# CAMEROON RENEWABLE ENERGY: PROJECT POSSIBILITIES

A report to the U.S. Agency for International Development identifying actions required to develop an assessment of Cameroon's energy needs

Prepared by
Charles Steedman

Ann Arbor, Michigan
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## PREFACE

In response to a request from the Minister of Economic Affairs and Planning of the United Republic of Cameroon dated December 28, 1978, the U.S. Agency for International Development (US-AID) hired me under a technical services contract to identify actions required to develop an assessment of Cameroon's renewable energy needs. The scope of work was as follows:

1. To prepare a report which shall be used as the basis for developing a Project Identification Document. The report should deal with the following topics:

   a) Actions required to develop an assessment of Cameroon's energy needs and to develop appropriate procedures for measuring wind and solar rays as required. This section of the report shall also outline proposals to design appropriate solar energy and other alternative energy projects in the Mandara mountain region.

   b) The report shall focus on how the activities described in paragraph 1. a) could be implemented through ONAREST's Center for Energy Research and what assistance might be required to ONAREST to implement such activities.

2. The report will be used as the basis for developing a Project Identification Document. (15 copies) A preliminary report shall be submitted to the Mission Director in Yaoundé prior to departure.

The period spent in Cameroon was from June 7 to 21, 1979.

Charles Steedman
Ann Arbor, Michigan
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## ACKNOWLEDGEMENTS

The task of gathering information and opinion for the preparation of this report was made much easier than it might have been by outstanding help provided by Marcel Ngué of the US-AID Mission. He was an invaluable guide and companion throughout. He now knows a great deal about the renewable energy situation in Cameroon and will be a valuable asset if the project is pursued. He can give a firm sense of continuity.

ONAREST/IRTISS was also very helpful and solicitous. The cooperation of MM. Melende and Simo of the Energy Research Unit and of MM. Soba Djallo and Ebenezer Epié of IRTISS was excellent. IRTISS/CRESS provided us with a car to make rounds in Garoua and Maroua and to travel between the two. The driver turned out to be a most welcome interpreter when we visited an onion farmer at Meskin, just outside of Maroua.

Thanks should also be extended to Jack Huxtable and Norm Green of the US-AID Mission for their help, advice and hospitality. The Mission very kindly provided excellent transportation facilities in Yaoundé, permitting us to cover a lot of ground in a short time.

Clarence Kooi of Palo Alto, California, was most helpful as a technical advisor in the preparation of the report, but he has not seen the final product and any technical mistakes are mine, not his. Jane McCormick has done an excellent job typing this report in a very short space of time.

NOTE: For meaning of abbreviations, see Appendix B, page 38.

# INTRODUCTION

Blessed with large amounts of hydroelectric potential and off-shore oil deposits, Cameroon has not given much attention to the use of renewable sources of energy such as solar, wind and biomass. As an official in the Ministry of Mines and Power puts it, there is no government program for these new energy sources and no clear idea of how they might be harnessed. There are some stirrings, however.

1. One of the institutes belonging to the national scientific and technical research organization (ONAREST) has set up an energy research unit (ERU). The unit has a budget of only about $25,000 to cover salaries, rent and other operating costs, but it exhibits an admirable sense of determination.

2. A handful of teachers at the National Polytechnical School (ENSP) are working or intend to work with students on biogas production and solar drying projects, even though there is no instruction on these subjects in the curriculum.

3. A West German technician has built seven experimental household biogas plants in and around Douala. Several more are planned.

4. Some industrial plants transforming agricultural products (sugarcane, cotton, oil palm) use by-products to produce electricity for their own use. Lumbermills do likewise.

5. Two or three photovoltaic solar pumps will be installed in northern Cameroon within the next few months. These are isolated units financed by France, the European Development Fund and the United Nations. Unfortunately, little is known about them by Cameroonian government agencies. A SOFRETES-type thermo-dynamic pump is operating at Makari.

6. A consultant from the UN Economic Commission for Africa, a French engineering student, and a French consortium have separately made recommendations to the Cameroonian government on the design of renewable energy programs.

7. The government has made one request--to US-AID--for help in establishing such a program.

8. Photovoltaic panels will energize railroad signals and telephone relays between stations on the Douala-Yaoundé line. Experimental units are being installed at Belabo.

