'solar factor' is psychologically well accepted ('free energy', independence from other energy sources, the 'magical' aspect). Here, comparisons with diesel power are distorted considering that the Center's alternatives at the outset were:

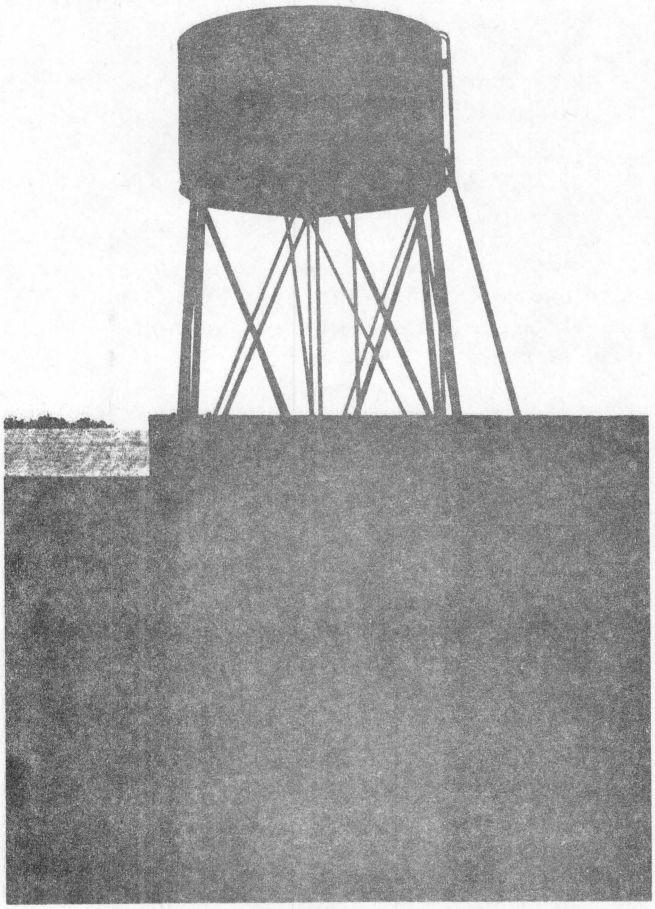
- a solar pump donated by the Coopération Française,
- a motor pump unit + diesel engine donated by the IUCW, if the Center could prove it had the equivalent of two years' operating and maintenance costs at its disposal.

15. Repair service in the event of technical difficulties

There are no plans at present. The Center's coordinating committee would call on Guinard, France.

16. Comments

- This Guinard installation seems well prepared. The maximal simplification of each element and the clarity of the unit overall are very appreciable.



. Water tower (16 m^3)

- Excellent impact in northern Cameroon, where everybody is familiar with this project. Very good publicity for photovoltaic energy and for French technology.

- Very good design -- coordination of the generator / load / tank / demand for water / well capacity.

- No training whatsoever for the Center's director.

17. Conclusions

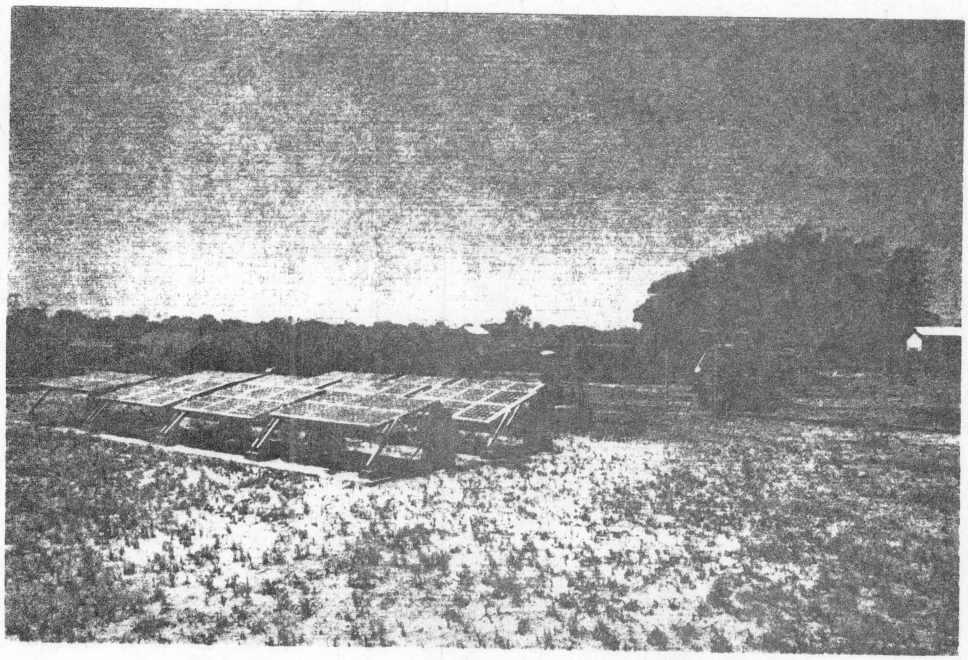
This experiment was successful in the sense that:

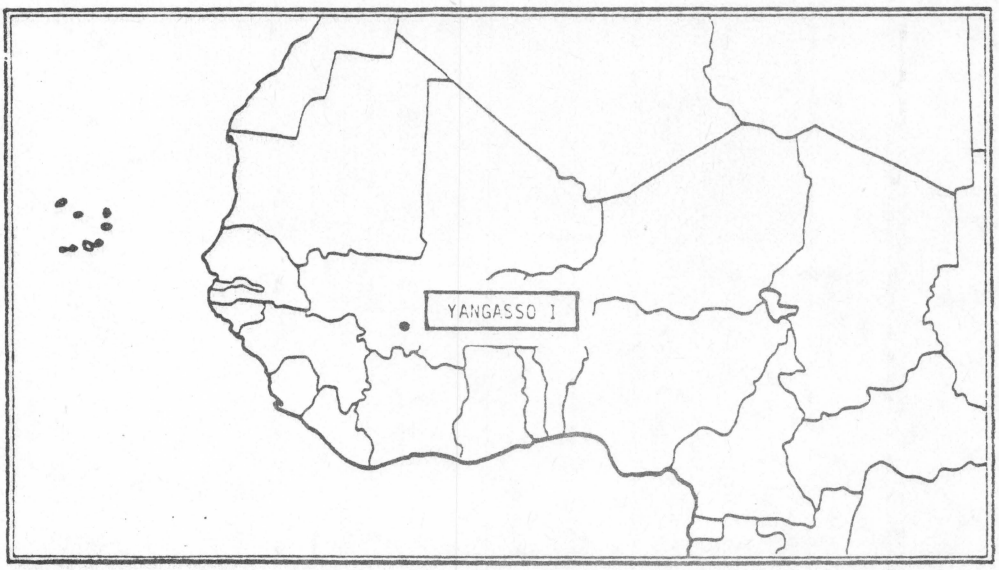
- the pump has been operating for fourteen months without technical problems or maintenance;

- the water pumped is useful and adequately satisfies the needs of the receiving organizations;

- the receiving organizations are part of a national program with an excellent reputation, supported by the efficacious cooperation of a non-governmental organization;

- this installation, easily reached from Maroua (1.5 hours by road), serves as publicity for French technology in the field of photovoltaic energy.




YANGASSO I

EXAMPLE 3	GUINARD PHOTOVOLTAIC SOLAR PUMP AT YANGASSO 1 / MALI TRUCK FARMING - VILLAGE WATER SUPPLY
Inspection reports: 22 June 1980 23 October 1980	

1. Location

The pump was set up in 1978 at the C. A. R. (Centre d'Animation Rurale) of Yangasso, 55 km west of San.

2. Specifications

- Generator = 1,300 peak watts, Solarex 4200 J modules
- Guinard Alta X F 6.5.8 pump
  rated output = 50 m^3/day
  rated manometric head (MH) = 20 m

3. Related hydraulic equipment

- Irrigation tank located near the pump
- Water tower 100 meters away (drinking water)
- Secondary tanks used as relays for irrigation and the watering of livestock

4. Utilization

Irrigation of the truck farming zone of the C. A. R. (1.5 hectares) and supply of drinking water for the community connected with the Center (trainees and their families, supervisory personnel).

5. Financing

EDF, CCF (Comité Contre la Faim), Fondation de France.
Construction: Mali Aqua Viva.

6. Evaluation of the service rendered

a)- Receiving organizations: The C. A. R. has been in existence since 1963. There are about fifty similar centers in Mali. The trainees are chosen in the various villages of the district and carry out their military service at the C. A. R. They live there with their families for one to two years. Approximately seventy persons (including supervisory personnel) live at the C. A. R. in Yangasso. The young couples returning to their villages, where they are guaranteed land at their disposal, make it possible to spread cultivation techniques taught at the C. A. R.

b)- Utilization of the solar pump: Construction of the solar pump made the development of truck farming and fruit cultivation possible, with the help of the Volontaires du Progrès (two volunteers are based in Yangasso). The well that existed previously was largely inadequate. This pump is thus truly useful. One and a half hectares were reserved for this cultivation (men: 1 ha, women: 1/2ha).

PROCES VERBAL D'ESSAI

POMPE SOLAIRE : ALTAX F6.5.8. 1300 W — Localisation : Yangasso 1 — Date d'essai : 22.6.80

Caractéristiques nominales : Transmission : 26 m — Centre d'Animation Rurale — Réalisé par : J.P. MEHR

Météorologie : ciel très dégagé

Heure	Ensoleillement W/m2		MOTEUR				DEBIT			Niveau	Hauteur	H. MT	V	V	OBSERVATIONS
	G	D	V_v	I_A	P	Ntr/mm	Index compteur	Volume (l)	Débit horaire	DYN (m)	REF (m)	(m)	X	Y	
9 10	557	156	50,5	10,0	505	1499							25,5	25,5	Débit dans bassin
9 30	639	144	50,0	10,6	530	1538			2,45	17	5,2	23,7	26,0	26,0	Débit dans chateau d'eau
10 20	757	170	53,0	11,1	588	1570							26,8	26,6	Bassin
10 40	796	142	53,0	14,5	769	1619			2,81	17	5,4	23,9	27,0	27,0	Chateau d'eau
11 15	862	129	53,0	17,0	901	1591			4,58	17	2,0	19,5	27,0	26,8	Bassin
11 50	909	156	53,0	15,0	795	1621			2,76	17	5,5	24,0	27,0	27,0	Chateau d'eau
12 45	928	161	54,0	14,5	783	1614			2,73	17	5,7	24,2	27,0	26,8	Chateau d'eau
												en circuit ouvert :			
													33,4	32,6	

The following crops were raised:

- truck farming: potatoes, tomatoes, onions, lettuce, cucumbers, eggplant, soy beans, beans, carrots, sweet potatoes, garlic, cabbage, niebe leaves, peppers, melons, watermelons, and sweet corn;

- forest tree nursery: rapid growing varieties for heating wood, such as gmelina and margosa;

- fruit orchard tree nursery: banana, papaya, and citrus trees;

- traditional rain water crops, such as gumbo and capsicum, which make it possible to have fresh condiments during the dry season.

A detailed crop growing program was developed in October 1980 that will make full use of the water from the bore-holes. Domestic water consumption has been limited to 5 m^3 while the gardens and orchards have 40 m^3 at their disposal.

c)- Reliability: Previous programs were disturbed by two breakdowns:

- all the modules (Solarex) had to be replaced in March 1979 following a break in the contact between the cells (high expansion of the alloy used). This first breakdown lasted three months;

- the pump's strainer clogged in November 1979; the second breakdown lasted three months. This type of breakdown is frequent and is due to the nature of the bore-hole, which is not lined.

d)- The pump's usefulness

After two years of difficulty in starting up, the solar pump will be able to operate at 100% capacity, which will make six or more harvests possible every year, depending on the crops.

7. Measured performance

a)- Readings taken on 22 June 1980: A complete series of readings was taken that day, with good insolation (clear skies throughout the day). The results of these readings, listed in the following table, encouraged the following remarks:

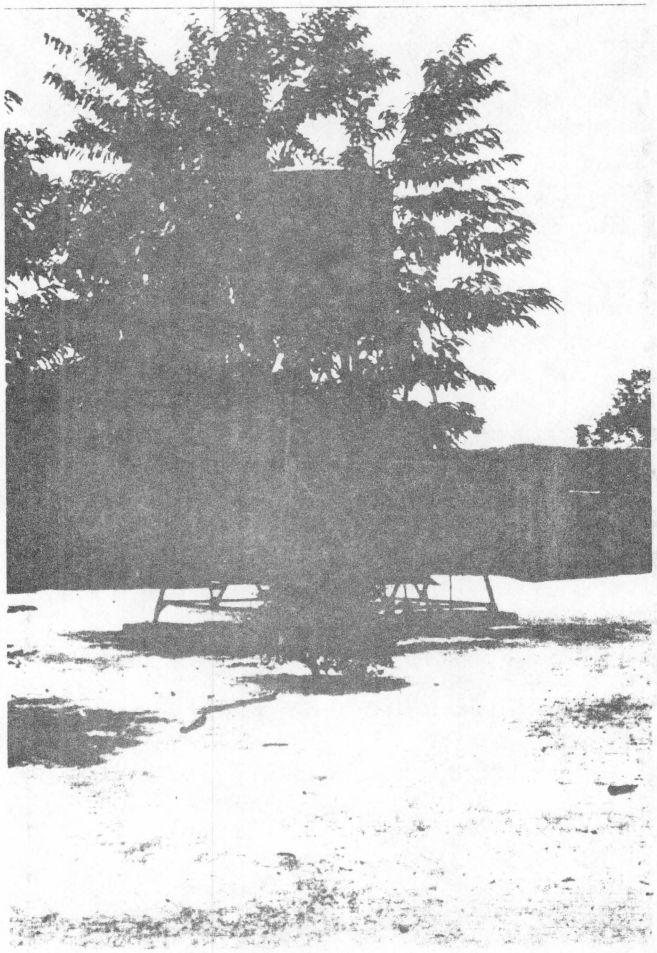
- the pump's delivery rate is probably somewhat lower than rated:

. approximately 35 m^3/day given a MH of 20 m,
. approximately 22 m^3/day given a MH of 24 m,
. given a total solar radiation of 900 W/m^2, the pump produced 2.8 m^3/hr. with a MH of 24 m and 4.6 m^3/hr. with a MH of 20 m;

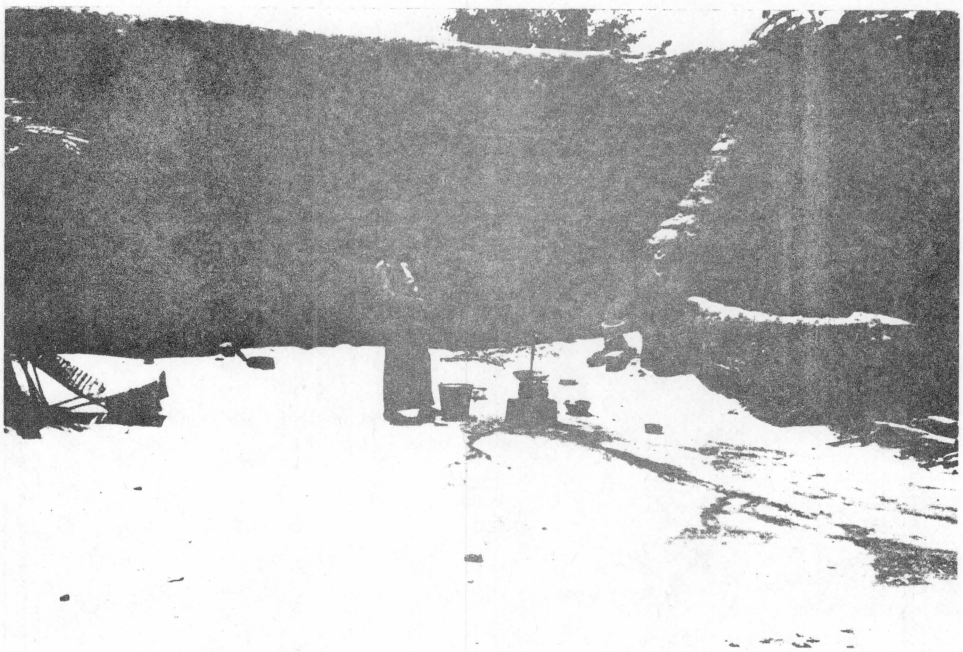
- the solar array operates correctly with:

. good output, between 8 and 10% approximately,
. operating points close to the rated characteristics (reference temperature for the cells = 70°C),

. Water tower



. Hydrant

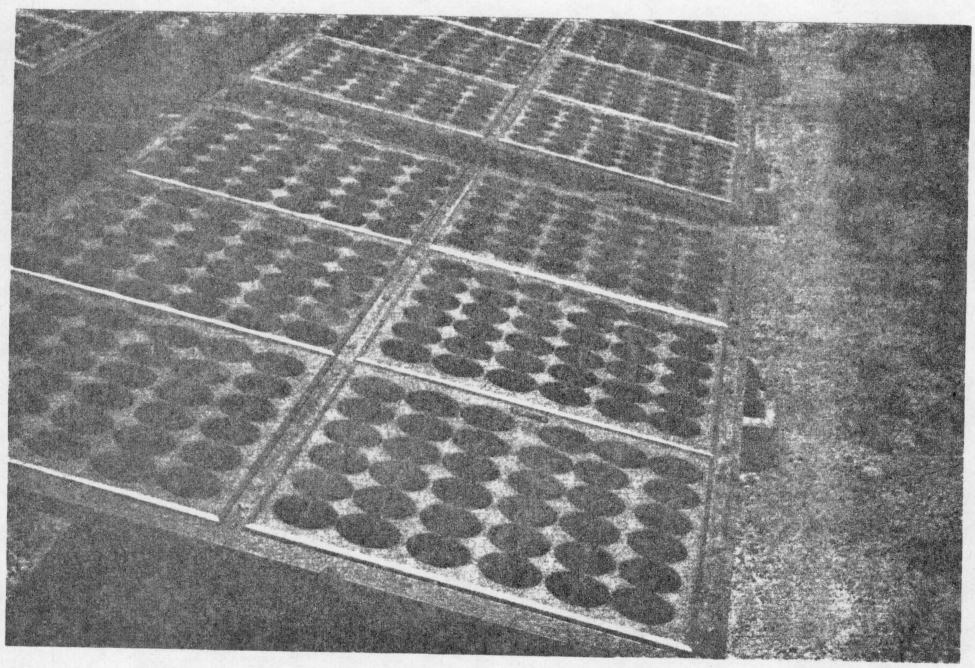


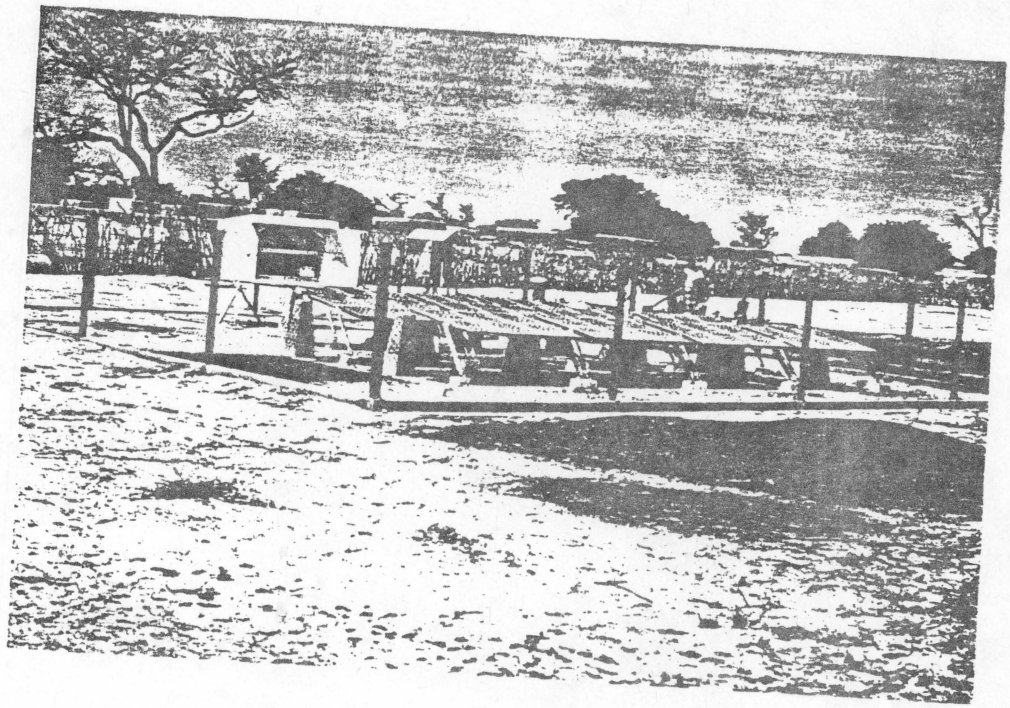
. good positioning of the operating points, representing good coordination between generator and load,
. the power of the modules depends greatly on the ambient temperature.

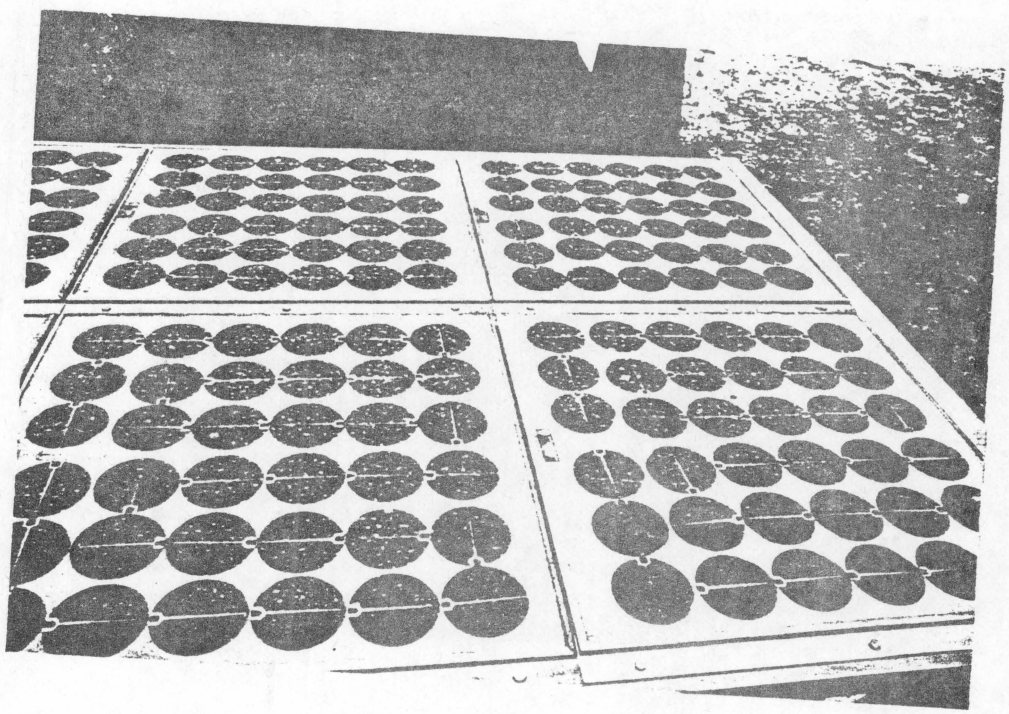
- the motor pump unit produces an output approximately 25% below normal. This can be explained, perhaps, by a partly clogged strainer. A more careful diagnosis would be necessary in order to explain that result. It should be noted that pump speed is somewhat low.

b)- Readings taken on 23 October 1980: Readings, taken rapidly on 23 October 1980, produced the following results:

- total radiation = 710 W/m²
- delivery rate = 2.45 m³/hr. with a MH of 20 m (water tower)
  5.6 m³/hr. with a MH of 15 m (tank).







EXAMPLE 4	GUINARD PHOTOVOLTAIC SOLAR PUMP AT YANGASSO 2 / MALI NURSERY IRRIGATION
Inspection report: 21 June 1980	

1. Location

The pump was installed in December 1979 in the Cercle de Yangasso (near the Bla - San road, 55 km west of San).

2. Rated specifications

- Generator: 1,300 peak watts, Solarex 4200 J modules
- Guinard Alta X F 6 pump
  rated output = 50 m^3/day
  rated manometric head (MH) = 30 m
- no related hydraulic equipment

3. Utilization

Irrigation for a district nursery project under the auspices of the commandant of the Cercle de Yangasso.

4. Financing

- 5 million Mali Francs from the 68 villages of the Cercle de Yangasso;
- 15 million Mali Francs from Mali Aqua Viva (1 Mali Franc = 0.01 French Francs).

5. Evaluation of the service rendered

The day of our visit, the nursery planned had not yet been created; the pump was thus underutilized and was used only to provide part of the village with drinking water. This project, the initiative for which comes mostly from the commandant of the Cercle de Yangasso, has thus not been completed for lack of the financial means to purchase saplings and agricultural equipment, and to pay two or three permanent workers.

A solution for hiring gardeners will probably be found (external assistance, volunteers sent by the villages, for example). The related equipment (a tank) was in the process of being built by Mali Aqua Viva. The Volontaires du Progrès, who were being lodged by the neighboring C. A. R. promised supervisory assistance.

Hopefully, the project will be completed by June 1981, and the water will then be utilized to the fullest. The pump's reliability has been excellent until now; there have been no breakdowns.

6. Measured performance

The measurements made by SEMA on 21 June 1980, under quite good conditions of insolation, reveal the following conclusions:

PROCES VERBAL D'ESSAI

POMPE SOLAIRE : ALTA X F6 1 300 W

Caractéristiques nominales : Transmission 18 m

Localisation : YANGASSO 2
(Projet de pépinière)

Date d'essai : 21.6.80
Réalisé par : J.P. MEHR
Météorologie : Ciel couvert, puis dégagé

Heure	Ensoleillement W/m2		MOTEUR				DEBIT			Niveau	Hauteur	H. MT			OBSERVATIONS
	G	D	V_v	I_A	P	Ntr/mm	Index compteur	Volume (l)	Débit horaire	DYN (m)	REF (m)	(m)	V_a V	V_b V	
10^{00}	691	144	50	12,5	625	1 530			5,63				25,5	25,0	
10^{45}	809	156	52	14,8	770	1 576			6,00				26,8	26,2	Bon équilibrage du générateur
11^{30}	884	183	54	14,5	783	1 604			6,32	16	1,0	17	26,8	27,0	
12^{30}	774	255	50	13,0	650	1 445			5,90				24,0	23,5	Importance du rayonnement diffus

. The pump's delivery rate although adequate, was noticeably lower than rated. The day of our visit, with good, although not exceptional, insolation (maximum of 885 W/m²), the pump produced approximately 40 m³/day with a manometric head of 17 m. Under conditions of greater insolation, it should be able to reach 50 m³/day.

. The hourly delivery rate was 6.3 m³/hr with a manometric head of 17 m for 885 W/m² (21% diffuse).

. The solar array operated correctly, with:

- acceptable output of about 8.5%,
- operating points well situated according to the specifications of the manufacturer, Solarex (at 70°C),
- the two panels had compensated voltages.

. The motor pump unit had a good output (approx. 40%), but it would be higher if the pump operated at its rated operating point (MH =20 m).

7. Measurements made by Sir William Halcrow & Partners

A flow gauge and a sunlight meter were installed on this pump at the beginning of June 1980 by Sir William Halcrow & Partners (Vineyard House, 44 Brook Green, London W6, Tel: (01) 603-3377). The Cercle de Yangasso makes careful daily readings. These readings show an average delivery rate of 30 to 40 m³/day. It should be noted, however, that some incoherence appears in the figures, such that the cumulative delivery figures on certain days are lower than those on the preceding day.

PROCES VERBAL D'ESSAI

POMPE SOLAIRE : GUINARD — Localisation : TION MALI — Date d'essai : 24/1/81

Caractéristiques nominales : 600 Wc FRANCE PHOTON
Pompe STP 95 B 11et

Réalisé par : G. OLIVIER
Météorologie :

Heure	Ensoleillement W/m2		MOTEUR				DEBIT			Niveau	Hauteur	H. MT	OBSERVATIONS
	G	D	V_v	I_A	P W	Ntr/mm	Index compteur	Volume	Débit(1) horaire m3/h	DYN (m)	REF (m)	(m)	
9h	719		24	15	360	1610			4,8	8		10	
9h30	791		26	15	390	1675			5,0	8		10	Rendement générateur : 9,5 %
10h00	863		29	16	464	1726			5,5	8		10	Rendement moteur-pompe : 32 %
10h30	935		28	16	448	1729			5,5	8		10	Rendement global : 3,2 %
11h00	970		29	15,5	450	1720			5,5	8		10	Rendement générateur : 8,9 %
11h30	970		28,5	15,8	450	1722			6,0	9		11	Rendement moteur-pompe : 40 %
12h00	970		29	15	435	1760			5,8	10		12	Rendement global : 3,6 %
													* La pompe fonctionne bien tant pour
													la partie électrique que pour la
													partie hydraulique.

(1) Valeur à + 10 %

EXAMPLE 5	GUINARD PHOTOVOLTAIC SOLAR PUMP AT TION / MALI VILLAGE WATER SUPPLY
Inspection report: 24 January 1981	

1. Specifications: Guinard pump

   - Power = 600 W
   - Cells = France Photon - C 36 V
   - Pump = S T P 95 B
   - Shafting = 18 m
   - Average daily delivery rate = 36 m^3

2. Utilization:

   - Drinking water
   - Rouissage du Dah

3. Financing:

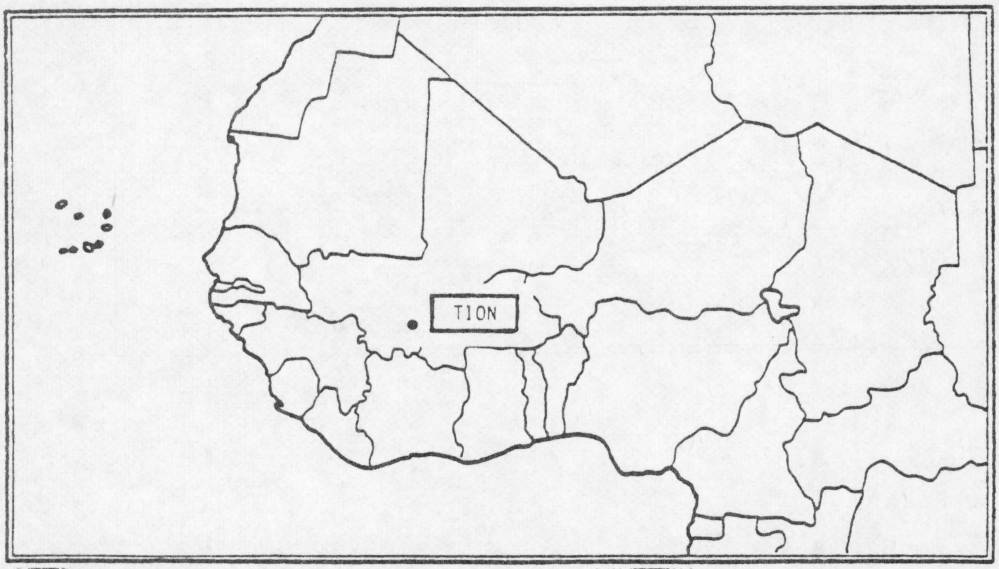
   EDF - CEAO

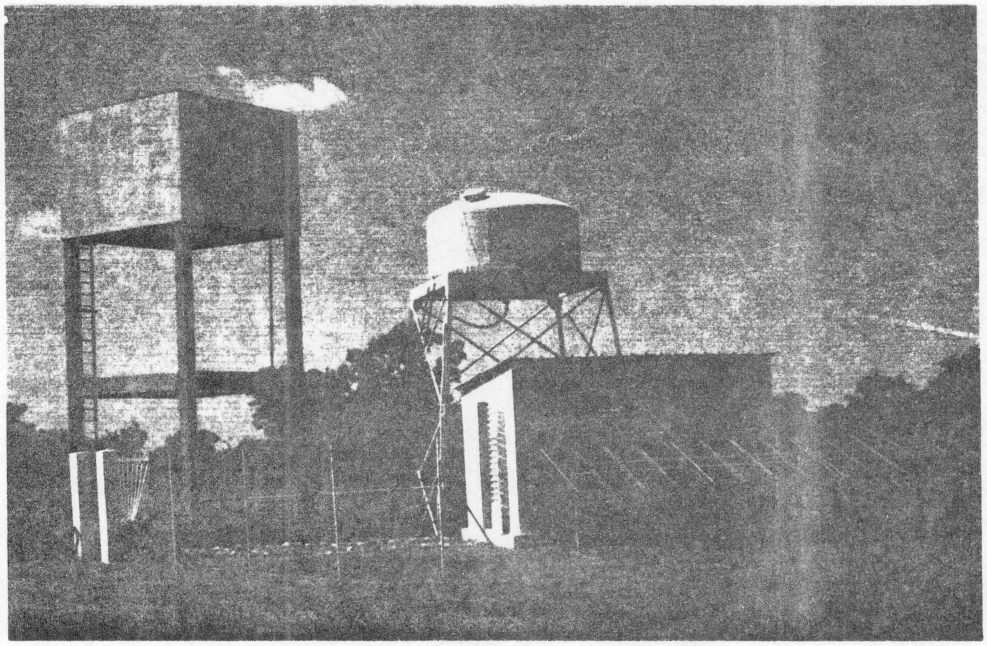
4. Installation:

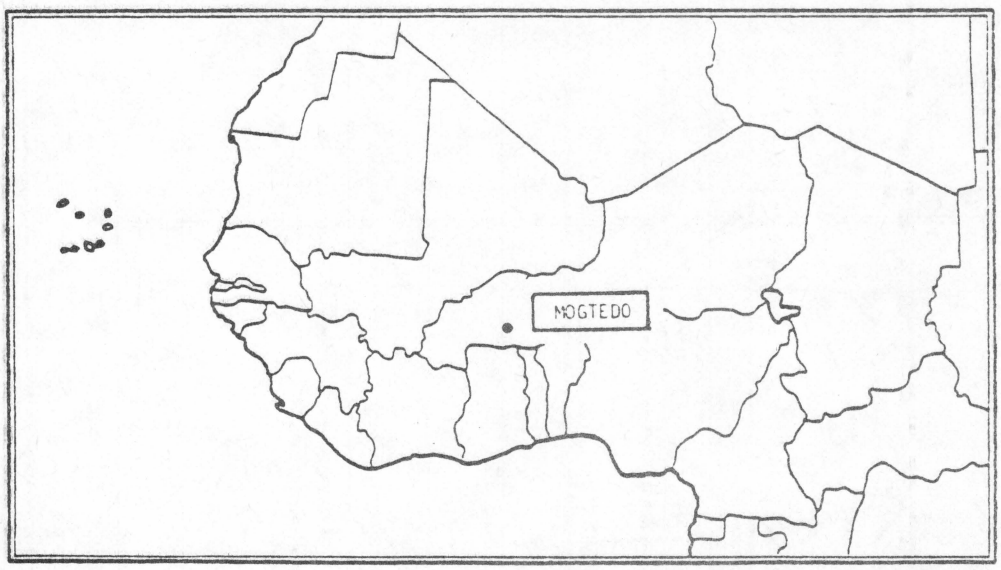
   - Drilling: Mali Aqua Viva
   - Civil engineering: Mali Aqua Viva
   - Assembly: Mali Aqua Viva
   - Date: October 1980

5. Technical performance:

   Performance is good, as can be seen in the enclosed report.






MOGTEDO

EXAMPLE 6	BRIAU PHOTOVOLTAIC SOLAR PUMP AT MOGTEDO / UPPER VOLTA VILLAGE WATER SUPPLY
Inspection report: 16 May 1980	

1. Location

Mogtedo is located 85 km east of Ouagadougou on the road to Koupela. The pump is located near the agricultural training center which it serves entirely. There is no electricity there.

2. Rated specifications

The present pump at Mogtedo was planned for the Kaibo site, which could not be equipped. Its rated specifications are:

- daily delivery rate = 10 m^3/day, or 1.45 m^3/hr.
- manometric head (MH) = 40 m = 35 m + 5 m (discharge)
- possible utilization of a 50 W/48 V transmitter-receiver, operating 2 hours per day
- one 10 m^3 tank, placed 5 m off the ground
- peak power = 900 W (eighty-four BP X 47 A 11-watt modules)

3. Start-up date: Beginning of 1979

4. Pump performance

The pump suffered numerous breakdowns, essentially due to problems with:

- the control panel (faulty relays?)
- deteriorated belts

The pump is now directly coupled -- motor/solar array -- and its delivery rate is high.

5. General condition of the equipment

- Both the civil engineering and the equipment (panels, motor, pump, tank, etc.) show good construction.
- The entire installation is protected by a fence whose gate is generally closed. The interior space is used, in part, for a garden. Good overall appearance.

5.1 Water towers:

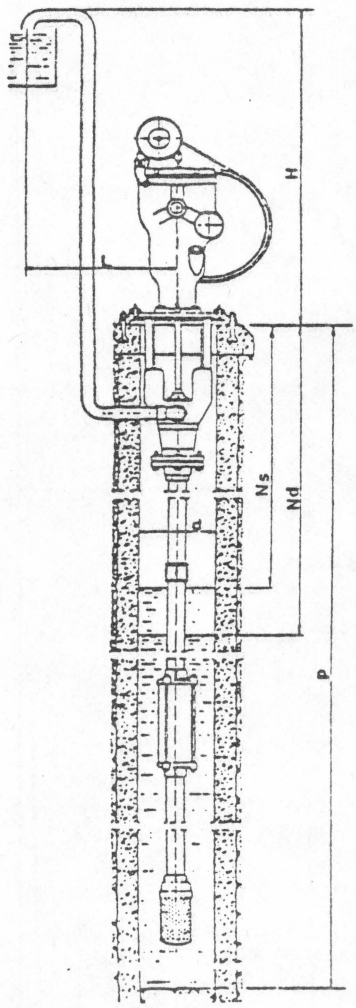
Briau Water tower (10 m^3): steel, on a metallic framework, very recent white paint, good condition.

AVV Water tower: less than 10 m from the Briau water tower is the concrete water tower of approx. 25 m^3. The cubic tank (approx. 3 x 3 x 3) is placed at a height of about 7 m off the ground (lower part). This tank, installed before the other, was previously filled by motor pumps located by a dam a few hundred meters away. These motor pumps are no longer operating.

Type SIRIUS	VEUILLEZ RENVOYER CE QUESTIONNAIRE PLEASE RETURN THIS QUESTIONNAIRE	BRIAU SA

NOM / NAME : MOGTEDO - HAUTE-VOLTA

Adresse / Address :



• Débit journalier demandé / Daily flow wanted		10 m3/j
• Disposez-vous d'un puits ou d'un forage ? / Do you dispose of a well or a borehole ?		forage m
• Diamètre du puits ou du forage / Diametre of well or borehole (PVC)	d	140 mm
• Profondeur - Depth	P	60 m
• Distance du sol à l'eau avant pompage / Distance from ground to water before pumping	Ns	14,8 m
• Distance du sol à l'eau pour le pompage du débit de ..... m3/h / Distance from ground to water before pumping of the flow of m3/h	Nd	- 31,0 m
• Hauteur maxima de refoulement au-dessus du sol / Maxima discharge height above ground	H	+ 6,5 m
Tuyauterie de refoulement, si elle existe / Discharge pipings, if present :		
• a) Longueur développée / Developped length	L	10 m
• b) Diamètre - Diametre		60 mm
c) Nombre et nature des coudes / Number and nature of elbows		
• d) Distance du puits au réservoir / Distance from well to reservoir	L	4 m
• Si la pompe est placée dans un bâtiment indiquer la hauteur sous plafond / If the pump is inside of a building, indicate height underneath of ceiling		m

BRIAU SA B.P. 43 - 37009 TOURS CEDEX - FRANCE – TELEX 750729 F – TEL. (47) 61.38.17 –

Connection between the water towers: the two water towers are connected to the same delivery pipe, however, the AVV tank cannot be filled without a valve on the riser pipe of the Briau tank (since the Briau tank is lower, it overflows; it is thus necessary to close its admission pipe in order to fill the second tank). The addition of this valve makes it possible to increase substantially the water reserves.

5.2 Pumping cabin:

Careful, solid construction, good ventilation.

5.3 Electrical equipment:

Photovoltaic panels: eighty RTC BP X 47 A 11-peak watt modules:
- . pointed due south, collector angle = +20°
- . solid, careful construction, no corrosion
- . modules apparently in good condition

Batteries: twenty-four CIPEL VP 215 batteries:
- . measured voltage = 48 V, not connected to the panels during pumping, adequate water level, no reserves of distilled water at the site

Control panel:
- . complex wiring, in disarray following work done that modified the original schematic

Electric motor:
- . Brot 1,500 RPM, ref: 90/80, U rated = 52 V, rated power = 450 W, visibly in good condition, generator brushes show considerable wear (15 mm)

5.4 Displacement pump: Briau. Visibly in good condition, the oil level in the gear casing is a bit low, strong vibrations during operation, most probably due to the overspeed associated with direct coupling (working voltage too high: 61 V instead of 52 V).

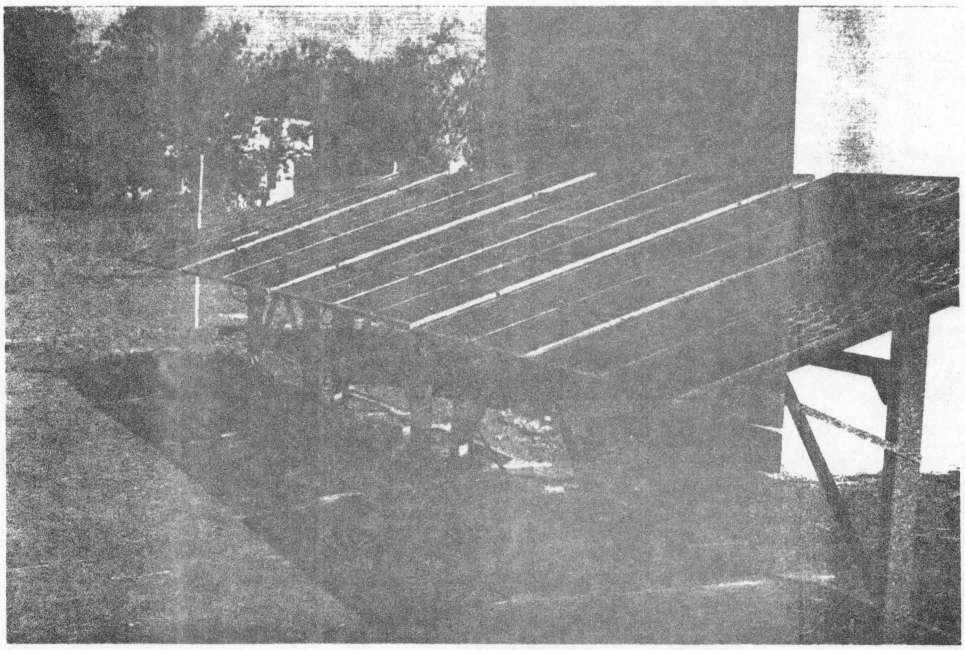
6. Observations based on the measurements

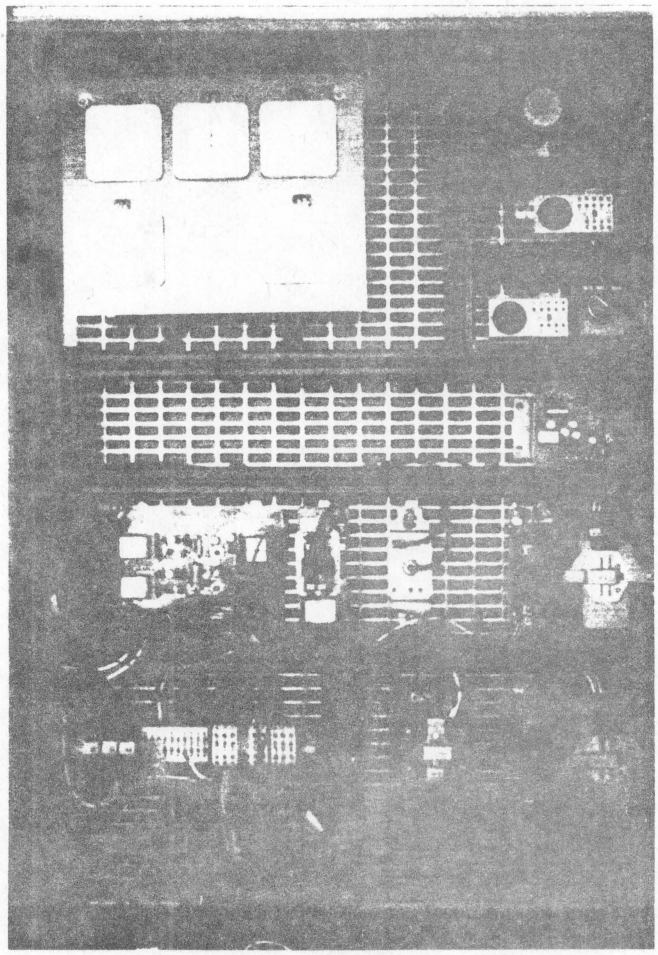
6.1 Pump start-up: abnormal situation

- The displacement pump is very slow in starting up (almost one minute before reaching normal speed), which can be explained by this pump's very high starting torque.

- To protect the motor during start-up, the initial set-up included a starting resistor that was cut off after a certain amount of time by means of a timed relay. This additional resistance was, in fact, essential, considering the parallel coupling: battery/solar generator/motor.

- Start-up is now executed in direct coupling between the solar array and the motor, without additional resistances, and with the battery disconnected from the circuit. Pump start-up is basically done by means of a short circuit with the resistance of the system -- wires + motor -- at 0.3 at stop.





This situation, while acceptable for the electric motor (the current is limited to approx. 12 A), is nevertheless risky for the solar array, which is not protected by diodes connected in parallel, in accordance with the RTC ONA 104 manual, pages 47 to 56. There is thus a risk of causing heat stress, which is harmful to the modules, especially if start-up time is late during a period of high insolation.

6.2 Slippage of the belt linking the motor to the pump: The flat belt tends to slip during start-up, considering the force of the starting torque. It starts to overheat, which can be explained in part by the frequent deficiencies blamed on the belts. It should be noted that at Mogtedo, the caretaker had a product that reinforced the belt's adhesion.

6.3 Rotation speed higher than rated: Working voltage was formally set at between 48 and 52 V by the battery in parallel. Direct coupling thus eliminates the battery and the working voltage stabilizes at about 61 V (instead of 52 V). The motor therefore runs much too fast (speed essentially proportional to the voltage) thus causing the pump to operate at a speed higher than originally planned. The delivery rates observed, much higher than the rated levels, confirm the situation. This is followed by increased fatigue for the pump. The high level of vibrations observed at Mogtedo can probably be explained by this overspeed.

6.4 Elimination of the electric protections: The Briau pump was originally equipped with numerous protective devices against:

- bore-hole drainage
- water tower overflow
- motor overcurrent
- unusual motor overheating
- insufficient voltage, etc.

The present configuration of the direct coupling -- panels/motor -- eliminated all these protective systems, that are nevertheless necessary for this type of pump (risk of jamming due mostly to piston seizure).

6.5 Analysis of the measurements made on 16 May 1980: The results of the measurements made can be found in the table below. The following comments are based on these measurements:

a)- The pump's delivery rate is much higher than the rated value of 1.45 m^3/hr or 10 m^3/day, with a manometric head of 40 m, since, towards noon, an hourly rate of 2.67 m^3/hr at MH 37 m is obtained, and since over 10 m^3 has been pumped in 4.5 hours (from 8:45 AM to 1:15 PM). Over the course of an entire day over 16 m^3/day is pumped.

b)- The operating point is very far from optimum. Modification of the initial installation (where the operating point was determined by the battery at about 50 V) led to a serious maladjustment that is harmful to the output of both the generator and the pump (excess speed). In fact, this is located on the vertical portion of the characteristic curve for BP X 47 A modules. Electric power stabilizes very rapidly, despite the increase in solar radiation by moving the operating point into the zone of decreasing output. The high ambient temperature accelerates this maladjustment, with the vertical portion of the characteristic curve tending to move towards the left.

PROCES VERBAL D'ESSAI

POMPE SOLAIRE : BRIAU 920 W — Localisation : MOGTEDO (Haute Volta) — Date d'essai : 16 mai 1980

Caractéristiques nominales : 10 m^3/jour - hmt = 40 m. — Réalisé par : B. MEUNIER, G. COMPAGNE

stockage batterie - pompe volumétrique — Météorologie : temps clair

Heure GMT	Ensoleillement W/m2 G	D	MOTEUR V_v	I_A (1)	P W	Ntr/mn	DEBIT Index compteur	Volume (1) sur 15'	Débit horaire	Niveau DYN (m)	Hauteur REF (m)	H. MT (m)	OBSERVATIONS inclinaison panneaux -20° - sud
8h.00	323	34%				N.D.				-14,8			
8h.30	410						0,230			-14,8 N.S	+1,0	15,8	étalonage du compteur par remplissage d'un fût —> le compteur exagère de + 10%
8h.45	477						0,870	640			+4,7		<— Début remplissage château d'eau
9h.00	511	25%	57	6,9	393		1,440	570		-25,5	(4,8)	30,3	Q x h = 69 Q m^3/h, h en m
9h.15	559		59	7,3	431		2,060	620			(4,9)		
9h.30	604	22%	60	7,5	450		2,690	630	2,55	-29,5	(5,0)	34,5	Q x h = 87 t ambiante 35°C, t panneaux 47°C
9h.45	645		61	7,5	458		3,310	620	m^3/h.		(5,1)		
10h.00	682	19%	61	7,7	470		3,985	675		-30,7	(5,2)	35,9	Q x h = 97
10h.15	719		61	7,8	476		4,680	695			(5,3)		
10h.30	746	17%	61	7,8	476		5,300	620	2,61	(-30,8)	(5,4)	36,2	Q x h = 90
10h.45	770		61	7,8	476		5,960	660			(5,5)		
11h.00	789	16%	61	7,9	482		6,600	640		(30,9)	(5,6)	36,5	Q x h = 93
11h.15	807		61	7,9	482		7,270	670			(5,7)		
11h.30	821	15%	61	7,9	482			670	2,67	(31,0)	(5,8)	36,8	Q x h = 99

(1) I oscille suivant la position de la pompe - il s'agit donc de moyennes.

c)- Generator performance is acceptable considering the coupling arrangement. For 800 W/m² of solar radiation, an electric power of 480 W at 61 V (or approximately 15 V per module) was generated. The RTC table lists 500 mA at 15 V, or 7.5 W for T = 60°C, which should give 80 x 7.5 = 600 W. Observed performance is thus at 80% of the manufacturer's rating.

d)- Mixed panels/battery operation: At 1:30 PM the two switches were placed on the battery and manual positions, respectively. The battery was thus switched into parallel with the motor. This produced the following values:

- total solar radiation (flat plate collectors) = 738 W/m²
- panel voltage = battery voltage = motor voltage = 50 V = V1
- panel current A1 = 10 A
- motor current A2 = 6 A
- battery current A3 = 4 A (the battery recharges itself)

Simultaneously recharging the battery and operating the pump leads to motor slowdown compared to direct coupling. This mixed position is not currently in use because the caretaker was issued instructions to operate the pump in direct coupling. Generally speaking, the lack of secondary utilizations for the electricity and highly regular insolation reduce the need for the storage solution.

e)- Statistics of the daily delivery rate at Mogtedo: The caretaker, Mr. Ali Koné, keeps a log of daily readings of the counter and pumping hours. Pumping usually begins at about 9:30 AM and ends between 2 and 4 PM, depending on the demand for water. The pump's capacity exceeds demand, and the caretaker therefore limits pumping time. As can be seen, the pump has produced up to 25 m³/day.

7. Maintenance problems

Numerous malfunctions occurred, as we said, for various reasons (faulty relays, fuses, belts, etc.). The present caretaker received no instructions whatsoever for routine maintenance (oil level, battery water level, belt adjustment, generator brush replacement, etc.).

Maintenance was carried out essentially by the EIER under difficult conditions (lack of familiarity with the sophisticated monitoring equipment, lack of spare parts, etc.). The Briau company, since it had no local servicing installations, could not make regular visits, nevertheless, its relations with the EIER were very good.

PROCES VERBAL D'ESSAI

POMPE SOLAIRE :

Caractéristiques nominales :

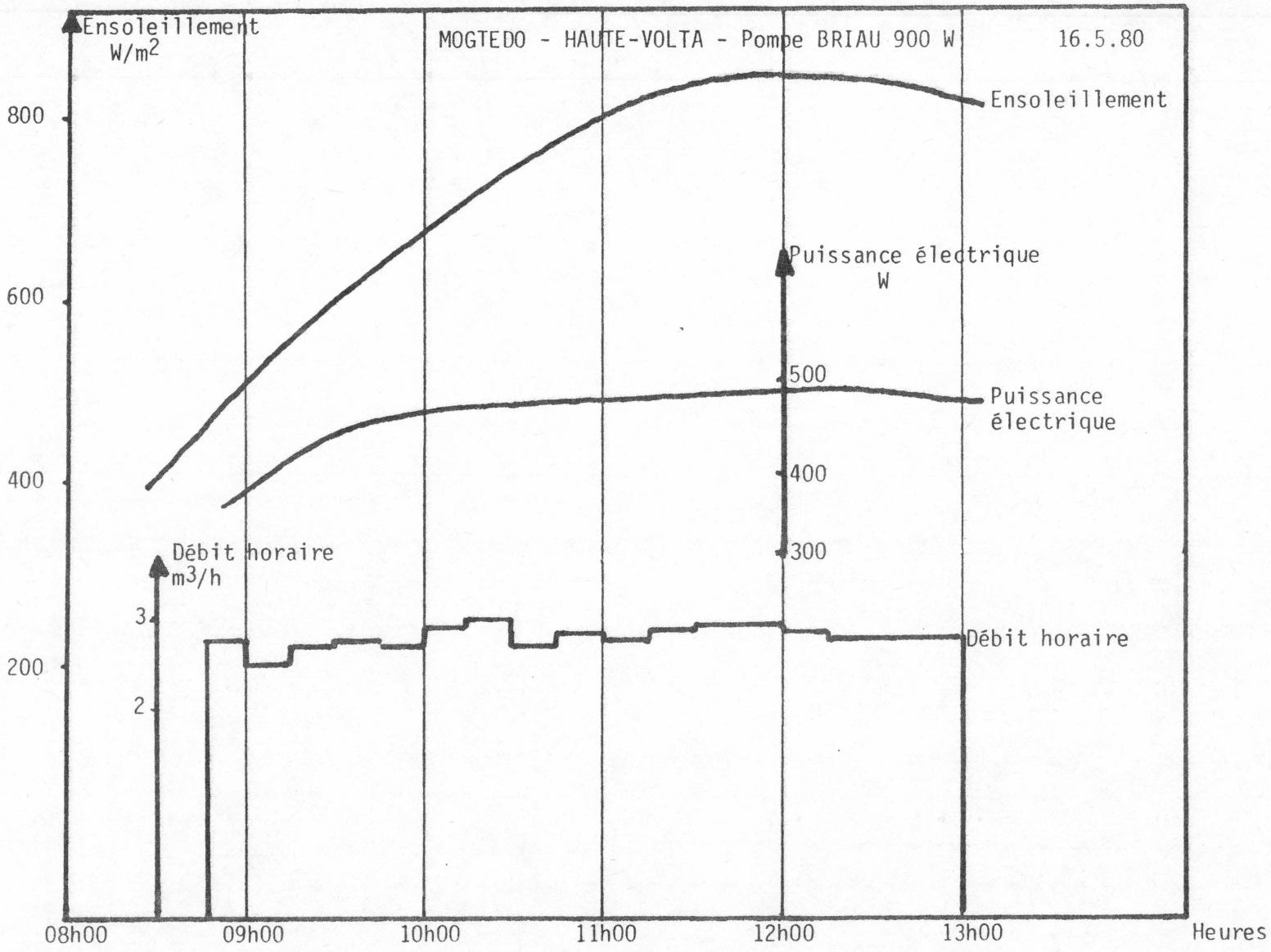
Localisation : MOGTEDO

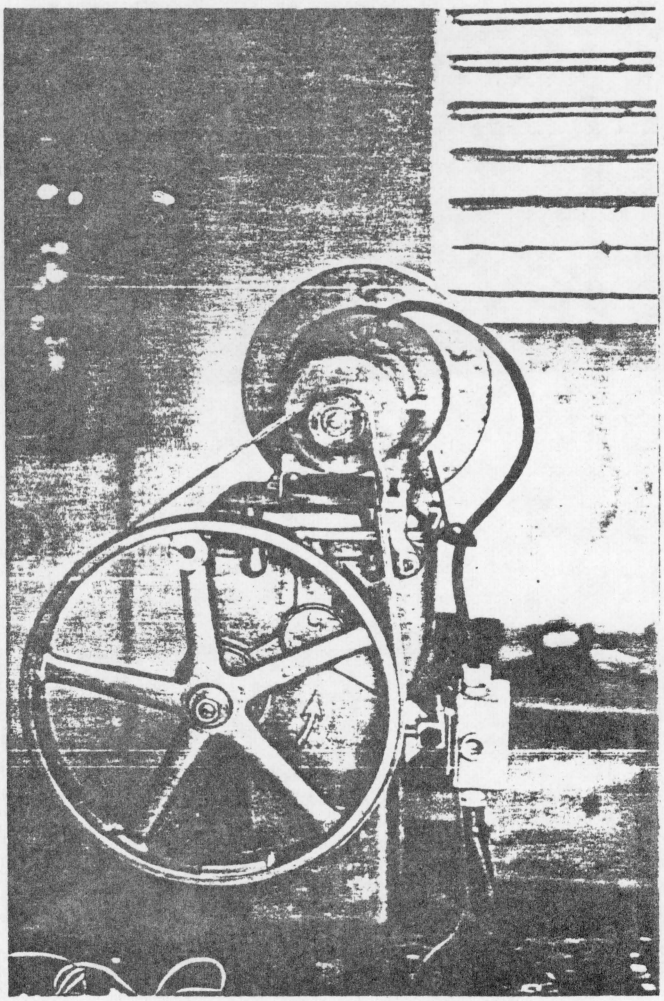
Date d'essai : 16 Mai 1980
Réalisé par :
Météorologie :

Heure	Ensoleillement W/m2 G	D	MOTEUR V_v	I_A	P W	Ntr/mn	DEBIT Index compteur	Volume (l) sur 15'	Débit horaire	Niveau DYN (m)	Hauteur REF (m)	H. MT (m)	OBSERVATIONS
11h.45	825		61	8,0	488		8,610	670	2,67		(5,9)		t ambiante 35°C t cellule 47°C
12h.00	829	15%	61	8,0	488		9,270	660	m3/h	-31,0	(6,0)	37,0	rayonnement maxi 908 W/m2 à l'horizontale
													Q x h = 98
12h.30	826	15%	60	7,9	474		10,570	650			(6,2)	37,2	Q x h = 97
									2,60				
13h.00	801	15%	60	7,9	474						(6,4)		Q x h = 97,5
13h.15							12,520	650		-31,0	6,5	37,5	réservoir 10 m3 plein - arrêt pompe
13h.30										-15,0			le niveau statique est retrouvé en moins de 15 minutes.

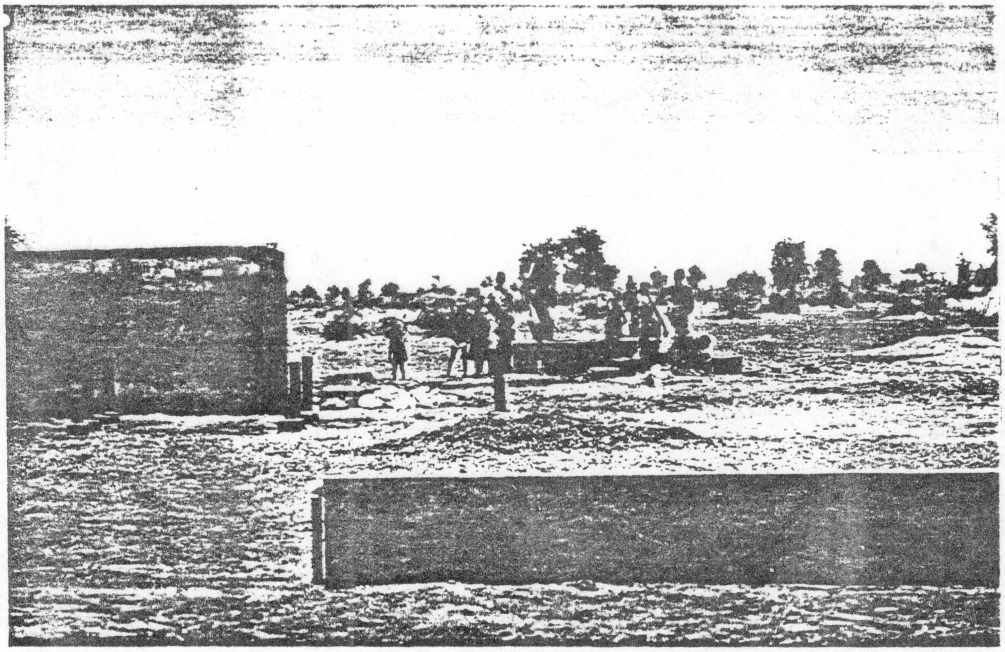
in m^3/day

	January 80	February 80	March 80	April 80
1		7	14	11
2		7	--	--
3		3	13	13
4		3	--	--
5		11	15	6
6		21	--	--
7		10	14	6
8		10	--	4
9		17	14	4
10		12	--	--
11		10	14	9
12		8	--	7
13		6	16	10
14		14	--	--
15		10	7	12
16		--	--	--
17		8	25	12
18		9	12	--
19	20	--	--	17
20	15	14	16	--
21	14	13	14	10
22	17	--	--	7
23	--	6	14	12
24	12	7	12	--
25	14	12	--	7
26	14	12	16	11
27	11	--	13	--
28	22	13	7	10
29	--	--	--	11
30	9	--	15	--
31	8	--	--	--

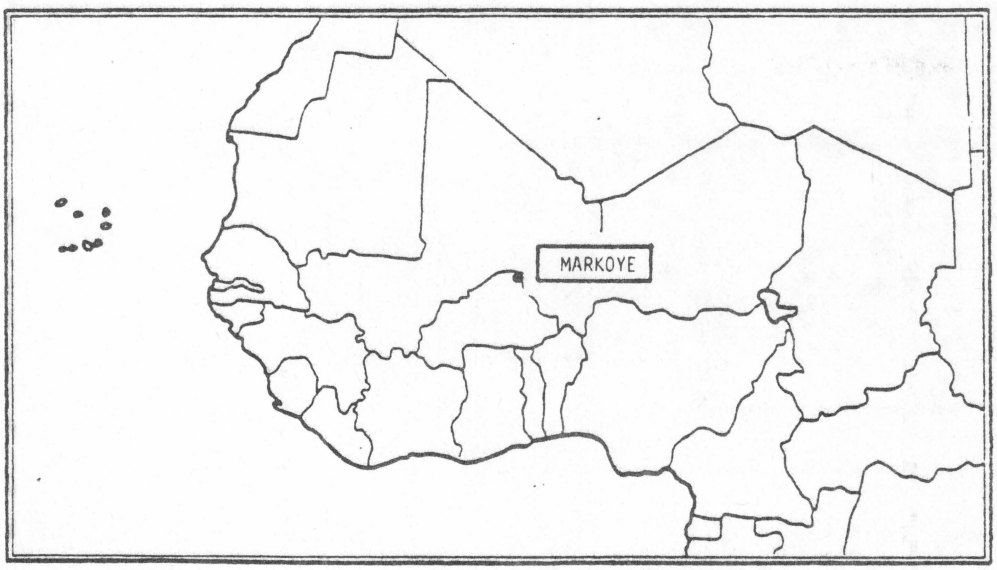

Ensoleillement
W/m2
MOGTEDO - HAUTE-VOLTA - Pompe BRIAU 900 W
16.5.80
800
600
400
200
Ensoleillement
Puissance électrique
W
500
400
300
Puissance
électrique
Débit horaire
m3/h
3
2
Débit horaire
08h00
09h00
10h00
11h00
12h00
13h00
Heures



. Moteur à courant continu et pompe



. Site



EXAMPLE 7	GUINARD PHOTOVOLTAIC SOLAR PUMP AT MARKOYE / UPPER VOLTA LIVESTOCK WATER SUPPLY
Inspection report: 5 February 1981	

1. Location

340 km northeast of Ouagadougou, 37 km from Gorom-Gorom.

2. Rated specifications

- Generator = 924 peak watts (fifty-six RTC BP X 47 B panels)
- Rated manometric head (MH) = 15 m
- Alta X pump
- one 50 m^3 tank + four troughs

3. Completion date: December 1980

4. Results of measurements

The rated head measured (from 18.50 to 21.50 m) is clearly higher than specified. This explains (1) why the flow rate measured the first time (29 m^3/day for an insolation of 6.2 KWh/m^2/day) is lower than the rated flow rate (60 m^3/day for an insolation of 6 KWh/m^2/day). Generator output is good (9 - 10%). Motor/pump unit output is satisfactory (35 - 40%) considering the preceding comment. Overall output of the equipment is satisfactory (3.6 - 4%).

5. Financial package

The package is divided up as follows (excluding tax):

- solar array:	74,000 French Francs (financed by COMES)
- other elements (pump):	54,000 FF
- shipment	25,000 FF (financed by Eau Vive)
- technical assistance:	12,000 FF
- assistant water technicians, initial hiring of caretakers (3 months):	64,000 FF (financed by the Union Fraternelle des Croyants)
TOTAL:	229,000 FF

Active participation on the part of the population (supplies of sand and gravel, labor) is evaluated at 4,000 FF. The caretaker's salary (400 FF/month) is also to be paid by the breeders as of the fourth month.

(1) Increasing the manometric head and the least acceptable adjustment between the generator and the pump, which results from that, produce a drop in output.

PROCES VERBAL D'ESSAI

POMPE SOLAIRE : ALTA X 900/15 + 6 m d'aspiration Localisation : MARKOYE (Haute-Volta)

Caractéristiques nominales : 900 Wc - hmt = 15 m

Date d'essai : 5.2.81
Réalisé par : M. THIBAULT
Météorologie : Ciel clair + vent, sable intermittent

Heure	Ensoleillement W/m2		MOTEUR				DEBIT			Niveau	Hauteur	H. MT	OBSERVATIONS
	G	D %	V_v	I_A	P	Ntr/mn	Index compteur (1)	Volume	Débit horaire m3/h	DYN (m)	REF (m)	(m)	
8h15	526	35	25	13	325		42 503		2	16	2,50	18,50	Début débit
8h30	616		27	15	405		43 257		3				
8h45	639	30	27,5	15,5	426		44 090		3,3				
9h00	676		28,5	17	485		44 951		3,4				9h00 η générateur : 9,8 % ; η moteur pompe : 36,3 % ; η global = 3,6 %
9h15	691	31	29	17	493		45 863		3,6				
9h30	744		29,5	17,5	516		46 821		3,8				
9h45	751	30	30	18	540		47 816		4				ϑmodules = 39° ϑambiante = 28°
10h00	774		30	18	540		48 868		4	19	2,50	21,50	
10h15	812	28	30	20	600		49 918		4				
10h30	834		30	20	600		50 925		4				
10h45	894	25	30,7	20	614		51 928		4				
11h00	909		31	20	620		52 934		4				
11h15	940	23	31	20,6	638		53 935		4				ϑmodules = 40° ϑambiante = 30°
11h30	940		30,9	20,2	624		54 942		4				
11h45	917	22	30,2	19	574		55 950		4				

(1) compteur volumétrique préalablement vérifié.

PROCES VERBAL D'ESSAI

POMPE SOLAIRE : ALTA X 900/15+6m d'aspiration — Localisation : MARKOYE (Haute-Volta) — Date d'essai : 5.2.81

Caractéristiques nominales : 900 Wc - hmt = 15 m — Réalisé par : M. THIBAULT

Météorologie : Ciel clair + vent, sable intermittent

Heure	Ensoleillement W/m2		MOTEUR				DEBIT			Niveau	Hauteur	H. MT	OBSERVATIONS
	G	D %	V_v	I_A	P	Ntr/mm	Index compteur (1)	Volume	Débit horaire m3/h	DYN (m)	REF (m)	(m)	
12h00	917		30,2	20	604		56 956		4				12h00 : η générateur : 9 % ; η moteur pompe : 38,7 %
12h15	910	24	30,5	20	610		57 963		4				η global : 3,5 %
12h30	940		30,5	20	610		58 968		4	19	2,50	21,50	
12h45	947	20	30,2	19	574		59 974		4				
13h00	932		30	20	600		60 976		4				ϑ modules = 44° ϑ ambiante = 33°
13h15													
13h30	895	20	30	20	600		61 974		4				Nota : la hmt : 21,5 m est nettement
13h45	857	18	30	18	540		62 961		4				supérieure à la valeur nominale : 15 m.
14h00	827	20	29,5	17	501		63 957		4				ceci affecte le rendement de la pompe.
14h15	767	20	29,5	17,5	516		64 962		4				
14h30	752		29	16,5	478		65 913		3,8				ϑ modules = 43,50 ϑ ambiante = 33°
14h45	752	20	28,5	17	484		66 815		3,6				η générateur : 9,4 %
15h00	654		28	16	448		67 710		3,6				15h00 : η moteur pompe : 41,5 %
15h15	616	23	27	15	405		68 351		3,3				η global : 3,9 %
15h30	564		26	14	364		69 280		3	15	2,50	17,50	

PROCES VERBAL D'ESSAI

POMPE SOLAIRE : ALTA X 900/15+6 m d'aspiration — Localisation : MARKOYE (Haute-Volta) — Date d'essai : 5.2.81

Caractéristiques nominales : 900 Wc - hmt = 15m — Réalisé par : M. THIBAULT

Météorologie : Ciel clair + vent, sable intermittent

Heure	Ensoleillement W/m2		MOTEUR				DEBIT			Niveau	Hauteur	H. MT	OBSERVATIONS
	G	D %	V_v	I_A	P	Ntr/mn	Index compteur (1)	Volume	Débit horaire m3/h	OYN (m)	REF (m)	(m)	
15h45	451	28	24	13	312		69 935		2,6	15	2,50	17,50	
16h00	429		22	11,5	253		70 412		1,9				
16h15	376	24	19	9,5	180		70 746		1				ϑ modules = 38° ϑ ambiante = 33°
16h30	300		16,5	8,9	146		70 850		0,4				
16h35			15	7,5	112,5		70 874		0,1				Arrêt du débit
16h40													Arrêt de la pompe
Total	6,2 kWh						Volume pompé		29 m3				

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6. History of the project

The project's initiator is the Union Fraternelle des Croyants, a private, apolitical, self-help association uniting the Christian and Moslem communities. The project originated at the beginning of 1979.

The bore-hole, clogged in December 1980, was made productive by means of a blowing + air lift operation. The manometric head, greater than planned (up to 21.50 m) forced Mr. Thibault, who installed this pump and took the initial readings, to work with a suction head of 6 m. The bore-hole thus produced 6 m^3/hr. in February 1981. The initial readings show that the pump stabilizes around a flow rate of 4 m^3/hr. for an insolation of over 700 W/m^2. Inauguration took place on 3 March 1981 with numerous personalities present.

7. Trends in utilization

The pump, originally planned for livestock water supply, will also make it possible to provide water for the people residing in surrounding nomad camps.

8. Conclusion

This project was very positive from three points of view:

- this is the only existing photovoltaic project for livestock water supply,
- the UFC is a local non-governmental organization concerned with the project's follow-up and the participation of the local population,
- for Upper Volta, this is the first installation of a photovoltaic pump at a great distance from the capital city.

D. ELECTRICAL APPLICATIONS OF PHOTOVOLTAIC SOLAR ENERGY

D. ELECTRICAL APPLICATIONS OF PHOTOVOLTAIC SOLAR ENERGY

Example 1: Solar array for the hospital at San (Mali) pg. 167

Example 2: Solar array for the infirmary at Akok (Gabon) pg. 175

Example 3: Solar arrays powering community educational equipment (Niger) pg. 178

Example 4: Solar arrays powering VHF retransmitters on Cameroon Mountain (Cameroon) pg. 183

Example 5: Solar array for school lighting at Kimparana (Mali) pg. 184

1. Electricity needs in isolated locations

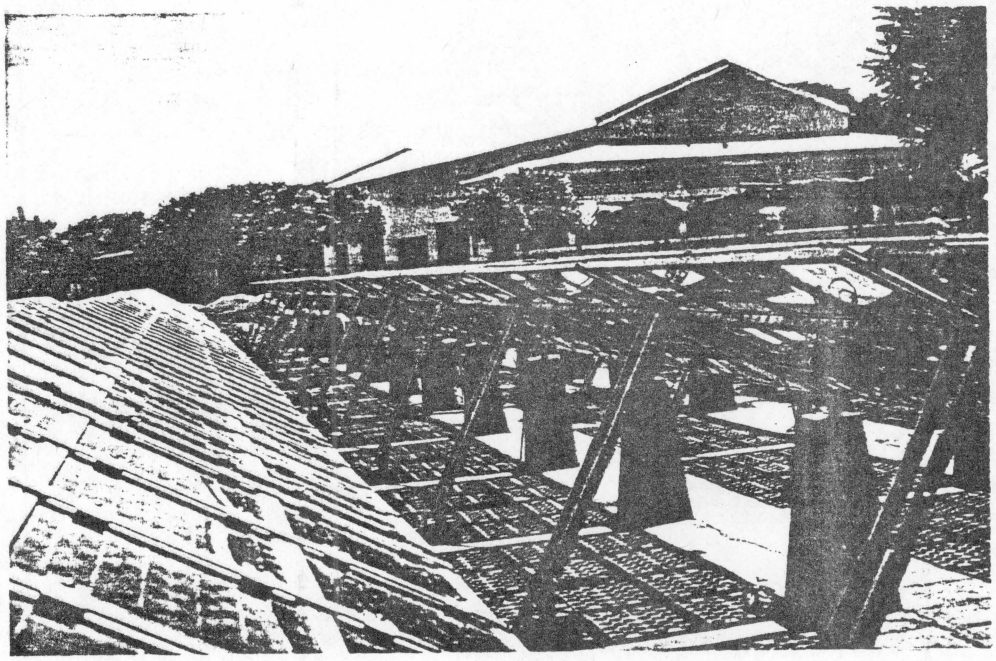
- Lighting: Lighting is a need that is poorly satisfied using traditional energy solutions (oil, karite butter). Villagers feel better equipped with lamps operating on oil or other fuels that are steadily increasing in cost. These fuels are used parsimoniously and provide limited satisfaction. Surveys conducted in rural areas show that lighting is one of the least satisfied needs at the present time. Setting up a minimal public lighting system and possibly even home lighting systems would be seen as a leap forward, breaching the gap that separates the village from the city.

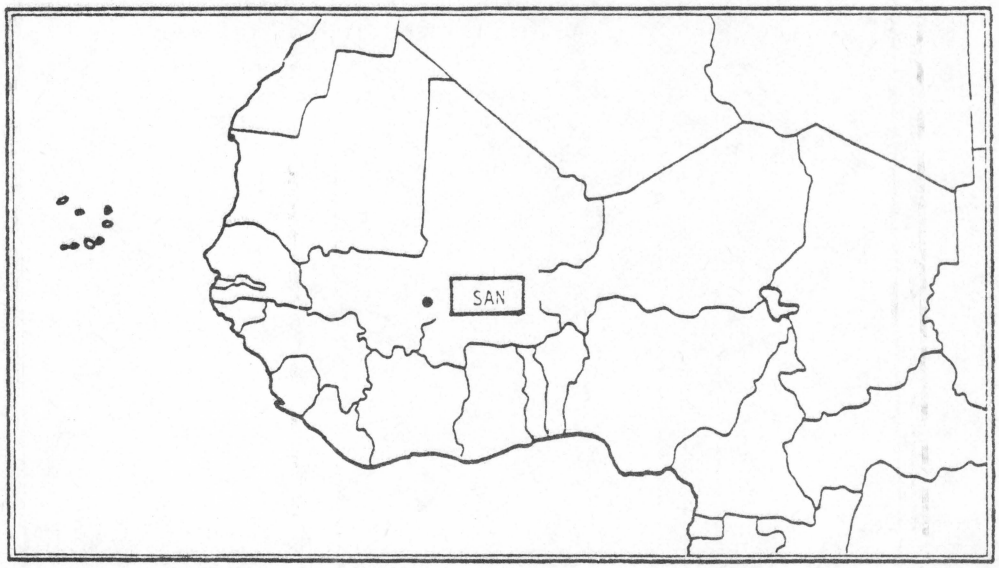
- Other needs: It is necessary to mention a series of needs that are equally important as the one cited above, and for which no satisfactory solution is currently possible due to the limited extension in the distribution of conventional energy sources:

- Health
- Education
- Communications, etc.

There is no need to emphasize the extent to which these needs are not satisfied in rural areas. Everyone recognizes this as the major handicap to the region's development.

The organization of basic health training courses in outlying areas and the creation of a scholastic television network to compensate for the lack of teachers would create energy supply problems, above all. Solutions must be found for powering medicine refrigerators in rural infirmaries and television relay transmitters for broadcasts aimed at village classrooms. Conventional energy sources can no longer provide adequate solutions. More and more, electricity production by means of photocells seems to be a satisfactory means of supplying energy for highly differing needs, as seen in the following examples.




SAN

EXAMPLE 1	SOLAR ARRAY FOR THE HOSPITAL AT SAN / MALI
Inspection report: 19 June 1980	

1. Location - receiving organizations

San is a sub-prefecture 400 km from Bamako. The hospital at San, the only one in the region, was chosen for this first installation because of the quality of the receiving organization and the support offered by Mali Aqua Viva.

2. Utilization of the generator

a)- Powering the equipment of a current operating theater:

. electric scalpels,
. special lighting,
. hot air and other sterilizers,
. suction pumps,
. air conditioners,
. fluoroscopes, etc.

b)- Lighting and ventilation in the other hospital buildings (part time)

c)- Projected: the generator was also designed to power:

. a new operating theater (under construction),
. a dentist's office,
. an ophthalmologist's office.

d)- Pumping: a pump supplies water for the entire hospital.

3. Basic specifications

The equipment supplied and assembled by Guinard (Leroy Somer) comprises principally:

- an 8,580 peak watt generator; RTC BP X 47 A modules divided into 5 units of 1,716 peak watts each;
- a 120 V/500 Ah Oldham battery;
- a 220 V AC/4 KVA LRCE inverter;
- a control panel;
- a Guinard Altax pump.

The schematic diagram of the equipment will be presented later.

4. Financing

The project, which costs 1,350,000 French Francs, was financed by the Ministère de la Coopération (France) and COMES as part of the Sahel Energies Nouvelles (New Energies) program.

GENERATEUR ENERGIE ELECTRIQUE SAN (GUINARD)

MESURES DU RENDEMENT DU GENERATEUR ET DE LA CHARGE DES BATTERIES

Date d'essai : 19 juin 1980
Réalisé par : J.P. MEHR - G. OLIVIER - M. DIARA

Heure	Ensoleillement W/m²		Température °C		Générateur			Rendement générateur %	Batterie(charge)			OBSERVATIONS
	Global	Diffus	Panneaux (surface)	Ombre	V V	I A	P W		V V	I A	P W	
08.00	183	183	31	29,5	25,7	10,0	257	10,4	25,7	10,0	257	Ciel entièrement couvert.
08.30	348	183	33	30	26,0	19,0	494	10,5	26,0	19,0	494	
08.45	454	184	35	30	25,9	23,5	609	9,7	25,8	23,0	593	apparition du soleil
09.15	615	184	38	31	26,3	30,0	789	9,5	26,2	30,0	786	ciel dégagé.
09.30	660	191	40	31	26,2	31,5	825	9,2	26,0	31,5	819	
10.00	720	213	42,5	32	26,2	35,0	917	9,3	26,0	35,0	910	
10.30	791	227	46	33	26,2	37,5	983	9,2	26,0	38,0	988	mesures sur 156 modules
11.00	855	220	48	33	26,3	39,5	1039	9,0	26,2	40,0	1048	BPX 47A
11.30	901	220	48	33	26,9	44,0	1183	9,7	26,1	45,0	1175	
12.00	915	213	48	33	26,5	45,0	1193	9,6	26,1	45,0	1175	Densité électrolyte :
12.30	915	220	48	33	27,0	40,0	1080	8,7	26,5	40,0	1060	10.30 : 1,165
13.00	888	241	48,5	34	27,2	39,7	1080	9,0	26,7	40,0	1068	12.00 : 1,166
13.30	844	255	46	35,5	27,2	38,3	1042	9,1	26,8	38,0	1018	13.30 : 1,167
14.00	811	241	47	35	27,2	36,0	979	8,9	26,8	36,0	965	15.30 : 1,168
14.30	723	230	47	35,5	26,8	33,4	895	9,1	26,5	33,8	895	17.30 : 1,170
15.00	496	200	46,5	35	26,2	25,0	655	9,8	26,3	25,0	657	
15.30	420	200	44,5	34	26,5	19,0	504	8,9	26,5	19,0	504	
15.45	592	220	44,5	34	27,1	28,5	772	9,6	26,7	28,2	753	
16.15	447	223	44	34	27,0	23,0	621	10,3	26,5	21,0	557	Rendement moyen générateur sur la journée = 9,5 %
16.30	410	140	44	34	27,2	20,5	558	10,1	26,7	19,5	521	
17.00	310	100	40	34	27,0	14,0	378	9,0	26,5	13,0	345	
17.30	100	92	37,5	34	26,0	5,0	130	9,6	26,0	5,0	130	Ce rendement prend en compte toutes les pertes dûes aux diodes, aux câbles, aux déséquilibres entre branches, à la saleté des modules etc. Ce résultat est très positif.

5. Assessment of the service provided

Since 1979, the solar generator has been supplying all the electrical energy for the hospital (medical equipment, lighting, ventilation), as well as the energy needed to pump the water used by the hospital. This represents an average daily demand of 20 KWh/day (220 V AC) divided up between twelve hours of operating theater per week and seven hours of lighting per night. Over 500 surgical operations have been facilitated by this installation.

Users have shown unanimous appreciation for the installation, their only complaint being that the equipment is not powerful enough to provide lighting and ventilation for the patients. It should be noted that the present non-optimized power distribution system is responsible for serious KWh losses. Reorganizing the system into two distinct systems, one on direct current (fluorescent lighting, fans) and the other on alternating current, would eliminate serious KWh losses and improve service.

6. Reliability

The system has proven itself reliable over a 15-month period; total down time amounts to under thirty hours. The breakdowns, of minor consequence, dealt with relays (effects of lightning) and the battery fuses which are slightly too weak. The pump itself suffered only one breakdown, due to a broken cotter, that lasted one day. The hospital's water supply has never been interrupted.

7. Maintenance

Maintenance was carried out by a team from Mali Aqua Viva, including a French army corps engineer and a Mali technician. They took care of the maintenance of all the solar pumps installed by Mali Aqua Viva. Actual maintenance over the 15-month period was thus greatly reduced.

8. Technical evaluation

After eighteen months of operation, the equipment's technical performance can be termed satisfactory, as can be seen from the two series of detailed measurements carried out by SEMA and the engineer assigned to the project (Mr. Olivier), on 19 - 21 June 1980 and 13 - 14 January 1981, as well as from a certain number of daily readings.

a)- Solar array:

- Condition of the modules: Very good, slight yellowing in the corners, due to the use of poorly fitting synthetic stops; replacing them put an end to the yellowing. The problem of bird droppings made frequent washing necessary.

- Generator output: Average generator output was close to 10% (see enclosed tables), which is a good result considering the size of the generator, all the losses (wires, diodes, junction boxes, etc.), and the high temperatures.

b)- Limiting devices: This equipment operated well, properly protecting the batteries (correct voltage indicated).

GENERATEUR ENERGIE ELECTRIQUE SAN (GUINARD)

MESURES DE RENDEMENT DU GENERATEUR

Date d'essai : 13 et 14 janvier 1981
Mesures : G. OLIVIER

	Heure	Ensoleillement W/m2	Température °C ambiante	Tension V	Intensité A	Puissance W	Rendement générateur surface active : 13,534 m^2 pour 1/5
13 janvier 1981	09.00	490	-	27,0	23,3	629	9,5 %
	09.30	504	-	27,0	27,5	743	10,9 %
	10.00	647	-	27,0	31,5	851	9,7 %
	10.30	719	37°C	27,5	35,0	945	9,7
	11.00	755	37°C	28,0	37,5	1050	10,3
	11.30	791	-	28,0	41,5	1162	10,9
	12.00	791	41,5°C	28,5	41,3	1177	11,0
	12.30	827	-	28,5	40,0	1140	10,2
	13.00	791	44,5°C	29,8	38,3	1141	10,7
	13.30	784	-	28,8	37,3	1074	10,1
	14.00	715	45°C	30,0	31,0	930	9,6
	14.30	547	-	30,0	25,5	765	10,3
	15.00	539	44°C	31,5	20,3	638	8,7
	15.30	396	-	30,0	15,5	465	8,7
	16.00	287	37°C	28,5	11,0	313	8,1
14 janvier 1981	12.00	705	33,5°C	28,0	41,0	1148	12,0
	12.30	863	-	28,0	40,8	1142	9,8
	13.00	720	33,5°C	29,0	36,9	1070	11,0
	13.30	683	-	32,0	32,5	1040	11,3
	14.00	575	34,0°C	30,0	30,3	909	11,7
	14.30	360	-	28,5	21,0	600	12,3
	15.00	431	31,5°C	32,0	18,8	602	10,3

Rendement moyen du générateur = 9,9 %

résultat très bon

Rendement moyen du générateur = 11,2

résultat excellent

GENERATEUR ENERGIE ELECTRIQUE SAN

MESURES DE DECHARGE DES BATTERIES

RENDEMENT ONDULEUR

Date d'essai: 19 juin 1980

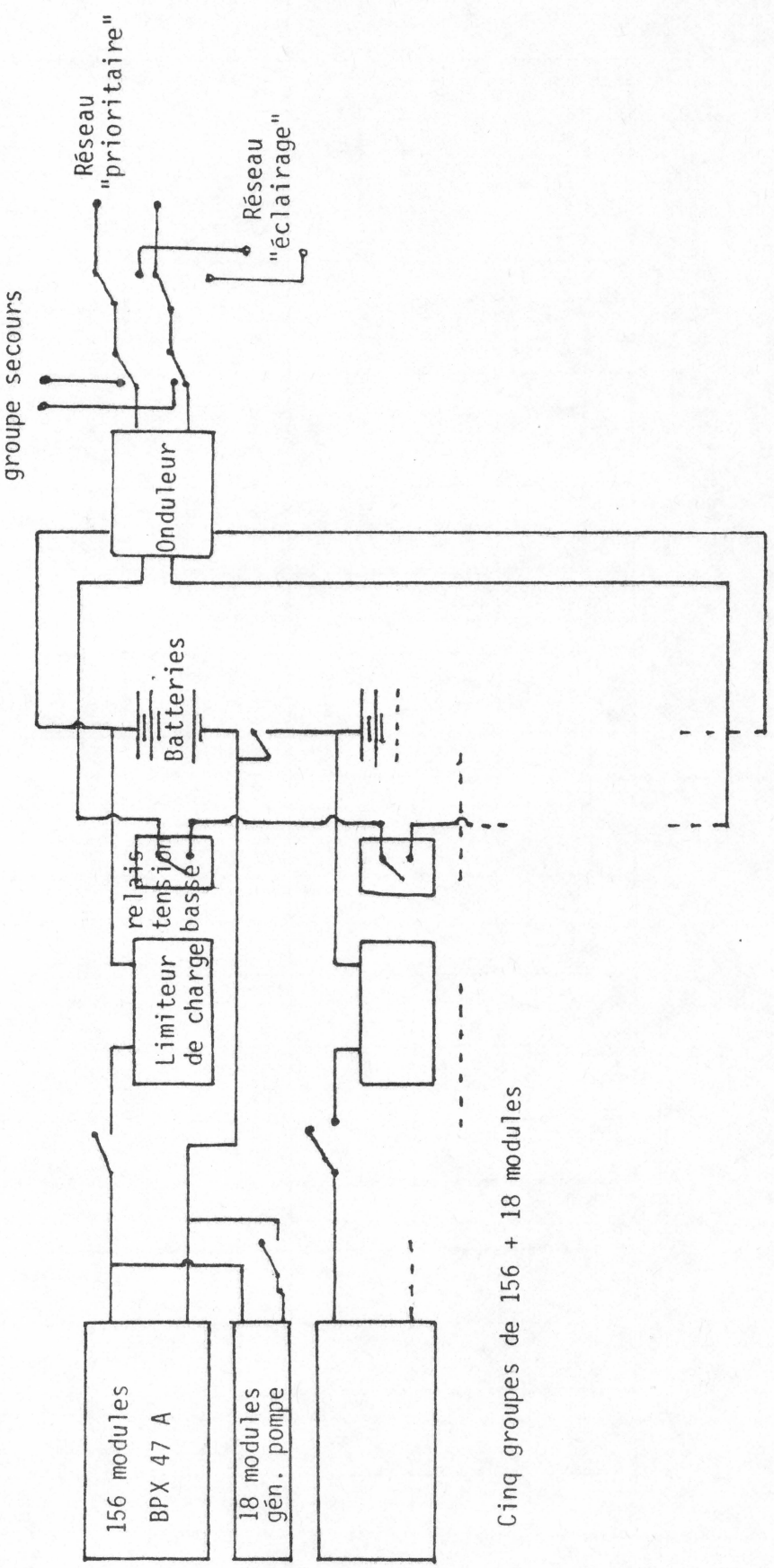
Réalisé par : J.P. MEHR - G. OLIVIER - M. DIARA

(charge)

Heures	Batterie nè			Ensemble 5 batteries				Alternatif				VI ≃	cos φ	Rendement onduleur VI ≃ / VI =	OBSERVATIONS
	V V	I A	P W	V V	I A	P W	Energie Wh	V V	I A	P utile W	Energie Wh				
08.40	25,5	24,0		135	19,0	2565		220	10,0	1550		2200	0,70	0,86	
09.15	26,2	30,0		136	10,0	1360		220	4,0	600		880	0,68	0,65	mise en route
09.30	26,0	31,5		137	10,0	1370		220	4,0	600		880	0,68	0,64	circuit prioritaire
10.00	26,0	35,0		136	19,5	2652		220	10,0	1950		2200	0,89	0,83	appareils médicaux
10.30	26,0	38,0		137	21,0	2877		230	10,8	2000		2484	0,81	0,86	en cours d'utili- ↓ sation
11.00	26,2	40,0		138	22,0	3036		230	11,0	2250		2530	0,89	0,83	
11.30	26,1	45,0		139	22,0	3058		230	11,0	2250		2530	0,89	0,83	
12.00	26,1	45,0		139	21,0	2919		230	10,5	2150		2415	0,89	0,83	fin opération
12.30	26,5	40,0		140	11,0	1540		230	4,5	850		1035	0,82	0,67	
13.00	26,7	40,0		140	16,0	2240		223	8,8	1500		1962	0,76	0,88	circuit éclairage
13.30	26,8	38,0		140	15,0	2100		225	8,0	1400		1800	0,78	0,86	↓
14.00	26,8	36,0		141	15,0	2115		225	8,0	1400		1800	0,78	0,85	
14.30	26,5	33,8		140	13,8	1932		223	6,8	1225		1516	0,81	0,78	
15.00	26,3	25,0		140	10,5	1470		223	4,9	850		1092	0,78	0,74	circuit prioritaire
15.30	26,5	19,0		140	10,5	1470		223	4,9	850		1092	0,78	0,74	sans utilisation
15.45	26,7	28,2		140	11,0	1540		225	5,0	850		1125	0,76	0,73	appareils médicaux ↓

181.

Fig. 1 - HOPITAL DE SAN - SCHEMA GENERAL DE L'INSTALLATION ACTUELLE

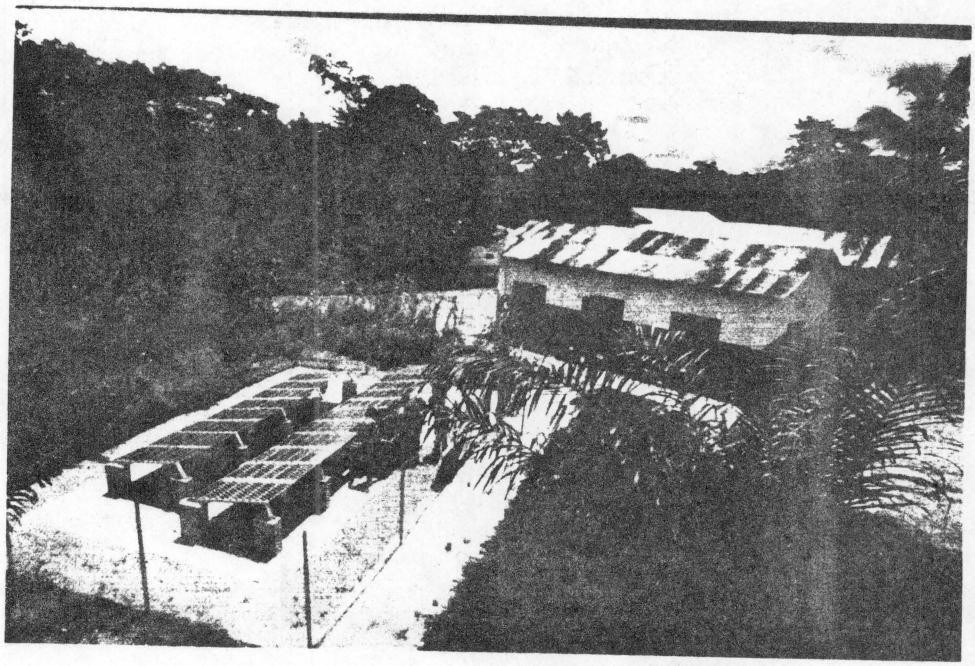


c)- Batteries: No problems encountered; measured densities were normal; the water level went from maximum to minimum in thirteen months, which indicates good charging conditions. Battery output was evaluated at 75 - 80%.

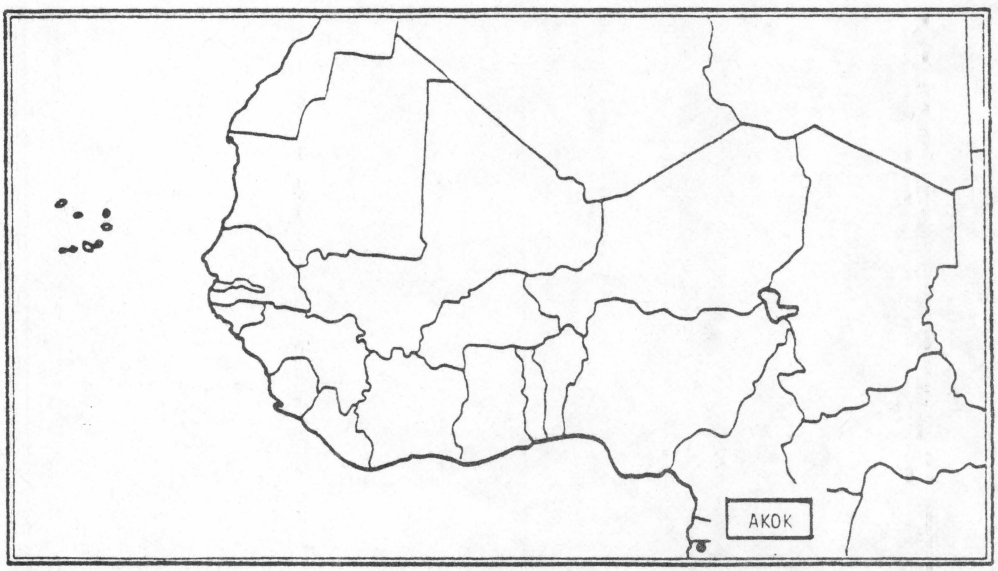
d)- Inverter: No problems encountered until present. Measured outputs of the inverter correspond almost exactly to rated values; thus there was a reading of 85% for 2.7 KW. Load voltage remains stable when the power drawn varies.

* * *

All the results presented above, backed up by the following tables of measurements, confirm this first project's excellent performance.



(Source : ELF)



EXAMPLE 2	SOLAR ARRAY FOR THE INFIRMARY AT AKOK / GABON
From Dienic project fact sheet	

1. Location

The Akok infirmary is located in a non-electrified village in the middle of an equatorial forest, 60 kilometers northeast of Libreville.

2. Equipment installed

Considering the rate at which people come to this infirmary, it was decided to electrify it using a solar array and to install the following equipment specifically designed for this type of generator:
. three fluorescent tubes, one per site; 3 hours of use per day,
. two fans, 4 hours of use per day,
. one radio socket,
. one 160-liter refrigerator for chilling vaccines and medicines to + 4°C.

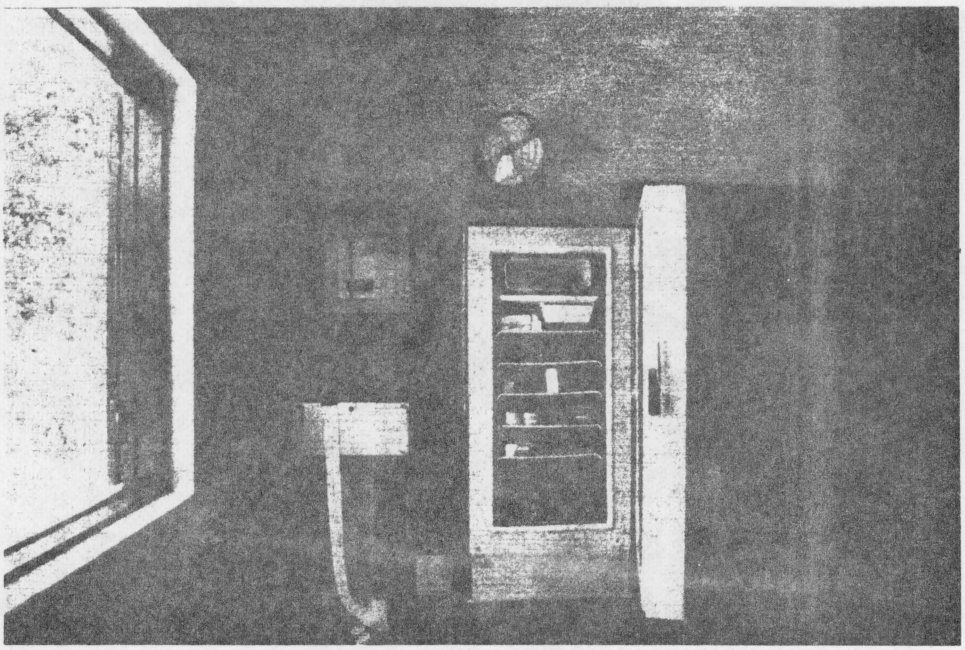
In addition, the infirmary is located in the center of the village, opposite the school, and thus a lamp post was to be erected nearby. The lamp post is to operate automatically five hours per day. Lastly, a television receiver, powered by an independent generator, was planned for educational television as well as national television (3.5 hours of use per day).

3. Equipment

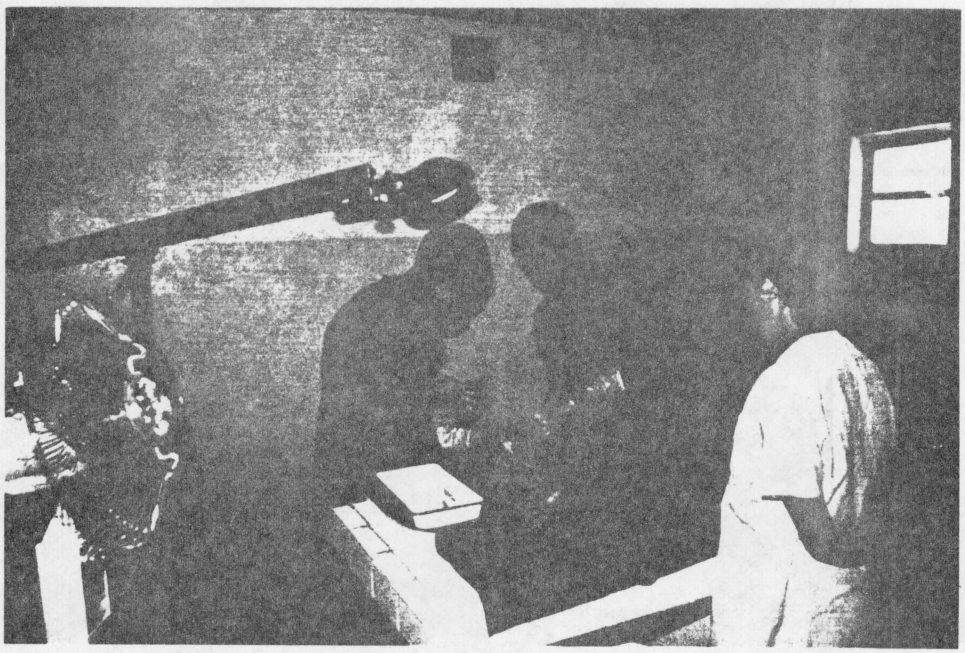
The entire project was set up on-site at the end of 1980:

Total consumption of the equipment installed	Solar generator
Infirmary plus lamp post 2,450 Wh/day 24 Volts	fifty-eight Photowatt modules 31 F 36 GC = 1,117 peak watts lead-acid battery = 1,050 AH one break regulator with priority threshold according to the batteries' level of charge one control panel for all the equipment
Television 70 Wh/day 12 Volts	one Photowatt module 415356 C = 32 peak watts one lead-acid battery, 160 Ah one dissipation regulator

In order to ascertain the equipment's utilization, a measurement station with a 15-track recorder was installed for one year. During a second phase, in order to guarantee the school infirmary's and population's water supply, a solar pumping station was on the same site during the month of January 1981. The desired flow rate is approximately 20 m^3/day.