These initial stirrings of activity indicate that there is potential for using renewable energy sources in Cameroon. The country offers a range of climate, from the sun-baked Sahelian zone in the far north to the rainforest in the south, in which there should be numerous possibilities. A wide variation in population density also opens up the prospect of decentralized, renewable energy sources being viable in low density zones, even where conventional sources are available.

So far little is known with precision about this potential. With the exception of some measurements taken in Yaoundé a few years ago by a university professor, there is no data on the intensity of solar radiation. The Department of National Meteorology does have information on sunshine duration for several of its stations since 1955, but this data is far less useful than that on intensity.

Little or nothing is known about energy use and the energy needs of the rural population throughout the country. The 1976 census had one question relevant to energy consumption: what does the household use for lighting? Nationwide, most rural households use kerosene lamps, but in the Northern Province's rural areas almost two thirds of the households use firewood. The table below shows how the north differs from the rest of the country in this respect.

Table 1. Source of Energy for Lighting, Rural Households (in percentage)

| | Entire Country | Northern Province |
|---|---|---|
| Electricity | 0.5 | 0.2 |
| Kerosene | 71.0 | 31.4 |
| Firewood | 26.7 | 65.0 |
| Other | 1.8 | 3.4 |
| | 100.0 | 100.0 |

Source: Direction de la Statistique et de la Comptabilité Nationale. Recensement Général de la Population et de l'Habitat d'Avril 1976.

Lighting is of course only one of many uses of energy in rural areas. Cooking with firewood, crop residues or dried animal dung is an extremely important form of consumption, but little seems to be known about it in Cameroon. We found no data or even estimates on consumption of firewood. Nor did a cursory look at the publications of the Institut des Sciences Humaines reveal any study of the subject by the Institute's social scientists. We had less time to find out about the availability of forest and agricultural waste for use in pyrolysis, but it is likely that there is much to be discovered.

## GENERAL COMMENTS ON A POSSIBLE PROGRAM

From the realization that solar intensity has briefly been measured only in one spot and from the apparent lack of inquiry into rural energy use, the first two elements of a possible renewable energy program emerge. Clearly, if Cameroon intends to use solar energy in more than a haphazard way, even though no real need may be felt for a number of years, a time series of solar radiation measurements will be required. The time to start making them is now.

There is also a need to find out more about the role of energy (other than animal and human) in the rural milieu. This is generally true of West Africa as a whole, where one study of fuelwood consumption (in The Gambia) is universally cited because there seem to have been no others. The danger, however, is that since so little is known, effort will be dispersed in trying to find out too much. What would be most useful for those who want to meet Cameroon's rural energy needs is to have studies focused directly on the more pressing problems, with solid survey data to back them up.

Both of these efforts--solar radiation measurement and rural energy surveys--can be undertaken whether or not other elements of a program are envisaged. If properly done, they will lay groundwork and greatly improve the chances of success of later efforts, however modest or ambitious.

A third facet of a possible program deserves mention at this point. It would be desirable for one part of the national scientific research organization (ONAREST) to be both well informed on renewable energy efforts underway in the country and at the same time an active participant in testing and demonstration. The ERU does not yet seem to have the status or capability of doing so.

Despite the relative paucity of activity on the renewable energy front, we discovered instances where various participants were unaware of what others were doing. Photovoltaic pumps are a case in point. The ERU was in the dark on two of them and only marginally consulted on the third. It was initially involved in the French-financed effort to install a pump, first at Waza, then at Koza, but was bypassed when a French team arrived to make the installation. It turned out that the pump was not installed because the Koza tubewell was inappropriate for it. With regard to the others, we learned by accident in Maroua that the European Development Fund (FED) intends to finance a photovoltaic pump. The FED Delegate in Yaoundé later confirmed that one pump is intended for rice irrigation at Logone Birni, near Kousseri. The UN-financed pump, to be installed under the aegis of the Lake Chad Basin Commission, remains equally clouded with lack of information.

Somewhat less serious than the ERU's lack of involvement in solar pump activity is its absence from the biogas research efforts being led in Douala and at the Polytechnical School. So far there may have been little concern that the Unit be well informed on the progress of these programs, but as they proliferate, the absence of a central point of contact for researchers could become keenly felt. The ERU needs the status and the means to stay informed and to take the lead when appropriate. A third element of a possible program would thus be to determine how this might be accomplished.

A comment by someone long involved with solar energy research in Senegal is pertinent here: it is important that those leading the research effort approach it more from the point of view of the user than from that of the researcher. The former has a need to be met, a problem to be solved. The latter may prefer to see how a theoretical idea works out in practice or to solve a somewhat different but more solvable problem. In order to keep the perspective of the user, ERU would do best if it were field oriented and not burdened with the impediments of a sophisticated central laboratory/workshop complex. It has no such thing now and may not be avid for it, but the danger is there and to be avoided. A formula should be found for appropriate support to the Unit, in the form of a modest amount of measuring and test equipment, some appropriate training for staff, and the initial presence of an outside energy scientist/advisor.

The matter of status may be more important than it seems at first sight. The Unit, if it is successfully to lead a research and design effort, needs to have some clout vis-a-vis other government agencies. The dilemma facing similar R&D efforts in countries not unlike Cameroon is that the research organization lacks the means to conduct realistic field tests while the agencies that do have the means are more interested in carrying out their own programs. These agencies may operate in a number of different sectors (agriculture, public health, public works construction) and report to different ministries. Yet their willing collaboration is often essential. The complexity of dealing with them requires that an energy research organization have the status to carry out its task. In Cameroon, the position of ONAREST, its five institutes and their respective centers should make this possible.

These general observations having been made, the following sections of this report will discuss the individual elements of a possible program and make recommendations. There may be nothing new or startling about various components. Several have already been suggested by those who have looked into the renewable energy situation in Cameroon. Readers interested in what they have recommended will find brief summaries in Appendix E.

The principal themes informing the tenor of this report should be stated:

1. Measurement work, surveys and the build-up of a capable Energy Research Unit should be undertaken as soon as possible, no matter what else is done.

2. Initial efforts to adapt renewable energy technologies to Cameroonian conditions should be modest in scope. Applications should be chosen that are limited in ambition but have a high probability of success. Research should follow through until applications are operating successfully in the field.

3. The Northern Province should be a zone of concentration, not only because of low relative incomes and US-AID's commitment, but also because it has the greatest solar resource and the more acute fuelwood problem. It is safe to assume that the major centers in the north will be electrified within a few years but that most rural areas will probably never receive electric power from a central source (1).*

4. If a project design effort is decided upon, it should, to the extent it has time and resources, look at a number of alternatives--

*References are found on pp. 34-35.

some are suggested here and others have undoubtedly been overlooked--but should probably be selective in what it decides to support.

The sections below discuss in turn: data measurement, a survey of rural energy needs and uses, training, prototype building and testing, and, in more extended fashion, possible choices of technology for field application.

## DISCUSSION AND RECOMMENDATIONS

### Solar Data Measurement

The only solar measurements now being taken in Cameroon are those of the duration of sunshine in hours per day. Duration is measured with a heliograph, which burns a hole in a strip of paper when the sun shines. It is not an accurate nor a very useful measurement, but it is inexpensive and simple. Comparable data on sunshine duration from eight stations of the Department of National Meteorology are available for the period since 1955. Data for the Anglophone provinces are available since 1971 only, since prior to that year they were sent to Nigeria. Currently the Department of Meteorology publishes measurements for 18 stations, those in the north being located at Maroua-Salak, Garoua and Ngaoundéré. Average monthly hours of sunshine duration over a ten-year period for Maroua-Salak, Garoua, Ngaoundéré, Batouri, Koundja and Yaoundé have been obtained from the Meteorology Department and are shown in Appendix D. Frequency distributions for Maroua and Garoua are also shown.

The intensity of solar radiation, or insolation, is a much more important measure. It determines, with the aid of a pyranometer, the units of energy falling on a given horizontal area in a given period of time. It can be measured in calories per $cm^2$ per hour or watts per $m^2$ per hour and be averaged over days, months or years. The only measurements of insolation ever made in Cameroon were taken by Professor Guy Lacaze of the Faculty of Sciences, who has three and one half years of measurements of global insolation (direct plus diffuse radiation) at Yaoundé covering the period from November 1969 to May 1973. Unfortunately, his Kipp and Zonen "solarigraphe" broke down in 1973 and has not been used since. With a colleague, Lacaze has written an article for the

Annales of the Faculty of Sciences, giving the results of their statistical analysis of the data obtained (2). He graciously gave us a copy of the unpublished article. Graphs on the frequency distribution of days when global radiation was between 400 and 500 langleys, or calories per square centimeter, and when it was greater than 500 langleys are reproduced in Appendix D.