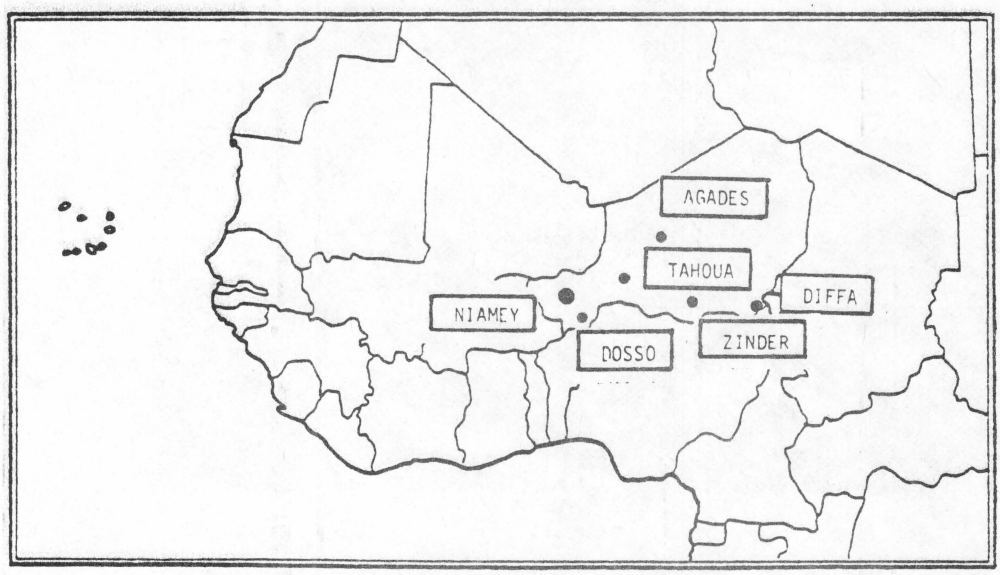


. Solar refrigerator (Source: Elf)



. Consultation room: lighting and ventilation (Source: Elf)

(Source : Yves HOUSSIN)



EXAMPLE 3	SOLAR ARRAYS POWERING COMMUNITY EDUCATIONAL TELEVISION EQUIPMENT NIGER
From the files of Yves Houssin	

1. The community television project

A television project was launched in Niger in 1964. One hundred twenty reception locations were equipped within a 100-km radius of Niamey between 1964 and 1972. When the national television commission was created in 1979, Niger authorities decided to install community television reception centers in villages within the seven departments covered by ORTN (Office de Radiodiffusion et de Télévision du Niger) television transmitters. At the same time, the former scholastic television network was converted into a community television network. Thus, by the end of the first quarter of 1982, approximately 750 community reception locations, powered by solar arrays, had been installed in the departments of Niamey, Dosso, Tahoua, Zinder, Maradi, Agades, and Diffa.

2. The equipment

2.1 Receivers

The television sets are all 61 cm (diagonal), black-and-white, cathode ray receivers. The installations completed before March 1981 included CI-17 receivers, which consume 30 watts on 32 V DC current. Since then, the network has been expanded using T 747 receivers which consume only 20 watts on 12 V DC current. This very reliable set was specifically designed for rugged environmental conditions by the Yves Houssin company. Its modular design is conducive to rational organization and management by little skilled personnel, capable of detecting and replacing defective modules, later to be repaired in a central workshop.

The new community centers include the following equipment:

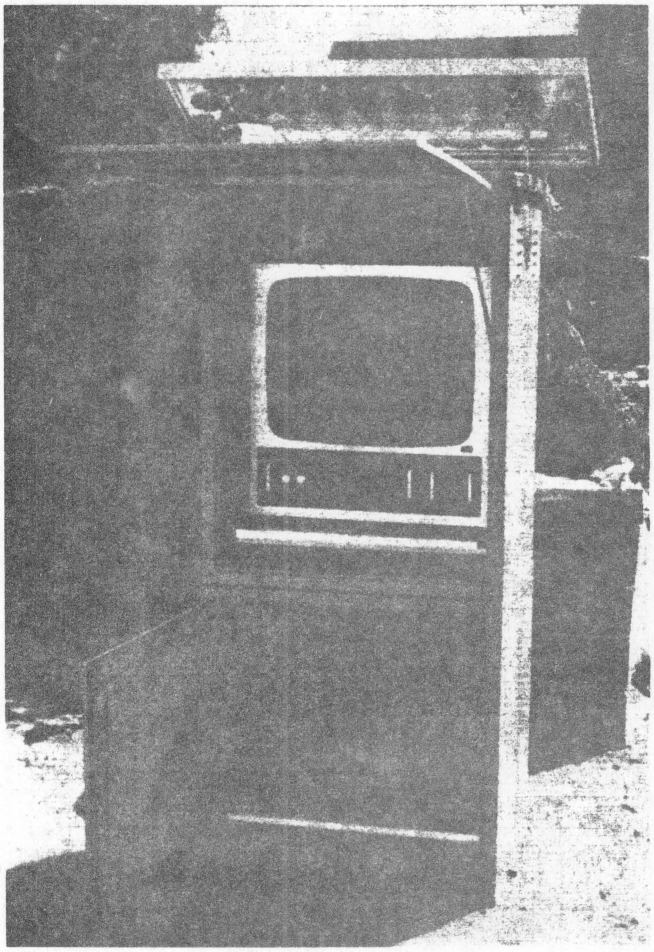
. a television antenna mounted on a mast 6, 12, or 18 meters in height (depending on reception conditions) connected to the television receivers with coaxial cables

. a T 747 black-and-white television receiver with a 61 cm screen

. a solar generator comprising:

- a BPX 47 C (Radiotechnique), 41 S 35 GC (Photowatt), or FPC 36 V (France Photon) 33 peak watt solar module, stand mounted, with connecting cable and accessories
- a battery of six Cipel Hydra VS 208 accumulators with a 140 Ah capacity, placed in a cabinet with valve diode and fuse.

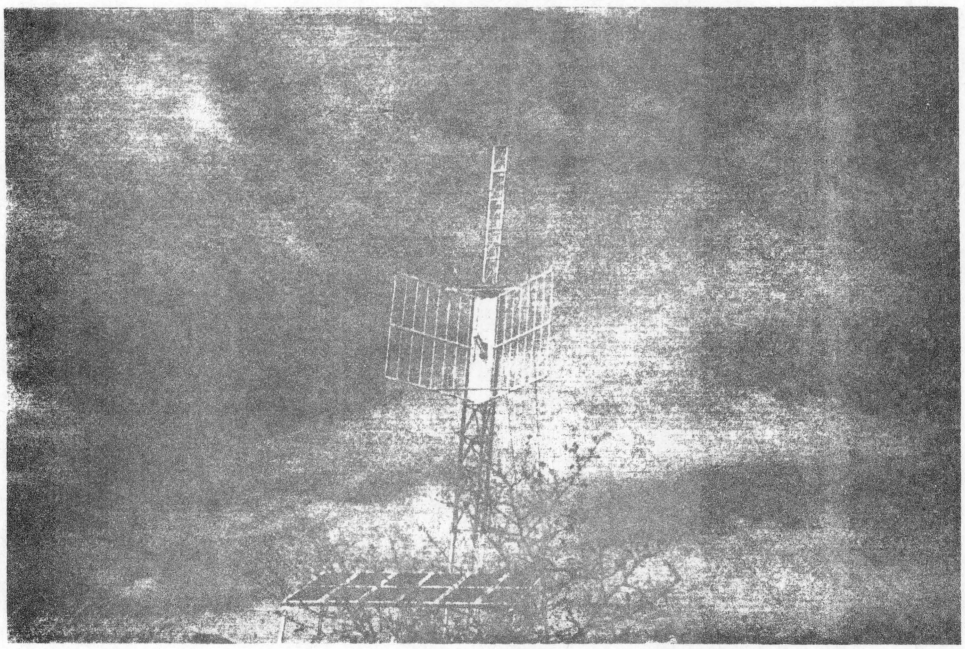
The automatic regulation and protection system of the accumulators is incorporated into the television set. The solar generator is designed to provide 900 Wh/week minimum and to guarantee power for the television set 35 hours/week during January, the least sunny month in Niger.



. Panel/receiver/battery unit

. Relay transmitter at Tillabery

(Source: Yves Houssin)



(Source: Yves Houssin)

It should be noted that since 1977, the cost of a solar generator for powering a television set has decreased by 50%. This reduction will continue due to a reduction in the cost of modules, which make up 28% of the cost of a solar generator. A serious effort will be needed in order to reduce the cost of shipment, by manufacturing locally an increasing percentage of the components.

2.2 Relay transmitters

Plans have been made to erect low-power retransmitters powered by photocells. The first experimental relay transmission station was set up at Tillabery in 1977. Others are planned. The television relay transmitter, designed by LGT for African climatic conditions and which consumes little power, is placed inside a sunken cabinet along with the accumulators. In this way, the equipment is protected from rain, solar radiation, sand storms, insects, etc. The temperature in the cabinet remains below 40°C, even during the dry season. The relay transmitter consumes 34 watts of power, and the remote control unit consumes approximately 4 continuous watts. The energy is provided by twelve BP X 47 A solar modules, with a peak power of 132 watts. Accumulator capacity is 80 Ah.

2.3 Television retransmitters

The RDT 960 television retransmission system, developed by the Yves Houssin company, was installed in order to carry television signals from the transmitter at Dosso to the Gaya area. This equipment consumes very little energy and is located inside a small reinforced polyester cabinet that is impervious to water seepage, close to an antenna pylon support. The head station, located at Kote-Kote is powered by a solar array composed of four BPX 47 CF panels, connected to a battery of twelve Hydra VS 208 accumulators and a charge regulation system. This generator provides the station with power for 60 hours per week of broadcasting (consumption = 40.8 W) and 108 hours of standby (consumption = 0.65 W). The Gaya terminal station, which only consumes 9.5 W in operation and 0.62 W on standby is powered by the local AC power grid. There are plans to extend the television retransmission system outside the coverage zones of the main ORTN transmitters.

3. Results of the operations

The community television reception network in Niger has now passed the transitory phase following the termination of the scholastic program. By creating the SNT (Société Nigérienne de Télévision) it has become possible to plan network expansion and to carry out the new installations in measure with technical and budgetary possibilities. Similarly, the SNT has been carrying out systematic maintenance visits, and in this way, each installation was visited three times in 1981. The frequency of visits could be reduced to two during the course of the year, considering the reliability of the equipment being used. In 1981, an average of under one servicing visit was required per installation for the entire network, no insignificant statistic, considering that some of the equipment dates back ten years.

4. Cost of the equipment

The average cost of a community reception center depends on several parameters:

(Source : Yves HOUSSIN)

. number of hours of station operation weekly
. insolation at the reception location
. signal strength at the reception locations, which implies the use of high-, medium-, or low-power field antennas and 6, 12, or 18 meter high masts
. distance from the technical station in charge of installation.

Considering these factors, the cost of a reception center can vary considerably from one place to another. However, taking economic indicators for the month of March 1982 into account, the cost can be situated at between 17,000 and 25,000 francs for a black-and-white installation. The cost for a color installation would run from 23,000 to 35,000 francs.

EXAMPLE 4	SOLAR ARRAYS POWERING VHF RETRANSMITTERS ON CAMEROON MOUNTAIN / CAMEROON
From Dienic project files	

1. Location

Designed to handle radiotelephone connections between Douala and offshore drilling stations located at distances exceeding 100 km, the retransmitters have been built at an altitude of 3,000 m on Cameroon Mountain, which previously was an obstacle to these connections.

2. Electrical consumption of the relays

- Standby = 250 mA/12 V
- Transmission = 3 A/12 V
- E/R = 0.5 - 0.8

3. Equipment

Considering the difficult access (by helicopter during the good seasons), solar arrays have been selected to power two of the three retransmitters installed at the end of 1977. The installation comprised:

. twenty-eight BP X 47-ampere modules by relays (panel on ground), for 308 peak watts

. one 400-Ah lead-acid battery

4. Reliability

The results turned out quite satisfactory after five months of operation. The third retransmitter was therefore similarly equipped during 1979.

EXAMPLE 5	SOLAR ARRAY FOR SCHOOL LIGHTING AT KIMPARANA / MALI

1. Location

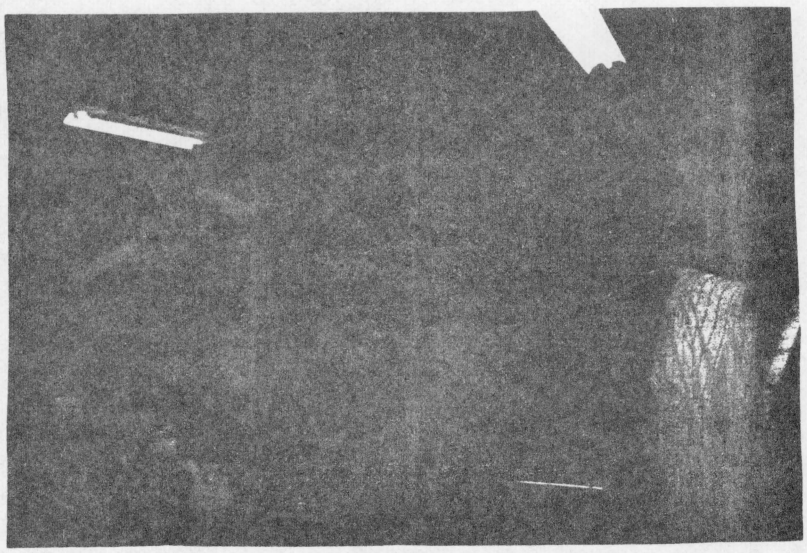
Kimparana is a small community 300 km east of Bamako. Average daily insolation during the least sunny month, with optimum collector angle is 5.2 KWh/m²/day.

2. Utilization

Lighting, evening classes

3. Equipment installed

- six 26 W fluorescent tubes operating from 15 to 18 hours per week (3 to 4 hours per class day), for a continuous consumption of 15 W
- one solar array, 160 watts peak power
- one 24 V/100 Ah battery storage unit, providing seven days of independent operation.



(Source LEROY-SOMER)

E. PUMPING AND OTHER WIND ENERGY APPLICATIONS

E. PUMPING AND OTHER WIND ENERGY APPLICATIONS

Multiple-blade wind turbines:

Example 1: Multiple-blade wind turbine for the Catholic Mission at Toesse (Upper Volta) pg. 189

Example 2: Multiple-blade wind turbine for the Protestant mission at Toesse (Upper Volta) pg. 191

Example 3: Multiple-blade wind turbine at Nagbare (Upper Volta) pg. 193

Example 4: Multiple-blade wind turbine at Kombissiri (Upper Volta) pg. 194

Example 5: Multiple-blade wind turbine at Djibo (Upper Volta) pg. 196

Example 6: Multiple-blade wind turbine at Dori (Upper Volta) pg. 198

Example 7: Multiple-blade wind turbine at Bazoule (Upper Volta) pg. 200

Example 8: Multiple-blade wind turbine at Gaban (Cameroon) pg. 202

Example 9: Sahores multiple-blade wind turbine (Mali) pg. 203

Savonius wind turbines:

Example 10: Savonius wind turbine at Dori (Upper Volta) pg. 207

Example 11: Savonius wind turbine -- EIER, Ouagadougou (Upper Volta) pg. 211

Example 12: Savonius wind turbine at Toesse (Upper Volta) pg. 213

Example 13: Savonius wind turbine IUT/Sinaes (Senegal) pg. 215

Aerogenerators:

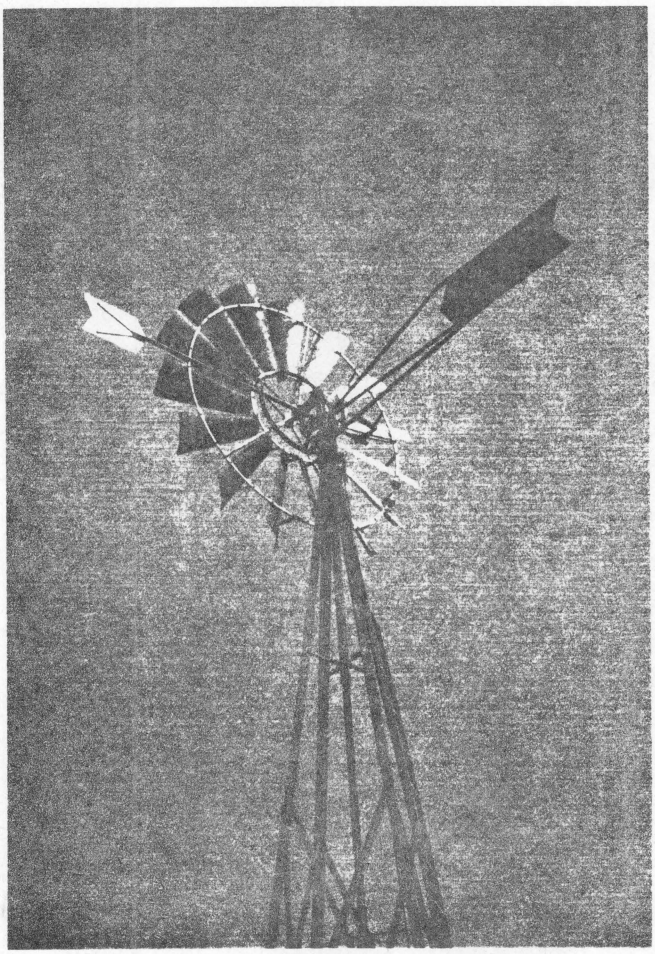
Example 14: Aerogenerator at Louly-Bentegne (Senegal) pg. 219

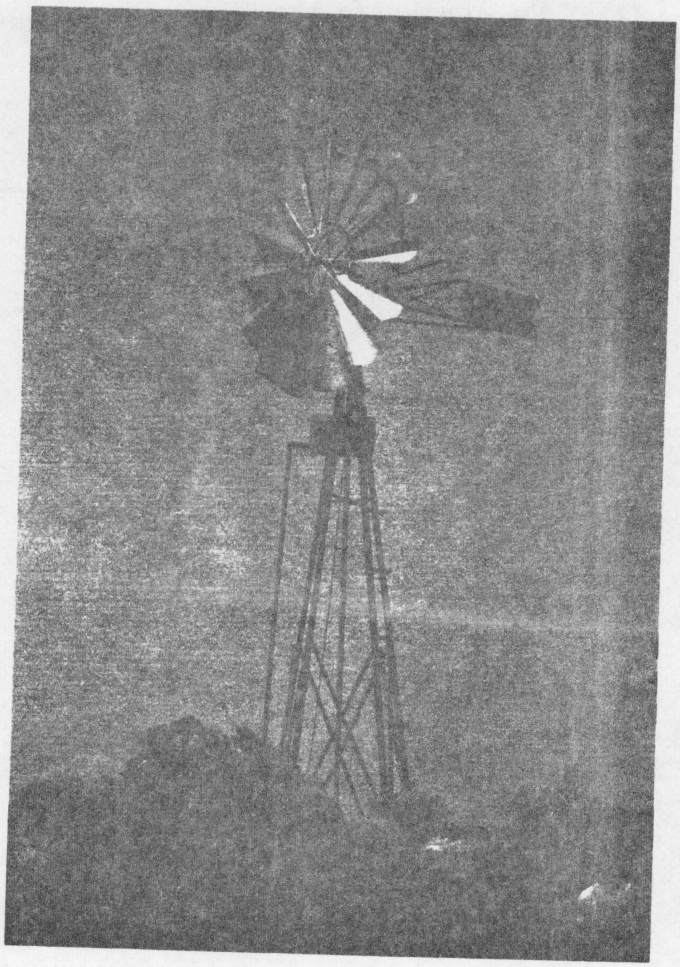
Example 15: Aerogenerator at Achada da Baleia (Cape Verde Is.) pg. 221

Example 16: Aerogenerator for the lighthouse at Luis (Cape Verde Is.) pg. 223

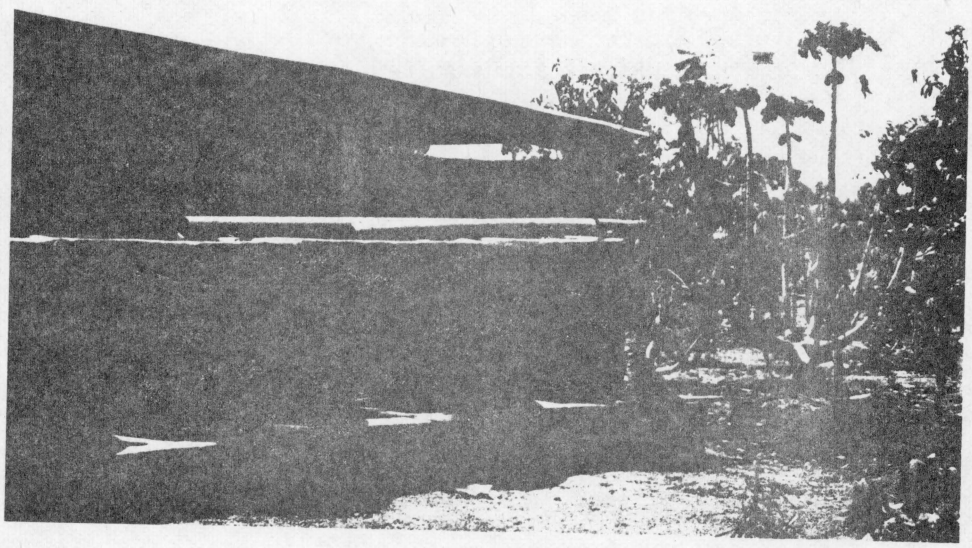
1 - MULTIPLE-BLADE WIND TURBINES

Multiple-blade wind pumps were invented over a century ago. Considering their numerous advantages (low cost, rustic simplicity, possibility of pumping at low wind speed, ease of maintenance, etc.), their use is becoming more and more widespread throughout the world, both in developed and developing countries. These same wind turbines are being used successfully in many African countries, as shown in the inspection reports. The encouraging results would justify starting up integral production units in Western Africa, as has been done for many years in the Cape Verde Is.





. Water storage
(10 m^3)



EXAMPLE 1	OASIS MULTIPLE-BLADE WIND TURBINE FOR THE CATHOLIC MISSION AT TOESSE / UPPER VOLTA
Inspection report:	

1. Location

Toesse is located 70 km south of Ouagadougou, on the route to Po.

2. Equipment installed

Oasis #3 multiple-blade wind turbine (Poncelet, France), installed in 1978. Manometric head = approx. 15 m.

3. Hydraulic system

The wind turbine can power several tanks. The mission has, in addition, a hand pump and two small motor pumps.

4. Means of installation

Members of the mission installed the wind turbine themselves, without any particular difficulties.

5. Utilization of the water

Drinking water for the mission, watering the garden.

6. Wind turbine performance

The wind turbine functions properly. According to Father Trappi, it usually provides several m^3 per day, the maximum being about 4 m^3/day.

7. Wind regularity

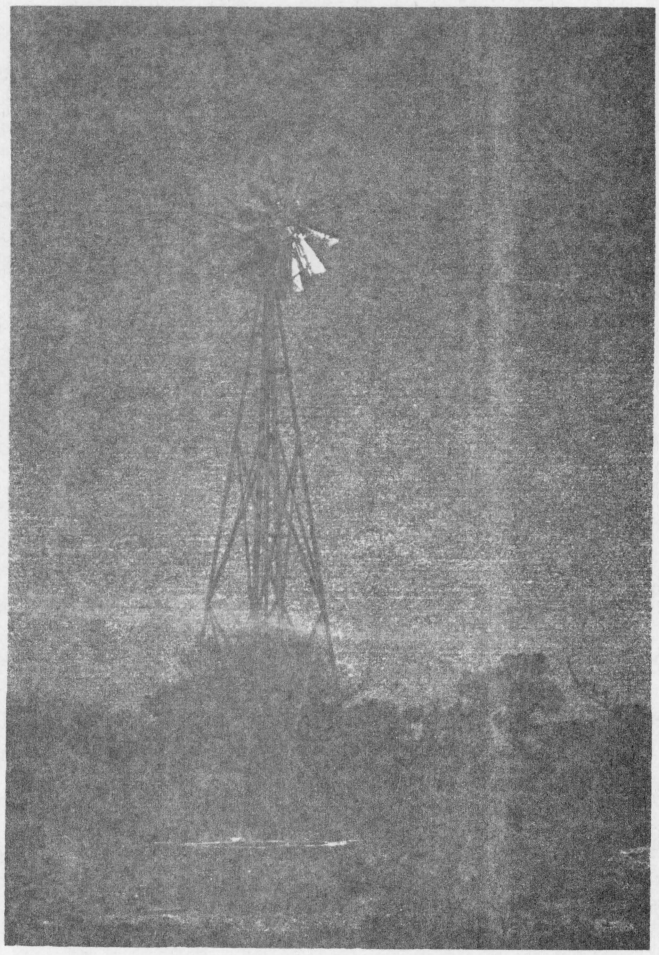
The wind, which is of average force, is very constant, except during the periods of wintering. The present tanks are amply sufficient.

8. Reliability

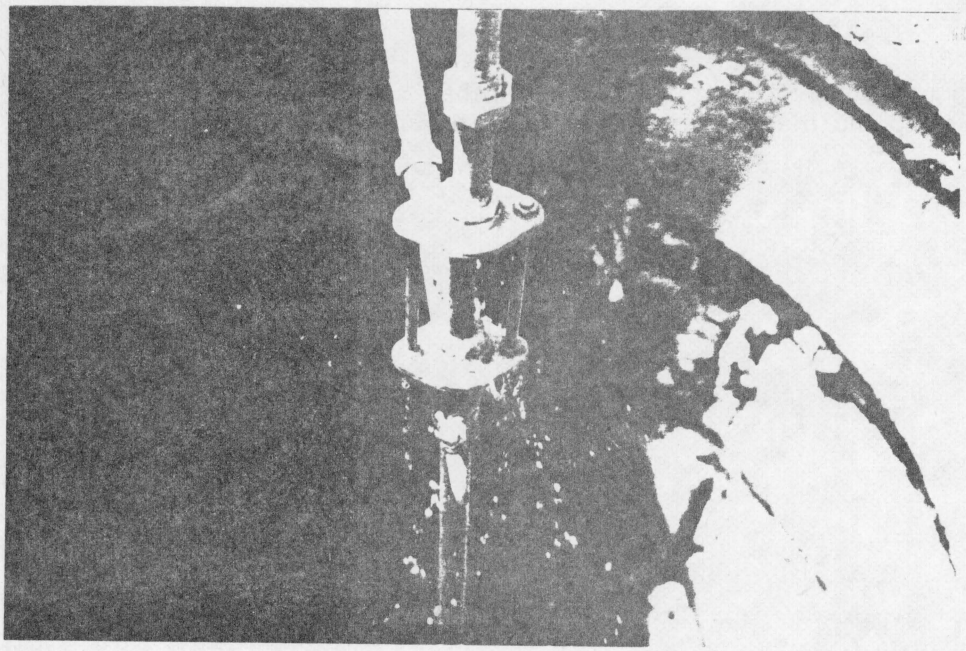
The wind turbine has suffered no breakdowns since its installation. It withstood several tornados without jamming. There are some spare parts at the site.

9. Cost of the wind turbine itself, with the pump

Approximately 300,000 CFA Francs, delivered Ouagadougou.



. Leak in the stuffing box



EXAMPLE 2	OASIS MULTIPLE-BLADE WIND TURBINE FOR THE PROTESTANT MISSION AT TOESSE / UPPER VOLTA
Inspection report:	

1. Location

Toesse is located 70 km south of Ouagadougou, on the route to Po.

2. Equipment installed

Oasis #3 multiple-blade wind turbine (Poncelet, France), installed about one year ago. Manometric head = approx. 12 m.

3. Utilization of the water

Drinking water for the Pastor's mission, watering the garden.

4. Wind turbine performance

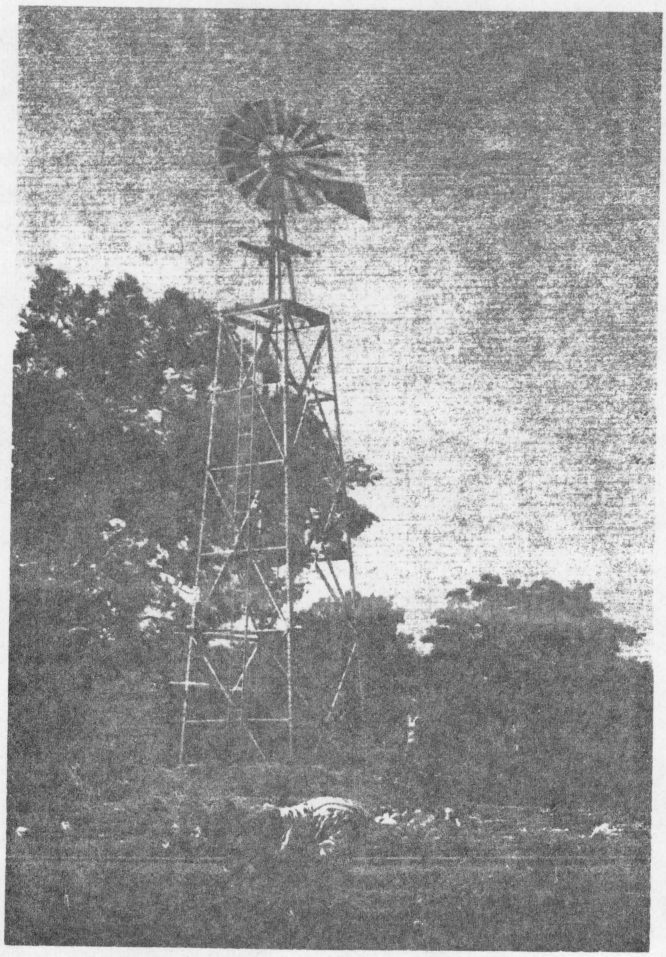
The wind turbine functions properly. Its delivery rate is too great for the mission, but insufficient for the garden, which is extensive, and includes many saplings.

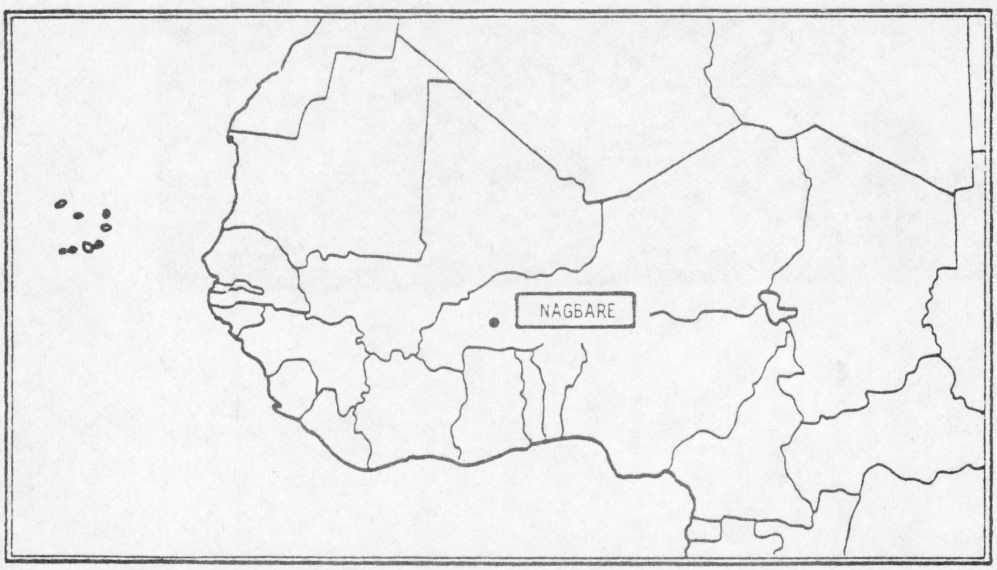
5. Reliability

The wind turbine has suffered no breakdowns since its installation. A water leak was noticed at the pump's stuffing box, but this is not serious (need to tighten the joint).

6. Spare pump

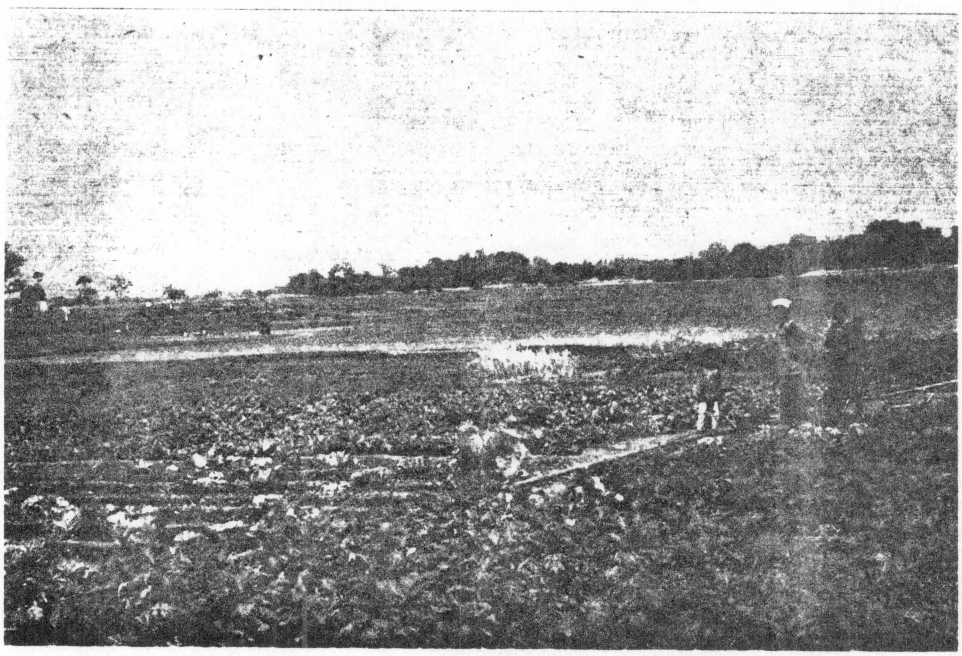
The mission has an electric generating unit that runs, among other things, a small immersible pump that goes with the wind turbine.




NAGBARE

EXAMPLE 3	MULTIPLE-BLADE WIND TURBINE AT NAGBARE / UPPER VOLTA
Inspection report:	

This wind turbine, shown in the photographs below, was installed in 1938. It provides water for a Protestant mission and a truck farming zone. It functioned without a problem for about twenty years.



. Truck farming zone

EXAMPLE 4	OASIS MULTIPLE-BLADE WIND TURBINE AT KOMBISSIRI / UPPER VOLTA
Inspection report:	

The construction project of the Catholic mission at Kombissiri (40 km south of Ouagadougou), operational in April 1981, includes:

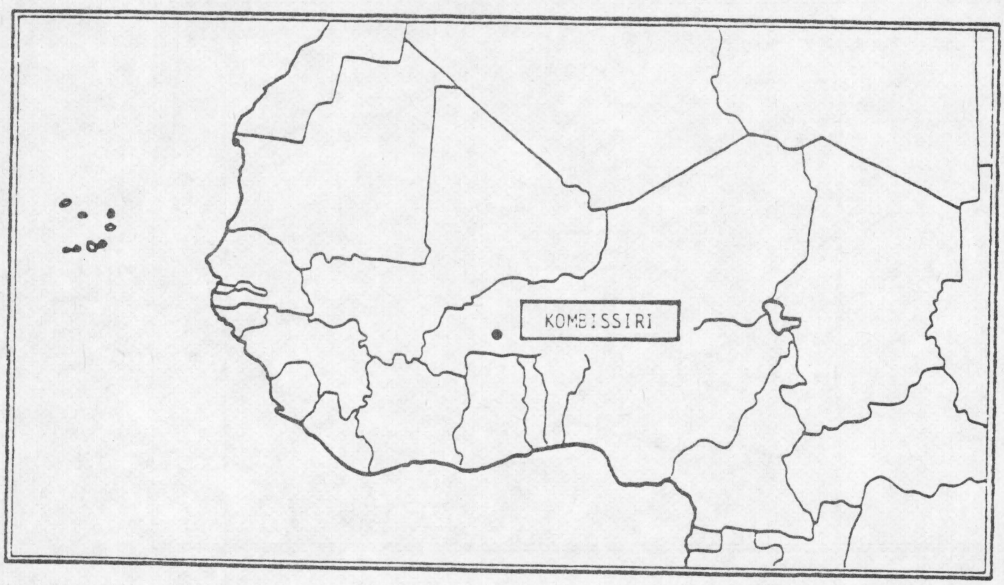
- an Oasis wind turbine (Poncelet, France)
  cost: 330,000 CFA Francs

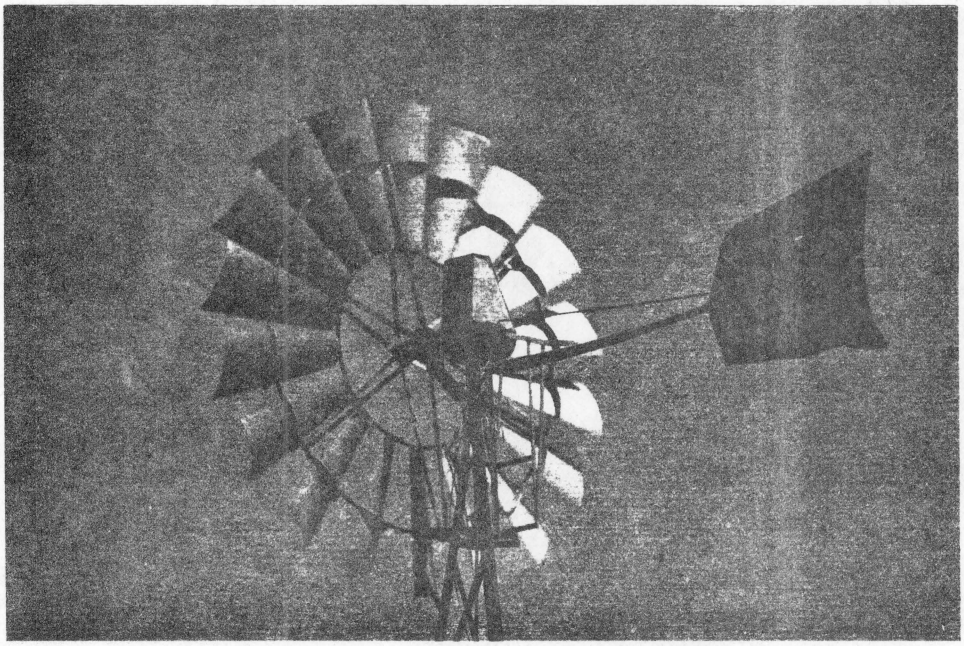
- a 4.5 m^3 steel water tower, raised 5 m off the ground
  cost: 225,000 CFA Francs

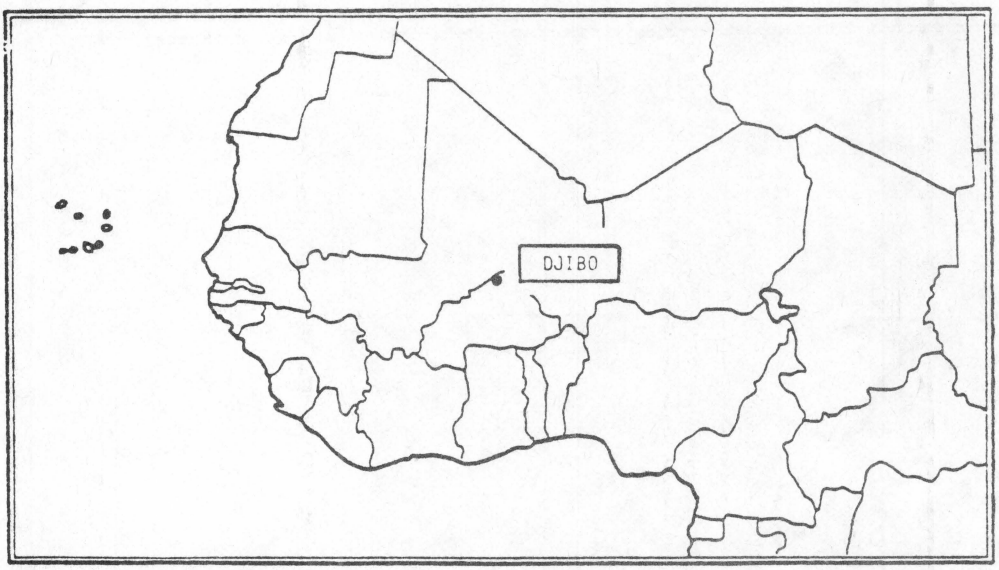
- a network of PVC tubing (thirty-two 6m, 1.25' Ø tubes)
  cost: 150,000 CFA Francs

The total cost will be approximately 700,000 CFA Francs.

The water will be used to supply the Catholic mission and a school that can board fifteen persons, which is managed by the nuns.

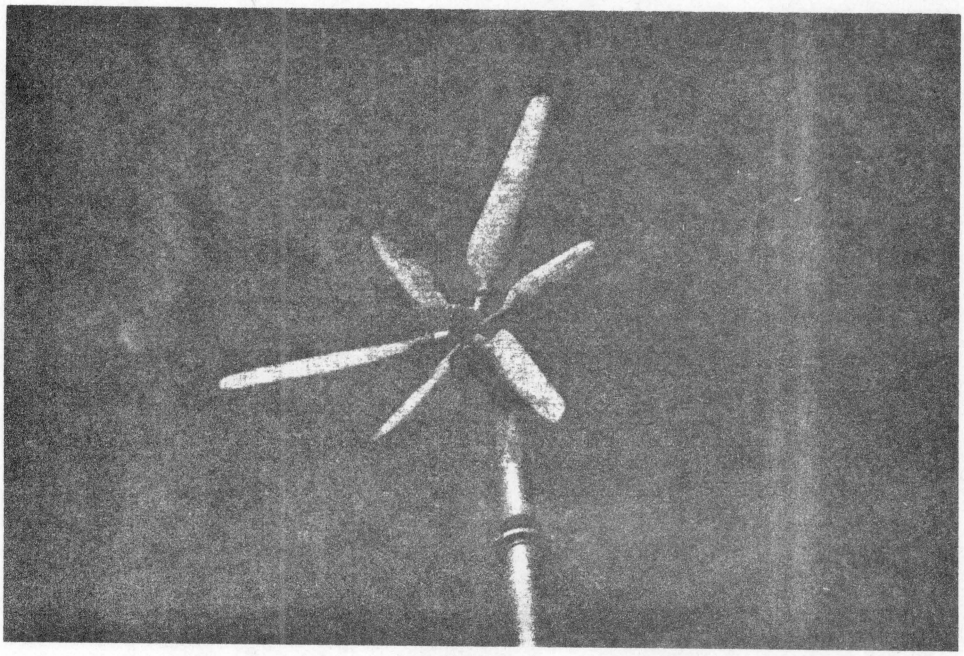


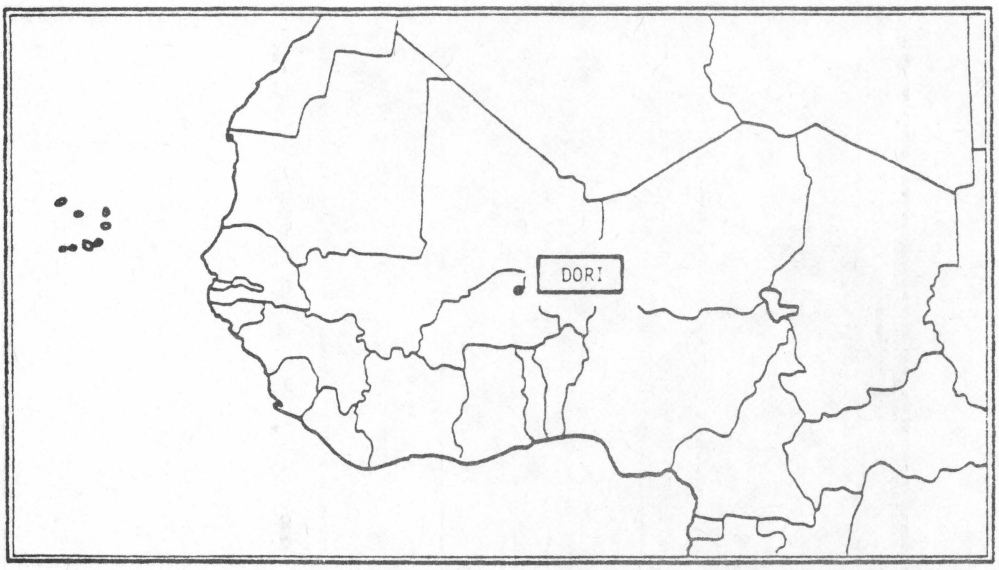



DJIBO

EXAMPLE 5	METTERS MULTIPLE-BLADE WIND TURBINE AT DJIBO / UPPER VOLTA
Inspection report: 22 May 1980	

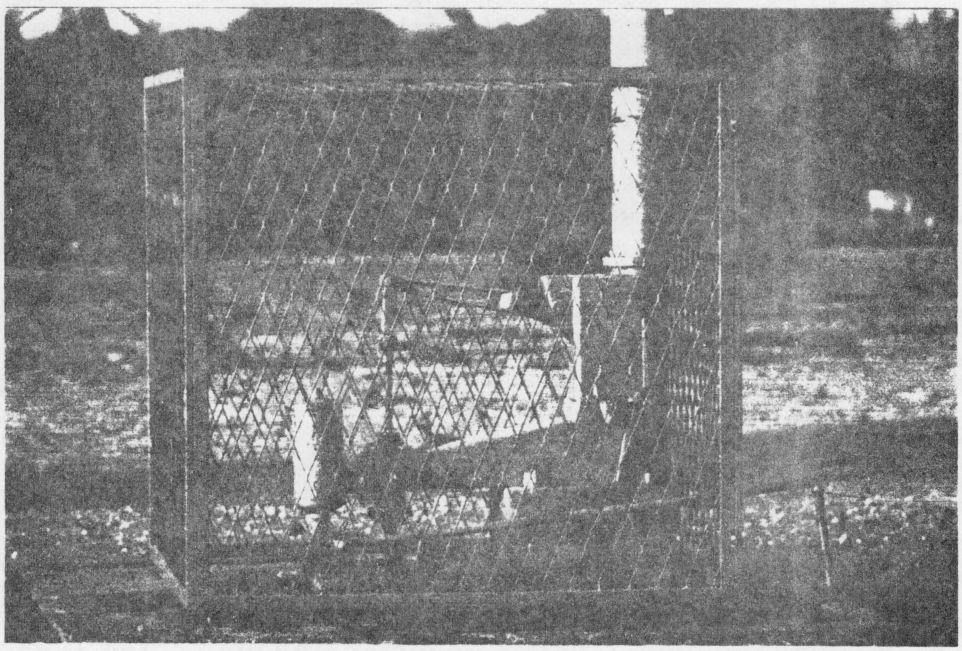
This multiple-blade wind turbine is located at the hospital in Djibo, in northern Upper Volta. It is a Metters wind turbine, with a diameter of about 4 m, and it operated satisfactorily when we visited it on 22 May 1980.

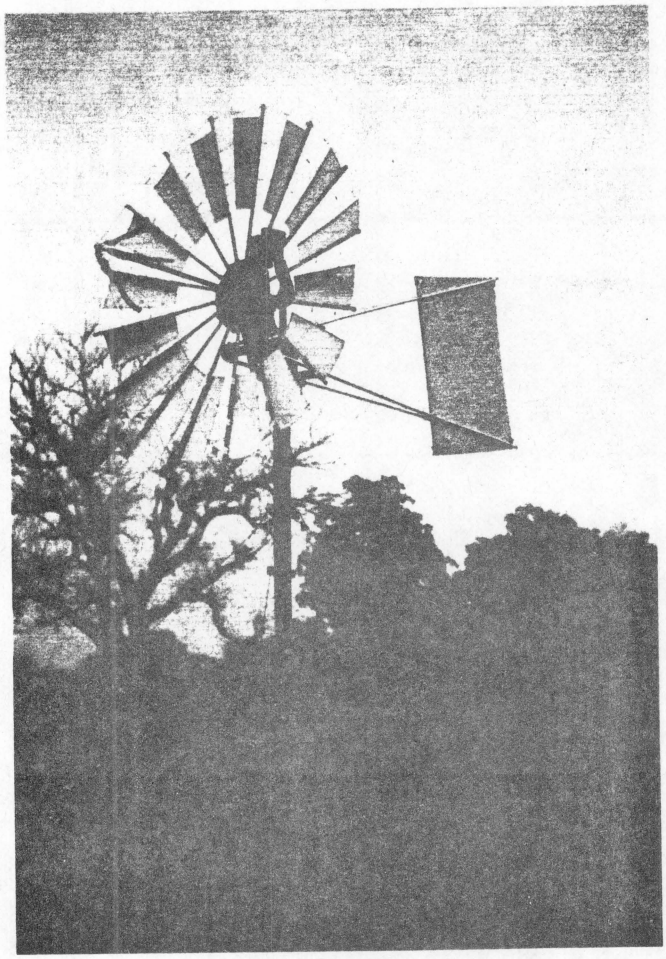


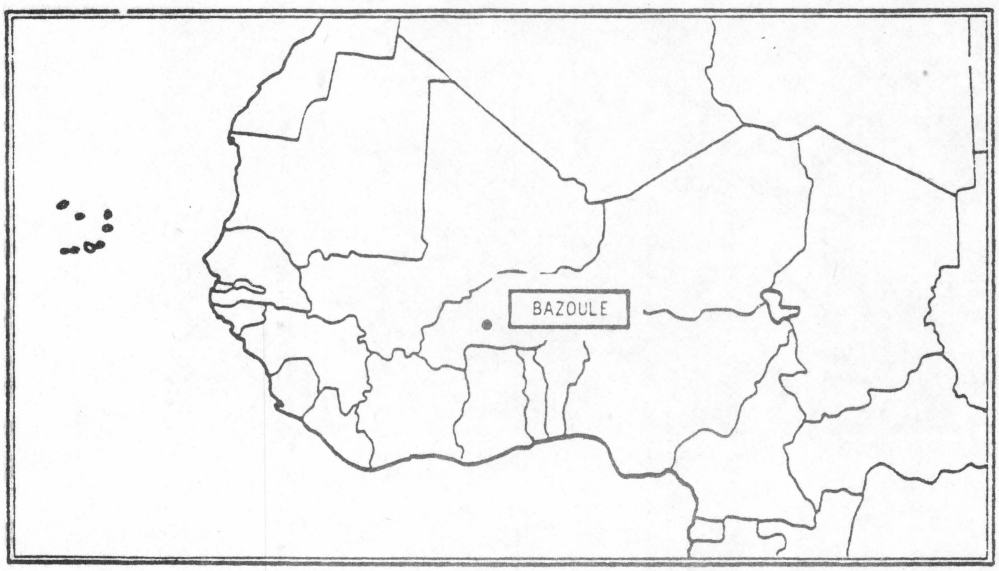

DORI

EXAMPLE 6	LUBING MULTIPLE-BLADE WIND TURBINE AT DORI / UPPER VOLTA
Inspection report: 21 May 1980	

This German-made wind turbine, significantly different from preceding models, comes equipped with plastic blades. It was operating satisfactorily the day of our visit. Another one of the same type has been erected in northern Upper Volta.






BAZOULE

EXAMPLE 7	MULTIPLE-BLADE WIND TURBINE AT BAZOULE / UPPER VOLTA
Inspection report:	

1. Location

Bazoule is located 30 km west of Ouagadougou.

2. Equipment installed

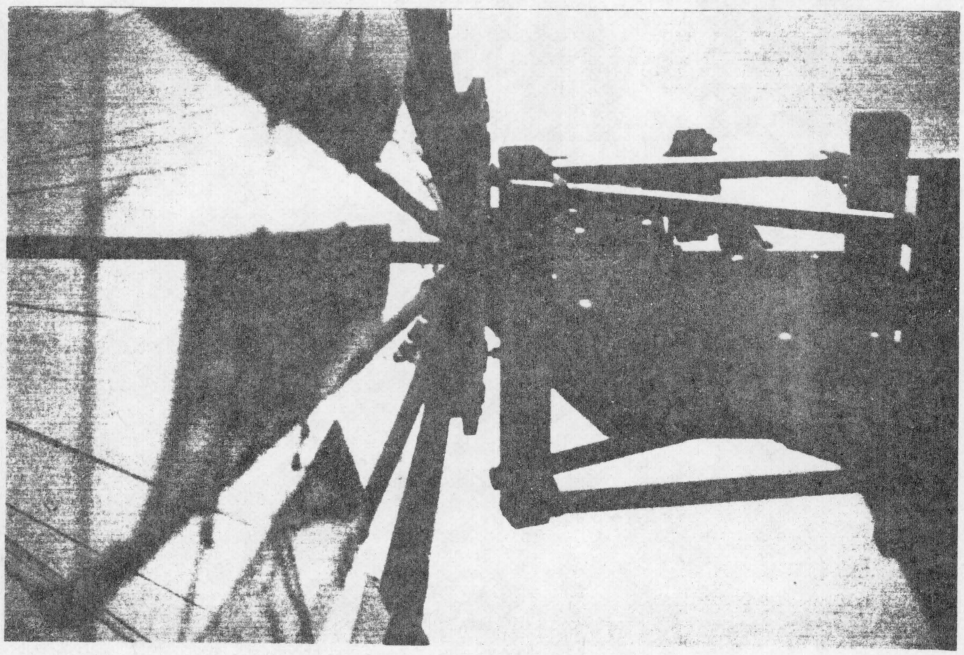
This wind turbine, almost entirely made of wood, has spokes of thin aluminum foil that retract under pressure from the wind during tornados. Circular motion is transformed into rectilinear motion by means of a wooden cam.