Professor Lacaze's measurements are at least a start, and he hopes to obtain equipment to take more, but the need for a time series of measurements at other locations, particularly those in the north, is clear and urgent. Professor Armand Morabin, also of the Science Faculty, has suggested that there be one solar radiation measurement station in each Province (3). He recommended automatic recording on a cassette that would need to be changed only every other month. His suggestion was that units manufactured by Enertec-Schlumberger be used, but our conclusion is that they are more sophisticated and expensive than is necessary. It should suffice to equip six or seven stations of the Meteorology Department with a set of two pyranometers each (one to measure total radiation and the other diffuse radiation) plus a two-channel strip chart recorder. The cost would be about $3,600 ex-factory for each station. There would be additional costs for shipping, cables, installation and paper.

As far as location is concerned, we tentatively agreed with ERU that Maroua-Salak, Ngaoundéré, Yaoundé, Bertoua, Bafoussam and Douala would be a minimum list. It would be advisable for the Yaoundé station to be located at the ERU or nearby and under its control so that ERU personnel would have hands-on experience with the equipment and get to know its foibles. Kribi might be added to the list on the grounds that its climate is allegedly different from Douala's. Those stations are in fact the seven that Prof. Morabin suggested. We do not think, however, that it is necessary to equip any substations (he recommended 37) with heliographs. The 18 existing heliographs should be sufficient.

Calibration of the pyranometers could pose a problem, but help could be available from the Sahel AGRHYMET program, which has been installing solar radiation measurement equipment in the eight Sahelian countries. The WMO project director is based in Niamey at the Centre Regional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationelle, B.P. 11011. There is also a pending proposal that the Center for Renewable Energy Research to be established in Dakar be provided with calibration equipment. Between the two, Cameroon should be able to call on sufficient assistance to get the job done. Responsibility for calibrations, instrument repair and periodic surveys of the equipment should be vested in ERU.

While the pyranometers would presumably be under the routine supervision of the Meteorology Department, it is important that a system be established to furnish ERU with a complete set of sun data so that it can handle, store, analyze and check it for evidence of malfunctioning equipment. An integrator, which gives the total radiation for a given day from the data provided by a pyranometer, would be a very useful piece of equipment for ERU.

Recommendations:

1. That US-AID consider ways to provide the basic equipment for measuring solar radiation described above in an expeditious fashion, without waiting for further developments.

2. That a system be worked out so that ERU is a direct recipient of the solar radiation data recorded at the stations of the Meteorology Department.

## Energy Survey

Elsewhere in this report mention has been made of the paucity of information that seems to be available on energy use in rural areas. The kinds and quantities of energy used and needed in villages for such things as cooking, lighting, pumping water, crop drying, heating in the cool months, ironing, and radio listening need to be determined for representative villages and households. The use of human and animal energy in agricultural production is another matter and one that is best treated in another context.

What is the best way of conducting such surveys? One source that has been suggested by others is the University of Yaoundé. Students of economics from the Faculty of Law and Economics, for example, could be oriented to the subject when choosing topics for their theses. Since travel to village sites would be involved and there would be living expenses and, ideally, enumerators to pay for, it would be necessary to envisage some kind of outside support for these students. Funds should also be available for analyzing and publishing the results.

The Institut des Sciences Humaines (ISH) is a logical candidate for participation in village energy surveys. If it does so in no other context, ISH might make such a survey one of the topics to be pursued under the Social Science Research and Training Program that US-AID has recently funded. The field work of this program is supposed to take place in the north in any case. If the subject matter is not yet fully determined, energy surveys by one or more of the program's research teams should be planned. Since ISH is a sister institute of IRTISS, close collaboration between the two should be possible.

If manpower and resources are not available from either ISH or the University of Yaoundé, it may be worth considering a contractual arrangement with an American university. Graduate students from the U.S., supervised by professors from their university and working in tandem with Cameroonian students or researchers, could be utilized. They should work under the aegis of either ISH or the University but the bulk of their funding could be provided by US-AID.

The ERU should be closely involved with the work of the field researchers so that the results can be used to guide the Unit in its development of prototype devices. In fact it would be desirable for ERU personnel to participate in the surveys from time to time in order to get a better sense of the real energy problems encountered at the village level. This brings us back to the idea of looking at R&D from the perspective of the user.

Recommendations:

1. That US-AID seek to include village energy surveys in northern Cameroon as one of the topics to be investigated under the Social Science Research and Training Program.

2. That in addition, US-AID determine whether it can provide modest amounts of funding to the University to permit students to conduct such surveys for their theses.

3. If neither of these avenues is open, that US-AID envisage the possibility of contracting with an American university for a set of

village level energy surveys at an early date.

Training

Unlike the Sahelian countries of Mali, Niger and Senegal, where solar energy research has been going on for some years and a number of nationals have studied solar energy, Cameroon is really just beginning. It appears there are only two Cameroonians who have concentrated on renewable energy topics at the University of Cameroon. One of the two is Augustin Simo, who was awarded the D E.A. diploma at Perpignan after a year's additional study of solar energy there and now works in the Energy Research Unit. He needs to spend another year working on a thesis to get the "doctorat du 3eme cycle" degree. He cannot prepare the thesis in Cameroon because the one professor in a position to supervise it, Prof. Morabin, was due to leave Cameroon for good at the end of July. The second student who has done some work in renewable energy is M. Fotso who has just completed his fifth and final year at the Ecole Polytechnique. Fotso did his thesis on a biodigester and was scheduled to defend it on July 2.

With the departure of Professor Morabin and of Fotso's advisor, there appear to be only a handful of teachers at the Ecole Polytechnique (and none at the Faculty of Sciences) who have an interest in renewable energy and who intend to work with students on renewable energy projects. It is worth noting that there seem to be no courses on renewable energy subjects anywhere in the University. Learning about the field has come through projects at the Ecole Polytechnique. The teachers who wish to do projects are:

1. Charles Minka and Nzumbe-Mesape Ntoko. Next October they will supervise two 5th year electrical/mechanical engineering students in (a) a solar drying project and (b) a solar water heating project. Their teaching duties, however, do not appear to give Minka and Ntoko much time to devote to solar energy matters.

2. Gerard Capolino is the head of a research group on electrical energy and electronics (GREEP) which hopes to be able to run experiments on the conversion of current produced by photovoltaic cells from DC to AC. They need, however, to get someone to provide the photovoltaic panels for the experiments. There would be three Cameroonian students and two other

French teachers working in this group.

3. Alain Lefevre, a newly arrived professor, also wants to work on a solar hot water heating project.

It seems important that Simo get the rest of his training out of the way as soon as possible. There is a professor at Perpignan who is ready to supervise his thesis. He himself would like to go there as soon as possible but also wonders whether there might be something more appropriate in the States. It would probably be best for him to go to Perpignan so as to be ready to work on a project. If he goes now he should certainly be back before any project gets started. It would mean his being absent when a PID or Project Paper were being developed, but it is more important for him to get additional training while there is time.

As far as training under the heading of a project is concerned, it would seem appropriate to consider three-to-six month training programs in the States or in Africa for two of the four people who are scheduled to be recruited for the ERU. The following new positions are envisaged.

a. An electronics specialist, who might well be recruited from among the three 5th-year students at the Ecole Polytechnique working with Capolino's group next year.

b. A chemist to work on biogas projects. This could be Fotso.

c. A physicist specializing in thermal applications. This person might be recruited from among Minka's students at the Ecole Polytechnique.

d. Another physicist, but a generalist who is good with statistics rather than an engineer. This individual might be recruited at the Faculty of Sciences.

Both of the first two individuals might benefit from some further technical training outside of the country. G. Saunier, an energy consultant from the Economic Commission for Africa suggested some possibilities after his visit in 1977. (See Appendix E.) A wide variety of post-secondary educational institutions in the U.S. where solar related courses are offered can be found in the <u>National Solar Energy Education Directory</u> published by the Solar Energy Research Institute (SERI) of Golden, Colorado, in January 1979 ( 4). Appendix F to this report also provides a short list of appropriate educational and training institutions in the U.S. for different renewable energy technologies.