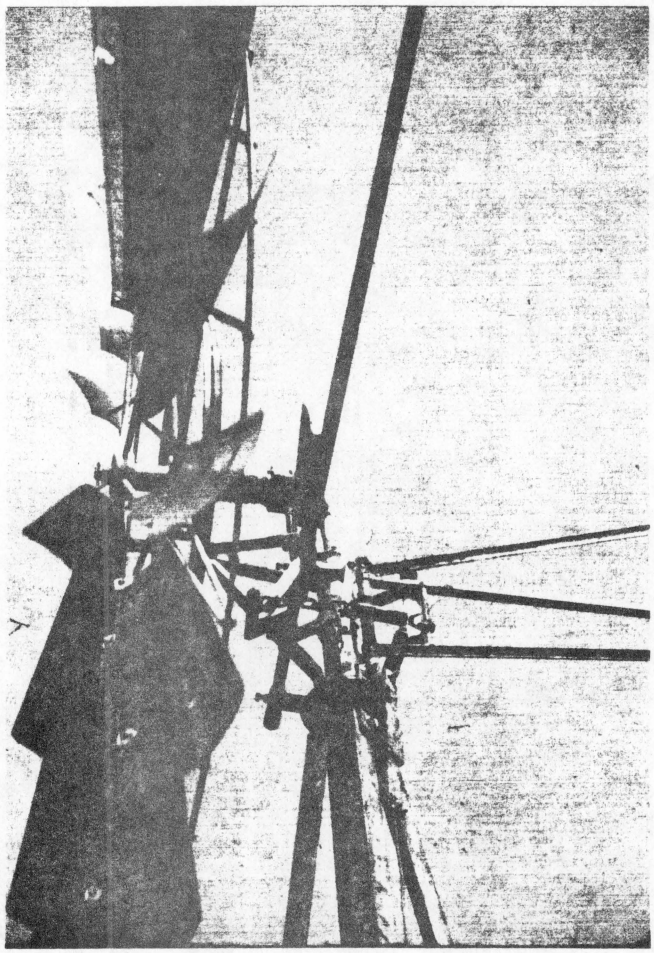
3. Utilization

The wind turbine runs a non-industrial pump by means of a lever.

4. Remark

This model is interesting in terms of the techniques used. It is probably fragile, though.





EXAMPLE 8	OASIS MULIPLE-BLADE WIND TURBINE AT GABAN / CAMEROON
Inspection report:	

1. Location

This wind turbine has been erected at Gaban (5 km from Lara), in the extreme northern part of Cameroon.

2. Equipment installed and its utilization

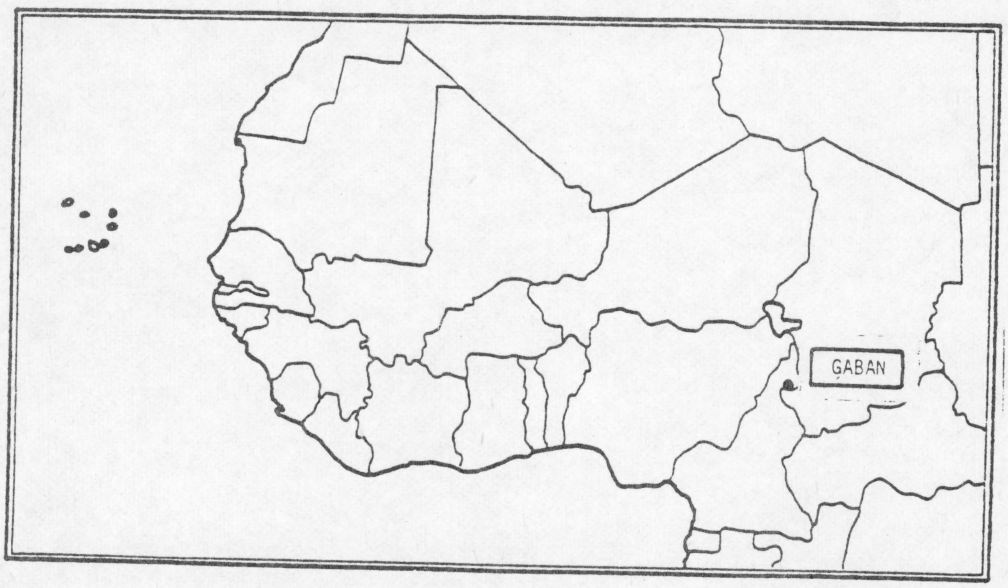
An Oasis wind turbine (Poncelet, France) was installed. It provides for the personal water needs of a couple of Volontaires du Progrès as well as for their vegetable garden. For this utilization it is clearly oversized. Its flow rate is estimated at 400 liters/hour with a manometric head of 20 m. Direct backflow when the tank is full avoids wasting the pumped water.

3. Reliability

The wind turbine operates constantly with virtually no maintenance (merely lubricating the connecting rod once every six months). It has been operating since 1978 without ever malfunctioning.

4. Cost

The cost of the wind turbine delivered to Gaban is 8,000 FF.

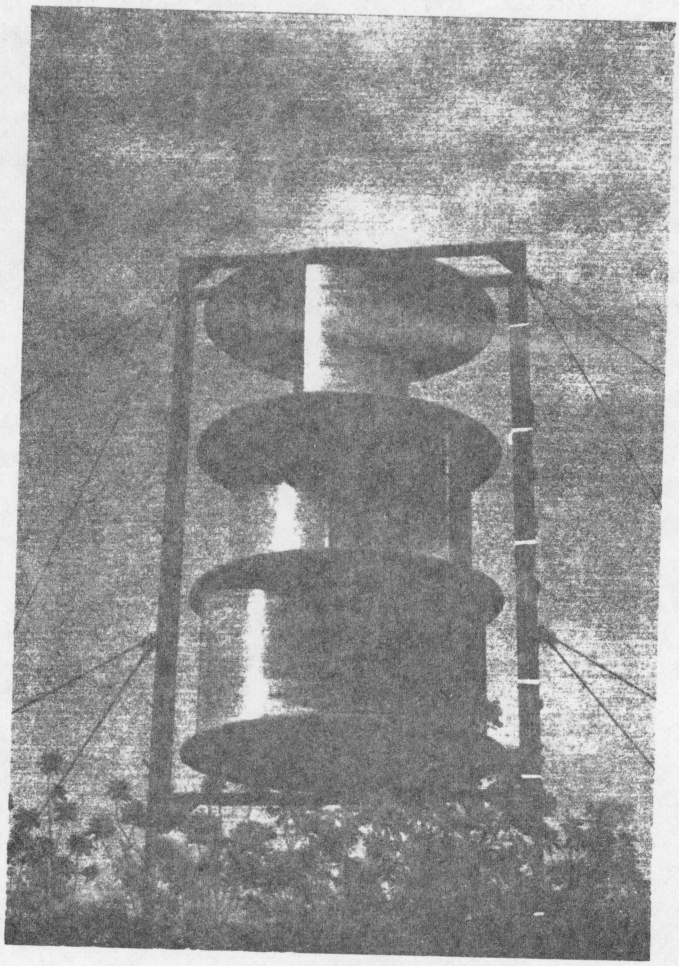


EXAMPLE 9	SAHORES MULTIPLE-BLADE WIND TURBINES MALI PUMPING

Several types of non-industrial wind pumps have been developed in Western Africa, thanks to the initiative of certain development organizations (GRET, Peace Corps). Among these is the Sahores type:

- rotor diameter = 2.70 m
- basic flow rate for a wind speed of 4 m/sec. = 1 m^3/hr., MH = 12 m, for an average of 8 hrs./day (Mali)
- cost installed = $200 - 300
- equivalent power = 7.5 - 15 kgm

Twenty-five wind turbines of this type have been erected in Mali. The life span of this equipment is still unknown.



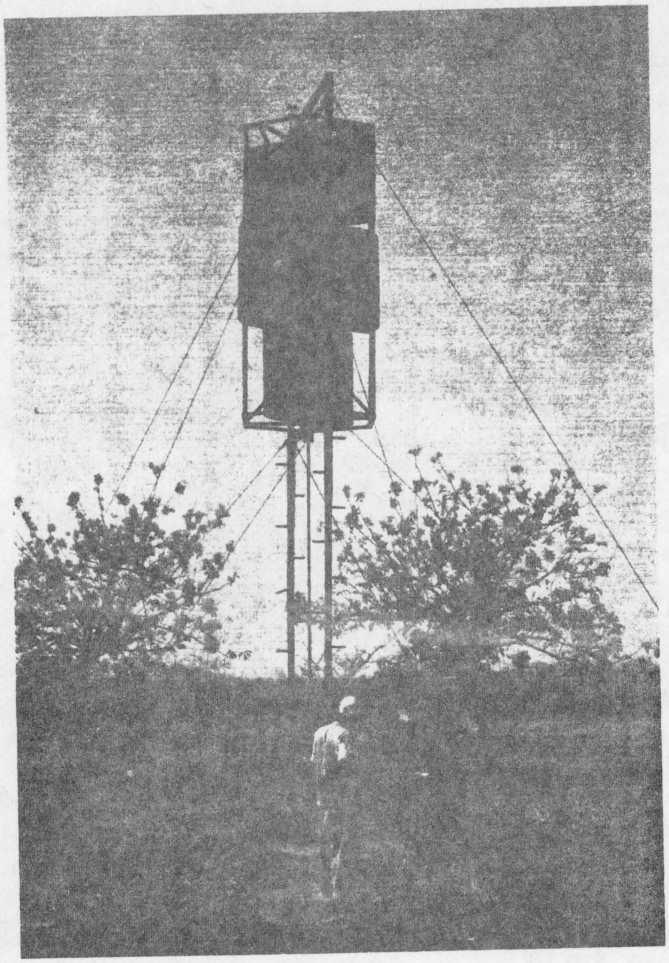
2 - SAVONIUS WIND TURBINES

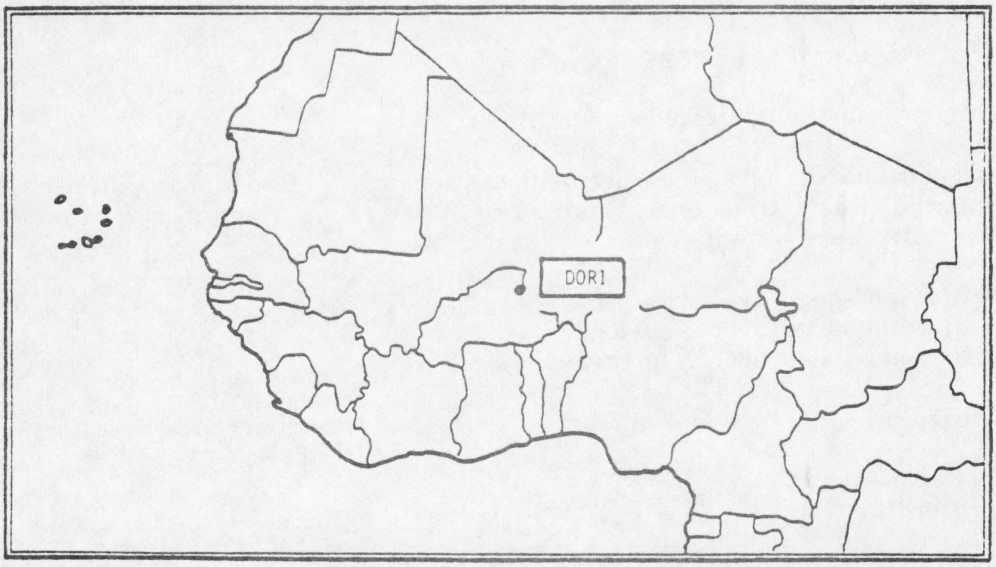
A large-scale applied research program in Senegal (IUT/Sinaes) and Upper Volta (EIER) has been concentrating on Savonius wind pumps. Their relatively simple design (rustic, possibility of local manufacture) and their ability to operate at low wind speeds (as do multiple-blade wind turbines) justify the hopes that have been placed in them. It is, nevertheless, difficult to appraise them, considering that they are still experimental in nature. Their reliability has not yet been fully demonstrated, even if important achievements have been made, that would tend to encourage a certain amount of optimism.

Another important question is if Savonius wind turbines are more interesting than conventional multiple-blade wind turbines in terms of:

- performance
- reliability
- investment cost
- maintenance costs
- ease of local manufacture, etc.

Although the answer to this question is not necessarily obvious, multiple-blade wind turbines do present some concrete advantages. Perhaps each is well suited to a particular environment in terms of desired flow rates, manometric head, local wind speed, etc. A more detailed comparison would be interesting.




DORI

EXAMPLE 10	E I E R SAVONIUS WIND TURBINE AT DORI / UPPER VOLTA
From E I E R evaluation report	

This wind turbine, erected three years ago in northern Upper Volta by EIER, has given interesting results. Below is an excerpt of the evaluation report drawn up by Mr. B. Giraud of EIER.

EIER - Experiments in Wind Energy

Since February 1978, EIER has been running tests on a Savonius wind turbine built by the school at Dori. These tests were designed to determine the reliability of this type of wind turbine, in a region where natural conditions are very tough, as well as the possibility of using this type of turbine for pumping water as part of a village water supply program. After two years in operation, this small prototype produced the following results:

Specifications of the wind turbine

- rotor diameter = 1.60 m
- rotor height = 3.00 m
- overall height = 8.00 m
- Vergnet pump, modified by EIER, submerged to a depth of 22 m
- static level of the bore-hole = 13 m
- maximum flow rate of the bore-hole = 250 - 300 liters/hr. with a lowering of 9 m.

Readings:

- average daily flow rate over a period of one year = 1.419 liters/day
- maximum recorded daily flow rate = 5.500 liters
- number of days that the flow rate is under 33% of the annual daily average

$$\left(\frac{1.419 \times 67}{100} = 946 \text{ liters}\right) = 11 \text{ days}$$

- average during the low-wind periods = 400 liters.

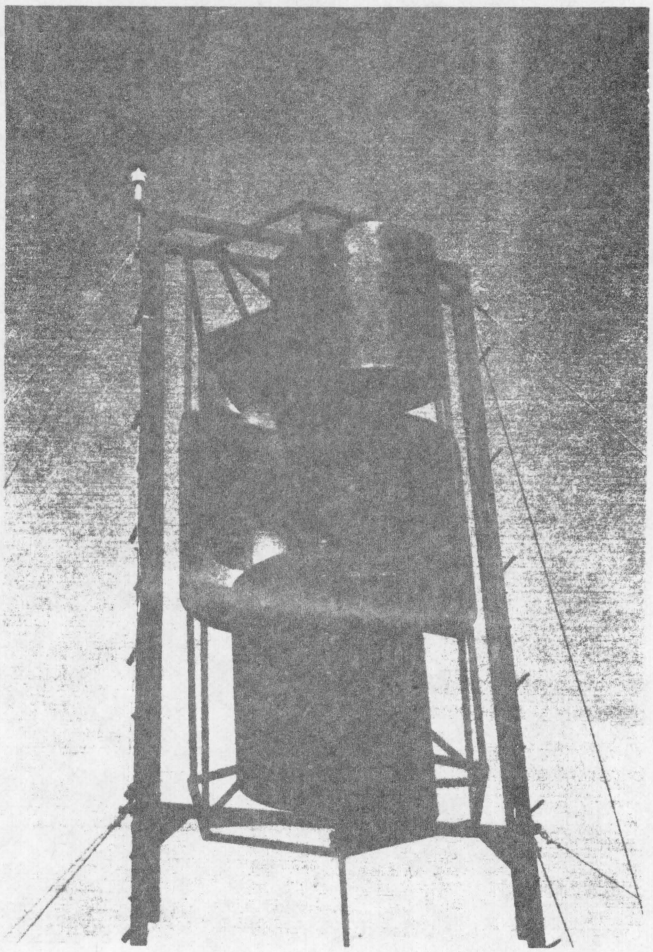
EIER designed and set up a measurement station on location whose purpose is to calculate the area's wind energy potential. After one year of operation the following results were noted:

- 4,500 hours of wind speed over 3 m/sec.
- 3,000 hours of wind speed over 5 m/sec.
- 1,000 hours of wind speed over 7 m/sec.

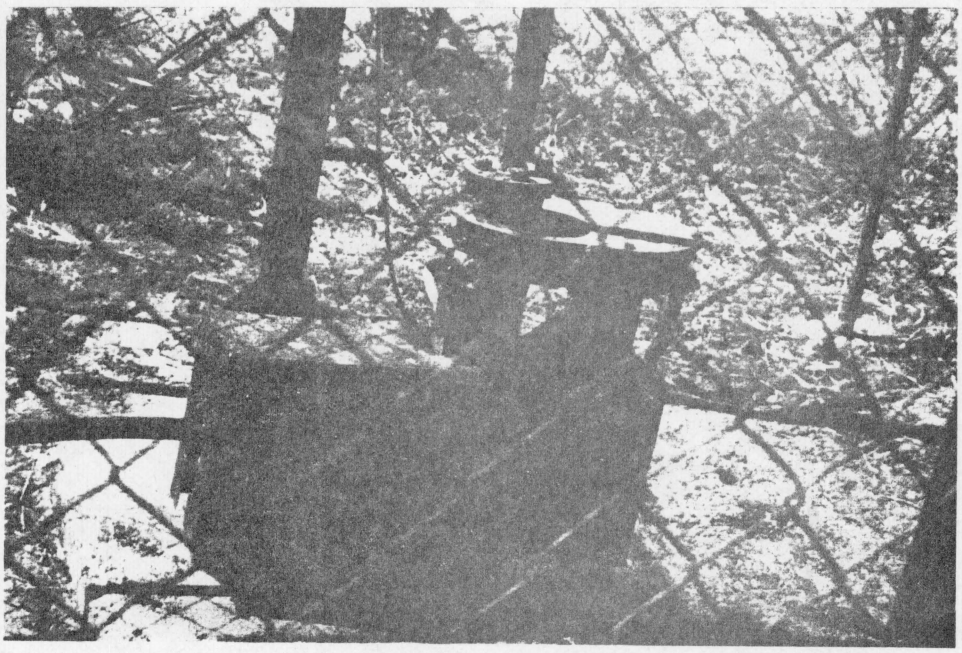
The three thresholds -- 3, 5, and 7 m/sec. -- correspond to different operating speeds:

- 3 m/sec. = rotor start-up
- 5 m/sec. = normal operating speed
- 7 m/sec. = initial operating speed

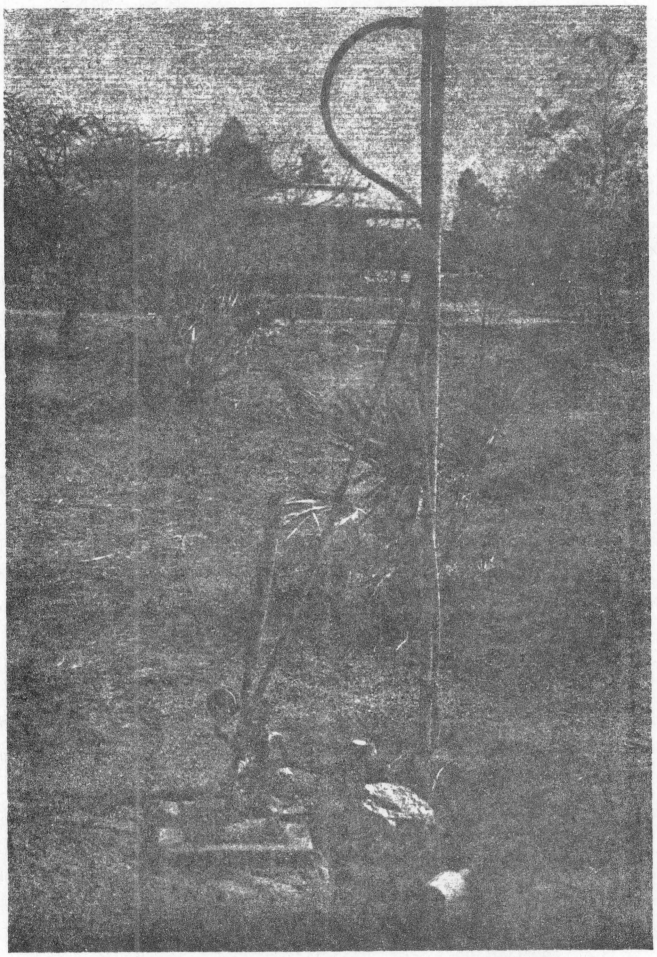
. Rotor

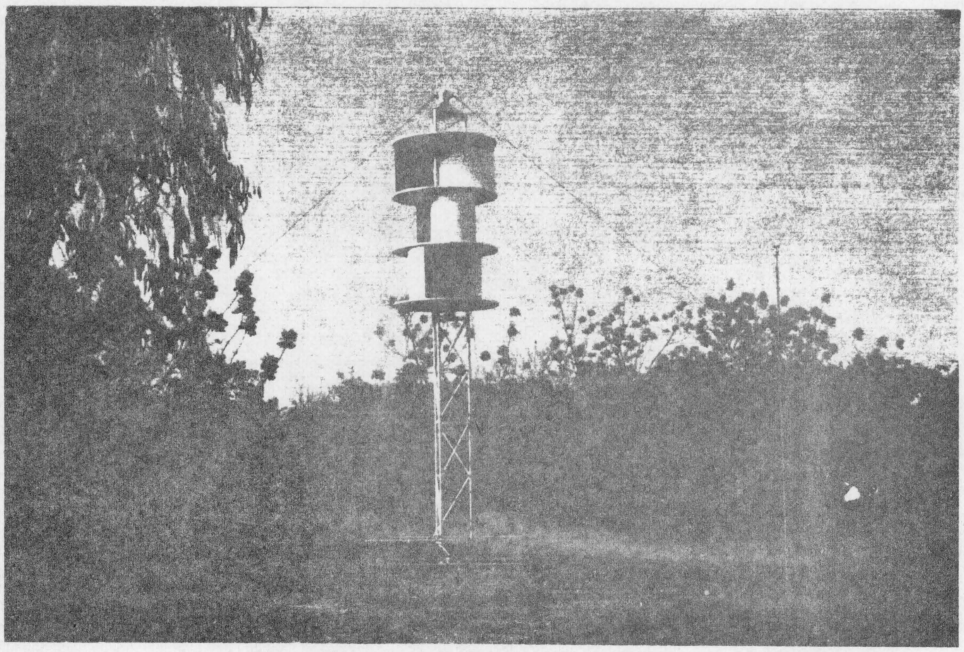


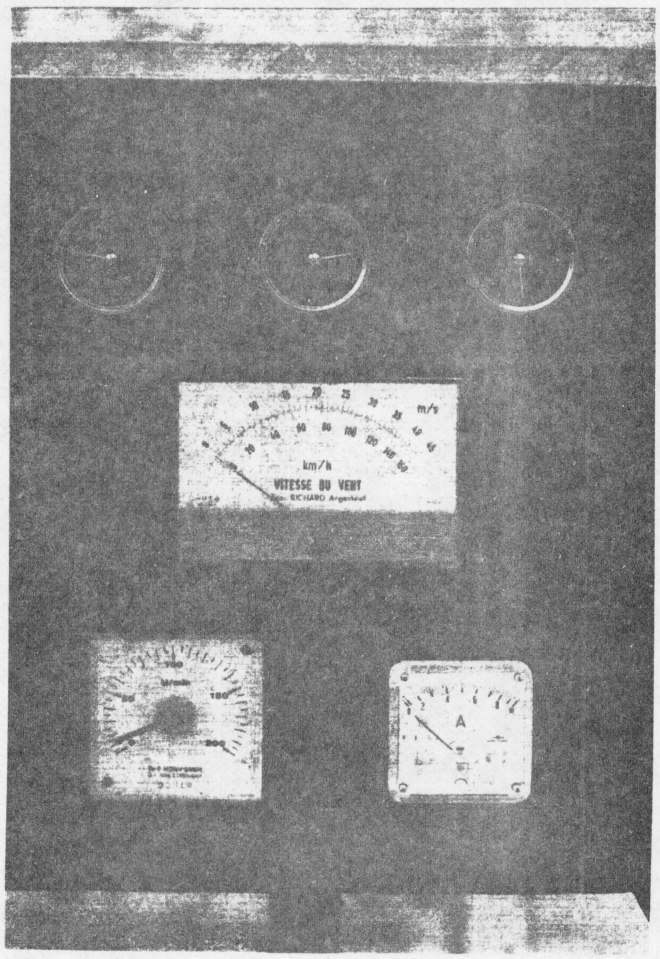
. Press connected to
a Vergnet pump



for a Darrieus rotor which, when combined with a Savonius rotor, undergoes a power increase of 400%. All the results recorded indicate that this type of wind turbine, with its low cost price, can be used for village water pumping if used in conjunction with a storage facility for periods of low wind.





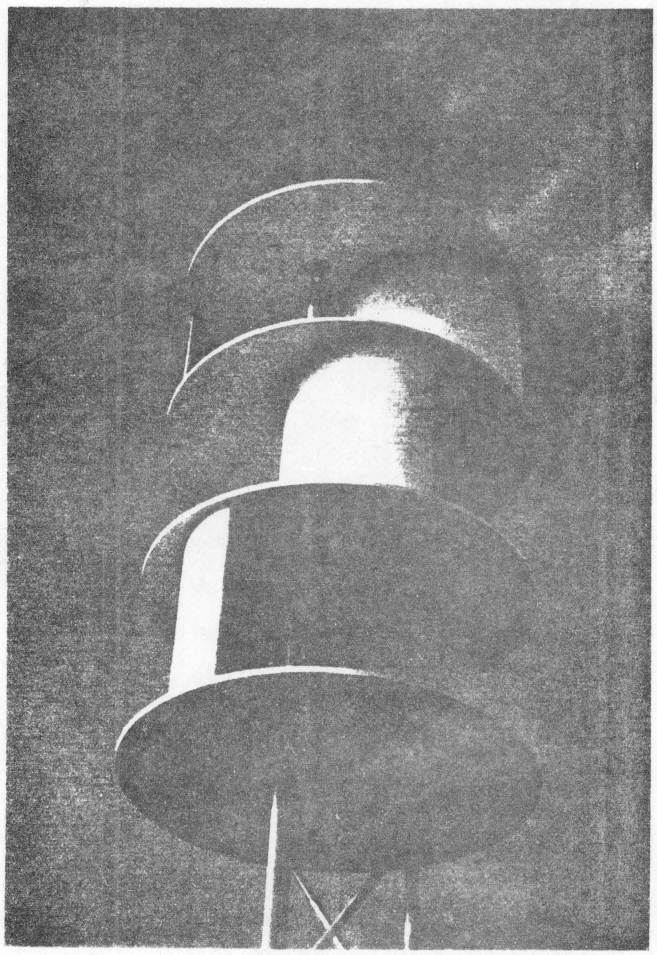


. Measuring wind energy potential

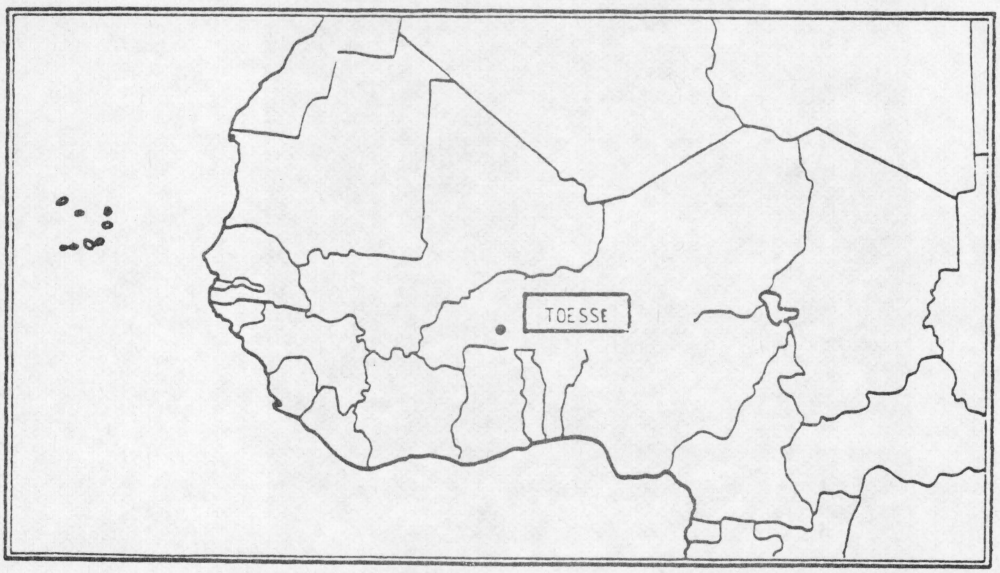
EXAMPLE 11	SAVONIUS WIND TURBINE OF THE E I E R OUAGADOUGOU / UPPER VOLTA

Location

The Ecole Inter-Etats de l'Equipment Rural (EIER), Ouagadougou.



. Rotor


TOESSE

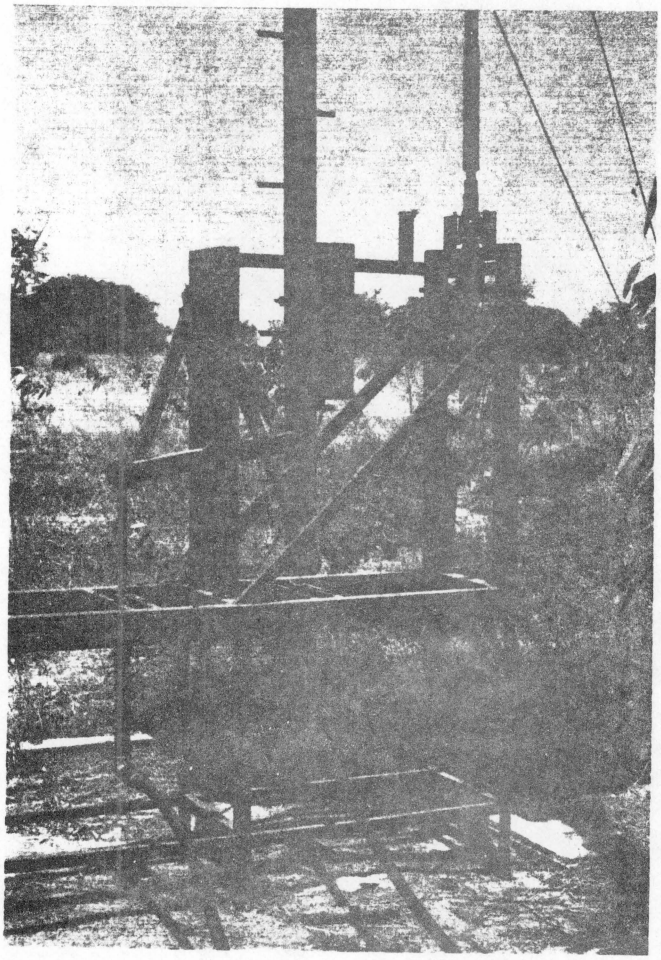
EXAMPLE 12	SAVONIUS WIND TURBINE OF THE E I E R TOESSE / UPPER VOLTA

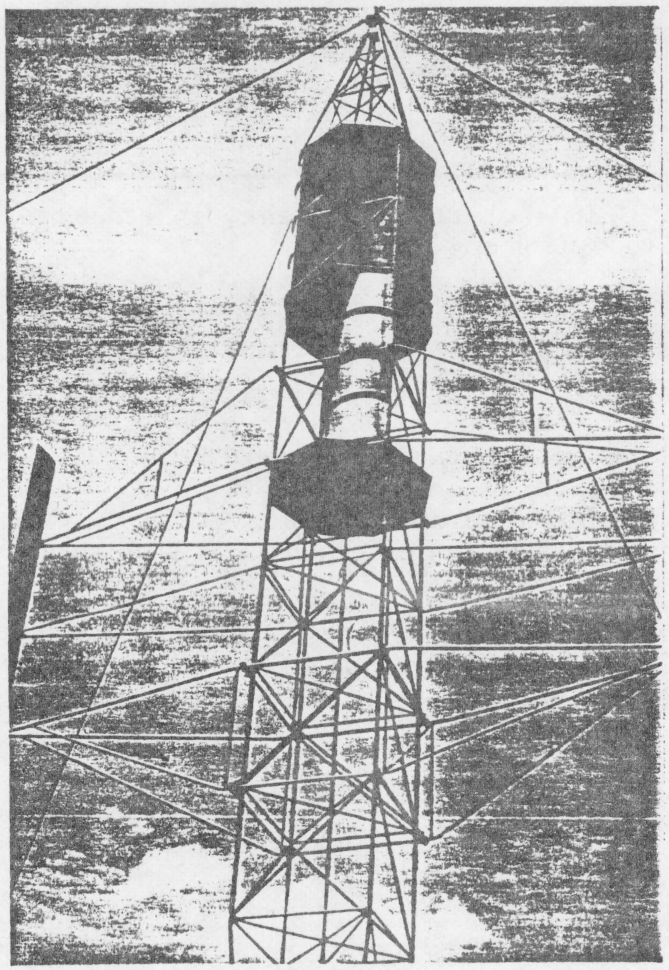
1. Location

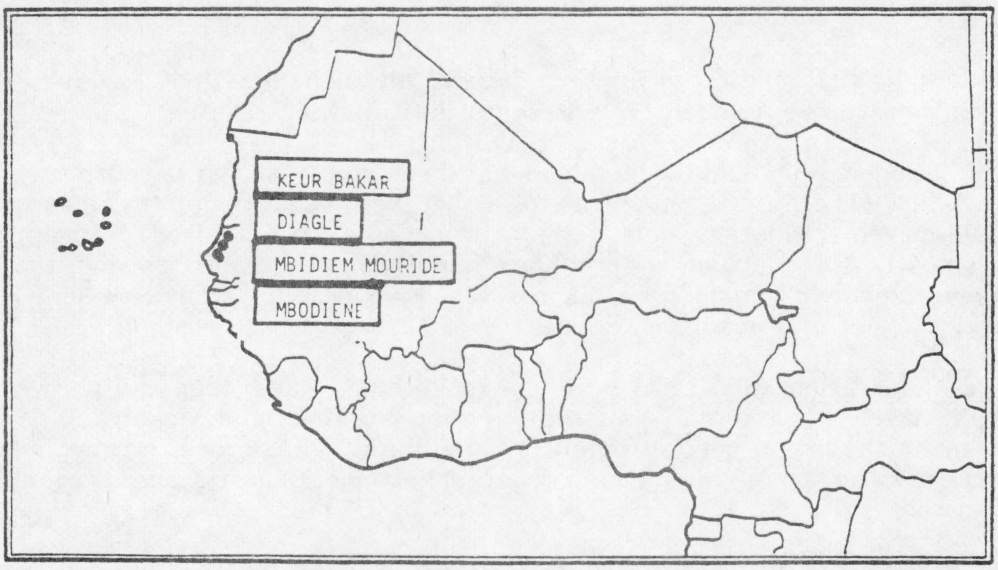
The Protestant mission at Toesse, 80 km from Ouagadougou.

2. Equipment installed

An EIER wind turbine driving two jacks connected to Vergnet pumps, by means of a cam.






KEUR BAKAR
DIAGLE
MBIDIEM MOURIDE
MBODIENE

EXAMPLE 13	SAVONIUS WIND TURBINE I U T - SINAES SENEGAL

Since 1975 the I. U. T. (Institut Universitaire de Technologie) of Dakar has built four types of wind turbines:

1st generation: 2 troughs (4 half vats, 200 liters each)
fixed design
working surface = 1.9 m²
maximum power 200 W at wind speed = 6 m/sec.

2nd generation SP4: 4 troughs, overall height = 9 m
turning design
working surface = 8.3 m²
maximum power 430 W at wind speed = 7 m/sec.

3rd generation BM3: 2 troughs, height = 20 m
turning design
working surface = 22.4 m²
theoretical maximum power = 1,150 W at wind speed = 7 m/sec.

4th generation BM4: combined Savonius (BM3) - Darrieus wind turbine
turning design
height = 30 m

After testing them at the IUT, 1st, 2nd, and 3rd generation wind turbines were erected in the bush. The BM3 prototype was tested for two months at the IUT. The BM4 prototype has not yet been erected (as of September 1980).

Performance

We could not visit these turbines in person at their locations. Nevertheless, a report dated September 1980 presents the following results:

- Savonius 1st generation: Only one model has been built, and it is currently located at Sao, where it is coupled to a Vergnet water pump by means of a chain-driven reduction unit (1:7). Unreliable, it required frequent servicing, mostly for mechanical problems concerning the bearings and the chain. Performance is mediocre -- approx. 20 W (hydraulic) at a wind speed of 5 m/sec.

- Savonius 2nd generation (SP4): Five SP4 wind turbines have been built, two by the IUT, three by a metal construction shop at Thies for Sinaes. Four of these machines have been erected in the bush. Each one is coupled to a Vergnet water pump by means of a crank connecting rod and a press (cylinder-piston).

Keur Bakar (April 1979) - Financed by the FAC: Wind turbine located in the center of the village, blanketed by a totem pole. Water pumped in small quantities. Still operational.

Diagle (January 1978) - Financed by the FAC: After having functioned under difficult conditions and requiring a number of servicing operations, this wind turbine was destroyed by a tornado in July 1979. It has never been replaced.

Mbidiem Mouride (June 1979) - Financed by the FAC: This wind turbine seems to operate correctly.

Mbodiene(April 1979) - Financed by USAID: This wind turbine was destroyed by a violent storm in July 1979 and rebuilt in January 1980. It operated correctly until July 1980 when it was dismantled due to misalignment caused by bearing wear.

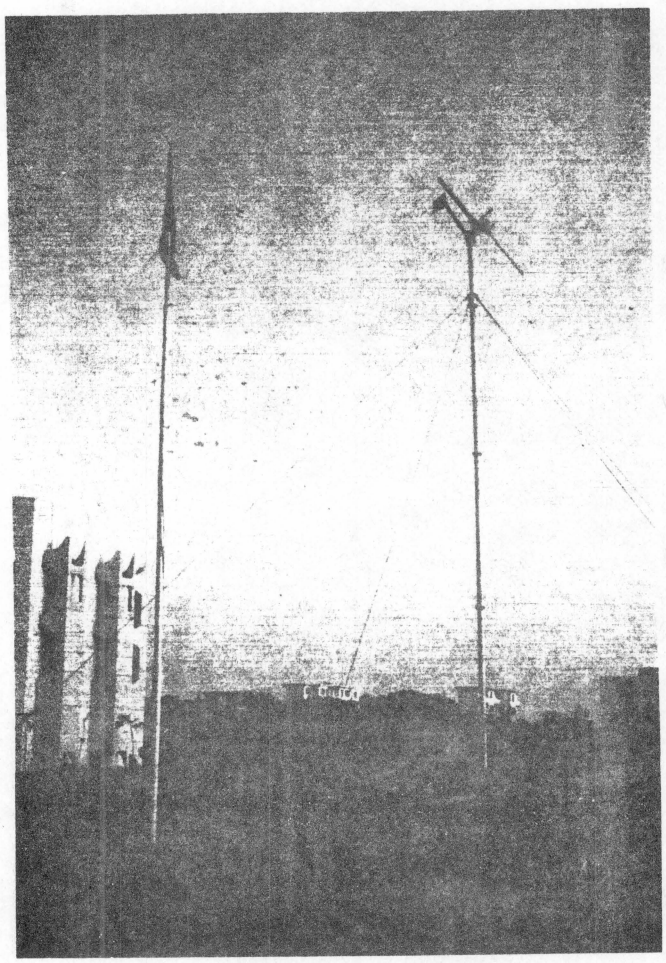
SEMA's comments:

These partially disappointing results do not indicate that the technology utilized is inappropriate, rather, applied research is needed before any large-scale distribution can take place in the bush, which is a very harsh environment. Coupling the wind turbines to Vergnet pumps is an interesting approach currently being applied by EIER in Upper Volta.

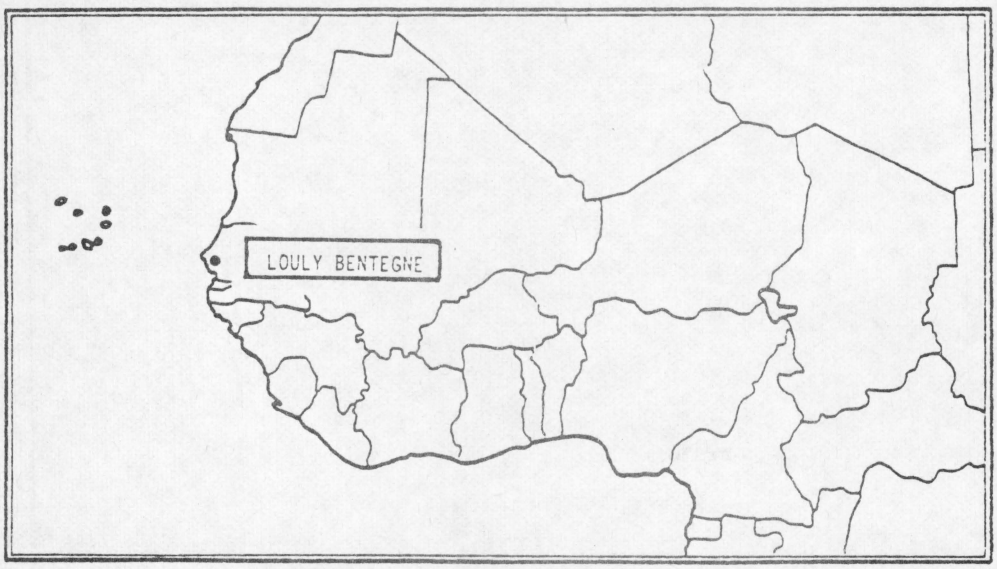
3 - AEROGENERATORS

In particularly windy locations, especially along the West African coast (Senegal, Mauritania) and in the Cape Verde Islands, aerogenerators can be seen as being an economically and technically interesting solution:

- for pumping, when used with an electric pump,
- more generally, for electricity production in isolated locations (marine beaconing, as in the example given).



(Source AEROWATT)



EXAMPLE 14	AEROWATT AEROGENERATOR AT LOULY-BENTEGNE / SENEGAL PUMPING
Inspection report: July 1981	

1. Location

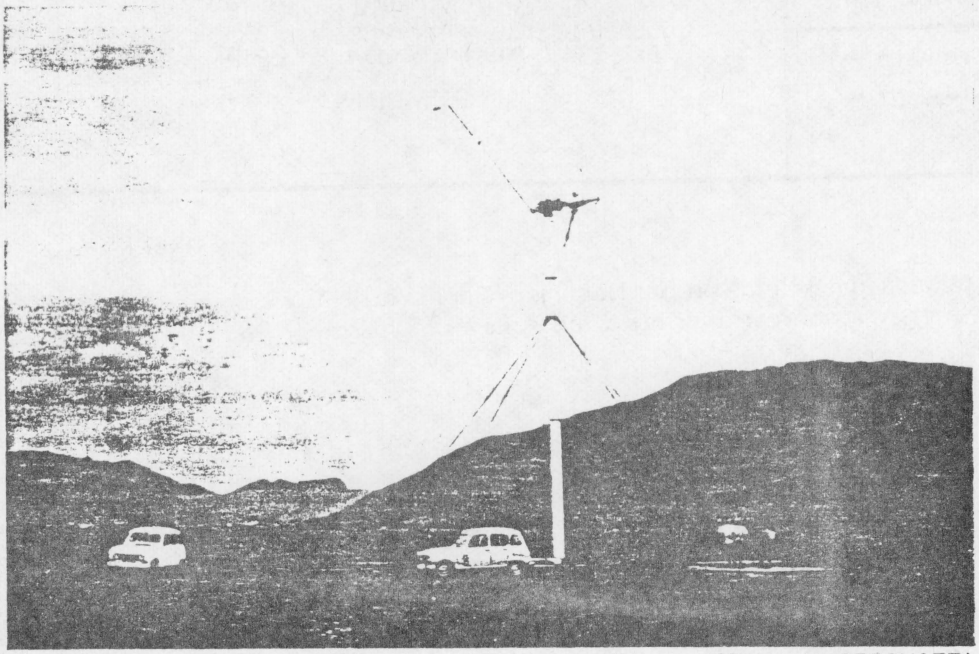
Louly Bentegne is a community located 10 km from M'Bour, south of Dakar.

2. Equipment installed

- An Aerowatt 1100 FP7 aerogenerator with a power of 1.1 KVA at 7 m/sec.
- A Guinard Alta F6/14 pump with a rated hourly flow rate of 17m³/hr. at a MH of 9 m.

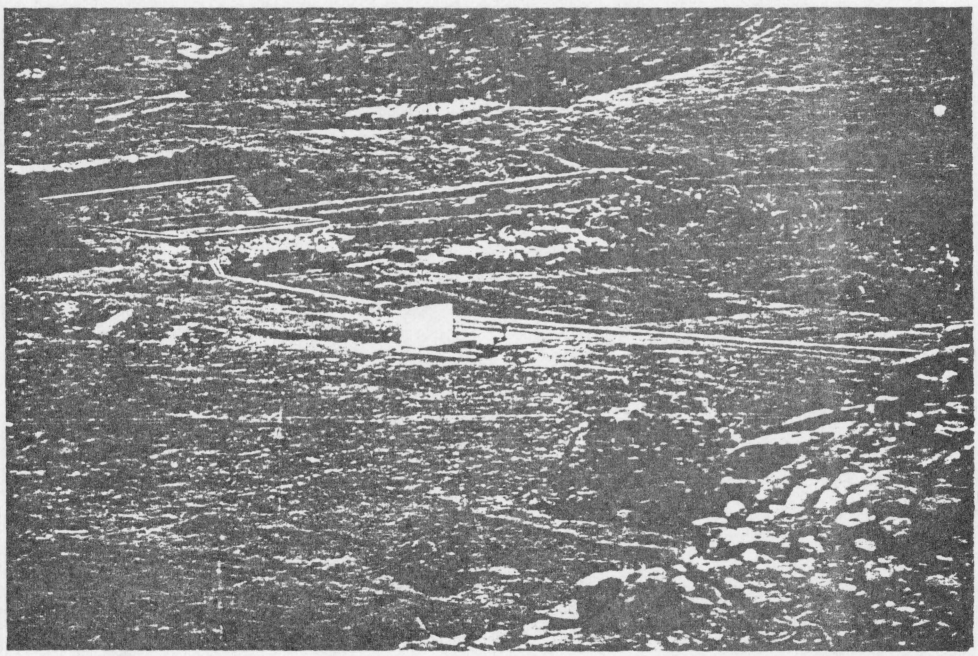
3. Utilization

The equipment, installed in June 1981 as part of the Caritas program, is currently used for a village water supply program in addition to Gueroult hand pumps. In its second phase (Autumn 1982), it will be used to supply water for crop irrigation.



(Source AEROWATT)

. Aérogénérateur



(Source AEROWATT)

. Pompe et périmètre maraîchers

EXAMPLE 15	AEROGENERATOR AT ACHADA DA BALEIA PUMPING
From Aerowatt files	

1. Location

- Station at Achada da Baleia, on Santiago Is. (Cape Verde Is.)
- Local wind energy reserves: average wind speed = 5 m/sec.

2. Utilization

Pumping water for two truck farming zones of 300 and 330 m^2.

3. Equipment installed

- Aerogenerator with a rated power of 4,000 W at 7 m/sec.
- DC motor
- Long-shaft multistage pump

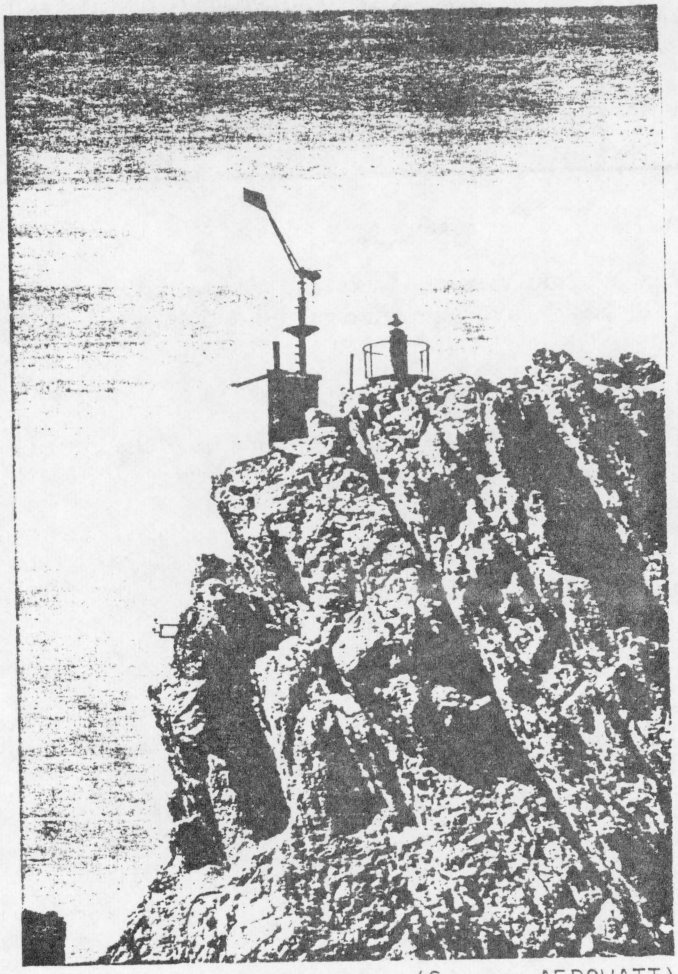
4. Operation

The aerogenerator makes it possible to provide water for either of the two zones at one time. The pumping specifications are as follows:

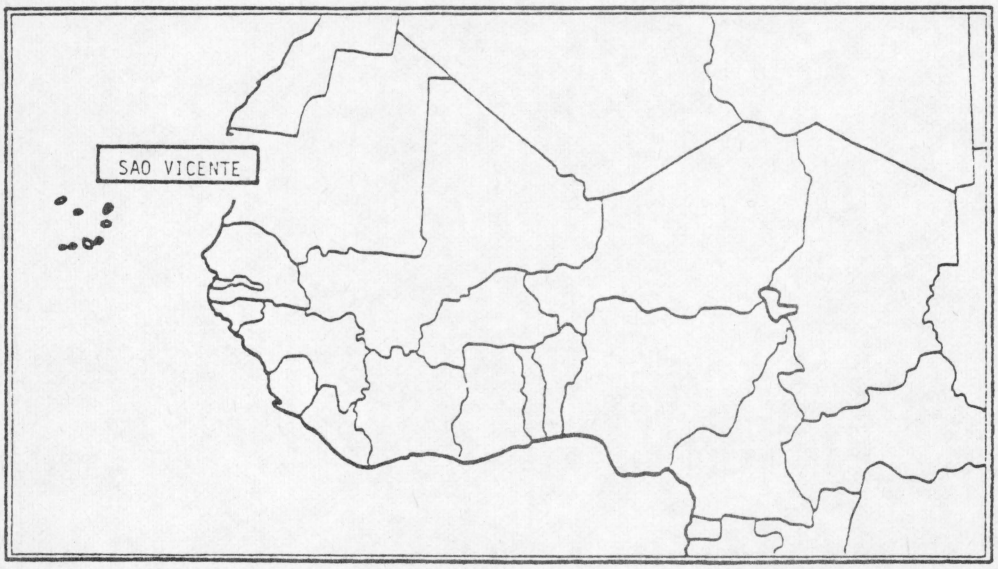
	M H	Average flow rate	Maximum flow rate
Zone 1	61 m	2.50 m^3/hr.	6 m^3/hr.
Zone 2	27 m	6.25 m^3/hr.	10 m^3/hr.