Recommendation:

Rather than specifying now what training should consist of and where it should take place, it would be more prudent to await the design of a project, if such there be, and let the project design team designate training choices in light of program content. William Mackie of SERI's international programs office has indicated that SERI would be willing and able to select appropriate training programs in the U.S. for Cameroonian participants.

Prototype Building and Testing

The desirability of strengthening the Energy Research Unit has already been mentioned. Recruitment of additional staff and further training is part of the process. The assignment of responsibilities for making solar intensity measurements at Yaoundé, for monitoring the collection of national data, and for analyzing it will add an extra dimension. The Unit also needs to start a reference library on renewable energy topics. There is not much available at the ERU today. It has only two subscriptions to technical journals: one to the International Solar Energy Society's Solar Energy and one to the Bulletin Signalétique 730 - Combustibles Energie published by the National Council for Scientific Research (CNRS) in France. Copies of some pertinent articles in English and French have been sent to the Unit (see Appendix H for a listing), but there needs to be financial provision for a systematic collection of reference works, documents and articles.

Staffed, trained, given authority, armed with reference works, informed by and participating in energy surveys, the Energy Research Unit would be ready to get involved in the building and testing of various prototype devices. This will make the staff participants in the process of adapting renewable energy technology to Cameroonian conditions. Experimentation will also go on at the Ecole Polytechnique, as it has in the case of the biodigester and as it will next academic year in various solar applications. The Ecole Polytechnique is a teaching institution, however, and the work done there is aimed at giving students a better understanding of their disciplines. It cannot be expected to have the concerns of the users of renewable energy technology primarily in mind. This should be the role of ERU. The Unit is a research organization but one whose mission can be that of bringing renewable energy applications within the reach of people in rural Cameroon.

While it may make sense for students and faculty at the Ecole Polytechnique to build solar devices from scratch, based for example on their theoretical understanding of the thermosyphon effect, it does not make sense for ERU. The Unit's role should be clear: to take technologies available elsewhere--solar fish dryers from Senegal or biodigesters from China--and adapt them to local conditions. There is no need to reinvent things. Since the economic aspect is so important, the building of reliable devices as far as possible with locally available materials must be thoroughly explored.

Equipping ERU to build and test prototypes should be done on a modest scale (5). We understand that the Unit already has access to the workshop at the Ecole Polytechnique provided it provides its own expendable materials. If this arrangement is workable, it should be continued at least for the next three or four years or until the need for something more ambitious is clearly felt.

In fact it would be a good idea to provide the Ecole Polytechnique with a modest amount of equipment to promote the teaching of renewable energy subjects through student projects. The professors who want to do projects now have a hard time getting equipment and material. They should definitely be encouraged to work with students on these subjects. Enough interest might eventually be generated to get some of them into the curriculum.

A possible solution for the short and medium term would therefore be to add to the equipment at the ENSP workshop on the clear understanding that it would be for the use both of ENSP faculty and students and of Energy Research Unit staff working on prototype development.

<u>Recommendations</u> for a project design team:

1. Look at the equipment now available at the Ecole Polytechnique workshop and determine to what extent it would be desirable to supplement it with equipment for the use of both ENSP and Energy Research Unit staff. Rights of access to the equipment would have to be clearly understood.

2. If the first recommendation can be implemented, determine what supply of expendable materials will be necessary for the ERU to

build the prototypes envisaged in its program.

U.S. Technical Assistance

In our final meeting with the Deputy Director General of ONAREST, he specifically requested that US-AID consider providing a renewable energy specialist to work with the staff of ERU. There is great difficulty in finding specialists of this kind who also speak French and are interested in spending a period of time in Africa. Considering the activity in non-conventional energy fields now gathering momentum in the U.S., it is understandable that talented physicists or engineers would be reluctant to leave for as much as two years. Accordingly, it seems more realistic to envisage the assignment of two or three specialists to work with and advise ERU for short periods rather than on a conventional two-year posting. It would in fact be desirable for the specialists to return periodically to assess progress and make new recommendations. The initial stay could be for four to six weeks, enough time to become familiar with the situation, to develop a work plan with colleagues at ERU, and to make recommendations on the ordering of equipment and supplies. Two or even three return visits at intervals of six to nine months would be ideal. In each case two or three weeks might suffice.

The choice of specialties should be left up to a project design team and should be made in light of program content and emphasis.

Peace Corps Volunteers could help with the development of wood-burning cookstoves and in fact have already been encouraged to do so, as explained below. If a woodburning and charcoal production specialist such as Ed Karch, a Peace Corps Volunteer in Senegal, could be brought to Cameroon for a week or two, he could give excellent advice and practical pointers to ERU staff, Peace Corps Volunteers and others interested in working on stoves and charcoal.

## FIELD TESTING OF RENEWABLE ENERGY TECHNOLOGIES

This phase of a program would be the logical culmination of all that is gone before. It presupposes that the other steps have been successfully taken. What follows is a discussion of various technologies that might be considered for inclusion in a program. The list is far from exhaustive. Possibilities that have not been included for lack of information include micro-hydro projects in western Cameroon, particularly the highlands of the North-west Province, and the production of gasohol from sugar cane, there being two sugar cane production centers in existence now and a third planned for the north. A project design team may wish to explore these and other omissions at the appropriate time.

Woodburning Stoves

The fuelwood problem in the north is one whose dimensions are unknown. It is likely that the situation is similar to what exists over much of the Sahel. The CILSS/Club du Sahel report on energy ( 6 ) underlined the urgency of the need to combat the depletion of fuelwood availability. Rather than attempt to force solar cookstoves, no readily acceptable models of which have yet been developed, many experts believe it would be better to encourage efficient woodburning stoves. Their general adoption would reduce fuelwood consumption by about one-half, perhaps more, allowing time for much greater reforestation efforts to bear fruit.

The immediate need is to develop models of woodburning cookstoves that can be made entirely of local materials such as mud brick and scrap metal worked by local blacksmiths. The effort can and should begin without further delay. Several models should be built in the north and tested both for efficiency of combustion and for compatibility with local cooking customs. A number of groups and individuals could be working on the problem at the same time in different locations. What is important is that they be able to compare notes frequently and stay abreast of developments in the Sahelian countries and elsewhere. The ERU would be the logical coordinator of this activity and should form part of a network consisting of the Renewable Energy Research Center in Dakar, the Solar Energy Laboratory in Bamako and others.

In hopes of getting something started, I have sent packets of materials on woodburning cookstoves to the ERU, to three Peace Corps Volunteers working in community development (Miriam Bergman in Yaoundé, Deborah Coates in Garoua and Kate Farnsworth in Maroua), and to Rick Embry of the Community Development Foundation, who is working on a pilot community development project at Doukoula-Karhay, southeast of Maroua.

A valuable local resource is the Centre Technique de Maroua. Three years old, the center was built by the Cameroonian Baptist Church and is operated with help from its West German counterpart. It is developing appropriate technology tools and equipment such as a pedal-driven lathe and a donkey cart of local materials with replaceable axle and bearings. The center is also working on improvements for local bread ovens, which are considered to be wasteful of heat. The director of the center told us that if some good designs were available, they would be interested in working on cookstove development.

One new source of designs is a publication of the Appropriate Technology Project of Volunteers in Asia. Entitled Lorena Owner-Built Stoves: A Construction Manual for Highly Efficient Low-Cost Stoves that Can Save at least Half the Firewood Normally Used in Cooking, this 80-page book has a number of practical drawings and photographs. It is based on the successful development of clay-sand cookstoves in Guatemala in 1976-77. I have sent copies of the book to the ERU, Rick Embry and Kate Farnsworth. Other sources for woodstove designs are the Village Technology Handbook, which is widely available, and a 1961 report for the FAO by H. Singer entitled Improvement of Fuelwood Cooking Stoves and Economy in Fuelwood Consumption. I have inquired, so far without result, into the availability of this work.

Peace Corps headquarters in Bamako has been experimenting with woodstove designs, and a group of four Volunteers assigned to AID's Renewable Energy Project in Mali will soon be working on the problem. They and the Volunteers in Cameroon mentioned above have been encouraged to correspond and compare notes.