5. Observation

The interest of this project lies mainly in the physical separation between the aerogenerator and the motor. The motor is located 500 m from the aerogenerator, at an altitude 30 m lower.



(Source AEROWATT)



EXAMPLE 16	AEROWATT AEROGENERATOR FOR THE LIGHTHOUSE AT LUIS / CAPE VERDE IS. MARINE BEACONING
From Aerowatt documents	

1. Location

- The lighthouse at Luis, on Sao Vicente Is. (Cape Verde Is.).
- Local wind energy reserves -- average wind speed = 5 m/sec.

2. Utilization

Power for a luminous beacon with a continuous consumption of 12 W.

3. Equipment installed

- An aerogenerator with a rated power of 150 W at 7 m/sec.
- Battery storage -- 6 days of self-sufficiency.

4. Observation

In this case, the aerogenerator seems clearly oversized, however, world wind reserve figures are only approximate, as these reserves are extremely variable. The experimental nature of this project, which has been integrated into a bilateral cooperation program, should be emphasized.

F. ANAEROBIC FERMENTATION -- BIOGAS

F. ANAEROBIC FERMENTATION -- BIOGAS

Example O: CIEH applied research program (Upper Volta) pg. 228

Example 1: Biogas digester for the hospital at Kongoussi (Upper Volta) pg. 238

Example 2: Biogas digester for the horticultural school at Kongoussi (Upper Volta) pg. 246

Example 3: Biogas digester for the truck farming zone at Kongoussi (Upper Volta) pg. 248

Example 4: Biogas digester for the Centre de Formation de Jeunes Agriculteurs at Kongsabla (Upper Volta) pg. 250

Example 5: Biogas digester at Ndiour-Fissel (Senegal) pg. 252

Many people place great hopes in anaerobic fermentation as promising, easy to adapt to rural environments, and an interesting solution to both energy (cooking, driving motors, pumps, etc.) and agricultural problems (fertilization using compost). An analysis of the following examples will make it possible to appreciate more fully the advantages and disadvantages of this technology.

- Without any doubt, the advantages of anaerobic fermentation are:

  . technical maturity of the processes, which have been mastered,
  . the interest of using compost (after anaerobic and aerobic fermentation) as fertilizer.

- Its disadvantages are economic in nature -- digesters are still very expensive, and it is difficult, economically, to justify using biogas for cooking (compared to wood, for example).

It remains to be seen whether users will accept the constraints associated with biogas production.

Approximate cost price of biogas per m^3
Estimate made from one example

Hypotheses: - 1 m^3 of tank produces an annual average of 250 l/m^3/tank/day.
CIEH - average cost of 1 m^3 of tank = 40,000 CFA Francs.

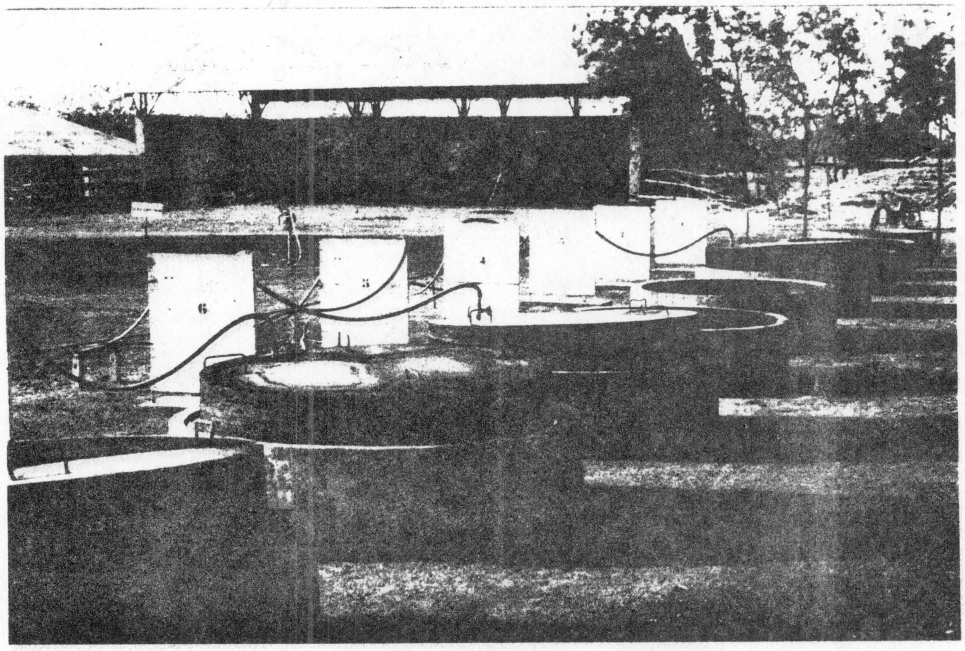
- annual production per m^3 of tank = 365 x 250 = 91.2 m^3/year
- Caloric value of the biogas produced = 91.2 m^3 x 5,000 Kcal/m^3
  = 456,000 Kcal.
  or the equivalent of 50 liters of crude oil (9,000 Kcal/liter).

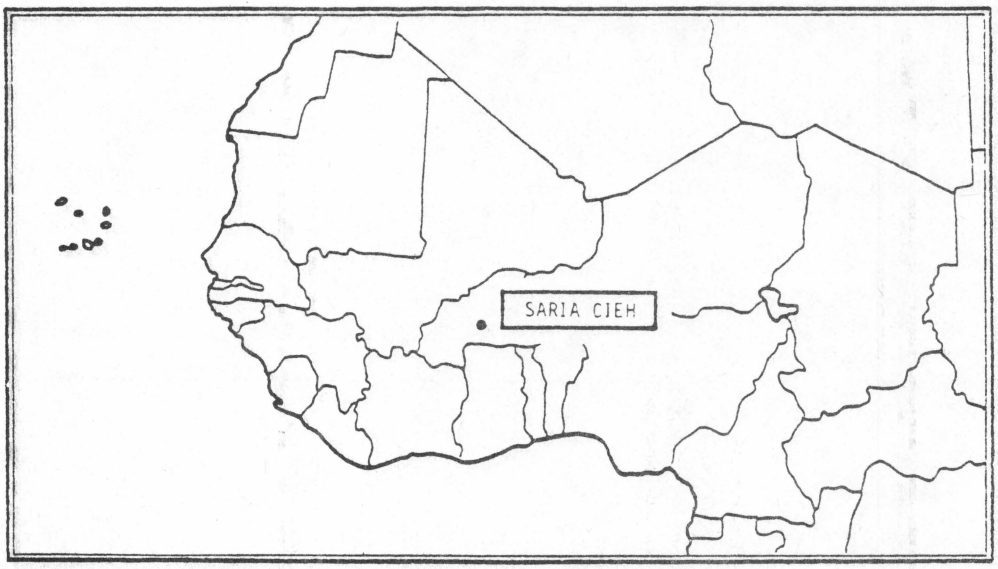
- Annual cost of the biogas produced (per m^3 of tank):

. annual depreciation (10 years, 10%) = 0.16 x 40,000 =	6,400 CFA Frs.
. annual maintenance = 5% of investment =	2,000 CFA Frs.
. labor (estimate): 50 hours at 50 CFA Frs./hr. =	2,500 CFA Frs.
. annual cost = 10,900 CFA Frs. for 91.2 m^3, or	

120 CFA Frs./m^3, or at an oil equivalent price of $\frac{10,900}{50}$ = 218 CFA Frs./l.

The minimum price of biogas is thus too high, using present techniques, even considering the value of the compost.




SARIA CIEH

CIEH APPLIED RESEARCH PROGRAM

1. Background on the CIEH program

Since 1976, the Centre Inter-Etats d'Etudes Hydrauliques (CIEH), in collaboration with the Délégation Générale à la Recherche Scientifique et Technique (DGRST), the Institut de Recherche Agronomique Tropicale (IRAT), COMES, IARD, and other institutes, has been carrying out an important program of applied research on biogas. Their meticulous work has served as an inspiration for other projects currently in progress (see examples below).

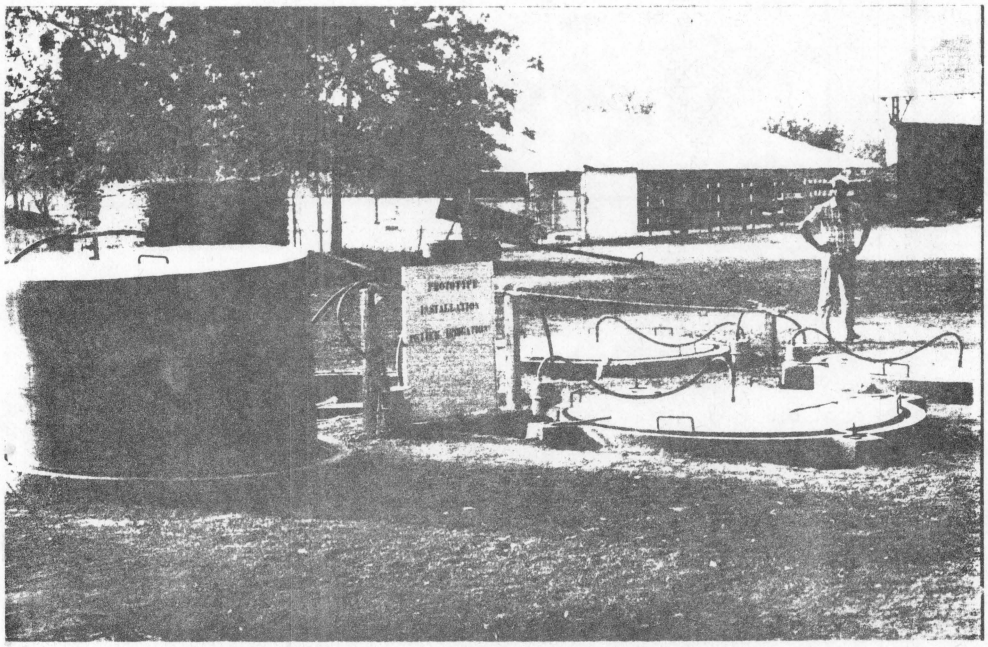
2. Technologies being tested

The CIEH has developed a batch wise (or semi-discoutinuous) digester that is particularly well suited to the Sahel (little available water and animal waste), whose output is often quite high thanks to numerous improvements in installation design and management. The CIEH compared its digesters to the Chinese and Indian models at the Saria testing station.

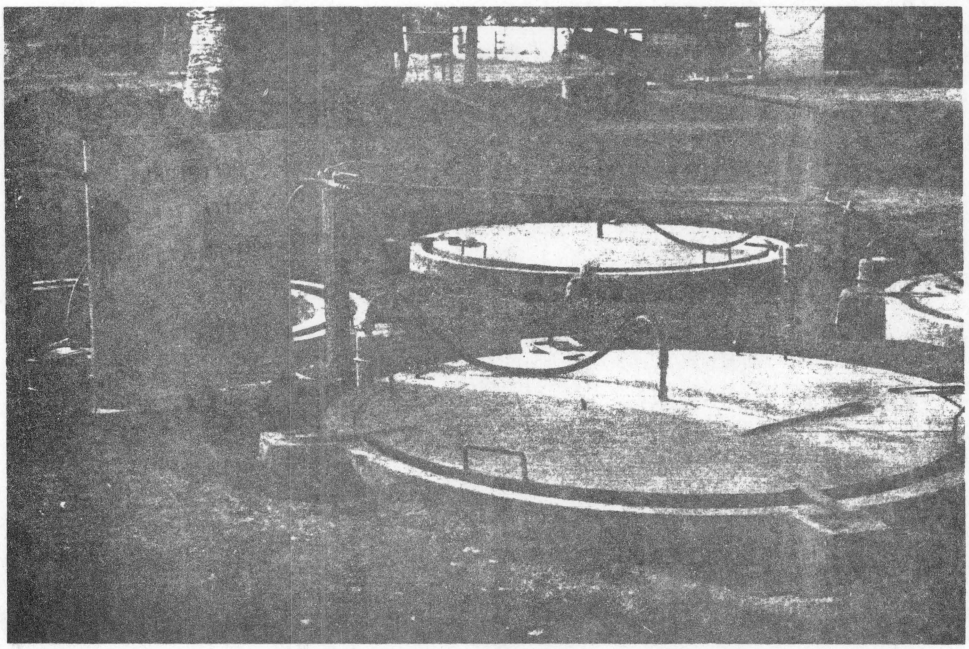
Table comparing the specifications of
Indian, Chinese, and batch wise processes

Type of installation	Indian	Chinese	Batch wise
Production volume (m^3 gas/day)	3	3	3
Practical output liters of gas/m^3 of tank/day	350	250	400
Necessary tank volume (m^3)	8.5	12	7.5
Estimated water needs (liters/day)	130	110	50
Surface of sheet metal gas holders and covers in m^2 (for a diameter of 2 m)	9.1		2 tanks + 1 gas holder = 12.3 m^2 2 tanks + gas holder cover = 18 m^2

(Source: CIEH)



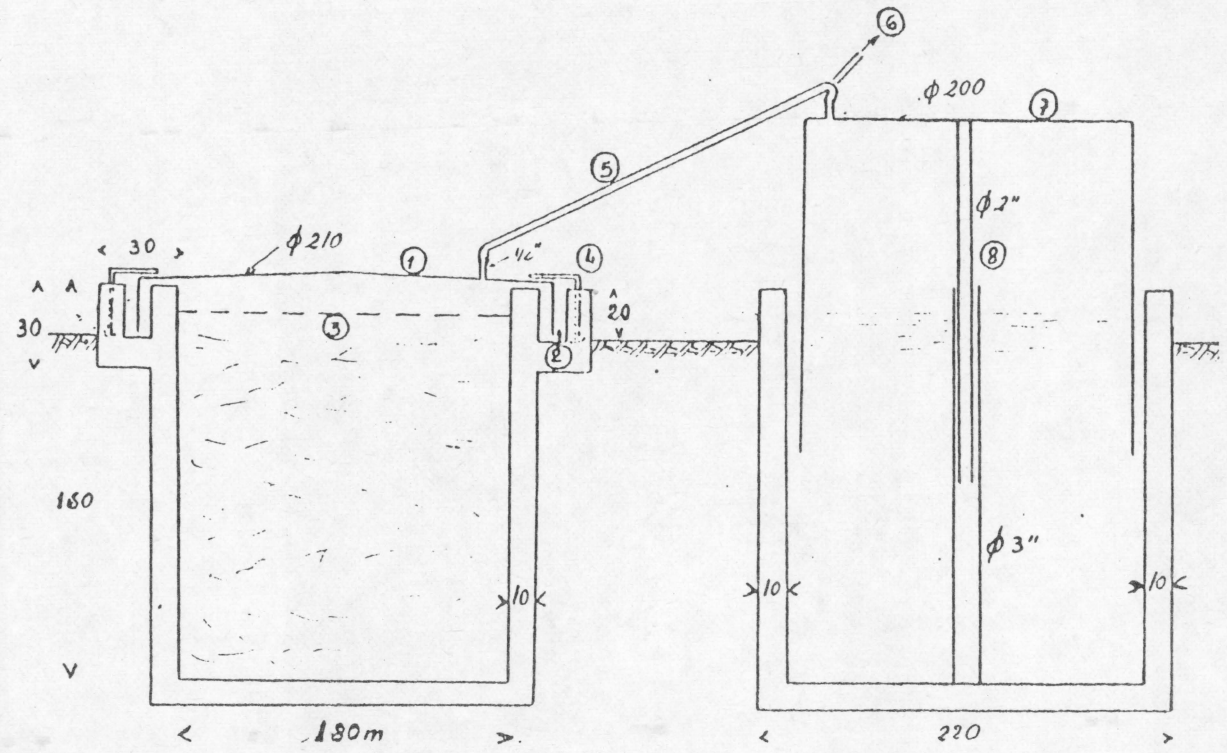
. Storage gas holder and digesters



. Digesters designed for pumping in small-scale irrigation

Installation énergie domestique

Type discontinu



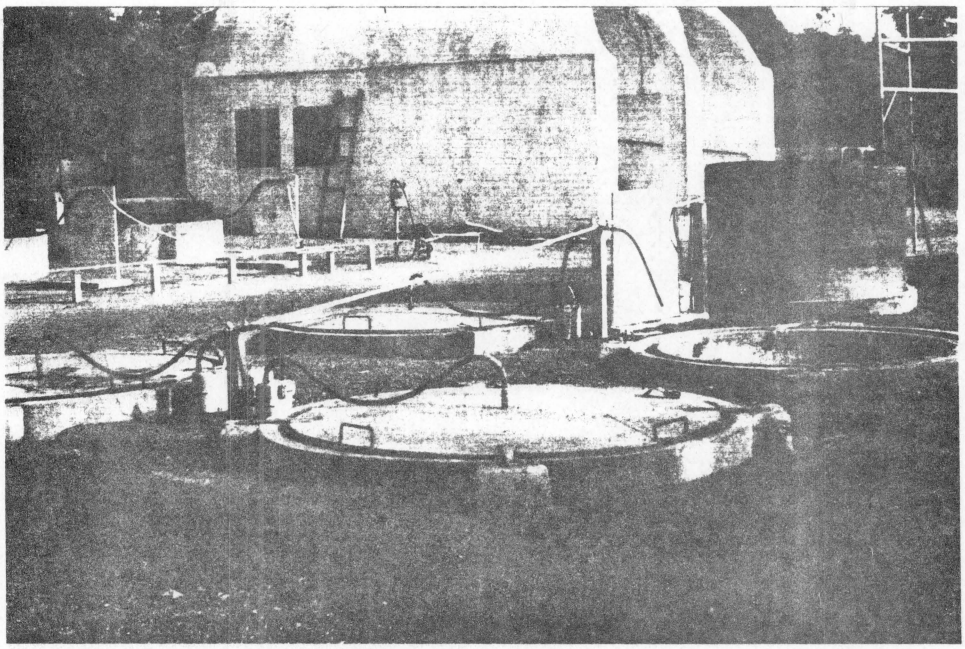
Légende :

1. couvercle fixe en tôle de 3 mm
2. joint hydraulique
3. grille de maintien en immersion
4. fixation du couvercle
5. raccord souple vers gazomètre
6. vers utilisation
7. couvercle gazomètre en tôle de 3 mm
8. système de guidage du gazomètre

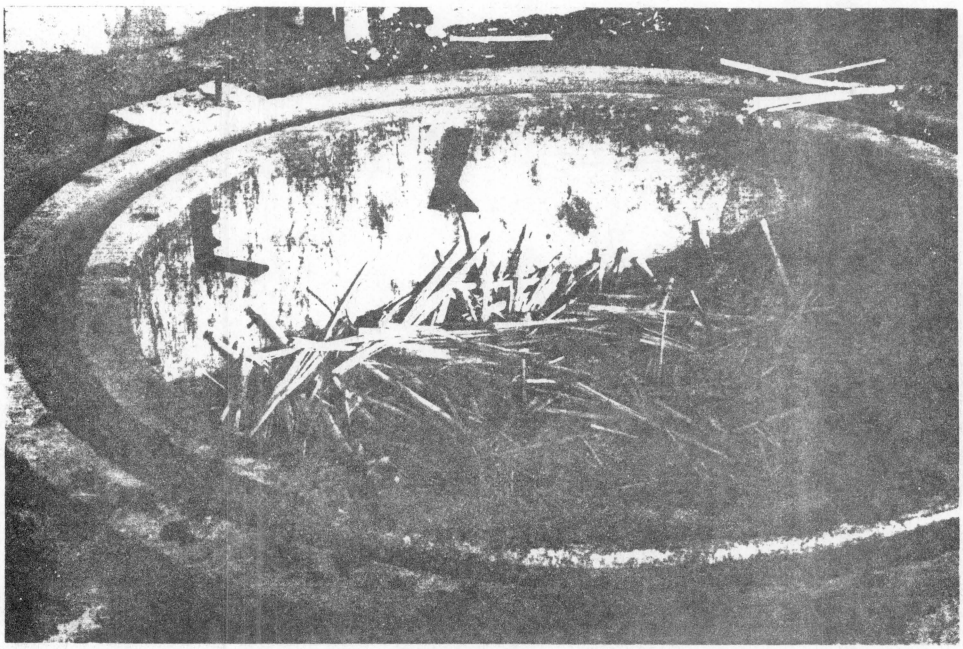
Cuve 1
et
Cuve 2

(Source : CIEH/EIER)

N.B. dimensions exprimées en cm.



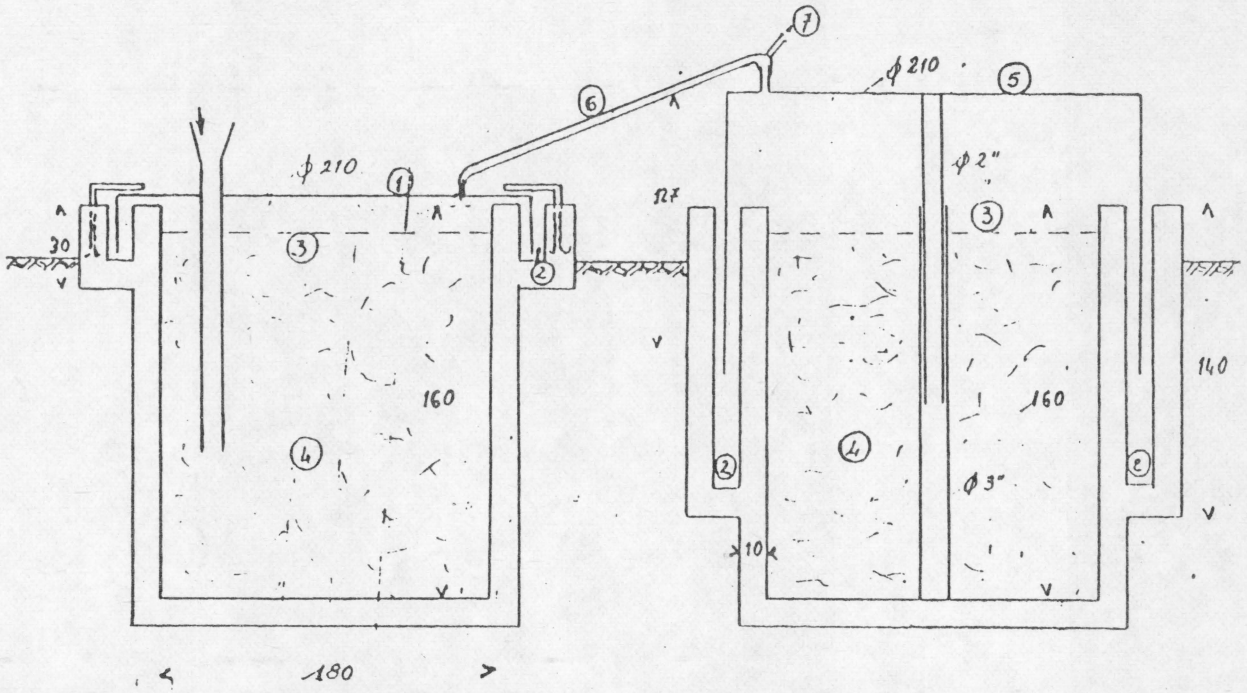
. Battery of four digesters



. Sorghum straw

Installation énergie domestique

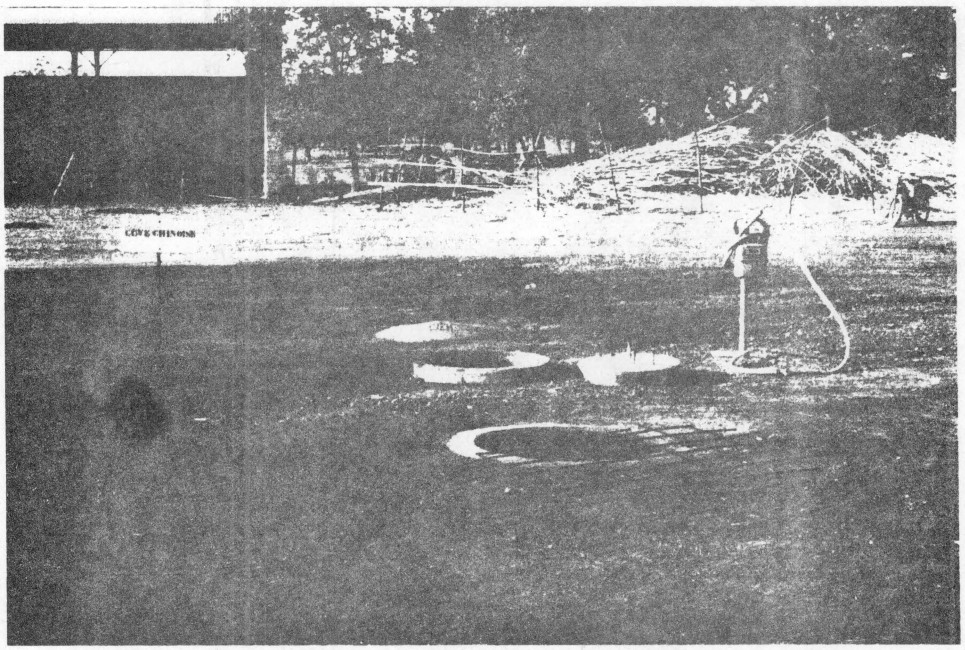
Type semi-discontinu



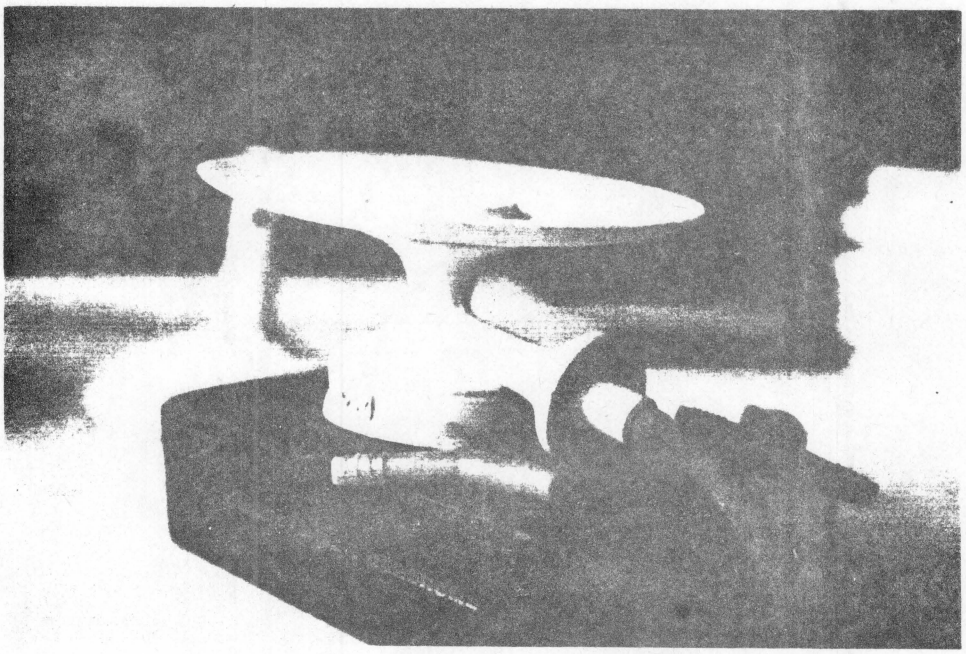
Légende :

1. couvercle fixe en tôle de 3 mm
2. joint hydraulique
3. grille de maintien en immersion
4. substrat en fermentation
5. couvercle gazomètre
6. joint de raccord souple
7. vers utilisation

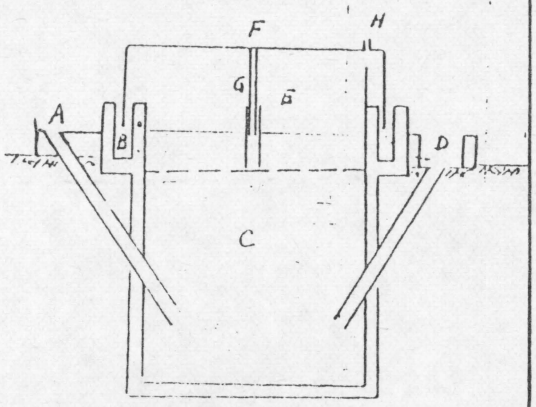
(Source : CIEH/EIER)



. Chinese tank



. Chinese clay burner



A : entrée du substrat

B : joint hydraulique

C : substrat en fermentation

D : sortie du substrat

E : volume variable de stockage et mise en pression du gaz.

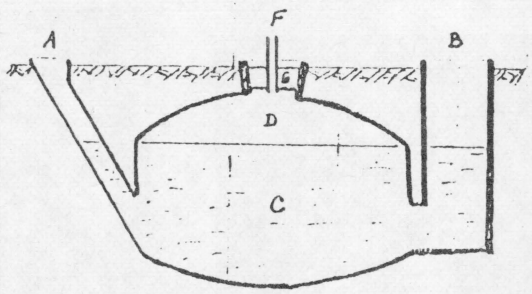
F : couvercle gazomètre

G : système de guidage du couvercle

H : sortie du gaz vers utilisation

Figure 2 : digesteur de type indien.

(Source : CIEH/EIER)



A : entrée

B : cuve de vidange

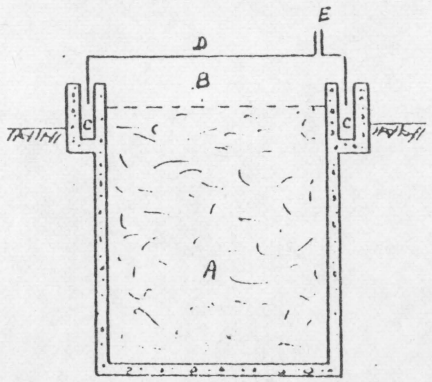
C : substrat en fermentation : volume utile.

D : volume de stockage du gaz

E : bouchon hermétique de vidange

F : tuyau de sortie du gaz vers l'utilisation.

Figure 3 : digesteur de type chinois.



A : substrat en fermentation

B : volume variable de stockage et mise en pression du gaz.

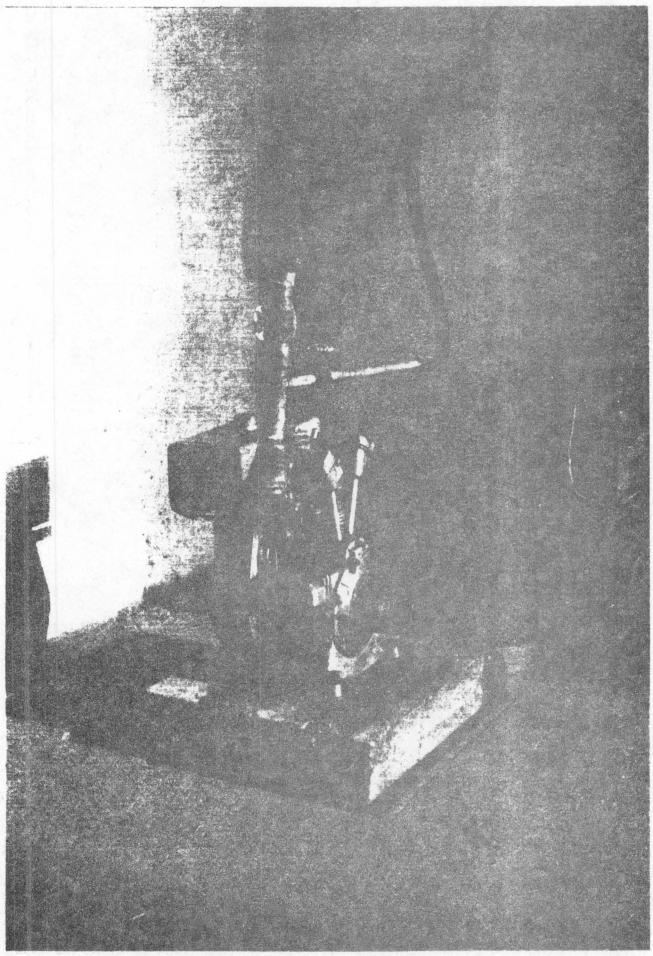
C : joint hydraulique

D : couvercle gazomètre

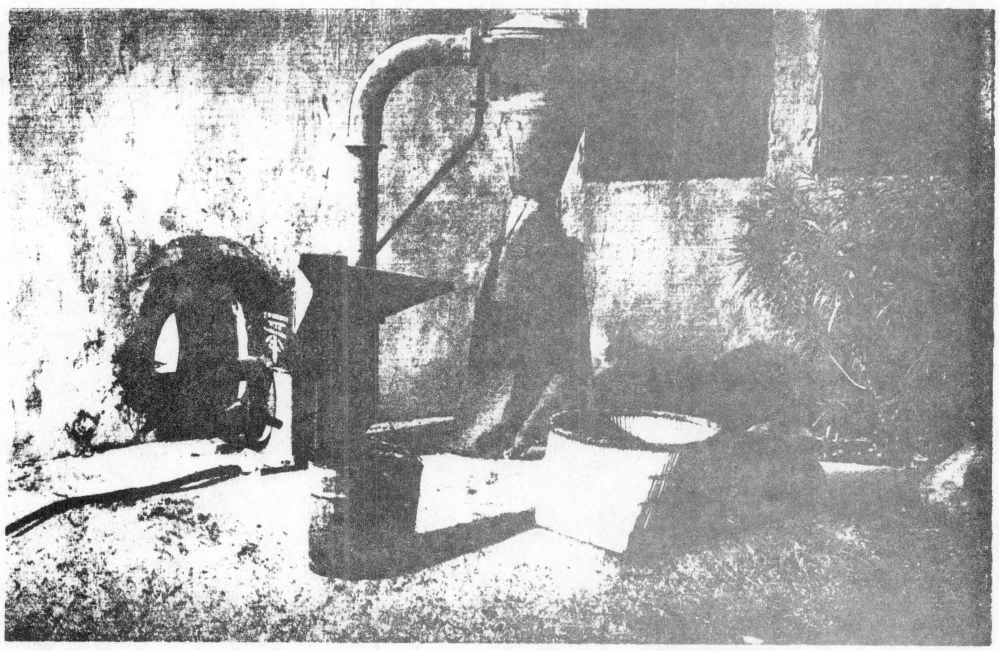
E : sortie du gaz vers utilisation

Figure 4 : digesteur de type discontinu.

. Bernard motor converted to biogas



. Cereal mill driven by a biogas engine



3. Practical operation of the CIEH batch wise process

This is a five-stage process:

1st stage: preparing the substrate --
- . shredding the plant matter substrate (cutting, trampling by livestock)
- . preparation of fermenting mixture (25% animal waste (dry matter), 75% plant matter waste)
- . aerobic pre-fermentation -- 8 to 10 days

2nd stage: loading the tank (reusing the anaerobic fermentation juices)

3rd stage: anaerobic fermentation -- the tank is closed and the gas is produced over a period of approximately fifty days

4th stage: draining the fermentation wastes

5th stage: aerobic completion of the fermentation wastes before utilization as compost; this stage, not originally planned, today seems indispensable to improve the fertilizing value of the compost.

4. Designing the installations

The CIEH has selected the following standards for Upper Volta:

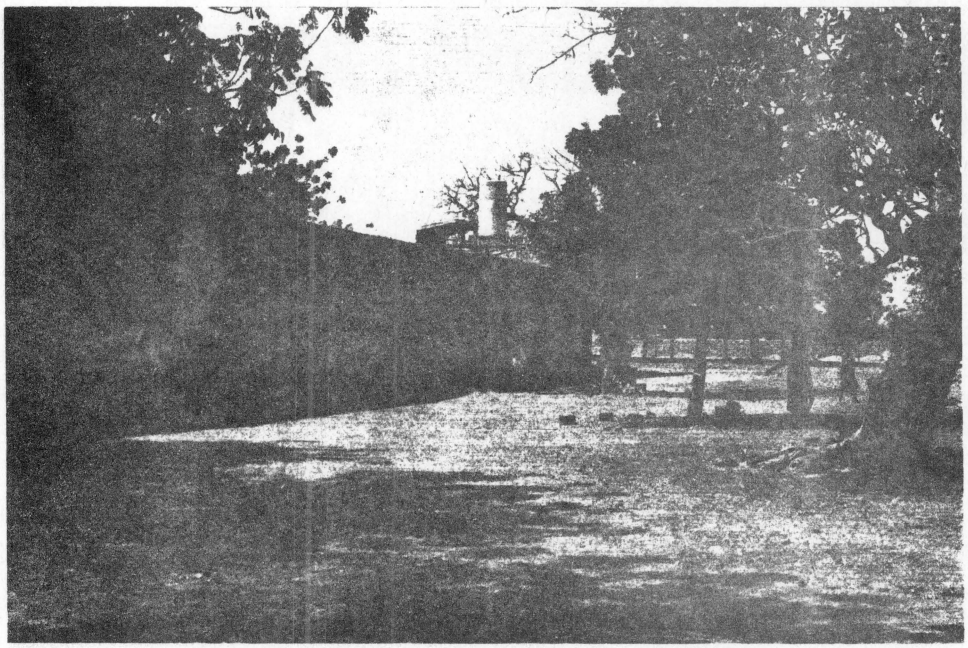
- 300 - 350 liters of biogas/m^3 of tank/day, from May to November
- 200 - 250 liters of biogas/m^3 of tank/day, from December to February

5. Cost of the installations (source: CIEH - October 1980)

The cost per cubic meter of tank installed is 35,000 - 45,000 CFA Francs. Below is a quantitative estimate for an 8 m^3 installation for the production of 2 m^3 of biogas/day, at a cost of about 300,000 CFA Francs.

Quantitative estimate for an 8 m^3 installation including one digester and one 'domestic energy' type water basin

Description	Units	Quantity	Observations
Pit	m^3	21.5	
Cement	T	2.15	
Gravel	m^3	3	
Sand	m^3	1.5	
Covers	units	2	
Metal gas holder	units	1	
3 mm Sheet steel	m^2	18	
2' Galvanized tubing	m	1.8	
3' Galvanized tubing	m	1.5	
6 mm Wire netting	roll	1.5	roll = 25m x 1.2m
Railing	unit	2	
Iron for concrete	unit	7	iron in 12 m bars



. Hospital at Kongoussi

EXAMPLE 1	BIOGAS DIGESTER FOR THE HOSPITAL AT KONGOUSSI KONGOUSSI / UPPER VOLTA
Inspection report	

1. Project background

The hospital at Kongoussi, built a few years ago by the European Development Fund, is located 110 km north of Ouagadougou. Its operating budget is particularly meager and the original equipment (electric generating units, pump, solar water heater, etc.) are inoperative today. Since 1978 the IARD (International Association for Rural Development, Brussels) has been carrying out an interesting experiment in the production of biogas in order to power some of the hospital's top-priority equipment (medicine refrigerator, Bunsen burners, sterilizers).

2. Technologies employed

IARD had to choose among three processes:

- the continuous process (developed by the Khadi and Village Industries, an Indian commission) which utilizes pre-diluted animal waste;
- the semicontinuous process, as used in China, which makes use of plant matter waste in small proportions;
- the batch wise process, developed by the CIEH (Upper Volta), which uses smaller quantities of water and animal waste.

IADR selected this third process.

3. Comparison of the results between the different digester models

a)- Digester #1 (September 1978):

The following outline gives a detailed description of this digester:

- Advantages:

  . bacterial juices easily drained
  . gas easily stored

- Disadvantages:

  . high cost of construction materials
  . gas loss between the digester walls and the gas holder (no seal)
  . difficult to fill due to tank height, greater loss of nocturnal heat than with sunken tank

- Measured performance:

  . 160 liters/m^3 of tank/day (average for 80 days)
  . 170 liters of gas/Kg dry matter, using the following raw materials:

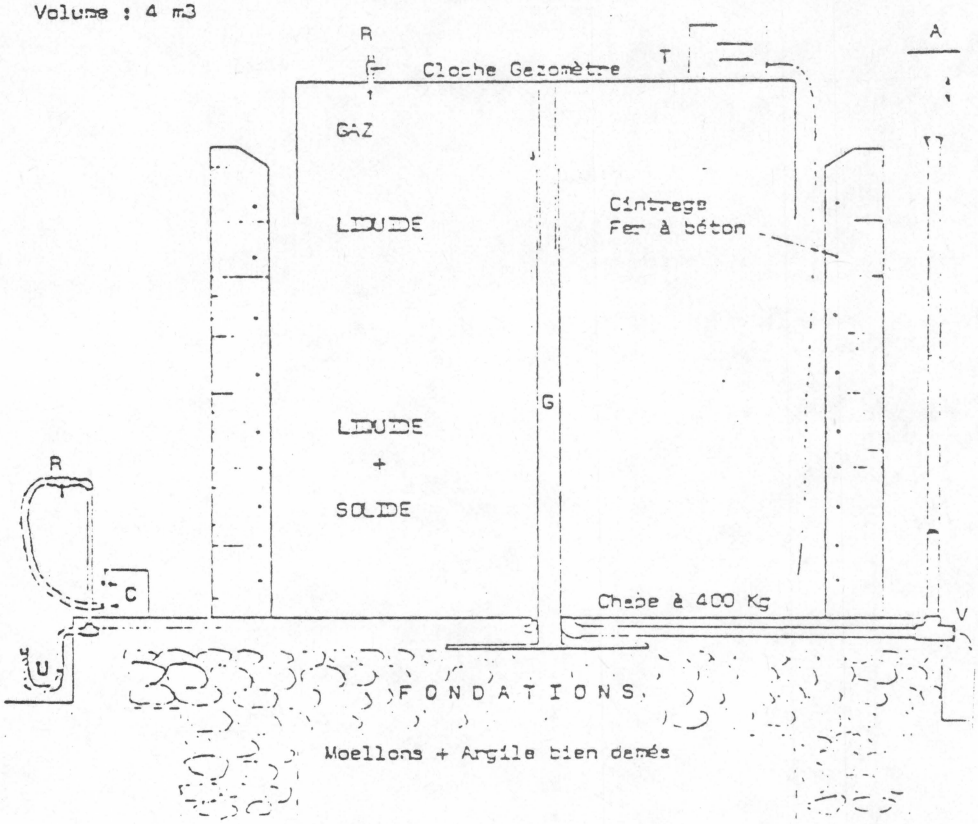
PLAN DU PREMIER DIGESTEUR réalisé en Septembre 1978

Hôpital de KONGOUSSI

Type : discontinu

Cuve cylindrique en briques pleines cuites (5,5 X 11 X 22)

Volume : 4 m3



T : Thermographe à sonde

C : Compteur à gaz

R : Robinets d'échappement du gaz

V : Tuyau PVC 50 pour la Vidange

A : Agitateur

G : Axe de Guidage (tube - acier de 66 X 76)

U : Tube U pour pression

(Source : A.I.D.R.)

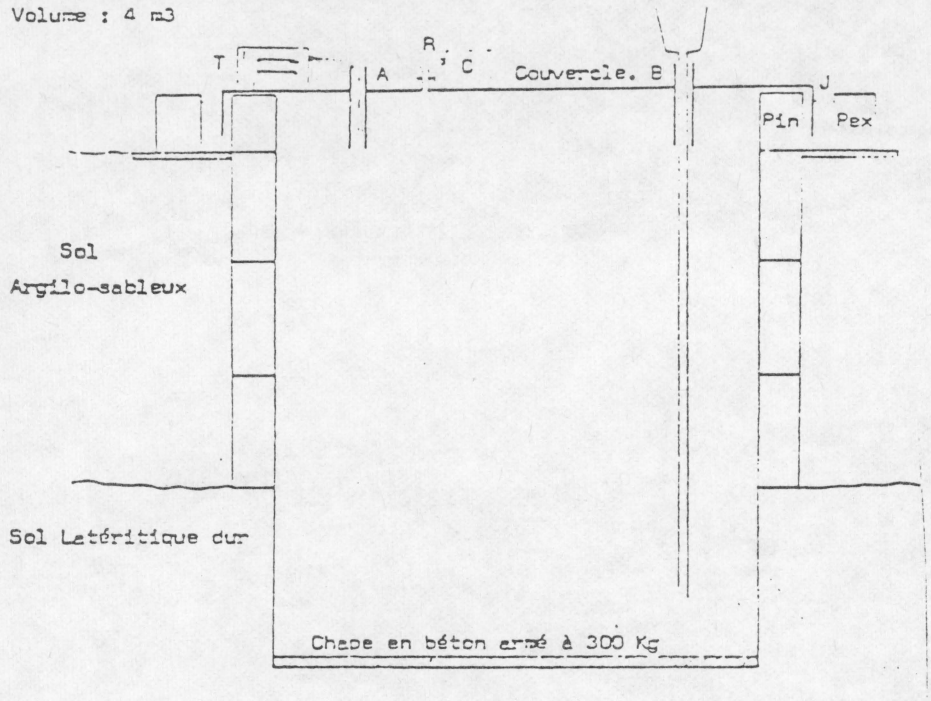
PLAN DU DEUXIEME DIGESTEUR REALISE EN JANVIER 1979

Hôpital de KONGOUSSI

Type : discontinu

Cuve cylindrique en parpaings pleins (15 X 20 X 40)

Volume : 4 m3



R : Robinet d'échappement du gaz vers un gazomètre indépendant

T : Thermographe à sonde

C : Compteur à gaz

A : Tube-acier 50 pour prise d'échantillons et introduction de la sonde du Thermographe

B : Tube-acier 50 pour introduction d'un autre tube (40) de chargement supplémentaire du produit de la panse

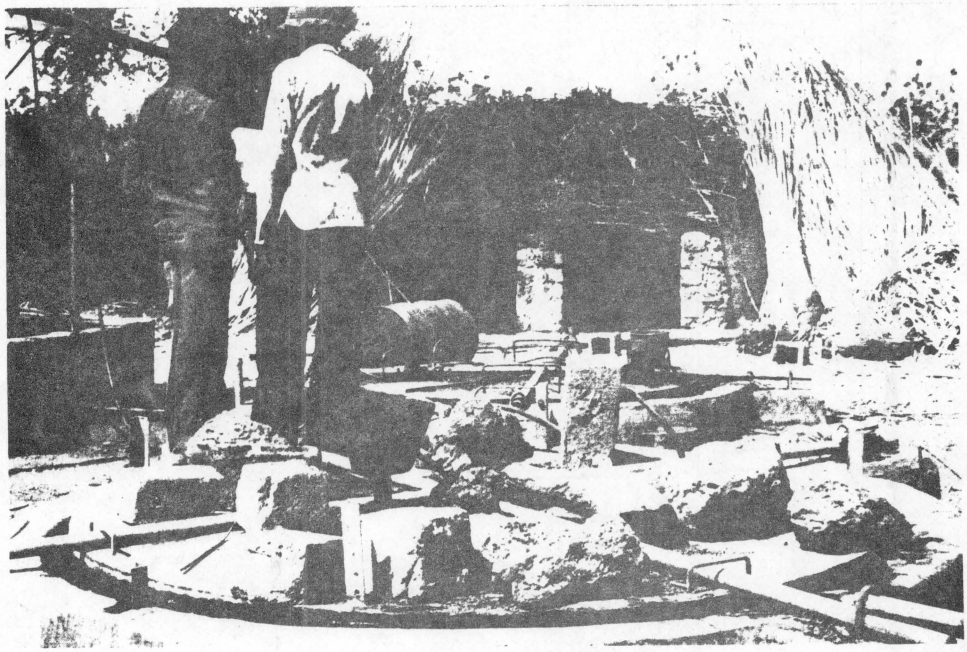
J : Joint Hydraulique

Pin : Paroi intérieure (crépissage ciment + sikalite)

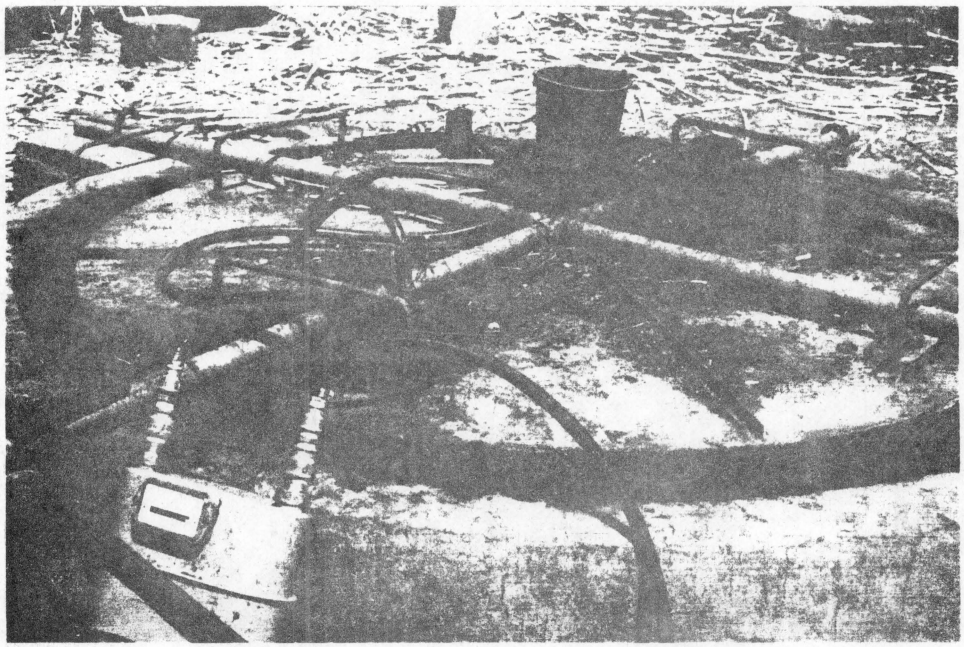
Pex : Paroi extérieure

N.B. : Le couvercle en tôle de 3 mm est fixé à la paroi extérieure de la cuve par une barre transversale.

(Source : A.I.D.R.)



. Millet straw and manure digester



. Close-up view of the fixed gas-holder

- 1 m^3 bacterial juices
- 150 dry Kg crushed millet stalks
- 35 Kg sheep entrails + 25 Kg on day #60
- 45 dry Kg dung
- 50 dry Kg millet husks

b)- Digester #2 (January 1979), see photograph:

The following outline describes the second model tested.

- Advantages:

. considerably lower in cost
. cover easy to handle
. greater usable production of gas (seal)
. possibility of semi-continuous operation

- Disadvantages:

. need for additional gas holder

- Measured performance (22 February - 31 July 1979):

. 250 liters of gas/m^3 of tank/day (average for 160 days)
. 300 liters of gas/Kg dry matter

with the following loads: 150 dry Kg sorghum stalks + 41 dry Kg bovine slurry + 53 dry Kg sheep entrails for a total of 244 Kg at the beginning, with 190 Kg added afterwards.

A second test (1 August - 30 September 1979) produced the following results:

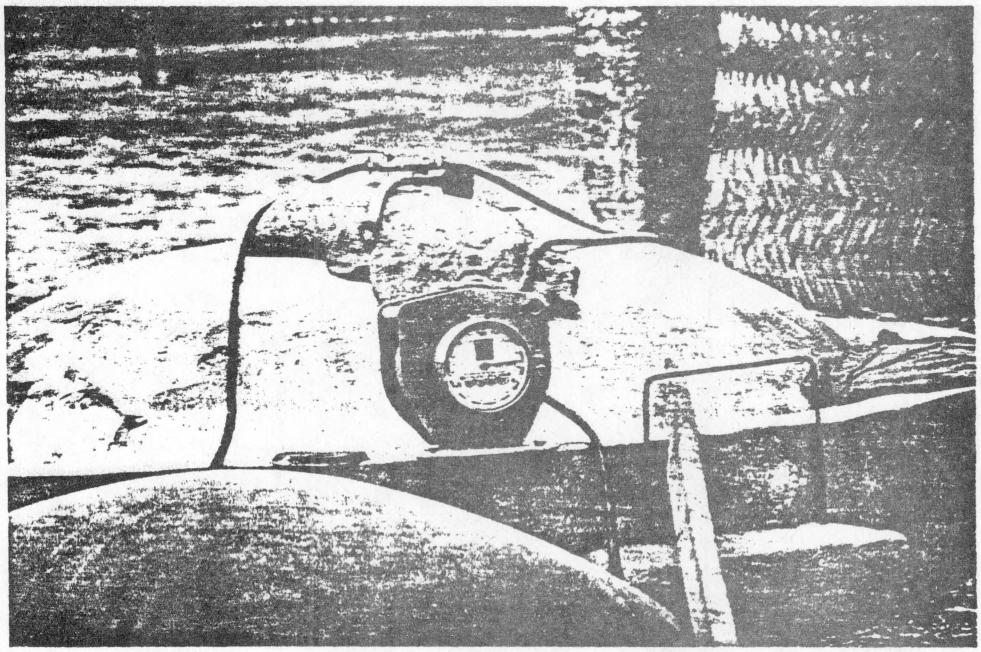
. 480 liters of gas/m^3 of tank/day, average for 24 days, which corresponds to 250 liters/dry Kg (sourda + entrails)
. 555 liters of gas/m^3 of tank/day, average for 30 days, which corresponds to 290 liters/dry Kg.

c)- Digester #3 (September 1979):

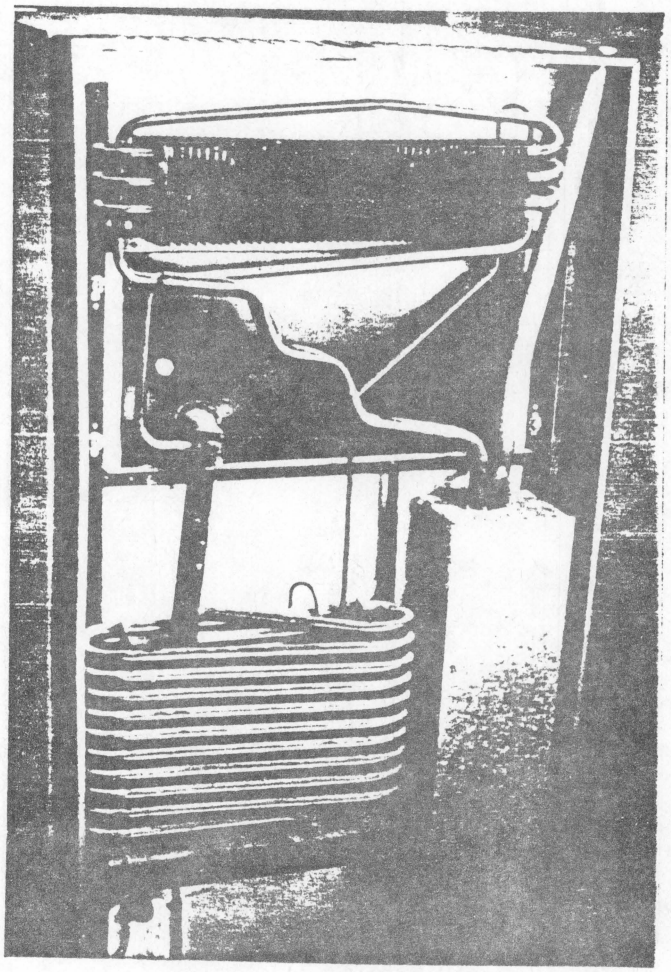
- Description:

. 12 m^3 sunken tank, diameter 2 m, height 4 m
. capping of non-reinforced concrete for the bottom
. direct rough casting on hard laterite (lower part)
. full, rough cast parpen walls (upper part)
. seal
. gas holder, polyester at first, which did not stand up to frequent handling; replaced by a steel one.

The service supplied to the hospital is real but not great. The refrigerator does not operate with sufficient regularity for storing large quantities of medicines and vaccines. As a precaution, the head physician leaves a large supply of his medicines at a neighboring hospital. Even the electric generating unit does not seem to operate on a regular basis. The refrigerator, Bunsen burners, and sterilizers were operating the day of our visit.

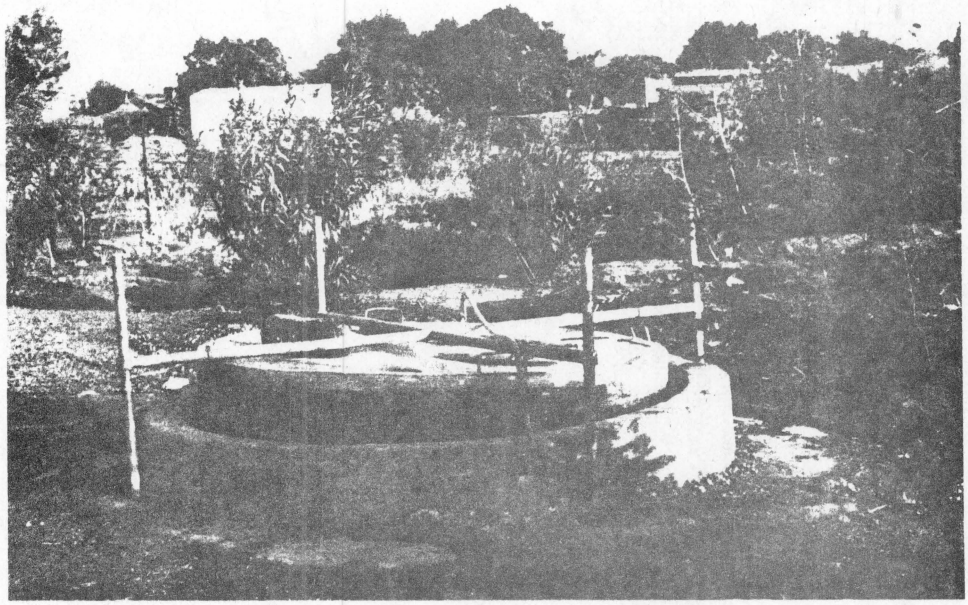


Cuve en polyester, compteur volumétrique et réservoir souple

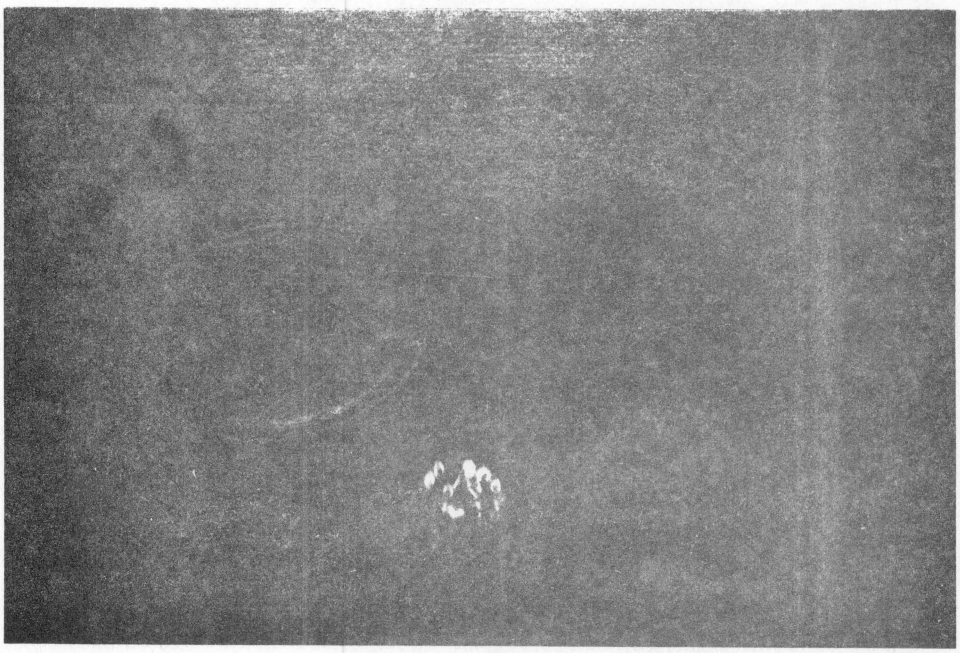


Réfrigérateur biogaz

Improved service could be possible if the two hospital directors managed the equipment more effectively. The cost price for the gas produced, while not established, is probably quite high. Nevertheless, it has little meaning considering the pilot nature of this installation.



. Digester run on garden waste



. School kitchen using biogas (for about 15 persons)

EXAMPLE 2	BIOGAS DIGESTER TANGHIN HORTICULTURAL SCHOOL OUAGADOUGOU / UPPER VOLTA

1. Project background

Every year, the Tanghin horticultural school, run by Brother Laurent, trains fourteen or fifteen gardeners who easily find work after completion of their studies. The students put themselves through school by selling the flowers they grow. They live at the school in a residence built by the EDF.

2. Biogas installation

A 5.5 m^3 tank was built (see photograph). The school was in charge of digging the pit, making the parpen walls and the bottom slab, and providing labor and water. IARD paid for a mason, materials (sand, gravel, cement) and the gas holder.

Technical data:

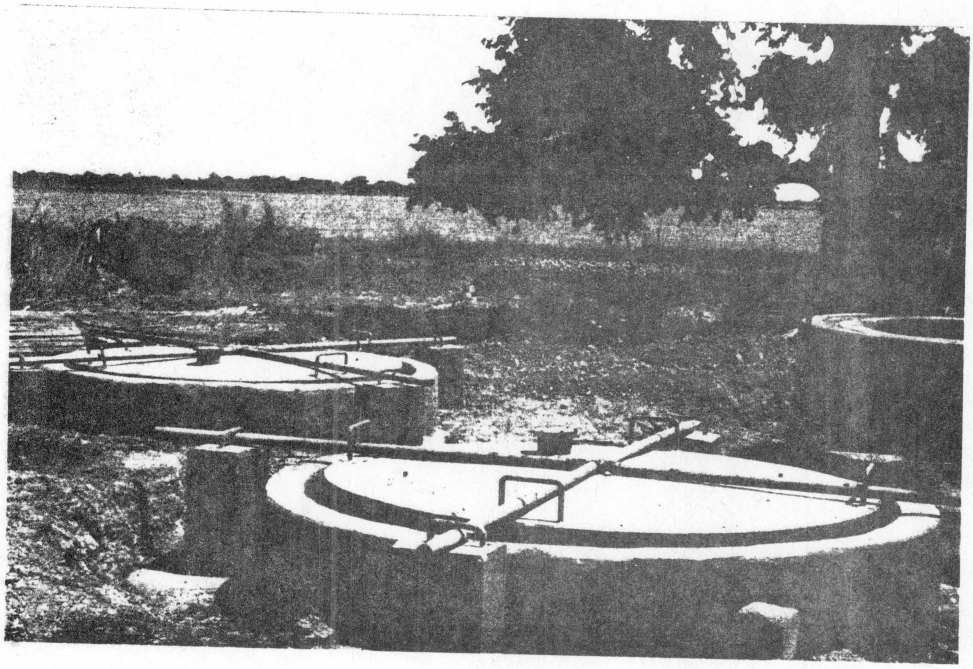
- pit: diameter = 2 m, depth = 3 m
- cement: 30 bags
- sand: 20 wagon loads
- gravel: 6 wagon loads
- gas holder: sheet metal 2 m/m, diameter = 2 m, height = 0.6 m, capacity = 2 m^3 of gas

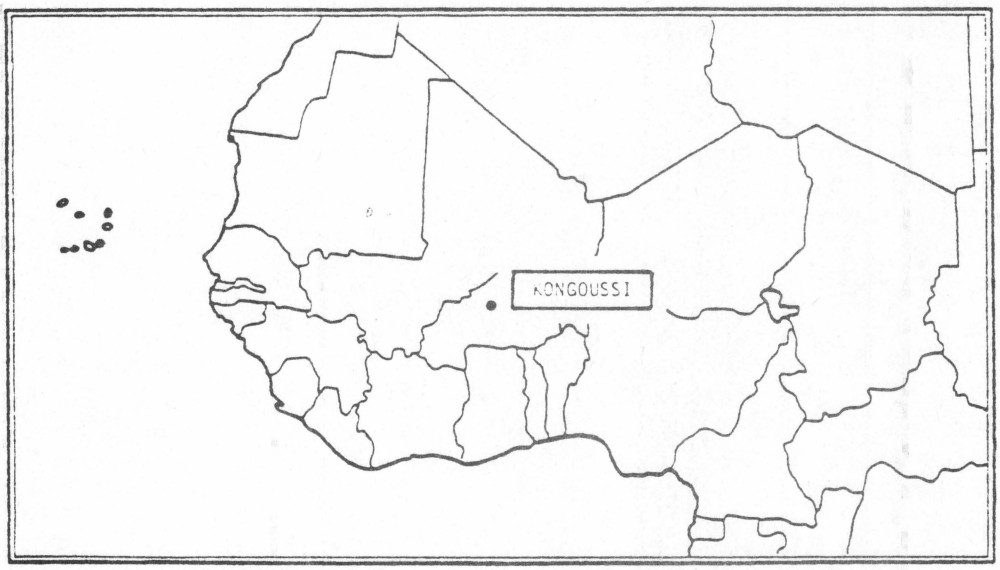
3. Raw materials used

- garden waste
- manure purchased from nomadic breeders in the area -- 5 to 6 wagon loads per month at 400 F/load, for a total of 2,000 F/month
- the compost from fermentation is used in gardening

4. Utilization of the biogas

The equipment provides fuel for the students' kitchen. The students expressed a great interest in the experiment and have taken on the responsibility of running the installation. There is also a project for installing a gas lamp. We saw the gas burner (of non-industrial fabrication) operating satisfactorily (see photograph). This burner consumes 240 liters of gas per hour and operates a few hours per day.




KONGOUSSI

EXAMPLE 3	BIOGAS DIGESTER FOR THE TRUCK FARMING ZONE AT KONGOUSSI / UPPER VOLTA
Inspection report	

1. Project outline

The 1.5 hectare truck farming zone is located along Lake Mbam, at Kongoussi, north of Ouagadougou. It belongs to Mr. Sawadogo, a villager, who has been farming the zone for many years.

2. Crops raised

Dry season (with irrigation): green beans, onions, cabbage, corn, carrots, tomatoes.
Rainy season: sorghum, niebe, lettuce, cabbage.

3. Current pumping equipment: (see photograph)

One Bernard 0.5-liter motor pump (20 m^3/hr. at MH = 10 m) is used. The water is brought up through PVC tubing and falls by force of gravity. The irrigated area = 0.5 ha.

4. Biogas project (see photograph)

- three 8 m^3 parpen wall sunken tanks (two with fixed covers, one with movable cover acting as gas holder; capacity = 3.75 m^3);
- one extra gas holder, 15 m^3, made of a plastic envelope.

The project is almost terminated. The equipment will power a new biogas-powered motor pump (gasoline operation will still be possible).

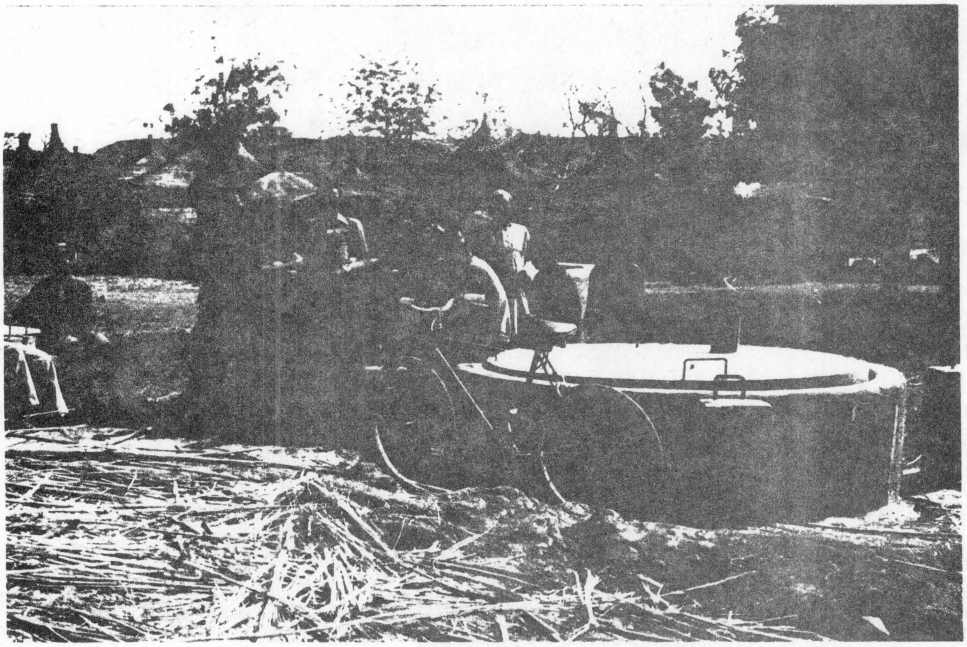
5. Raw materials used

- straw: three tons of dry matter can be produced yearly using half the straw produced in the zone;
- manure: the user has one donkey, seven sheep, and twenty head of cattle penned up at night nearby, for a yearly production of 7.2 tons of dry matter.

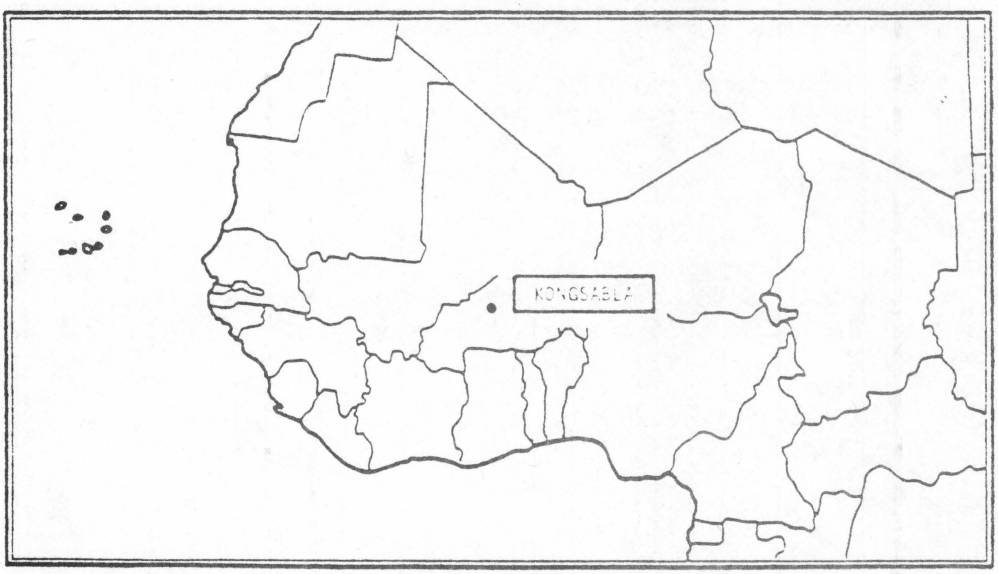
According to IARD officials, these raw materials can provide sufficient power for 240 5-hour pumping days.

6. Some comments

This project, soon to be operational, should be interesting to monitor, as it represents an ideal biogas application (good receiving organization, regularly available waste, utilization of the biogas produced instead of easily transportable and convertible energy sources, high user motivation). The success of this project would make mass distribution possible, considering the great number of truck farming zones of this type in Upper Volta.



. The two tanks under construction



EXAMPLE 4	BIOGAS DIGESTER FOR THE CENTRE DE FORMATION DE JEUNES AGRICULTEURS (CFJA) AT KONGSABLA / UPPER VOLTA

1. Project outline

The CFJA (center for the training of young farmers) at Kongoussi welcomes fifty-four students. It is located on the edge of Kongsabla (a village 15 km from Kongoussi) next to a women's training center (Caritas) where about twenty hogs are raised. The center now has:

- 2.5 hectares of crops: cotton, millet, sorghum, groundnuts;
- two oxen and one donkey with a night pen equipped with two manure pits;
- a poultry breeding sector;
- a well 24 meters deep;
- a group of buildings;
- a traditional kitchen with two hearths and three 10-liter pots.

2. Description of the installation

The installation, as seen in the enclosed photograph, includes two digesters, one of which has movable gas holder. The installation was being completed when we visited it (March 1981). Technical and financial assistance has been provided by IARD.

3. Raw materials used

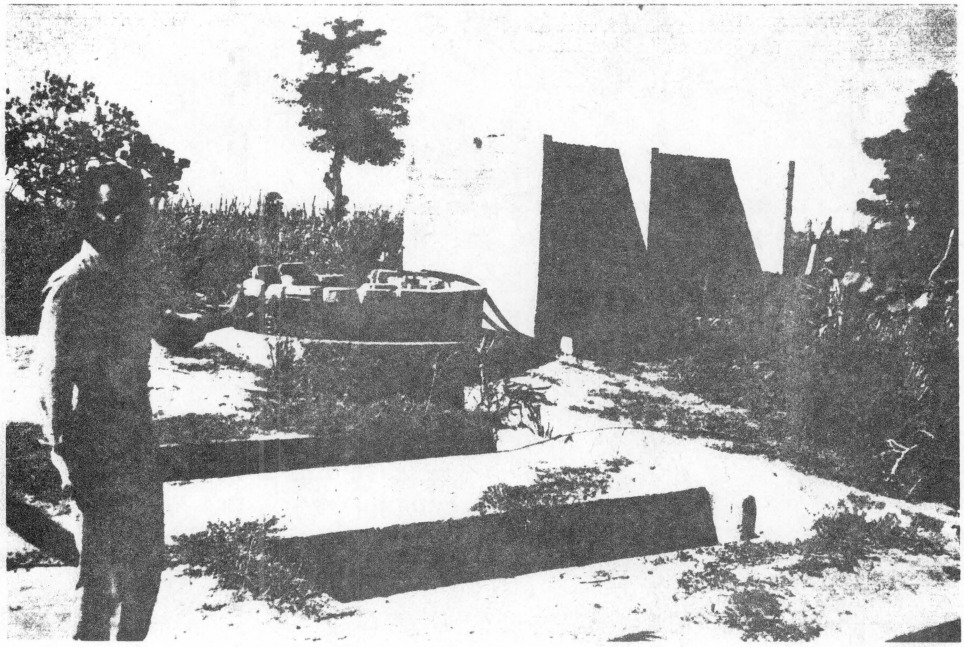
The CFJA plans to fill the digesters with cow and hog manure (available at the center), and sorghum stalks.

4. Utilization of the gas

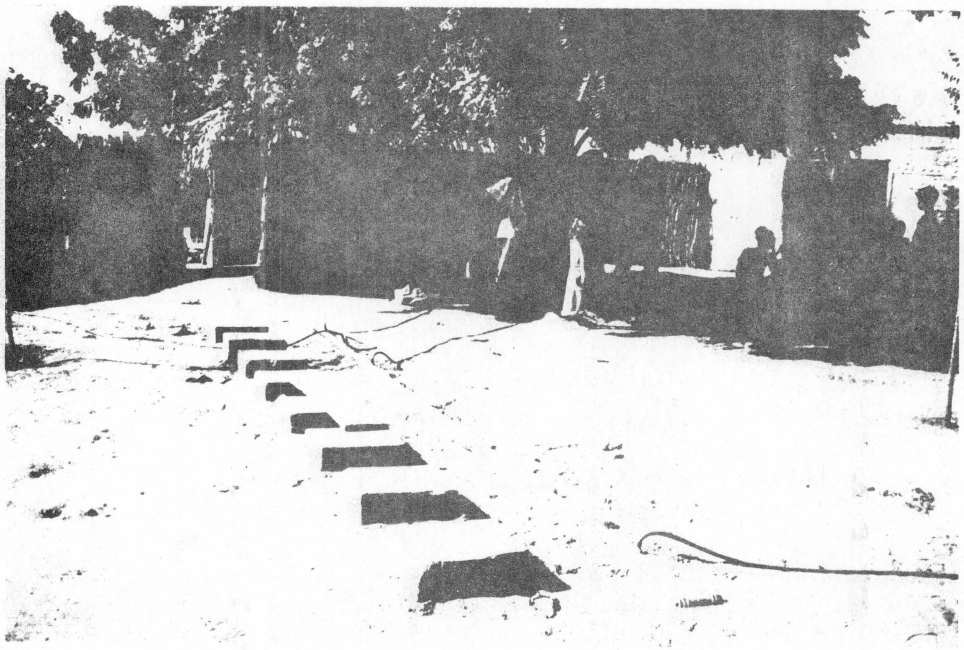
- fuel for portable stoves for the kitchen
- fuel for an egg storage refrigerator (planned).

5. Remarks

The installation greatly interests the students. Its distance from the well could make it difficult to fill the equipment. Cooking is not considered a top-priority utilization of the gas produced, since wood is still easily available in the village. (Sorghum and millet stalks and wood could be used as fuel for the hearths, since they are not in short supply.) The equipment could be much better utilized for the refrigerator or a small cereal mill. IARD thus intends to finance these additional applications.



. The fermentation tank



. The gas distribution circuit

EXAMPLE 5	BIOGAS DIGESTER AT NDIOUR-FISSEL / SENEGAL

1. Location

Ndiour-Fissel is a small village near Mbour, approximately 100 km south-east of Dakar.

2. Type of installation

This installation, shown in the photographs below, operates mainly on human waste using a continuous process digester.

3. Project promoter

The project is being promoted by Caritas, a charitable organization, working in close collaboration with village youths who have completed a farmer training program (also managed by Caritas).

4. Utilization of the biogas

Fuel for a village family's cooking and lighting (butane lamps).

5. Reliability

The installation seems to operate well. The users, who were asked briefly about it, seemed satisfied.

6. Evaluation

A more detailed analysis of this experiment would be useful in preparing future distribution of the equipment.

G. IMPROVED STOVES

G. IMPROVED STOVES

Example 1: IARD/FED improved stove program, Ouagadougou (Upper Volta) pg. 260

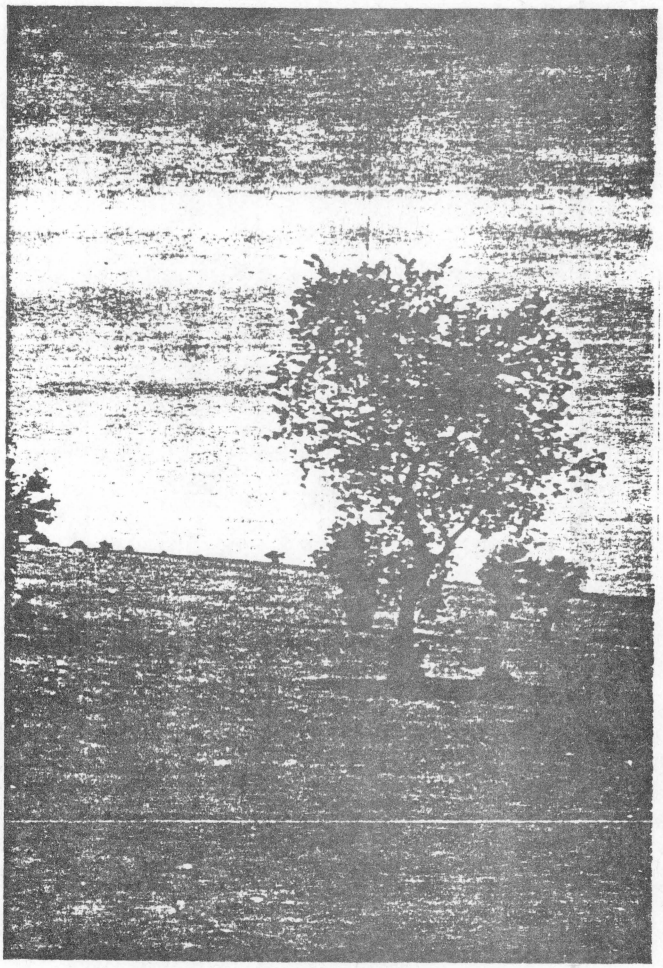
Example 2: Improved stove program of the Mission Allemande Forestière and the Ministère de l'Environnement et du Tourisme, Ouagadougou (Upper Volta) pg. 265

Example 3: CATRU improved stove program, Ouagadougou (Upper Volta) pg. 266

Example 4: Improved stove program of the World Chruch Service and the Association des Femmes Nigériennes, Niamey (Niger) pg. 268

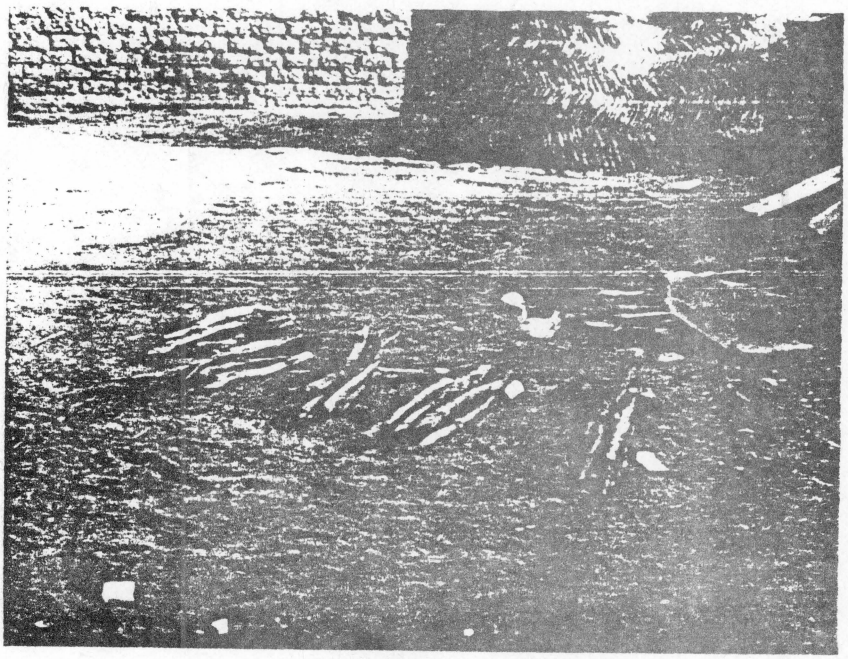
Example 5: 'Ban ak Suuf' improved stove program, CERER (Senegal) pg. 272

Vers la désertification



Vers la pénurie de bois

(Source : COMES)



The forest is disappearing slowly but surely from the Sahel landscape. Various factors are responsible for this -- a demographic squeeze causing an ever-increasing demand for fuel; the nature of the forest potential, which is composed for the most part of old trees and presents slow or zero growth and a lack of natural regeneration; the drought that has persisted for twelve years, causing mass destruction of certain species; brush fires; increasing herds, which destroy the young shoots; shepherds who prune excessively; the continual extension of arable fields, through slash burning, to the detriment of the forest.

Deforestation is also due to the overexploitation of certain zones for heating wood and charcoal production, particularly around the cities. At present, in order to find wood, it is often necessary to travel fifty or one hundred kilometers from capital cities. This is also true near watering places for herds, as well as in certain regions of the north, near the Sahara, where wood resources are rare and fragile.

The problem of ligneous fuel supplies has become a sensitive issue for villagers who must go farther and spend more time every year collecting wood, or accept the alternative of using inferior fuel sources, such as straw and animal excrement. Wood and charcoal prices in the cities have been increasing at an alarming rate, to the point where they have doubled in the space of two years. Some of the more underprivileged households have reached the point of occasionally skipping hot meals at certain times of the year.

This deforestation phenomenon tends to be self-perpetuating. Excessive pruning reduces tree growth, the removal of young trees that are easier to fell reduces the forest's regenerative capability. Collecting various residues deprives the soil of nutritive elements that are essential for its fertility. Pulling out stumps and shrubs destroys the soil's protective cover.

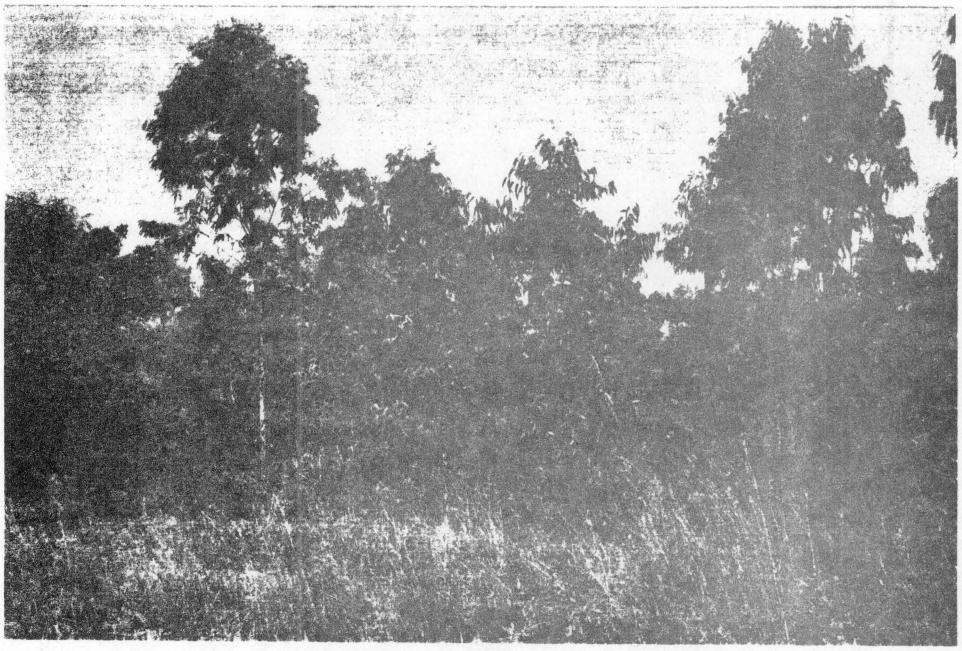
The impoverishment of wood resources has grave consequences on population settlements going well beyond energy considerations. Deforestation contributes to such large-scale modifications of the ecosystem as climatic aberrations and the lowering of the water table, and along with overgrazing and increasing salinity of the soil due to insufficient drainage, it encourages soil erosion and the destruction of arable earth, ultimately reducing the land to a desert.

The wood shortage poses a double threat that becomes more menacing with each passing day:

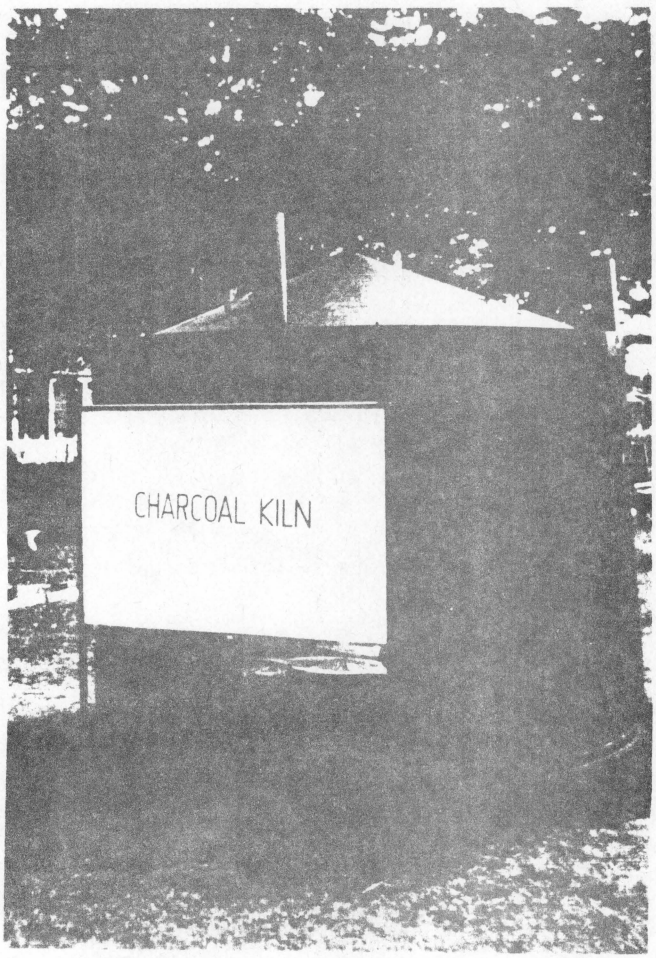
- shortages among rural and underprivileged urban populations, and
- the death of the Sahel.

Faced with this threat, the countries of the Sahel realize the need to adopt a policy of rational management and defense of forest resources. This policy is centered around three points:

- the development of wood resources, thanks to intensive plantations of rapid-growing varieties (eucalyptus, acacia) and village reforestation programs;



. Eucalyptus plantation



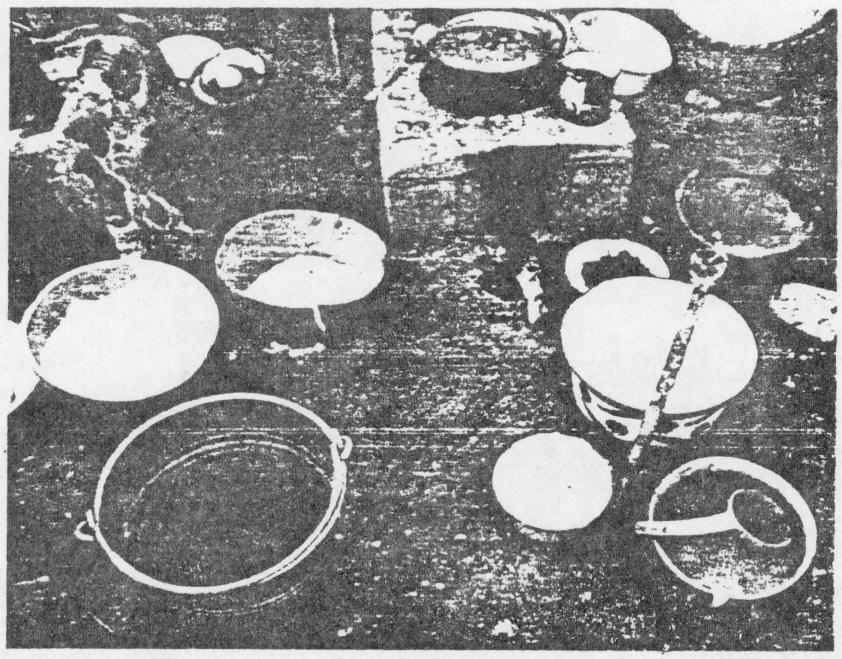
. Modern charcoal kiln

(Source: COMES)

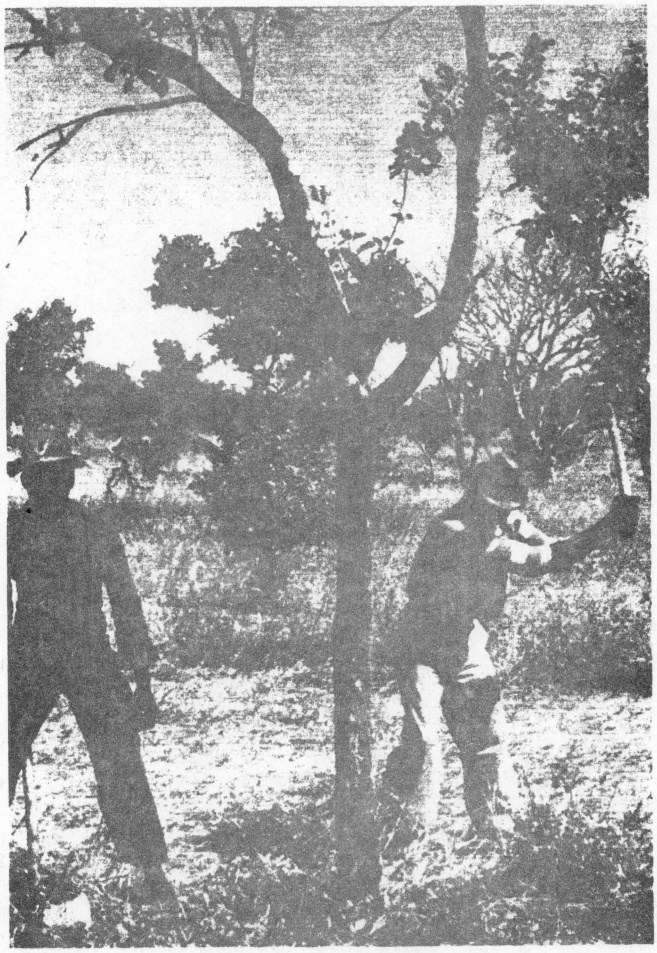
- improving wood production, processing, and distribution circuits by means of rational organization and exploitation of the most well-off areas, introduction of modern carbonization techniques, and the elimination of unscrupulous middlemen from the commercial sector;

- better utilization of wood and charcoal.

Because of slow program execution and inadequate financing, hopes of easing the pressure on the Sahel forests in the near future, either through reforestation or a more rational use of forest resources, seem slim. It was decided, therefore, to place more emphasis on the utilization of the fuels themselves. The improved stove programs represent a totally original approach toward the development of modern technologies that must be perfectly compatible with traditional values.



. Felling trees



. Shipment to the city

(Source: COMES)

EXAMPLE 1	I A D R - F E D IMPROVED STOVE PROGRAM OUAGADOUGOU / UPPER VOLTA

1. Heating wood problem in Upper Volta

Some statistics to illustrate the problem:

- heating wood satisfies over 80% of the energy needs of Upper Volta;
- cooking alone accounts for almost 90% of all consumption of heating wood;
- wood consumption (almost 2 million tons per year) currently exceeds the forests' production capacities (500,000 m^3/year); fifteen years from now all forest resources could be irreversibly destroyed;
- the wood consumed in Ouagadougou must now be shipped in form forests over 100 km away;
- the price of wood in Ouagadougou has risen from 7.5 CFA Francs in 1976 to 15 CFA Francs in 1980, while incomes changed only slightly; a large percentage of families living in Ouagadougou spend over one-fourth of their household budget on wood;
- present-model stoves (the three-stone system) waste close to 95% of the potential heat contained in the wood.

2. The IARD program

The International Association for Rural Development (IARD), with financial assistance from the European Development Fund, opened two workshops for the construction of improved stoves, one in Ouagadougou (in the Dapoya neighborhood) and the other at Bobo-Dioulasso, in which twelve artisans and two organizers work.

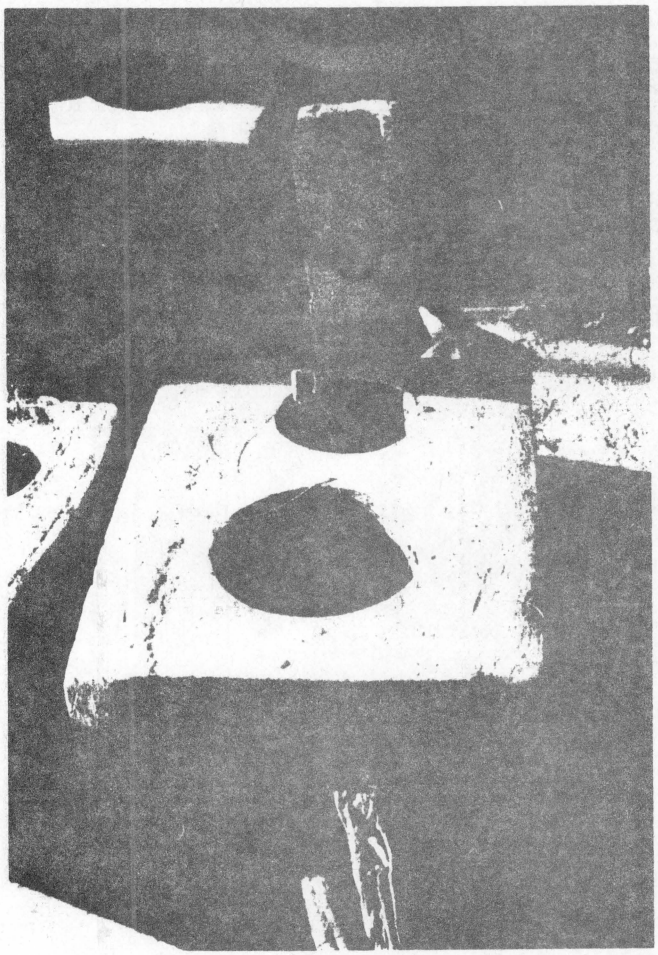
2.1 Program guidelines

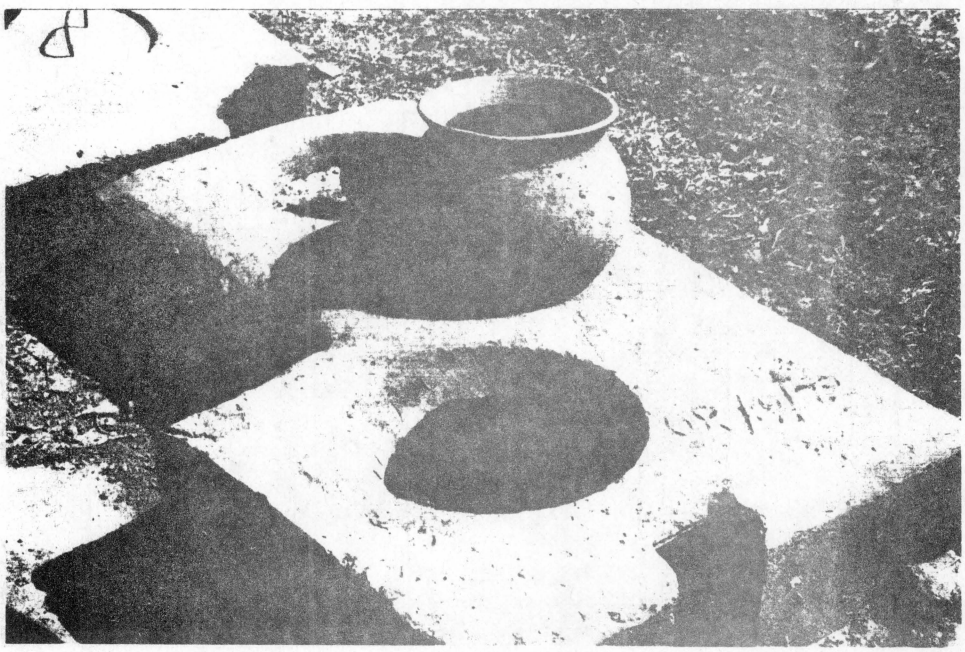
Stove design is based on two criteria:

a. making best use of the heat energy from wood through proper combustion and an adequate transfer of heat to the pots.

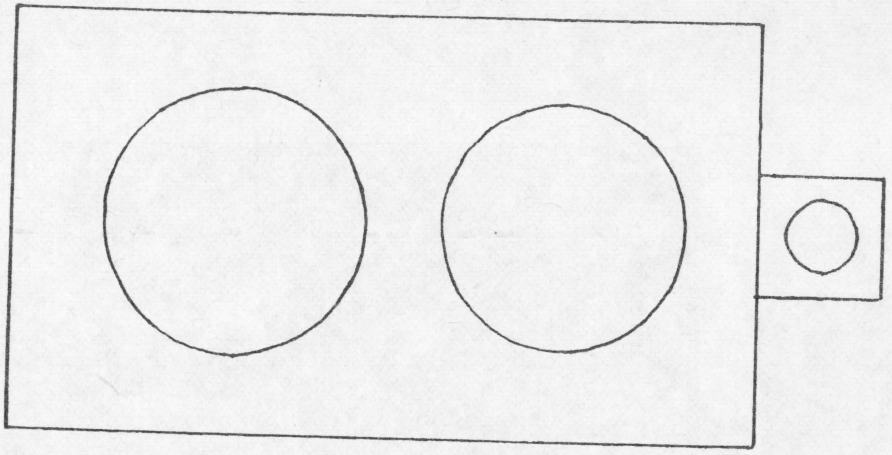
In order to obtain this type of complete combustion, it is necessary to:

- provide the wood with a sufficient but not excessive quantity of air, otherwise the heat is lost,
- create a thorough mixture of combustion gases and air,
- wait for a temperature hot enough to ignite the gas-air mixture,
- provide for enough space so that the gas has the time to burn completely,
- reduce sensible heat losses and those due to non-combustion and dissipation.

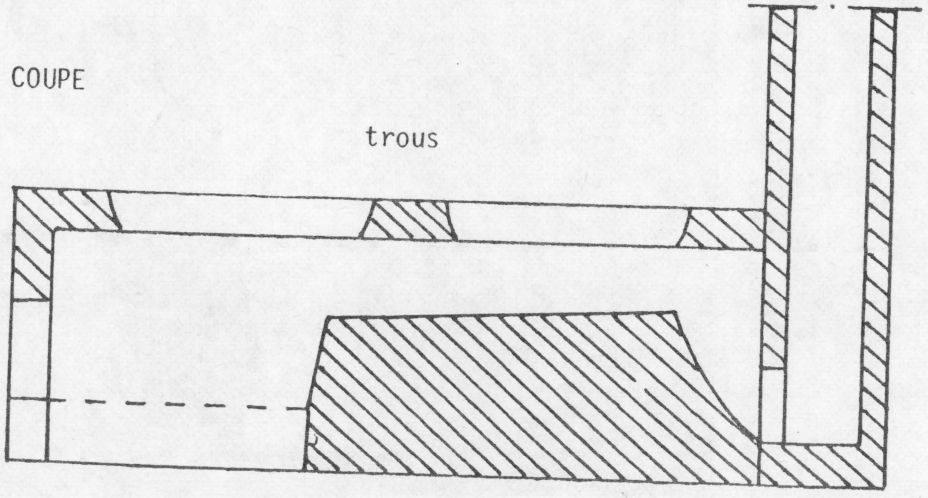




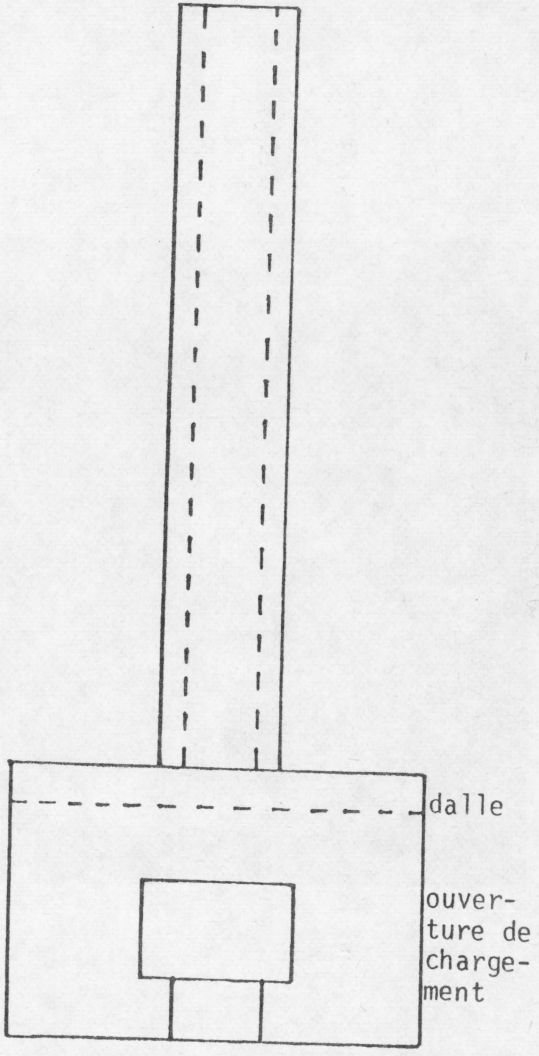
PLAN

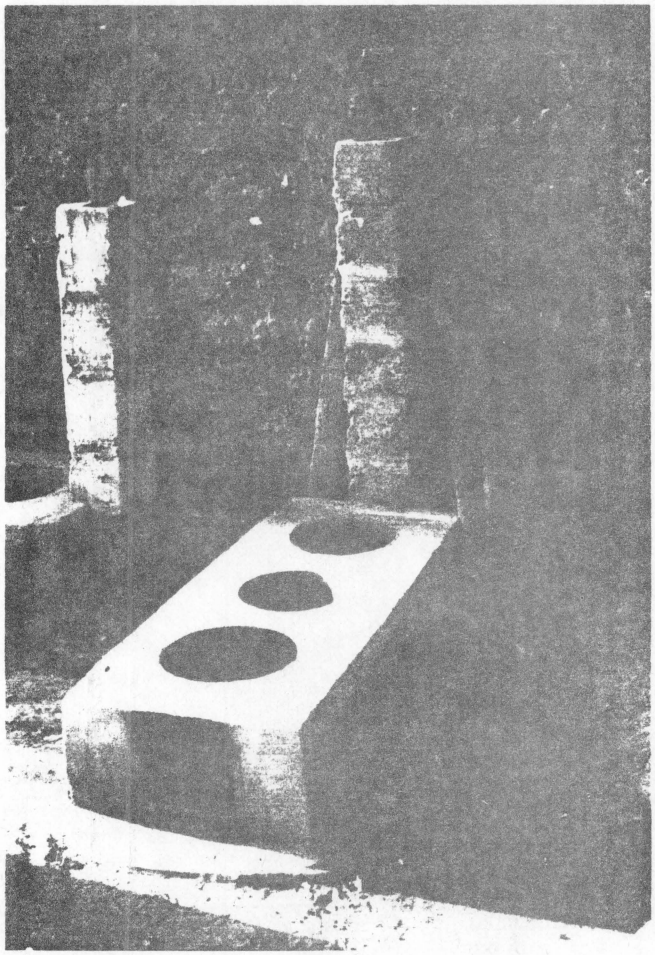


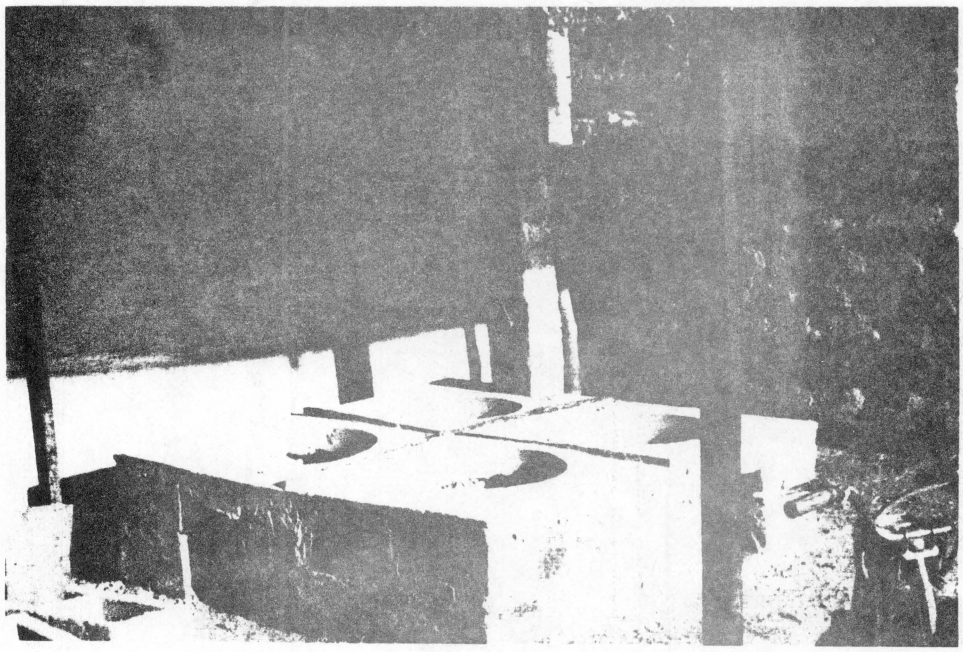
COUPE



CHEMINEE







b. offering stove models that are inexpensive enough for urban families in Upper Volta. This implies:

- utilizing free or inexpensive materials and limiting the use of expensive materials (cement, metals);
- designing simple construction techniques within the reach of little skilled labor.

The models selected represent an effort to adhere to the imperatives of high efficiency and low cost.

2.2 The solutions chosen

Inside the IARD stoves, the fire is enclosed within a thick-walled brick chamber covered with a thin slab. Pots are placed over holes cut into the slab. At one end there is an opening for loading the wood, at the other end, there is a smoke stack for exhaust and venting. Using a two-holed hearth, for example, the pot containing the national dish is placed over the first hole, the other pot is placed over the second hole. The wood burns under the first hole only. The heat passes under the second pot before reaching the exhaust. By carefully designing the hearth the heat can be concentrated under the second hole, thus limiting heat loss (using tubing, with a greater diameter than the smoke stack, mounted on a slant). After cooking, the openings are closed and pots of water are placed over the holes. In that way, hot water can be obtained without burning any additional wood.

The improved stoves are made of cement and clay. Their extremely simple construction is carried out in two stages:

- constructing the shell, the upper surface, and the smoke stack out of cement;
- casting the internal surfaces in clay.

The asking price is about 4,000 to 5,000 CFA Francs, depending on the size of the stove. At the current cost of wood, the stove can be written off in a matter of months, as it can reduce wood consumption considerably (by 40 - 50% according to information supplied by users). This performance can be improved even more thanks to the following technical developments:

- grill for the ashes,
- metal latch for locking the opening for the wood,
- bi-level air intake,
- replacing the holed slab by a cast iron or steel plate.

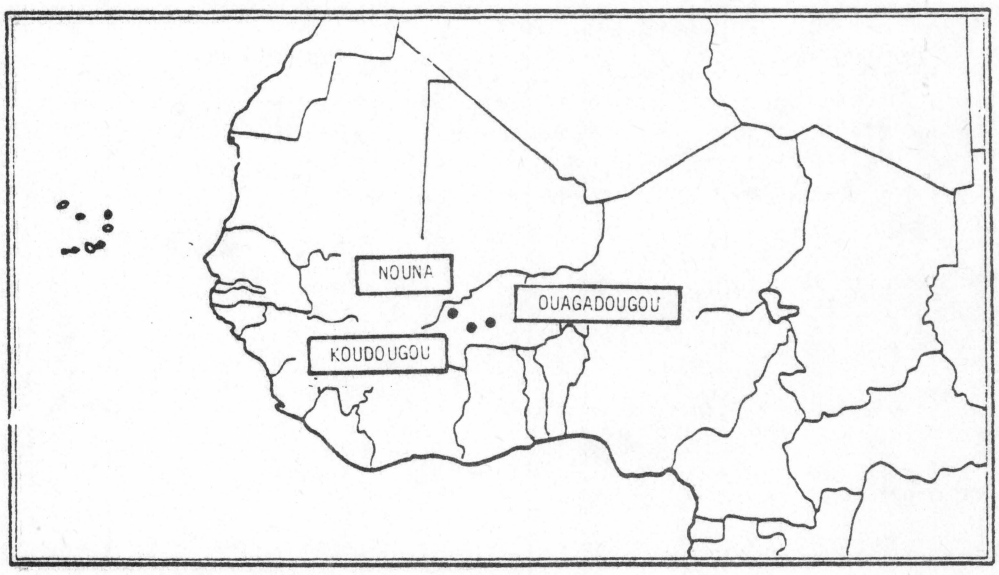
These improvements can increase output from 25 to 35%, although the materials used are more costly.

2.3 Results and perspectives

Over 500 of these stoves have been built in Ouagadougou, Bobo-Dioulasso, and Kongoussi. A large-scale information campaign has been undertaken by the radio, cooperative associations, women's organizations, and others, in order to increase distribution of these stoves. Considering their efficiency and simplicity, as well as the potential impact of this technology on Upper Volta's environment, increased efforts in this area are entirely in order.

EXAMPLE 2	IMPROVED STOVE PROGRAM OF THE MISSION ALLEMANDE FORESTIERE AND THE MINISTERE DE L'ENVIRONNEMENT ET DU TOURISME OUAGADOUGOU / UPPER VOLTA

This project is the oldest of its kind in Upper Volta (1977). The Mission Forestière Allemande of Upper Volta runs three training centers for demonstrations and prefabrication. The main center is located in Ouagadougou and the two others in Nouma and Koudougou (since May 1981). In each of these centers teams of masons offer different models of improved stoves, the most popular of which consists of a large, three-burner structure with two chimneys that are prefabricated at the Center. The ovens are added on afterwards, at the purchaser's home, at which time he is instructed in their use. No follow-up of performance or acceptance of the new stoves seems to have been executed.



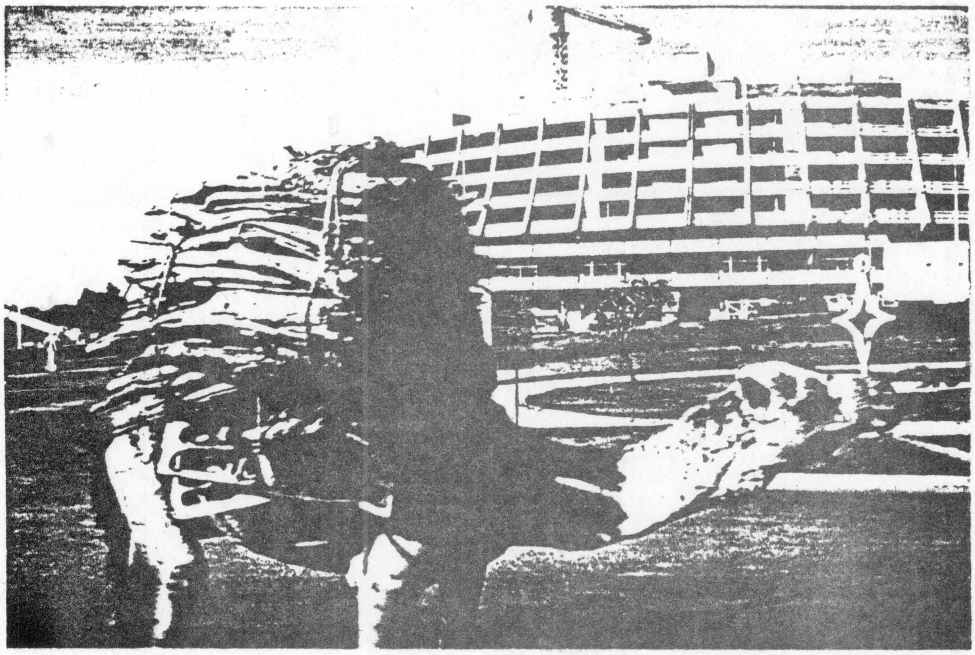
EXAMPLE 3	C A T R U IMPROVED STOVE PROGRAM OUAGADOUGOU / UPPER VOLTA
From SERI documents	

The C A T R U (Centre d'Applications des Technologies Rurales et Urbaines) is an 'appropriate technologies' unit of the C N P A R (Centre National pour le Perfectionnement des Artisans Ruraux). Over the past few years developments and demonstrations of improved stove prototypes have been taking place.

The C A T R U is concentrating on 'top of the line' models. Their latest one is probably the most efficient oven built in Western Africa. It comprises:

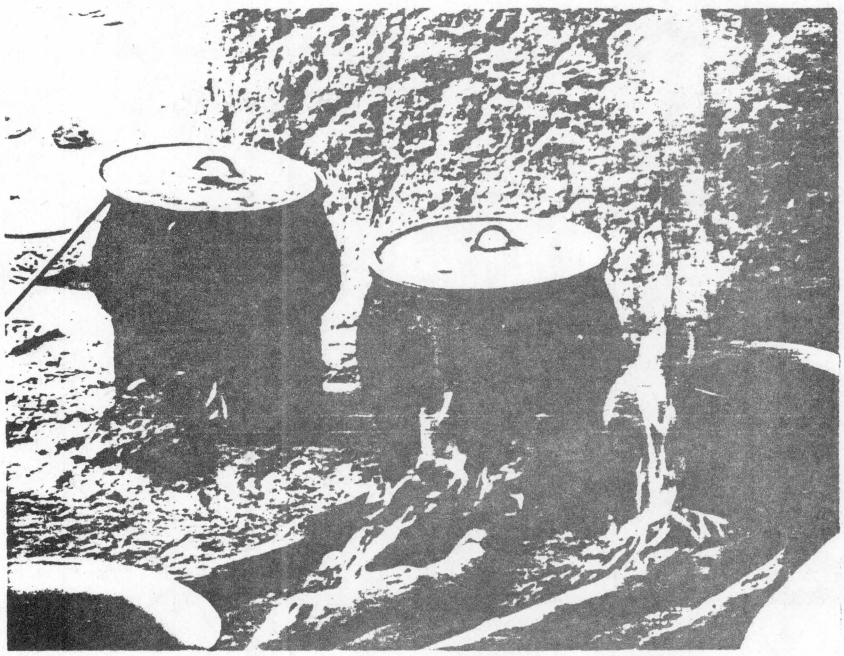
- cement walls
- a molded interior coat of clay and sand
- an upper tray in cast aluminum, designed to hold specially designed soup pots.

. Pots of the Sahel



(Source : COMES)

. Transport du bois



. Cuisson sur fourneaux urbains traditionnels

EXAMPLE 4	IMPROVED STOVE PROGRAM OF THE WORLD CHURCH SERVICE AND THE ASSOCIATION DES FEMMES NIGERIENNES NIAMEY / NIGER
Inspection report: April 1981	

1. The heating wood problem in Niger

There are four characteristics of wood sales and consumption:

- The sale of wood is uncontrolled and subject to little regulation. The number of permits issued bears no relationship to the volume of sales. (Wood is shipped by donkey, camel, or motor vehicle.)

- Prices tend to increase rapidly, having risen by a factor of 2.6 from 1973 to 1978. A 6- to 8-member family spends 10 - 20% of its income on fuel. In the Niamey area, particularly on the route to Kolo, some households now have to resort to millet stalks and animal waste.

- The increase in population has progressively destabilized the ratio of offer to demand. Defoliation is currently taking place over a 50-km radius around Niamey.

- Cooking habits (open-air cooking of food, for 2 - 3 hours, on round iron support stands) are responsible for the overconsumption of wood.

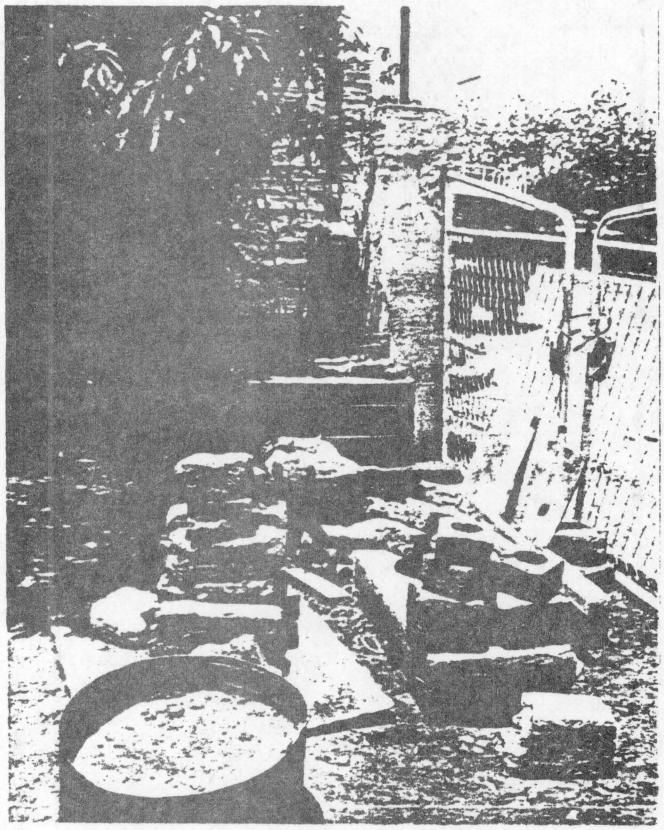
2. The program of the Association des Femmes du Niger

In October 1980 the Association des Femmes du Niger, with technical and financial assistance from the World Chruch Service, an American non-governmental organization, launched a program promoting the construction of improved stoves of the type built in Upper Volta (Lorena). A first series of about two hundred stoves has already been completed in different neighborhoods of Niamey. Users chose from among several models, the most popular being:

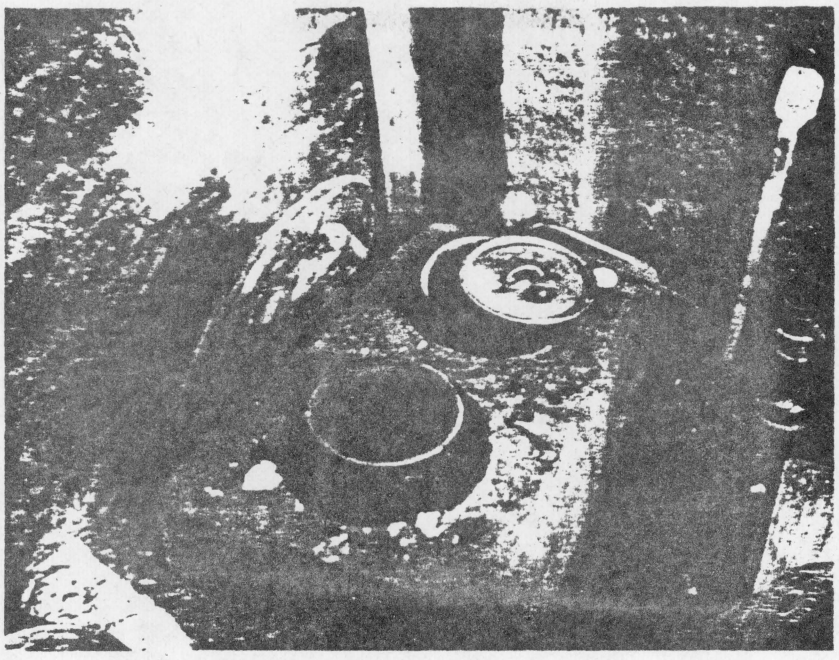
- those in cement, rather than clay,
- low, ground-level models, which correspond to the cooking habits of Niger women,
- those with optional wood or corrugated metal cowls to protect against inclement weather.

This experimental distribution provided a valuable information concerning how Niger housewives appreciate their stoves. The exceptionally low price offered (one-tenth actual cost) and the protective cowl, which in itself renders the investment worthwhile, put limitations on the conclusions that can be drawn from this first phase concerning perspectives for greater distribution.

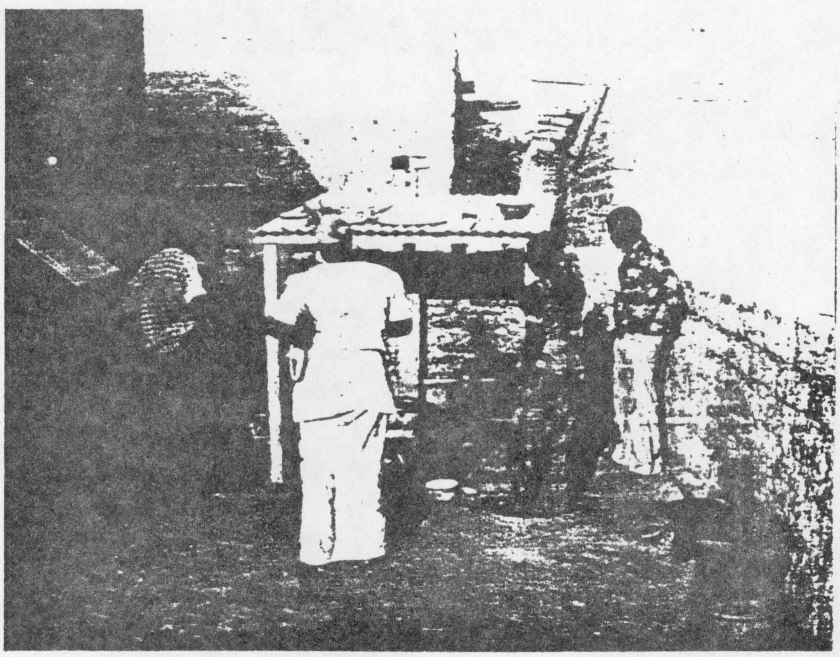
. Construction
des fourneaux



. Technologie artisanale...



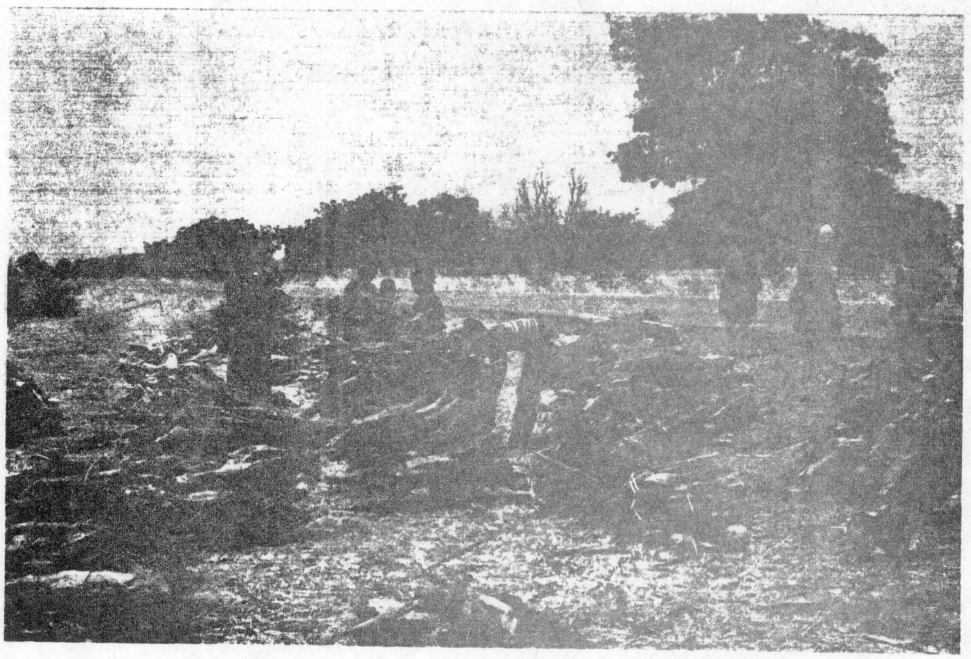
. Cuisinière améliorée



. Animation et formation des utilisatrices

. Shipping wood on a small scale...

... and on a large scale



EXAMPLE 5	'BAN AK SUUF' IMPROVED STOVE PROGRAM C E R E R / SENEGAL
From CERER documents	

1. Heating wood problem in Senegal

Despite the great wood reserves in the south (Casamance, Eastern Senegal) Senegal is also faced with a wood shortage problem, in the center, the north, and especially, the high consumption coastal region (between Dakar and Thies). This situation will only worsen in the decade to come, and Senegal will be confronted with a general wood shortage.

- The situation will be particularly difficult in the center and north where the forests will have disappeared to a large extent.

- Wood and charcoal dealers will be forced to go much farther south in order to stock up. This will entail continual price rises for these fuels (charcoal in Dakar and the major cities, wood elsewhere).

Several reforestation projects are under way (at Bandia, south of Dakar, the east-central program) that will alleviate limitations on supplies for the capital but will fall far short of solving the problem on a national scale.

2. History of the program

The Senegalese program for the distribution of 'Ban ak Suuf' (Wolof, for 'clay and sand') improved stoves was launched in February 1980 with financial assistance from USAID. The program was divided into two phases:

- first, an evaluation phase, until the end of 1981, during which time a few thousand stoves would be built;

- second, a mass distribution phase aimed at reaching 80% of the rural population over a period of three years.

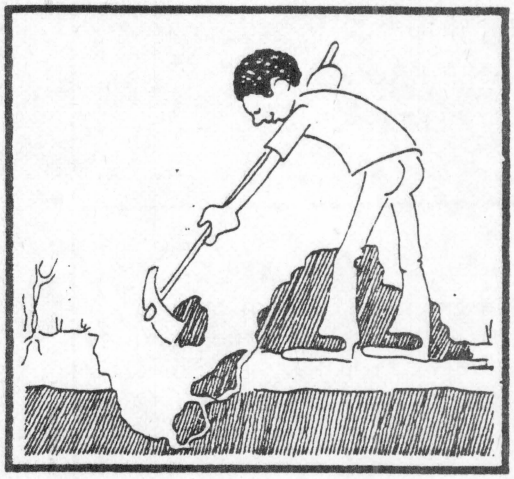
The CERER organized a team consisting of an engineer (part-time), a technician, and five masons. This team is divided up into two units of varying size, depending on current needs.

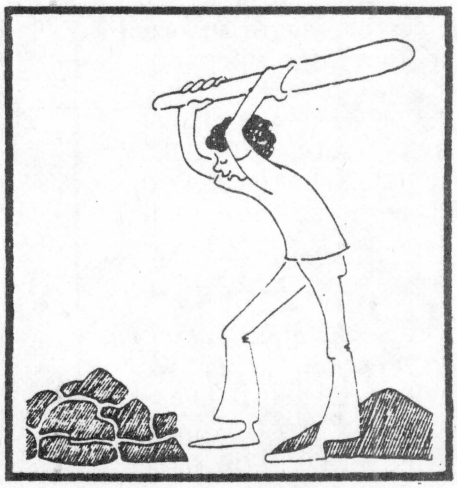
- One unit is responsible for the following tasks:

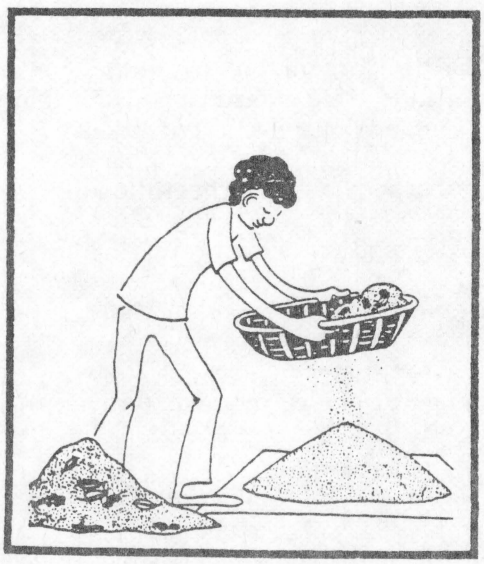
  . scientific and technical testing of the different models of improved stoves,
  . researching solutions to technical problems (where to place the pots, impervious coating),
  . training for many masons,
  . launching of new models (stoves using charcoal or peat, community stoves, etc.).

- A mobile unit for the rural areas is responsible for:

  . giving demonstrations on construction and utilization,
  . training village masons,







(Source : CERER)

. providing follow-up for the different models built,
. helping train instructors and organizers connected with the different development organizations participating in the program.

This team organized the first phase of the 'Ban ak Suuf' program and :

- completed the design for the 'Ban ak Suuf' stoves,
- perfected construction techniques,
- evaluated performance and appreciation for the new stoves,
- developed a method of distribution.

3. Design of the 'Ban ak Suuf' stoves

There is no one model per se, but a general design corresponding to the following criteria:

- The heat coming from the fire is either reflected towards the hearth or the pot, or it is absorbed by the body of the oven, which stores the heat and then partially releases it at the end of the cooking cycle, in order to simmer foods or heat water.

- The body of the stove, made of a mixture of clay and sand, maintains the interior hearth walls at a high temperature, thus promoting better combustion.

- The stove has several holes for pots so that several dishes can be prepared simultaneously (cereals and sauce, for example) using the heat from only one fire.

- The contours inside the hearth (mounds, spirals, etc.) and the smoke channels retain the gases resulting from combustion and bring them into contact with the cooking surfaces.

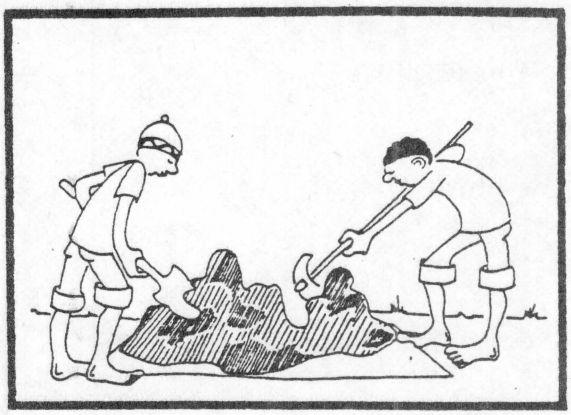
- The air intake can be positioned in such a way as to create special turbulence patterns in order to improve the output from combustion, raise the temperature of the flame, and reduce the level of smoke.

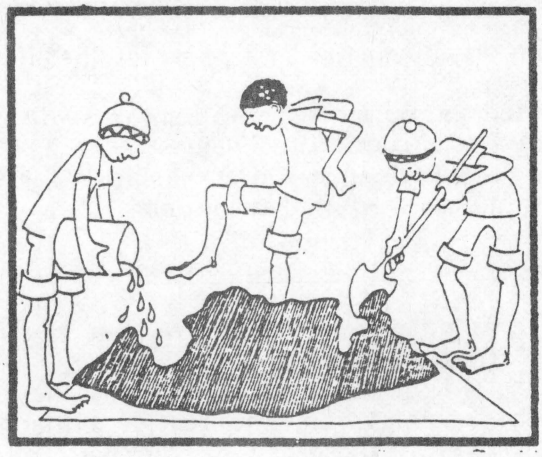
- The pots can be placed deep into their holes, protecting them from drafts and reducing energy losses.

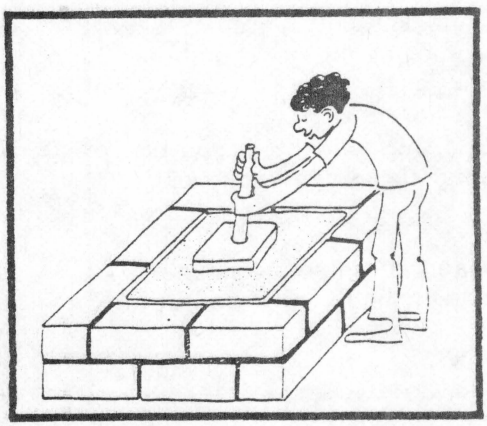
By respecting these guidelines, each stove can be adapted to the needs of Senegalese households, whatever their culinary habits and family size, wherever they live.

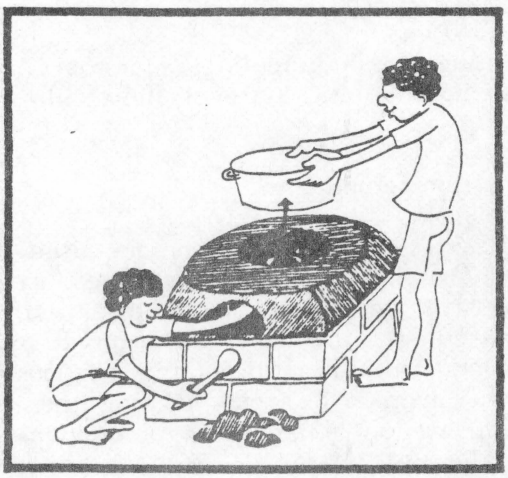
4. Construction techniques

The basic construction technique used for 'Ban ak Suuf' stoves is simple. The pots normally used by housewives are surrounded within a high thermal inertia mass of well mixed, crushed, and sifted clay and sand. The proportions of the ingredients are first determined by a series of manipulations. Then, a base is constructed in proportion to desired oven height. Afterwards, the body of the oven is built by packing the mixture in successive layers around the pots, using one's hands or a tamper, and leaving a space between the base and the pot bottoms. This space constitutes the hearth (connected to the wood input) which is hollowed out when the oven is completed and slightly hardened.









(Source : CERER)

The final operation is undertaken once the pots are removed. This consists of sculpting the contours controling smoke circulation and exhaust. In the simplest model, a very narrow space is hollowed around the pots. The smoke escapes through this space and along the sides of the pots. The other models are equipped with a smoke stack made up of hollow cylinders, cast in clay and sand using metal cans, for example, and placed one on top of the other. The smoke stack is connected to the hearth by a channel hollowed into the body of the stove.

Construction is cottage industry style. Its two weak points are having to determine the proportions of clay and sand (affecting the quality of the mixture) and shape the stove's interior contours (an essential factor in its efficiency). Experience provides simple solutions to those problems posed by the materials. Cracking due to high temperatures is remedied by installing expansion joints (pieces of cardboard) and creating discontinuities in the body of the oven. Outdoor stoves (about 10% of those built) are protected from the wintering season rains by coating them with gum arabic or drain oil.

5. Evaluating performance and appreciation

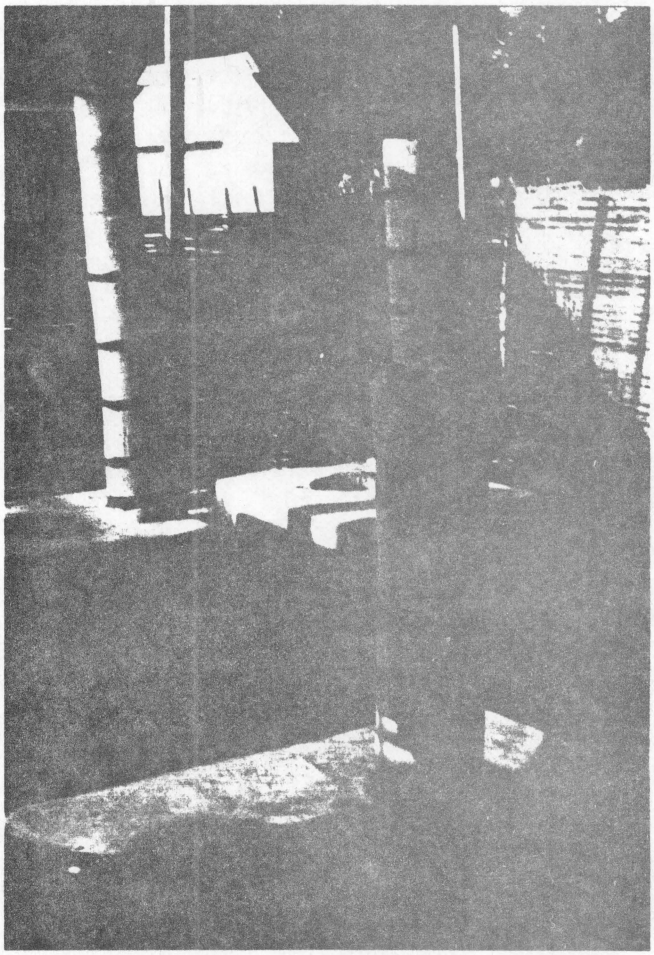
Almost 3,000 measurements were made in about 100 homes. Fuel consumption comparisons were made between traditional stoves and 'Ban ak Suuf' stoves under actual conditions. Two-thirds of the stoves tested showed substantial savings in wood, averaging 41% and going as high as 60% for certain prototypes. The others had inferior results due to poor utilization of the new stoves. The first experiments with limited distribution were greatly appreciated by the rural organizers and especially by the new users.

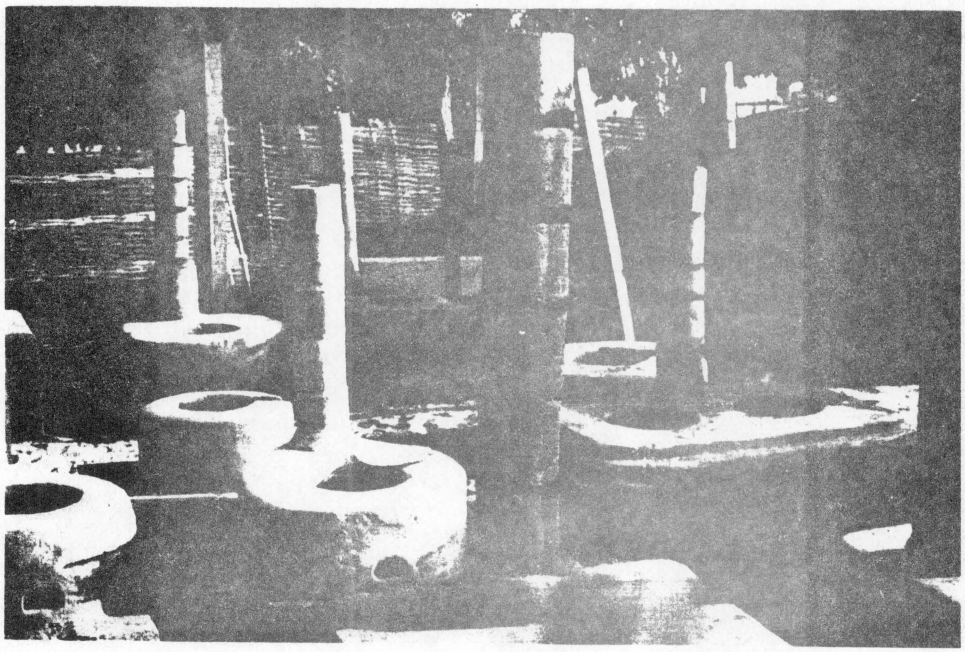
6. Determining a method of distribution

During the program's preliminary phase, field experience was used to determine mass distribution strategy for 'Ban ak Suuf' stoves. This strategy is soon to be introduced. The main body and program mover is composed of mobile training units led by three regional coordinators and one technical team operating out of the CERER.

Before the mobile teams commence their field activities a first contact is made and a local 'correspondent' is selected (a development agency, local association, traditional chief, or religious organization, whichever is the best integrated, most dynamic partner in the village or neighborhood). The correspondent, aided by the instructors from the mobile units, carries out a short evaluation survey concerning all phases of cooking, in order to determine what practical and symbolical significance the ovens hold for the local inhabitants, and to discover the socio-economic groups that will become distribution agents. Afterwards, an awareness campaign is started among the people. The mobile units then organize demonstration and training sessions for the villagers, the craftsmen who will build the stoves, or the members of the corresponding organization who will in turn train others.

The relationship between the central body and the corresponding organizations makes it possible to distribute the stoves and set up a system of relays that will eventually handle all local distribution and training. The relays are organized for each organization depending on its particular qualifications.





The training is intended mostly for women in rural environments. They are the first to be concerned because they are in charge of providing the fire wood and spices, while the men supply the cereals. The women have developed their own organization and training system consisting of short apprenticeships in the villages where each participant starts by building his own stove. Other units are then assembled as a group effort. These are generally occasions for song and dance, contributing to the successful distribution of the stoves within and around the villages. In the more urbanized areas, this training is intended for craftsmen. The apprenticeships are more technically oriented, lasting two weeks. Upon completion, the trained masons sell their know-how at 1,500 to 3,000 CFA Francs per stove.

6. Results and perspectives

Approximately 3,000 stoves have been built throughout Senegal. The first phase of the evaluation is thus complete. The second phase involves the mass distribution of from 300,000 to 500,000 stoves, equipping almost two-thirds of all Senegalese households, over a period of three years. This requires the training of about 10,000 builders by mobile units and instructors:

- rural women's training units, for village women who will build their own stoves and spread their know-how;

- rural and semi-urban men's training units, for village masons;

- urban craftsmen training units, for masons who wish to sell stoves.

This also requires the assistance of all the Senegalese development organizations and the different media.

7. Conclusions

The first phase of the 'Ban ak Suuf' program is coming to a successful close. The second phase appears extremely ambitious. A serious follow-up effort is in order. Judging from the scope of the project and the originality of the methods employed, this is certainly one of the most innovative development programs in Western Africa.

PART 2

RECOMMENDATIONS

CHAPTER 1

IMPACT OF RENEWABLE ENERGY PROJECTS ON DEVELOPMENT: USER SATISFACTION

It is difficult to make an overall evaluation of both the impact of renewable energy projects on development and the degree to which users are satisfied, partly because the contexts and technologies called for are varied, and many of these projects are still very recent. The first part, which includes actual evaluations of a wide variety of projects, should indicate the magnitude of the 'event' in the life of a village that is associated with the installation of solar energy equipment. Next we shall see some of the major ideas that our field study brings to light.

1. Impact on the development of the villages in question

In most instances the projects carried out had a very positive effect on the development of the villages in question.

2. Satisfaction of the most pressing needs

These projects dealt with satisfying the most urgent needs:

- village water supply,
- livestock water supply,
- truck farming,
- tree nurseries,
- water and/or electricity supply for hospitals and infirmaries,
- telecommunications, community television, and so on.

3. Reasons for the particular success of certain projects

The most successful projects, those that were the most heavily utilized, were those implemented in conjunction with other development programs already under way.

4.Varied effects on the villages in question

The impact on the development of the communities concerned has been very varied:

- feeling of confidence in the village leading to renewed hopes (young people remaining, for instance),
- preservation of villages threatened by drought (Mali),
- creation of tree nurseries for reforestation (Mali),
- start-up of a truck farming activity bringing the villages much needed revenue (example: Samane, Senegal),
- improvement of the food situation (fruits and vegetables),
- motivation for students and trainees in the centers taking advantage of these projects,
- improvement of operating conditions for the health-related infrastructures (infirmary at Kolakani, hospital at San),
- youth and adult training (community television).

5. Importance of the receiving organizations

The projects that were associated with good receiving organizations produced superior results from every standpoint (reliability, utilization of the pumped water, etc.).

6. Psychological impact

On the whole, users have greatly appreciated the renewable energy projects, and thus, their psychological impact has been considerable. This implies that the projects have been carefully prepared.

7. Respect for the equipment

Users displayed an absolute respect for the equipment, assigning caretakers to protect the installations (no vandalism took place).

8. Reliability of the equipment

Photovoltaic equipment ranks among those systems studied that performed well in the field. It showed a high degree of reliability despite some initial difficulties (in terms of the quality of the first generation of modules).

Today, the breakdown rate for photovoltaic pumps is considerably lower than that of diesel or gasoline engines operating under the same environmental conditions. Villagers consider this an essential criterion, since breakdowns can have devastating consequences (threatening their crops, for example).

9. Maintenance -- after-sales service

The quality of service of solar equipment leaves much room for improvement.

The maintenance infrastructure is still incomplete (causing several weeks, even months of down time for certain pumps).

From this viewpoint, the maintenance infrastructure of the Mali Aqua Viva program is quite good. The scope of the program itself facilitated its implementation.

10. Lack of related equipment

Several of the projects inspected were handicapped by the lack of equipment for water distribution and storage. As a result, the solar energy equipment went underutilized.

11. Users' contributions to investments

Users of both sexes clearly appreciate the improvements brought about by photovoltaic pumps (ex.: Samane).

Moreover, villagers readily invested their time and money in the equipment (Ziniare, Markoye, etc.).

The projects in which users invest are better utilized and maintained afterwards.

Projects that are simply donated often fail (when an installation is 'planted' in a community, its operation becomes the administration's responsibility).

12. Risks associated with experiments carried out in actual villages

Villagers, who evidently do not appreciate taking part in experiments, hold a dim view of the failures of certain thermodynamic pumps. As a rule, they show great confidence in this equipment and are therefore severely disappointed when it does not operate correctly. In Niakhane (Senegal), for instance, many villagers relocated their homes in order to be closer to the pump; the pump's breakdown came as a great dissapointment.

Experiments should virtually never be made in actual villages.

13. Other reliable equipment

Besides solar photovoltaic pumps, whose results have been highly encouraging, very positive results have been obtained from:

- multiple-blade wind turbines, which are reliable, require little maintenance, and are well suited to small communities;
- solar arrays for powering radio relays, television sets, radio navigation beacons, etc.

14. Utilization of biogas

The impact of biogas on rural environments is still little known. A large-scale program has just been started in Upper Volta, the results of which should be monitored on site (power for a hospital, truck farms, training centers, etc.).

In conclusion:

- very encouraging results have been obtained in the field;
- users have well accepted and well maintained their reliable solar equipment;
- the utility of the majority of renewable energy projects is undeniable;
- the reliability of certain pieces of equipment is now greater than that of conventional equipment;
- future projects will have to be prepared with the greatest of care.

CHAPTER 2

TECHNICAL EVALUATION OF SOLAR ENERGY EQUIPMENT

1. Photovoltaic pumps

1.1 - Reliability

After some initial difficulties concerning solar arrays, photovoltaic pumps today enjoy a high standard of reliability that currently surpasses that of diesel- or gasoline-powered pumps.

a)- Reliability of the solar arrays: The modules showed low resistance to climatic conditions and presented many problems (delamination, break in connections between cells, etc.). Virtually all brands of modules presented problems on site; the newer models, supplied under the terms of the warranties (5 years) operate satisfactorily. Glass models appear to be more resistant to sand, cold, water infiltration, etc. Certain faults were due to initial design errors (generator engineering, inadequacy of diodes, etc.).

b)- Reliability of the pumps: The direct coupling centrifugal pumps are extremely reliable. The most common breakdowns were due to initial errors (pumps erected over wells that were still being dug -- sand quickly destroys pumps) or to clogged strainers in the case of unlined bore-holes. Positive-displacement pumps produced disappointing results (1).

c)- Reliability of the electric motors: The motors used with the direct coupling centrifugal pumps presented no problems, with generator brushes lasting at least two years. The motors used with positive-displacment pumps developed some problems (wear noticed in catch basins, generator brushes wore out quickly).

d)- Reliability of the electrical cabinets: The electrical cabinets controlling the direct coupling centrifugal pumps never malfunctioned, thanks to their simple design. This has not always been the case for other types of photo-voltaic pumps (faulty relays, maladjustment of the impedance matching stubs, etc.).

1.2 - Ease of maintenance

Care of direct coupling centrifgal photovoltaic pumps is extremely simple. A maintenance crew can service a hundred pumps using only a small number of conventional tools. Maintenance for other pumps has proven more complex, particularly concerning the electronic monitoring aspects of regulation in countries where qualified electrician/electronics engineers are scarce.

1.3 - Comparison to rated performance

Manufacturers, in good faith, often give optimistic specifications ratings that do not reflect the numerous power losses at the solar array (due to the effects of temperature and electrical imbalance, improper selection of the array for given load requirements, etc.). Based on their experience, manufacturers today show greater prudence. It should be noted that rated performance can only be attained when the manometric head corresponds to the manufacturer's rating. In practice, actual manometric heads often differ greatly, whence a loss in performance to be expected.

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(1) This appraisal only concerns those pumps installed.

1.4 - Measured output

Direct coupling photovoltaic pumps, when in good condition, have an overall output (1) of about 4.5% (generator output: 10%, motor+pump output: 45%). This is a respectable figure, and is in fact five times greater than that for solar thermodynamic pumps (that is, a collector surface five times smaller produces the same delivery rate).

1.5 - Maturity of this technology

Direct coupling centrifugal photovoltaic pumps of under 10 peak KW have reached the commercial stage. Their life span will depend on the durability of the new photovoltaic modules. A target life span of ten years seems realistic. Other types of pumps are in the development stage (particularly, submersible pumps). They are very promising, but should not be distributed until they have been perfected.

1.6 - Modular configuration, operation in the event of partial damage

The great advantgage of photovoltaic pumps is their modular configuration, by means of which it is possible to keep up with changing needs. Their other great advantage is their capacity to operate at partial strength in the event of partial generator failure (increased security).

1.7 - Recommendations

. Simple technological solutions should be preferred, even if slightly lower energy output results.

. Electronic components, inevitable in the long run, should be integrated with extreme prudence and only after the most rigorous testing; they should be built into easy-to-replace modules.

. Only glass-enclosed photovoltaic modules should be used, as they are more resistant and cool down better.

. When motor and pump sizes are selected, actual, not theoretical power ratings should be used for calculations.

2. 1-KW Thermodynamic pumps

2.1 - Reliability

- Poor, on the whole, although some pumps have been in operation for several years without requiring major servicing.

- The disappointing results can be ascribed to both human failure (training for users, maintenance organization, etc.) and purely technical failure.

(1) Total output = hydraulic energy obtained/incident solar energy.

- Main breakdowns: positive-displacement pumps and hydraulic presses, leaks in the collectors, butane and freon losses.

- Even the circulation loop was more reliable than the more conventional related equipment.

2.2 - Ease of maintenance

- Servicing these pumps, while not difficult, requires specially trained personnel.

- It would be difficult for the receiving organizations to ensure total maintenance of these pumps.

- Spare parts and freon are difficult to obtain.

2.3 - Comparison to rated performance

- None possible -- in most cases the delivery rates obtained were significantly lower than expected.

- Explanation: average insolation under the 6.5 KWh/m²/day estimated by manufacturer, temperature of water in bore-hole too high, collector output lower than planned.

2.4 - Present condition of the equipment

- Original installation carefully executed.

- Repairs can easily be made on most of the equipment at modest cost (ex.: 6 pumps repaired in Upper Volta in the space of a few weeks).

2.5 - Maturity of this technology

These pumps were put into service too hastily; the transition from interesting prototype to the pre-commercial stage was too rapid. Appropriate development was not made in the field, considering the difficult environment.

2.6 - Recommendations

. There should be no on-site experimentation unless carried out by specially qualified receiving organizations (engineering schools, laboratories, universities, etc.).

. On-site experimentation is:

- unacceptable, regarding the users who do not wish to take risks;

- ineffective, from a technical standpoint, without monitoring, feedback, etc.;

- risky for the image of solar energy technology.

. Solar energy equipment should be fully developed before putting it into service in the field. Development is costly but essential.

3. High-power (10-KW) thermodynamic pumps

The recent nature of such projects as KARMA, DIRE, and BONDIE SAMB should temper any technical evaluation.

3.1 - Reliability

- Not yet established; some of the results are encouraging.

- Much greater complexity of equipment (start-up systems, refrigerant gases, electrical automation systems, etc.) capable of hindering reliability.

- Greater reliability of certain components (collectors, circulation loops).

3.2 - Ease of maintenance

Complex equipment; qualified technicians must always be available.

3.3 - Maturity of this technology

Still at the prototype stage, integrating several technological innovations (new engines, heat storage, refrigerant gas, automatic regulation, etc.).

3.5 - Recommendations

These installations are experimental. It is thus necessary to provide the means for carrying out an effective experimentation program for the sake of progress and the satisfactory termination of these projects, including:

- increasing the technical staff,
- increasing the quality and quantity of measuring instruments (DIRE),
- increasing the financial outlay to cover operations.

An in-depth evaluation will be necessary after these experiments in order to determine the interest in developing this branch (multi-criteria evaluation). It should be noted that these installations can be of significant value in the training of solar energy technicians.

4. Photovoltaic electric power stations

The study made for the hospital at SAN, presented earlier, shows that small, highly reliable photovoltaic electric power stations can be built in order to provide essential services.

Recommendations

. The construction of small photovoltaic electric power stations can now be recommended if the electrical energy is to be used in high-priority applications (infirmaries, for instance).

. Construction should not be limited only to high-power installations, such as the one at SAN (8.5 peak KW); only a few hundred peak watts are needed to provide significant service at modest cost (essential lighting, medical equipment, vaccine refrigerators, transmitter/receivers); modular construction could prove very interesting in this area.

5. Other photovoltaic equipment

5.1 - Reliability

Solar arrays, used to power a wide range of electronic equipment:

- community television sets,
- radio relays,
- radiotelephone relays,
- television relay transmitters,
- radio beacons, etc.

have already proven their reliability in use in Africa. They offer a quality of service far superior to that of competing energy sources (diesel, turbo-genrators, etc.)

5.2 - Ease of maintenance

Maintenance is extremely limited; only one or two inspections per year are required, and these can be carried out at the same time the electrically powered equipment is inspected.

6. Solar water heaters

6.1 - Reliability

Well-designed water heaters made from durable construction materials (fibrocement, aluminum, fiberglass, etc.), such as the ones built by ONERSOL (Niger), are very reliable.

6.2 - Ease of maintenance

Solar water heaters require only extremely limited maintenance.

7. Biogas

7.1 - Extent of development

Batch-wise system technology (CIEH, Upper Volta) can now be considered operational. User acceptance remains to be seen, and new ways to lower investment costs must be sought.

7.2 - Ease of maintenance

Biogas equipment requires regular servicing (anti-corrosion treatments, checks for leakage, cleaning, etc.).

8. Multiple-blade wind turbines

8.1 - Reliability

The reliability of multiple-blade wind turbines can be very great:

- if quality equipment is used,
- if the pump connected to the wind turbine is selected to fit the bore-hole (not oversized),
- if there is someone to provide a minimum of maintenance and to lock the machine before the wintering season tornados arrive,
- if the wind turbine is located in an appropriate place (little turbulence, lack of obstacles close by, etc.).

8.2 - Ease of maintenance

Maintenance is particularly simple -- lubrication once every six months and checking pump pistons for leaks. Spare parts are quite inexpensive and could even be produced locally in a modestly equipped workshop.

9. Solar dryers and improved stoves

Demand currently influences the development of solar dryers and improved stoves that satisfy a real and important need. The influence is felt:

- in actual design, represented by the dialogue between technician and user;
- in construction techniques and materials used in creating simple, operational equipment that is easy for users and local craftsmen to service.

10. General technical problems

As solar energy equipment has appeared only recently, it is normal to encounter problems in debugging. The number of problems could be significantly decreased:

- if all equipment underwent prolonged, conscientious testing at the factory, before shipment;

- if, before being set to destinations hundreds of kilometers from capital cities, equipment was reexamined in the importing country receiving organizations equipped to perform detailed check-ups;

- if conscientious troubleshooting was done in order to eliminate unpleasant 'surprises', late repairs, etc.

Evaluation of some different areas of solar technology

	Photo-voltaic pumps	Thermo-dynamic pumps	Photo-voltaic power plants	Solar water heaters	Biogas	Multiple-blade wind turbines
Technological maturity	commercial	development	commercial	commercial	development	commercial
Reliability observed	quite high	inadequate	high	very high	high	high
Skills required of user	little	very high	little	little	little	little
Ease of maintenance	very simple	complex	quite simple	very simple	simple	very simple
Investment cost	high	high	high	average	average	low
Possibility of local manufacture	partial	partial	partial	yes	yes	yes

CHAPTER 3

ECONOMIC COMPARISON BETWEEN RENEWABLE AND CONVENTIONAL ENERGY SOLUTIONS

1. Difficulties concerning economic comparisons

1.1 - Definition of 'systems' analyzed

In order to make a valid comparison, it is necessary to determine in advance all the goods and services, both direct and indirect, related to the solution under consideration:

. For example, if the cost of a diesel pump irrigation system is being analyzed, all the components entering into the system's operation must be included. This includes not only the diesel engine, but also the fuel tanks, fuel delivery vehicles, spare parts, investment and operating costs for the engine repair shop, costs related to direct and indirect labor, and much more;

. In many cases it can be seen that the total investment required for regular equipment operation is equal to several times the cost of the equipment itself. The problems that this environment creates for conventional energy equipment make it much easier to justify solar energy solutions, thanks to their independence and limited investment requirements.

1.2 - General lack of knowledge regarding investment, and in particular, operating costs for conventional energy equipment

Our experience in the field has shown that very few organizations have even an approximate idea of investment, and more so, operating costs for conventional energy equipment, for lack of detailed analytical accounting. Without such accounts, those persons to whom we spoke often tended to minimize considerably their operating expenses by considering only direct costs, such as fuel and caretakers' fees, while indirect costs (1), just as real, are essential to any system's operation and can often come out higher than direct costs.

An effort to better comprehend the real cost of conventional energy solutions would greatly facilitate the introduction of solar energy systems.

1.3 - Variables related to investment and operating costs

Differences in the investment cost of the same type of equipment can reach a factor of two, depending on where the equipment is manufactured (Indian made motor pumps are half as expensive as those made in Europe), the equipment installation arrangement (unit or group purchases, dealing directly or through a local agent, etc.), tax schemes, etc. Similarly, the actual price of fuel can as much as triple from one country to the next.

No overall comparison of economic competitiveness can be truly accurate, because each situation presents a particular context requiring particular services; each complete 'system' is unique.

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(1) Depreciation, spare parts, mechanics' traveling expenses, fuel delivery costs, administrative costs, etc.

1.4 - The considerable influence of choice of parameters on the relative competitiveness of conventional and renewable energy solutions

The advantages of solar versus conventional equipment greatly depend on the parameters used for calculations, as they are highly variable and relative to precise situations.

These parameters include:

- number of hours of operation per year,
- life span of the equipment,
- interest rates,
- maintenance costs (highly variable),
- required level of security (possible need for back-up equipment),
- cost of fuel.

The choice of accounting for inflation or not can also significantly alter the comparison between solar and conventional energy solutions.

1.5 - Limited significance of current prices for solar energy equipment

For the most part, solar energy equipment is sold in limited quantities. The high prices include numerous costs (overhead, development expenses, sales costs, etc.), most of which will greatly decrease with the opening of important markets and mass production. Great care should be exercised when comparing new products to mature products, such as diesel engines.

2. Investment costs and recurring charges

Solar energy solutions often present higher investment costs than conventional energy solutions, however, their operating costs are generally considerably lower. Solar energy equipment generates low recurring charges that users can easily afford; this is rarely the case for diesel equipment, which forces governments to offer increasingly heavy subsidies. (1)

For want of public funding for the high cost of equipment operation, many installations would now be idle (water distribution networks, small electric power stations, etc.). In light of this, solar energy equipment can be seen as an attractive answer to pinched operating budgets.

(1) Diesel motor pump irrigation projects almost always receive heavy community subsidies. The low cost of purchasing motor pumps is counterbalanced by the very high recurring costs (fuel, lubricants, maintenance, etc.).

3. Cost to the community of the unreliability of conventional equipment

It is well known that diesel engines require an excellent infrastructure in order to provide adequate service. In practice, this infrastructure is greatly lacking in Africa, and the life span of diesel equipment is often very short due to an absence of preventive maintenance. Frequent breakdowns can be very costly for communities in terms of lost harvests, inadequate water supply (often critical), electricity outages, ruptures in telecommunications relays, etc. The costs due to such breaks in service are evaluated all too infrequently. Very often, they exceed the cost of the equipment itself by a factor of ten or even one hundred.

A correct economic analysis comparing conventional and solar energy solutions must necessarily take into account all costs related to the extent of the equipment's reliability.

Taking the example of irrigation, it is well known that land development programs are very expensive per hectare. Logically, developed land should, in return, yield the greatest amount of produce without losses due to damaged motor pumps. In practice, solar energy equipment, although a costlier initial investment than diesel equipment, is far more reliable, and thus probably more economical. The increase in the total development budget (civil engineering + pumps) could be considered acceptable, keeping in mind the overwhelming cost of civil engineering. Aside from a more complete exploitation of the developed land, recurring costs could also be reduced considerably (elimination of subsidies).

4. Example of a cost comparison for a village water supply: electric generator unit + submersible pump/photovoltaic pump

4.1 - Comparison with present costs

. Preliminary remarks: Comparing the cost per cubic meter of water pumped by the various machines is relatively risky, considering the following points:

- the same criteria are being used to compare a mature, industrially manufactured product, that is sold by the millions, to new products of which only a few hundred exist;

- numerous essential parameters still remain unknown:

  . real performance of solar pumps,
  . maintenance costs and life span -- experience is still insufficient for an accurate analysis of these parameters, thus reasonable averages have been used;
  . total investment costs -- while FOB prices are common knowledge, the same cannot always be said for the cost of equipment installed.

Comparitive cost prices depend heavily on the utilization rate of the various pieces of equipment. Solar pumps operate up to capacity approximately 6 to 8 hours per day, while the output of diesel equipment can be three times as great without any need for additional investment. Security considerations also affect costs. The price of an electric generating unit included the cost of a back-up generator, while no emeregency equipment was included with the solar pumps.

The life span of the diesel model selected has been set at four years. This value, which appears low, takes into account the life spans, in the field, of engines of equivalent power. The high maintenance cost is also representative, keeping in mind the very high cost of spare parts, travel expenses for maintenance crews, etc.

. Main results: A look at the first table of comparisons (present situation) discloses the following:

- according to the criteria selected, the solar photovoltaic pump has a significantly lower cost price per cubic meter of water pumped than the diesel unit;

- operating costs per cubic meter of water pumped are considerably lower for solar pumps;

- the rate of discount taken into consideration is not more advantageous for the photovoltaic pump;

- the cost of fuel + lubricant represents approximately 40% of the operating costs of the diesel solution, and over 20% of total annual costs;

- if the life span of solar pumps is considered increased from 10 to 15 years, the cost price per cubic meter of water pumped drops by approximately 15 to 20%.

- this economic analysis does not account for certain non-quantifiable factors that are, however, essential: the assurance of fuel availability, the villages' autonomy, the impact on socio-cultural development, etc.

NOTE: The diesel equipment used in this comparison is relatively 'luxurious', in terms of its oversized electric generating unit, the presence of a back-up unit, its very solid housing, etc. It probably corresponds to the type of equipment found in relatively large towns. By limiting expenditures to a strict minimum, it seems possible to decrease investments by at least 30%.

Diesel operation over a great number of hours per year -- for example 3,000 -- would bring the cost price down considerably (by about 20%).

1 ECU = 6 FF
1 FF = 50 CFA Francs
$ 1 US = 5.5 FF.

4.2 Cost comparison to 1985

Solar photovoltaic pumps are already competitive compared to diesel pumps for village water supplies. Its comparative advantage will increase considerably from now to 1985.

Means of pumping	Technological progress expected	Effect on investment costs and operation per m^3 pumped (constant francs)
Diesel electric generating unit + submersible electric pump	Little technological improvement can reasonably be expected, since this is a mature, fully developed product.	. Investment costs show little variation, just as for maintenance costs. . Fuel costs will increase and make diesel pumping much more expensive.
Solar photovoltaic pump	Photo cells should see a considerable unit price drop. Mass production of these uncomplicated pumps should hasten this price drop even more.	The total investment cost should decrease considerably (cells represent over 60% of the present cost), and maintenance should also be low in cost (more reliable cells).

Comparison of the cost per cubic meter between diesel pumps and solar pumps by 1985 (1981 francs)

	Diesel electric generating unit + submersible electric pump	Solar photo-voltaic pump	
Hourly flow rate	7 m^3/hr at 30 m	30 m^3/day at 30 m	
Volume pumped annually	12,600 m^3	11,500 m^3	
Total investment	125,000 FF	140,000 FF (hypothesis 1)	70,000 FF (hypothesis 2)
Operating costs (1)	38,400 FF	2,500 FF	2,000 FF
Annual cost:			
- at 5%	59,000 FF	20,600 FF	12,400 FF
- at 10%	63,300 FF	22,800 FF	15,000 FF
Cost price of m^3:			
- at 5%	4.70 FF	1.80 FF	1.10 FF
- at 10%	5.00 FF	2.00 FF	1.30 FF
of which: operating costs	3.05 FF	0.25 FF	0.20 FF

NOTE: These figures are only tentative and should be accepted judiciously. The above table indicates that as of 1985, solar pumping should clearly be more economical than diesel pumping for village water supplies while providing a higher quality of service.

1 FF = 50 CFA Francs
1 ECU = 6 FF
$ 1 US = 5.50 FF

(1) The prices of diesel fuel and oil have been increased by 50% in this table compared to 1981 (constant francs). This is, of course, hypothetical.

CHAPTER 4

THE EXECUTION OF SOLAR ENERGY PROJECTS: MULTILATERAL COOPERATION AND NATIONAL SUPPORT ORGANIZATIONS

1. Observations

The execution of cooperation programs in the area of new energy sources assumes that in order for the projects to reach fruition to everyone's satisfaction:

a)- program goals must represent a common choice made by all parties prior to the commencement of any work;

b)- the obligations of each party must be specified in a contractual agreement;

c)- a local support organization must be established and furnished with adequate means.

In practice, this rational approach has rarely been implemented for many reasons, and the execution of solar energy programs, that are very positive overall, has met with numerous difficulties:

- inadequacy of management personnel for these programs, mostly at the local level;
- insufficient circulation of information among the parties concerned;
- underestimation of secondary problems associated with setting up solar energy equipment in rural settings;
- absence of national support organizations for determining projects, assembly, follow-up, maintenance, etc. For lack of these organizations, manufacturers find themselves required to provide services outside their fields.

It is easy to understand these numerous difficulties when considering the extremely innovative nature of solar energy projects. At the end of this report there will be a section dealing with suggestions for the strengthening of this type of cooperation. At this point, only a few aspects will be treated.

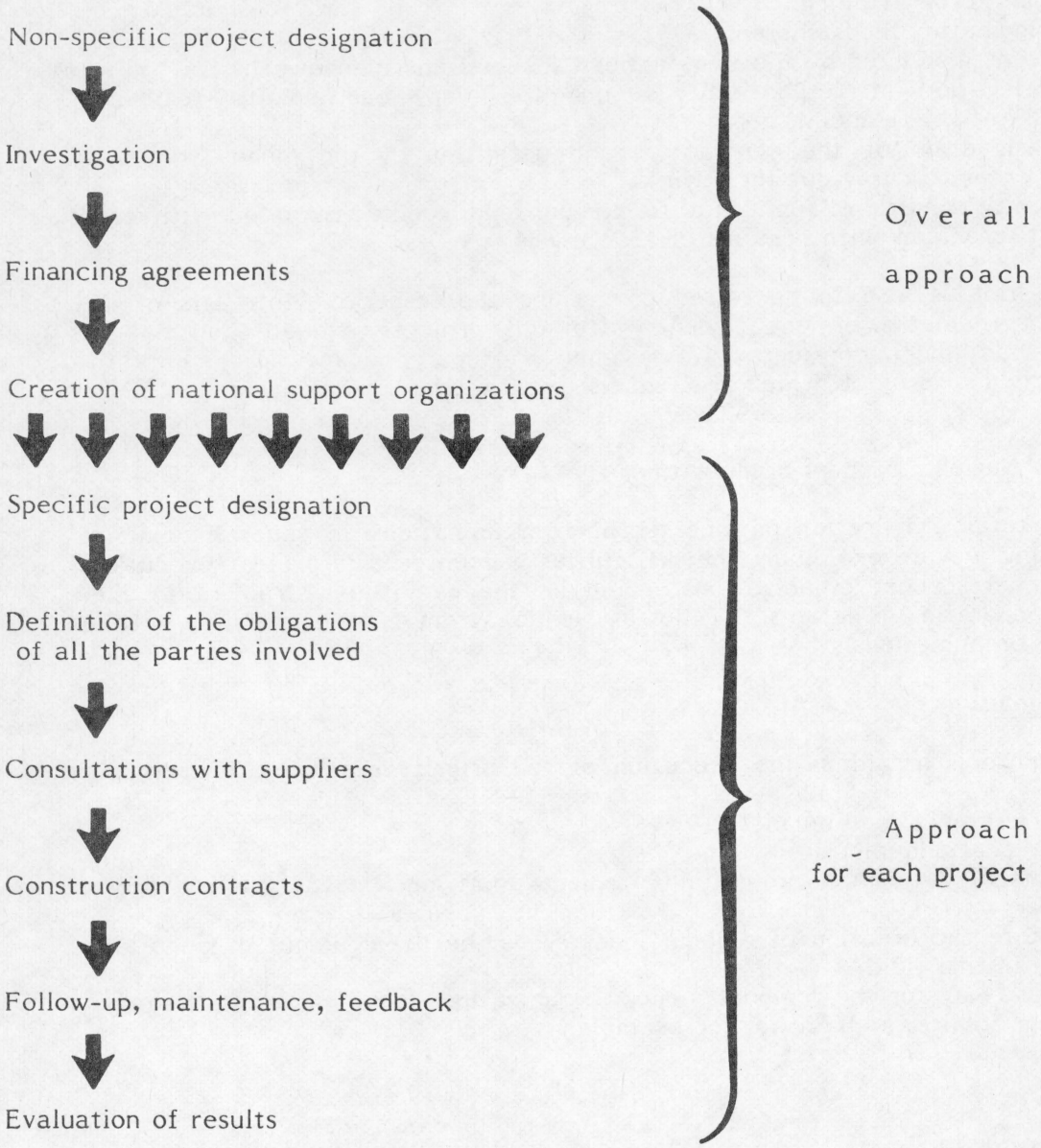
2. Recommendations

2.1 - General project designation assignments

Project designation assignments can be essential in:

. gathering information on projects in progress in different countries,
. making an informal examination of the desires, hopes, and needs of the different countries in this domain,
. determining which projects and activities are worth supporting and checking to see that they correspond to the priorities of the countries concerned,
. discerning the organizations and persons capable of assisting in the implementation of projects under consideration,
. discussing points of view with other organizations providing financial assistance for similar or supplementary projects,
. determining the direction to give to medium-range cooperation and approximating what will be needed, etc.

Principal stages in the execution of renewable energy projects



2.2 - Financing accords for each project

These documents must be sufficiently detailed and specify, in particular:

. the goals to be attained,
. the principal methods chosen,
. the means mobilized by the two parties (financial and manpower),
. the delegation of responsibility among the many participants (technical, administrative, financial, etc.),
. the designation of the contractors and definition of the means they will use in order to carry out their work,
. the fiscal conditions applicable to persons and goods associated with each project (problems with customs clearance).

The question is also to be raised concerning the respective interests of the master agreements of each country (for all projects executed within the time period under consideration) designed to supercede the agreements for each individual project, which are tedious to draw up and administer.

2.3 - National support organizations (1)

The total absence of national support organizations in several countries goes a long way to explaining the difficulties encountered in project execution. The national support organizations should be the essential instrument in executing cooperation programs. Following is an attempt to establish a profile for these organizations.

a)- Goals:

. to offer decisive aid in the execution of top priority renewable energy projects,
. to ensure project maintenance,
. to train local administrators,
. to aid local authorities in defining projects that take advantage of renewable energy sources,
. to promote the creation of a local industry or the development of a cottage industry in this field,
. to act as relay for the regional support organizations (CRES - Centre Régional d'Energie Solaire, at Bamako, for example).

(1) The role of these national support organizations will be treated in greater detail in upcoming chapters.

b)- Possible tasks:

. advance project designation (see chapter 5),
. project promotion and negotiations between the principal parties involved, search for financing,
. assistance in assembling equipment,
. reception of equipment,
. preventive maintenance and training for users,
. breakdown service and maintenance,
. equipment monitoring (interviews with users and establishment of regular intervals for taking readings),
. post-construction evaluation of results,
. training for caretakers, administration technicians, etc.
. technical evaluation of new equipment and applied research,
. organization and delegation of responsibility for local construction work (civil engineering, hydraulic networks, etc.) in conjunction with local companies,
. administrative assistance: program preparation, evaluation of affairs, etc.

c)- Status to be obtained:

. semi-public company with its own budget.

d)- Human resources, limited, for example:

. 1 director,
. 1 - 2 engineers,
. 3 - 4 technicians,
. 1 secretary/bookkeeper.

It is advisable to begin operations with a small staff.

e)- Material resources:

. 3 or 4 vehicles suited to bush conditions
. complete sets of tools,
. measuring instruments, etc.

f)- Possible resources, for example:

. annual national subsidy,
. subcontracting of construction work to professional contractors,
. users' contributions,
. fees for certain studies and collaboration by outside participants.

CHAPTER 5

PROJECT DESIGNATION

NECESSARY STEPS IN THE EXECUTION OF A SOLAR ENERGY PROJECT

1. Introduction

Some projects function poorly due to insufficient initial project designation. This step, essential for the success of any project, is often left unfinished or omitted entirely. This explains a good number of the difficulties observed in practice:

. equipment improperly selected for users' needs,
. expected performance levels not reached due to misrated equipment,
. no attempts at the outset to familiarize users and local officials with the projects,
. cost overruns because certain indispensable operations were not planned, etc.

Initial project designation, a necessary step, is relatively complex because it requires the gathering of a great amount of technical, socio-economic, financial information, etc., that is either not readily available, or available but imprecise. Designation includes, in particular, taking into consideration the viewpoints and priorities of all parties involved. It has been observed that omitting these initial exchanges creates impasses and causes certain essential information to be 'misplaced'. Recommendations aimed at promoting good preparation of renewable energy projects will be presented further on in this report.

2. Choosing the regions to receive installations

2.1 - Observations

Solar energy techniques are still to some extent (1) at the research and development stage. Their performance, and above all, their reliability is relatively unknown, as shown in the field evaluations. Choices for locations have often been made inappropriately (2) based on the assumption that the equipment in question was perfectly reliable and thus required no maintenance infrastructures. This is not so.

2.2 - Recommendations

- New energy project sites should be located within a reasonable radius of capital cities or support organization locations, that is, under three hours by road or 150 - 200 km.

- Only in the second phase, once solar energy equipment has proven its reliability in action, should it be installed in relatively inaccessible regions, provided the existence of an adequate maintenance infrastructure, trained personnel, spare parts, etc.

(1) Exception is made here for direct coupling photovoltaic pumps.
(2) In this sense, KARMA was a good choice, DIRE was a poor one.

These recommendations should be evident given the following facts:

- some sites are practically inaccessible for part of the year,
- local qualified manpower is still very limited,
- vehicle and fuel supplies are also very limited,
- it is impossible to monitor accurately new technology equipment at a distance of over 200 km from capital cities,
- the cost of travel by all-purpose vehicle is exceptionally high (over 150 CFA Francs per km, or 150,000 CFA Francs for a round trip of a total of 1,000 km, excluding personnel costs).

Regarding reliable solar energy equipment (photovoltaic pumps, multiple-blade wind turbines), it also seems advisable to avoid excessive geographic dispersion of the projects (progressively equipping one region, then another, and so on).

By grouping projects within specific regions actual maintenance crews can be set up at a reasonable cost per installation (for example, photovoltaic pumps in the SAN region are serviced by Mali Aqua Viva). Other regions should be equipped only when they have sufficiently important programs backed up by a valid maintenance infrastructure. (1)

3. Choosing the receiving organizations

3.1 - Observations

Project designation has inadequately evaluated the social and institutional environment in which the projects are to exist. Numerous difficulties, noticed afterwards, resulted from this oversight. Analyses are often limited to summary technical approaches.

The quality of receiving organizations is vital to the success of all solar energy projects. Hence, solar energy programs that are included in development programs supported by charitable organizations often provide clearly better results thanks to the quality and motivation of the receiving team on site. Such teams assume full responsibility for the projects, including the maintenance and proper utilization of the equipment.

3.2 - Recommandations

. Depend only on receiving organizations that have already proven themselves dynamic and productive. Solar energy projects do not themselves initiate development, they merely reinforce existing development programs. Prefer to collaborate within already existing development schemes.

(1) By concentrating on a given region, the negative effects related to population migrations toward new water sources (village and livestock water supplies) are diminished.

. Collaborate with local organizations set up under an integrated development program. They are well represented in the different regions and have at their disposal those means that are often vital for project success (human competence, maintenance shops, vehicles, etc.). Ensure that the population favors these development operations.

. Non-governmental organizations often have the great advantage of being intimately involved in the activities of the different regions and can thus constitute excellent receiving organizations. Nevertheless, their credibility, reputation, and achievements, as well as the state of their relations with local authorities, etc. should be evaluated.

. The 'relay' function provided by these receiving organizations is extremely difficult to replace, because governmental organizations lack the means to provide in-depth monitoring services. Choosing receiving organizations should, on the other hand, be done in accordance with governmental organizations, local authorities, etc. This condition is essential in order for the project to succeed.

. Receiving organizations should be consulted and integrated starting from the project designation phase (choice of options, establishment of priorities, selection of exact location, management arrangements for each project, etc.).

. As soon as possible, designate that person within the receiving organization who is to take control of the project. If this is done at the very beginning, that person will be much more highly motivated thereafter.

4. Choosing the village to accept the project - Local participation

4.1 - Observation

Certain projects were 'attributed' to one village or another without really consulting the local population. In these cases, villagers tended to show a lack of interest in the projects.

4.2 - Recommendations

a)- Choose villages that have already proven themselves dynamic through their success with preceding projects (truck farming, construction of buildings, etc.) (1).

b)- Accord priority to those villages that specifically request equipment and that are aware of the success of another project similar to their own.

c)- Ensure that there is clearly an active consensus among all the parties concerned by the project within the village.

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(1)CARITAS, a non-governmental organization in Senegal, only helps those villages that have shown a desire for development. Solar pumps replace the hand pumps that are widely used in truck farming.

d)- Avoid at all costs solar energy projects that are intended as 'gifts', where there is to be absolutely no participation from those to receive the equipment; experience shows that this is the surest way to guarantee that a project will fail.

e)- The users must make a real contribution to the project, in terms of work or money, within their means. Their participation assures the project's future, since it becomes a village's achievement, and thus, its pride.

f)- From the very outset, indicate all the work that can be undertaken by the villagers themselves with some technical assistance in the form of civil engineering, tank construction, laying pipelines, etc.

g)- Set down a basic structure of reciprocal obligations between villagers and their representatives, the receiving organizations, the national solar energy organizations, the financing organizations, etc. Each must specify what he intends to accomplish, and the entire arrangement must be agreed upon mutually.

h)- The village must agree, from the start, to provide a caretaker for the equipment and to provide for his needs by means of contributions (2) to be decided upon by the village leaders (3).

5. Evaluating users' needs

5.1 - Observation

Some of the solar pumps installed are poorly adapted to users' actual needs due to inadequate pumping capacity, poor location, related hydraulic equipment that is either inadequate or poorly adapted (for example, cattle troughs for cattle placed in a location more suitable for sheep troughs).

5.2 - Recommendations

Solar energy projects should not be forced on villages. The future equipment users should be consulted in order to:

- determine their various needs and priorities,
- evaluate quantitatively these needs today and for the future,
- determine any possible conflicts between groups,
- understand villagers' expectations,
- present villagers with all the pertinent comparisons between the project in discussion and the systems that exist in neighboring villages (diesel pumps, larger solar pumps, etc.),
- situate the various village needs (location of outlets for household drinking water, watering animals, truck farming, etc.).

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(2) This can take the form of payment in money or in kind (produce).

(3) Such a system was successfully established for several solar energy projects in Senegal (Merina Dakhar), Upper Volta (Markoye), and elsewhere.

6. Choosing a precise location - Selecting pump size

6.1 - Observations

Solar pumps are often poorly suited to the hydraulic characteristics of the bore-holes over which they have been installed. The result is low output and sometimes serious breakdowns. Bore-holes in the Sahel are very uncertain; rarely are actual hydraulic specifications the same as rated. Fewer than 10% of the bore-holes in Mali and Upper Volta, for instance, have a flow rate great enough to drive a solar pump.

6.2 - Recommendations

a)- Never order a solar pump for any village before having drilled the corresponding bore-hole.

b)- Confirm all information supplied by water services concerning the bore-hole or well. As too many errors have been committed, it would be preferable, in case of doubt, to run the bore-hole flow rate tests over (to check for variable or declining hourly flow rates) before ordering a pump.

c)- Question the villagers, especially the elderly residents, to see if the water resources of the wells and bore-holes last, particularly through the dry season.

d)- Pump output should be chosen for the dry season when the dynamic level is very low and the flow rate at its lowest. Place the strainer low enough in order to avoid the risks of drying up that have already been observed in the region. Location of the bore-hole should be chosen with respect to the needs for water. It is sometimes more economical to create a new bore-hole than to utilize an existing one that is too distant, as distribution networks are extremely expensive in Africa. Do not motorize the bore-hole or well unless it can be justified (volume required, bore-hole flow rate, possibility of guaranteeing maintenance, etc.).

e)- Maintain a reasonable margin between the minimum bore-hole flow rate and the solar pump flowrate.

f)- When selecting a solar pump, do not forget that the real flow rate in Africa could turn out to be considerably lower than the manufacturer's rating (due to temperature, variations in the manometric head, etc.).

g)- Avoid announcing optimistic flow rates to future pump users, for fear of disappointing them greatly if the actual flow rate is much lower than announced. This would require all projects utilizing water resources to be scaled down (in truck farming, for instance, 30% less water represents 30% less surface area cultivated).

h)- Do not install a solar pump over a well that villagers are using (water drawn manually), as the sand brought up damages the pump. Additional hydraulic equipment is as important as the pump itself. Choice of and financing for this equipment (water towers, siphons, tubing, valves, troughs, etc.) must be planned at the outset. Many solar pumps are underutilized for lack of such equipment.

i)- Back-up systems should always be planned in case a solar pump breaks down. It is unconscionable to leave villages entirely without water, as has already happened.

7. Who should execute the project designation studies, who should finance them

The above analysis shows that conscientious project preparation entails a considerable amount of preliminary work that is essential for making good equipment choices, for the project to succeed, etc.

7.1 - Who can do this

. For the projects of lesser importance, for which investments do not exceed 200,000 FF, for example, project designation studies should be carried out as much as possible by the national organizations constituted to prepare, set up, and monitor the solar energy projects mentioned previously (see chapter 4). These organizations should rely particularly on the receiving organizations best suited to assist in project completion.

. For the major projects, it seems advisable for the national organizations to enlist the support of foreign technicians specializing in the problematic areas.

7.2 - What the studies should include, to whom they should be presented

These reports, whose importance varies with the nature of the project, should contain as much useful information as possible concerning:

- location,
- receiving organizations,
- the project's technical specifications,
- evaluation of needs,
- technical choices and alternatives,
- practical organization,
- engagements made by the various parties,
- probable impact of the project on village development,
- local financial contributions,
- magnitude of project cost, etc.

The reports should be distributed to as many of the parties concerned as possible (administrations, non-governmental receiving organizations, local representatives of the financing organizations, corporate directors and local firms capable of supplying equipment, etc.).

7.3 - How to finance project designation studies

Project designation studies, whether brief or detailed, depending on the nature of the project, are always indispensable. A means of financing these studies (1) should be arranged. Several possibilities for this are open:

- annual subsidies from relief organizations and local government,
- individual negotiations (this can be difficult).

(1) The cost of a study should be 5 - 10% of the amount of investments, according to the project's scope.

CHAPTER 6

CONTRACT PREPARATION

1. Observations

The contracts concluded with solar energy equipment suppliers are often too imprecise regarding warranty periods, conditions for determining whether promised performance specifications have been met, technical documentation, spare parts, tooling, etc. The imprecise nature of certain deals, even where honest negotiators are concerned, greatly complicates project evaluation in terms of what was initially promised when the contract was signed. Moreover, some contracts are not suitable for pilot projects, prototype construction, etc. It is particularly advisable to distinguish between the costs for research and development (always high where prototypes are concerned), equipment, and services. For administrative reasons, the aggregate of all these costs results in misleading estimates that can be very far from the actual cost.

2. Recommendations

a)- Only design complete projects, where service is associated. All necessary investments should be included, both for equipment at all levels (ex. water distribution networks, water intakes, technical premises, spare parts, back-up equipment) and services (project designation, follow-up, reception, training, clearing customs, shipment, maintenance, etc.).

b)- Ensure the active consensus of all parties concerned and define in writing all reciprocal obligations and the means of implementing them. In particular, the distribution of supplies among the various services organizations should be clearly determined.

c)- Avoid rushing. Experience has shown that rushing is responsible for lost time afterwards. Contracts should be negotiated with companies after, not before the project designation studies.

d)- Do not draft similar contracts for fully developed products as for prototypes, as requirements can vary greatly.

e)- Develop detailed standard contracts that cover a great variety of subjects, such as:

- a detailed description of equipment;
- a detailed description of services;
- a clear definition of all guaranteed rated specifications and the conditions for measuring them (supplying hourly or daily performance charts for measuring solar radiation, the manometric head, temperature, etc.; a performance rating for a single given insolation of 1 KWh/m² or 6.5 KWh/m²/day at a single manometric head and temperature is virtually worthless);
- a definition of provisional reception methods and penalties to be exacted for failure to meet promised specifications;
- the supply of detailed documentation for:
  - . equipment functioning,
  - . diagnosing breakdowns,
  - . preventive maintenance,
  - . repairs;

- a definition of payment terms;
- a clear definition of local subcontracting -- extent, entities involved, amounts;
- a definition of guarantees for parts and labor, conditions for implementing the guarantees;
- a description of after-sales servicing schemes;
- a timetable for project completion;
- project-related training, etc.

f)- Subcontract locally as much as reasonably possible (to avoid importing things like water towers). Local industry is capable of building a considerable amount of equipment (supports, frames, civil engineering, etc.).

g)- The contract should stipulate a precise means of informing the main parties (1) at each important step in the completion of the project. All too often, the contracting company either remains silent or divulges information once it is too late to change something.

(1) particularly, the local representative designated by the relief organization.

CHAPTER 7

PROJECT RECEPTION

1. Observations

The solar energy equipment installed was never properly received. In most cases, the responsibility for reception is poorly defined and the local representatives of relief organizations lack the manpower and technical capabilities to tackle the job alone. Nowhere does there seem to be a budget set aside for reception by qualified technicians. Reception, even if properly carried out, would sometimes be problematic because some contracts do not specify the supplier's exact obligations.

2. Recommendations

. Always plan provisional on-site equipment reception, because this is the only way to verify that:

- all the equipment has been delivered and is in accordance with contract specifications,
- the project has been carried out carefully from all standpoints,
- the manufacturer has adequately trained the users to operate the equipment,
- a local maintenance service has been organized,
- operation, maintenance, and diagnostic documents have been delivered,
- project start-up will take place under propitious conditions (with a caretaker, maintenance, management, etc.),
- the receiving party is satisfied with the project (services provided corresponding to actual needs), etc.

. In order to make the provisional reception meaningful, it would seem desirable for a percentage of the payments to be contingent upon the results of the provisional reception.

. Provisional reception is particularly useful from a technical standpoint in order to ensure occasional equipment monitoring (solar arrays, for example). This function would thus serve as a sort of reference basis for subsequent measurement comparisons.

. Without a reception procedure, the notion of manufacturer's warranty is deprived of much of its meaning.

. Provisional reception should be carried out, inasmuch as possible, by the following persons:

- a technician representing the manufacturer,
- a solar energy technician provided by the national support organization, who could even represent the silent partner in his absence (for the smaller projects),
- a representative of the local administration,
- a representative of the silent partner,
- a representative of the local non-governmental organization or receiving organization that is promoting the project,
- a village representative.

. Bringing all these persons together could provide an opportunity not only to make technical observations, but also to exchange points of view on site as a means of becoming familiar with the project's usefulness and its inherent difficulties, among other things.

. A record of proceedings should be signed at the conclustion of the provisional reception. It should mention the major results of readings taken, all the observations made, the client's reservations, if he has any, etc.

. Where major projects are concerned,the cost of provisional reception should be budgeted from the start. The national support organization should supply the technician with the necessary (yet low in cost) measurement instruments.

CHAPTER 8

TECHNICAL FOLLOW-UP, MAINTENANCE, FEEDBACK

1. Observations

Few projects have been followed up regularly from the very beginning. In a certain number of instances, the condition of a project is unknown because it has not been inspected in over a year. The absence of a periodic maintenance scheme explains to a large extent the difficulties encountered with 1-KW thermodynamic pumps. Minor malfunctions, not corrected in time, have occasionally led to severe equipment damage. There has been a serious lack of feedback of information to the manufacturer, foreign volunteer organizations, civil servants, and others. Without it, on-site experiments, whatever their results, lose much of their interest. Recent efforts show that very positive results can be achieved in exchange for a modest investment (technical monitoring of the photovoltaic equipment in the region of San, thanks to the efforts of a volunteer worker).

2. Recommendations

2.1 - Ordinary maintenance

a)- Ordinary maintenance (preventive maintenance + minor repairs) should be entrusted to the project's receiving organization.

b)- The receiving organization should be given:

- an instruction manual for operating the equipment,
- a manual for diagnosing major malfunctions,
- an instruction manual for routine maintenance,
- instructions for contacting the company or persons to be informed immediately in the event of a breakdown.

c)- The choice of equipment caretaker should be made advisedly, because his job is essential. If possible, he should be educated.

d)- The caretaker's training should not be haphazard. The brief contact between the caretaker and the equipment installers is usually inadequate.

e)- Upon receiving adequate training, the caretaker should be capable of taking initiatives when confronted with the various situations covered by the instructor.

f)- Naturally, the caretaker should be supplied with basic tools and essential spare parts.

g)- The caretaker should keep a log of hours worked, measured flow rates, meteorological conditions, servicing done, malfunctions noticed, visits by outside personnel, dates when outside servicing was requested, etc.

2.2 - Special maintenance, follow-up, feedback

The national support organization for solar energy projects should provide four or five services:

a)- Visit each installation regularly (every three to six months) in order to:

- make a detailed inspection of equipment condition,
- ensure that preventive maintenance is actually being carried out,
- measure equipment performance,
- ask the caretaker about problems encountered and offer him assistance (training, spare parts, etc.),
- contact local users (concerning quality of service).

b)- Provide emergency service for equipment that is out of order or that is subject to abnormal malfunctioning, by immediately sending out a qualified technician with adequate troubleshooting equipment.

c)- Ensure feedback to all parties concerned in the form of measurement reports, operation reports, summaries of conversations with users, etc.

d)- Contact equipment suppliers for questions concerning equipment under warranty.

e)- Perhaps, represent the manufacturer(s) locally, the remuneration for which would go to the national support organization in the form of a servicing contract.

2.3 - Financing

An annual budget must be created in order to cover the operating expenses of the support organization. Financing could come from:

- annual government subsidies,
- annual subsidies from certain assistance organizations,
- contributions from manufacturers supplying the equipment for installations where the maintenance budget is low, thanks to the existence of the local support organization (taken from the savings on travel, inspection, and labor expenses),
- small contributions made by the users themselves,
- reinvoicing for services rendered.

CHAPTER 9

SUMMARY OF THE MAJOR FACTORS IN THE SUCCESS OF A SOLAR ENERGY PROJECT

LES FACTEURS DE RÉUSSITE D'UN PROJET SOLAIRE

Exemple : pompe solaire

LES PHASES SUCCESSIVES DU PROJET	ASPECTS ESSENTIELS A PRENDRE EN COMPTE	PRINCIPAUX ACTEURS
IDENTIFICATION INITIALE	- Choix d'une région d'implantation à distance raisonnable des structures d'entretien (intérêt des projets assez regroupés) - Identification d'une structure d'accueil fiable, volontaire, ayant réussi des projets de développement dans la région. - Choix d'un village, expressément demandeur prêt à participer activement au projet et à valoriser l'équipement solaire envisagé. - Recueil préliminaire de données sur les besoins locaux, les ressources en eaux, etc ...	- "Structure nationale d'appui" (cf. chapitre 4) - Structure locale d'accueil - Village concerné - Administration
ETUDE D'IDENTIFICATION DETAILLEE	- Analyse fine des besoins du village - Choix du site d'implantation - Etude approfondie des caractéristiques hydrauliques du point d'eau - Définition des équipements principaux et annexes à mettre en place - Evaluation des possibilités de participation locale de la population (financement + main d'oeuvre) - Définition des obligations entre les parties prenantes - Préparation consultation fournisseur : rédaction cahier des charges précis - Recherche du financement.	- Structure locale d'accueil - Structure nationale d'appui renforcée éventuellement d'experts extérieurs - - Contacts avec les fournisseurs - Contacts avec les administrations techniques - Contacts avec les représentants organismes d'aide et l'Etat.
PREPARATION CONTRAT DETAILLE	- Dépouillement des offres - Mise au point d'un contrat précis et exhaustif - Organisation des travaux et contributions des différentes parties prenantes - ~~Inclure un compteur volumétrique dans l'investissement.~~	- Structure locale d'accueil - Structure nationale d'appui - Représentants administrations et organismes d'aide
CONSTRUCTION DES EQUIPEMENTS GENIE CIVIL	- Visite en usine avant expédition - Inspection des travaux sur le site	- Structure nationale d'appui
MONTAGE RECEPTION	- Prévoir réception complète du projet avec mesures sur place - Vérification que tous les engagements prévus au contrat sont tenus	- Structure locale d'accueil - Structure nationale d'appui - Administration et organismes d'aide.
FORMATION	- Doit être prévue sérieusement - Remise de documents nécessaires (entretien, dépannage, liste pièces, etc)	- Structure nationale d'appui - Fournisseur matériel
ENTRETIEN . préventif . réparations	- Doit être mis en place dès le départ formation de l'utilisateur, outillage, etc - Une infrastructure spécifique doit être mise en place pour intervenir rapidement (pièces détachées sur place, outillage spécialisé, etc)	- Utilisateurs - structure locale d'accueil - Structure nationale d'appui + représentant fournisseur
FEED BACK EVALUATION	- Renvoi régulier d'informations techniques et socio-économiques sur les performances du projet - Cahier de fonctionnement rempli par le gardien : mesures, incidents, etc.	- Structure nationale d'appui

Liste non exhaustive - cf. chapitre précédent.

CHAPTER 10

SUGGESTIONS AND RECOMMENDATIONS FOR STRATEGY

1. Recapitulation of achievements

It is not easy to recapitulate accomplishments where renewable energy development projects are concerned, due to the extreme diversity of technologies employed and of national contexts in which these projects are situated. Nevertheless, the following observations can be made:

a)- Virtually all the projects carried out corresponded to top-priority needs (water, health, education, etc.). Overall, they were unquestionably helpful in attenuating the effects of the drought.

b)- These projects played a key role in sensitizing the international community to the problems of development and the perspectives offered by renewable energy sources.

c)- Their proliferation has created a momentum that can be seen in the programs launched by various multilateral and bilateral cooperation organizations.

d)- They have established the credibility of certain solar energy products (through testing in a harsh environment), such as photovoltaic centrifugal pumps, photovoltaic power plants, scholastic television equipment, and solar collectors.

e)- They have contributed greatly to on-the-job training of the main partners in these projects who learn to cope with unforeseen difficulties.

f)- They have been the driving force behind original technical collaboration arrangements (biogas in Upper Volta, Savonius wind turbines in Senegal, thermodynamic pumps in Niger, etc.).

g)- Renewable energy projects are thus responsible for the training of solar energy technicians in several of the countries involved and for having contributed to the know-how currently available in certain local institutions.

h)- They have bolstered local manufacturing ventures, such as the production of solar collectors by ONERSOL (Niger) and the creation of SINAES in Dakar.

i)- The political impact of these operations, while hard to measure, appears very positive overall.

The results would have been better still, if:

j)- The projects had been better administered by certain European countries and by the local participants. This is largely due to the insufficiency of human resources mobilized to carry out the various duties (designation, negotiations, follow-up, reception, evaluation, etc.). The novel nature of these projects explains many of the administrative difficulties.

k)- a nicer distinction could have been made between prototype and fully tested solar energy equipment.

l)- additional funds could have been earmarked for:

- preliminary development, in Europe or by the appropriate receiving organizations, of solar energy equipment that has not been fully tested.
- carrying out sufficiently detailed designation surveys
- meticulous reception of solar energy equipment
- maintenance for new installations over an adequate period of time.

The results of the programs executed can be termed very positive overall, especially considering the modest financial investments.

2. Supporting the measures already undertaken

Without any doubt, it is essential to support and expand upon those measures already undertaken.

1. As we have already seen, the overall results of the current program have been very positive.

2. The developing nations all await an increase in cooperation efforts in this original field (as seen from the volume of financing requested).

3. The majority of projects included in these programs represent a true contribution towards the development of the recipient countries (rural development, health, telecommunications, etc.).

4. Europe (particularly France and West Germany), thanks to its multilateral and bilateral agreements, occupies a prominent position in this type of cooperation arrangement. Renunciation of these efforts today would be incomprehensible in light of the important programs now being created (by UNDP, IBRD, CEAO, ADB, OPEC, USAID).

5. The consequences of these programs are far from negligeable:

- politically, since they help create a good image of European cooperation with the developing nations,
- economically, in terms of the momentum by which the solar energy industries both in Europe and the developing countries themselves are expanding.

3. Reappraisal of efforts and achievements

The generation of projects described throughout this work constitutes the first experimental stage in 'breaking in' the various technologies, and establishing new cooperation arrangements and distribution methods for new equipment within a traditional environment. At the present time, it seems necessary to reevaluate European efforts in terms of various factors:

1. Trends in technology -- some products have reached the manufacturing stage, others are still undergoing development.

2. Requests for cooperation have increased greatly.

3. Financial investments engaged are inadequate.

4. Present management methods are inappropriate where the more ambitious programs are concerned.

5. Cooperation arrangements with the recipient countries must be specific, taking into account our partners' advances, with the goal of promoting an increase in the transfer of technology.

6. The challenge presented by competing programs involving a more appropriate cooperation arrangement (degree of on-site material assistance, the integral nature of those projects that emphasize training, the intelligent utilization of local media, etc.).

7. Non-inclusion of solar energy projects in sectorial development programs, that is, relegating them to sub-programs. Many sectorial programs (health, rural development, telecommunications, etc.) can now rely on fully tested solar equipment to satisfy a sizeable portion of energy requirements. It is time, in our opinion, to bring certain techniques from the demonstration stage (which remains necessary at the beginning) to the operational stage.

4. Suggestions for future European renewable energy cooperation programs

European cooperation programs in renewable energy sources should now be able to take on more ambitious assignments:

- creating more important and more coherent projects
- creating the means to administer projects more meticulously
- helping the developing countries establish their own independent renewable energy projects.

This requires:

4.1 - Redefined aims

Serious thought must be given to goals before undertaking cooperation arrangements, in order to ensure their dynamism and coherence. This is especially true when choosing those goals to receive highest priority, including:

- assisting those countries most severely affected by the drought, the energy crisis, and the world recession;
- helping these countries define national renewable energy development programs and policies;
- placing emphasis on rural development programs (village water supply, irrigation, education, and health programs);
- strengthening the research, engineering, and production potentials of partner developing countries;
- making serious efforts to develop solar energy equipment before installing it on site;
- shoring up and structuring European industrial capacity in this area and encouraging contacts with manufacturers from developing countries;
- developing momentum in other industries (telecommunications, pumps, electrical equipment).

The European community could sponsor this sort of examination, which could be carried out by various high-level European cooperation directors for renewable energy programs. We suggest the formation of an ad hoc committee whose aim would be to design a new European cooperation policy in this field, based on an analysis of past experience, and to establish its major guidlines:

. selecting goals and ensuring they are coherent,
. selecting the technologies and equipment to promote,
. choosing the countries in which efforts are to be concentrated,
. coordinating the efforts of the different European countries as well as community involvement,
. searching for new cooperation arrangements that are more appropriate to the needs of the particular recipient countries,
. analyzing the human and financial resources required,
. determining the different phases of the strategies to apply and the transition between phases (sequential evaluation of results).

4.2 - Coordinated measures

On the basis of the outcome of the preliminary examinations, serious investigation efforts will be required in order to define coordinated strategies. Some suggestions could be made at the present time:

a)- For solar energy equipment still in the development or the pilot stage:

. European manufacturers should receive subsidies and low interest rate credits contingent upon specific contracts for established projects on which government and manufacturer have expressed approval. The aim of this assistance is to give manufacturers the means to carry out veritable development programs before installing their equipment on location abroad (financing for research, pilot plants, prolonged testing periods, etc.).

b)- For new solar energy equipment that is beyond the pilot plant stage:

. Increase demonstration operations abroad, in well-frequented places, not isolated locations that are totally unfamiliar to local officials (as often happens today). For these projects, the current demonstration system should be maintained and the effort increased.

c)- For fully developed and tested solar energy equipment that has truly reached the commercial stage, solar 'rider programs' (1) should be included in virtually all cooperation programs financed by the EDF, for example:

. Rural development:
  - pumps for irrigation
  - pumps for truck farming
  - photovoltaic lighting
  - multiple-blade wind turbines

. Telecommunications:
  - photovoltaic radio relays
  - rural telephone exchanges, etc.

(1) This already exists, but only at the experimental level.

. Health:	- photovoltaic vaccine refrigerators - photovoltaic pumps and lighting
. Education:	- photovoltaic lighting - community television
. Industry:	- food industries (waste recycling) - solar heat (textile, food, and other industries).

From 1 to 5% of corresponding financing, allocated to 'solar energy riders' would considerably accelerate the introduction of solar energy systems and would help increase momentum. This approach, quite realistic today, would make it possible to break loose of the limited field of demonstration projects and reach the stage of creating true solar energy equipment programs with European financing alone, or in conjunction with various organizations (IBRD, UNDP, ADB, bilateral financing arrangements, etc.). These programs would thus be dealing in volumes of several hundreds or thousands of pieces of equipment each time. It is thus important to provide adequate human and financial resources for setting up these programs. The interest in solar 'riders' lies in the possibility of considerably reducing both recurring costs and the fragility noticed in projects dealing with complex energy systems (such as irrigation). The actual implementation of the measures described above, through bilateral or multilateral cooperation efforts would certainly act as a powerful moving force in the development of renewable energy sources.

4.3 - Increased and diversified financial means

Until recently, programs have been operating on very low resources, which were probably quite sufficient during the initial phase of cooperation, where little operational solar technology and little human resources were called into play. Today, the situation has changed and we feel it is essential to provide sizeable and diversified resources in order to achieve the goals enumerated above. The lack of human resources has also had a damaging effect on the quality of our relations with partner countries and in the careful management of credits.

In order to execute effectively all of these tasks with flexibility, we believe it desirable to establish a European organization for operations, capable of:

1. coordinating the various cooperation programs and directing community efforts;

2. carrying out or assigning designation surveys, which are virtually always essential for:

   - defining a project,
   - defining the receiving organization(s),
   - verifying local data,
   - evaluating costs, etc.

3. preparing consultations or detailed invitations to tender, which would give manufacturers a clear picture of the scope of equipment and services required;

4. drawing up clear, complete contracts;

5. monitoring project progress by means of special files, regular inspections, etc.;

6. evaluating all results obtained;

7. promoting the implementation of national support organizations (see chapter 4) capable of enhancing the effectiveness of our efforts;

8. training national directors in this field;

9. supporting certain regional projects, such as the CRES;

10. helping manufacturers identify the equipment needed, develop it, and evaluate it on location;

11. compiling actual, reliable documentation plus a data bank;

12. preparing promotional campaigns in the developing countries (exhibitions, fairs, conferences);

13. publishing accounts of experiments carried out (in the form of a monthly newsletter, for example);

14. rapidly mobilizing investment sources, with verification to take place after the fact;

The cost of such an organization should be more than compensated by the following advantages:

. greater effectiveness in completed projects,
. more meticulous management of public funds,
. increased prestige for European know-how,
. development of momentum within the solar energy industry (emulation among relief organizations),
. faster opening of solvent markets,
. accumulation of references that are essential for penetrating markets on other continents, and more.

4.4 - One priority area -- wood

Lastly, an effort should be made to show what measures are actually being taken to combat the wood crisis.

- In terms of aims:

. Establish a coordinated strategy concerning the wood problem in conjunction with the Sahel countries and especially the international organizations, such as the CILSS (Regional Committee for the Fight Against the Drought in the Sahel) and the CEAO (West African Economic Community).

. Give serious thought to reforestation schemes, such as the choice between large, intensive forestry programs and village-level programs, and the conditions for the success of planting operations.

- In terms of action:

. Offer significant support to large-scale improved stove distribution programs (based on the experience in Senegal).

. Launch modern wood and plant matter carbonization operations (for agriculture and agricultural industries); no significant efforts have yet been made in this area in West Africa.

. Participate in the reforestation research and development program, both on the technical level (essences, etc.) and the socio-economic level (integration of village programs) as well as in large-scale reforestation programs (large planting schemes or many small coordinated programs).

- In terms of means:

. Set up financing programs with much greater means than are currently earmarked for wood programs.

. Assemble the human and technical resources as well as the methods necessary for launching large-scale wood programs, either by means of the organization suggested in the preceding chapter or by means of a specific entity.