CENEEMA, the appropriate technology workshop of IRTISS, has produced a metal coal-and-wood stove after a model designed in Bamenda in the 1960's. It has had some popularity among civil servants in the North-west Province but is made of concrete and metal, is expensive (75 to 95,000 CFA)*, and is evidently not suitable for wide distribution. Interestingly, the Société Nationale d'Investissement (SNI), a government company that takes equity positions in new enterprises, is seeking a charcoal stove model that is affordable by the general public. It has commissioned a study of the subject by CITACO, an Italian consulting firm.

Recommendations for a project design team:

1. Determine what developments in woodstove design and testing have occurred in Sahelian countries at the time of the design effort; see what progress may have been made by the Peace Corps Volunteers, Rick Embry, SNI and other groups in Cameroon; verify the extent to which the ERU has succeeded in gaining access to information on developments.

2. Consider what additional support from AID might hasten the development of efficient, acceptable models and/or encourage their

*215 CFA = $1

widespread adoption. In the latter regard, it would be necessary to determine what organization(s) involved in rural development is/are appropriate for an extension effort.

Wind Energy

The Department of National Meteorology takes wind measurements at 39 weather stations scattered around the country. Eight of these are in the Northern Province: Maroua-Salak (where the Maroua airport is located), Kaélé, Garoua, Poli, Banyo, Tibati, Meiganga, and Ngaoundéré. Only the first two are in the four northernmost Departments.

Anemometers located at the surface are read every three hours by weather station personnel, and mean wind speeds are calculated for each month. *A priori*, sites in the extreme north would be expected to have stronger average winds. The averages recorded for Maroua-Salak in 1978 were:

Table 2. Monthly Average Surface Wind Speeds at Maroua-Salak, 1978 (in meters/second)

| | | | |
|---|---|---|---|
| January | 3.1 | July | 2.1 |
| February | 3.0 | August | 1.5 |
| March | 3.1 | September | 1.7 |
| April | 2.8 | October | 1.7 |
| May | 2.6 | November | 3.0 |
| June | 2.4 | December | 3.4 |

Source: Department of National Meteorology, Douala

While it would be more useful to have a longer time series, to have wind measurements at a height of at least ten meters and to know the frequency distribution of wind speeds, the figures above indicate that there is not enough wind at Maroua to power wind systems. As a general rule, mean speeds of 4.5 meters/second (10 mph) are needed.

This preliminary conclusion does not rule out the possibility of using wind energy in northern Cameroon but holds that it is unlikely. The chief of the Génie Rural garage in Maroua informed us that there is a "wind corridor" in the region and that two windmills had once been used there. Both are still standing but are not operating. One at Moulfoudai turns but is apparently disconnected from its water pump. The other at Pette is said to be completely broken down.

It is unlikely that the wind corridor is windy enough to support wind systems. Wind speeds there could and probably should be measured, but an expensive measurement effort would not be justified. There is some interest on the part of the Génie Rural garage. If an anemometer and recording device were purchased, the chief of the garage (Gérard Pellegri) might be willing to install them and supervise the collection of wind data on behalf of the ERU.

Wind speeds in the Mandara Mountains are an unknown quantity. While at elevated locations they may be significantly greater than they are on the northern plain, it seems unlikely that wind energy can be harnassed to pump water, the population's primary need, because of the inaccessibility of underground water sources in the mountains themselves. A project design team may wish, however, to look into this possibility in an effort to find some way to use a renewable energy source in the Mandara Mountains.

Recommendations to a project design team:

1. If action has not already been taken, consider the desirability of installing a wind measuring device in the "windy corridor" under the aegis of the ERU and with the help of the Génie Rural garage in Maroua.

2. Explore the possibility that (a) there may be more wind in the Mandara Mountains than on the northern plain and that (b) there may be viable applications of wind energy to the needs of the local population.

## Photovoltaics (Solar Cells)

The barrier to wider use of photovoltaic cells (PVCs) at present is cost rather than reliability, though there still remain some questions in the latter respect as well. Terrestrial applications are relatively so new--and those in developing countries even more so--that some time will have to pass before it is clear how well PVCs will stand up over the long run. To date all indications are that reliability is at least satisfactory and probably much better than that. This is the judgment of specialists from the NASA Lewis Research Center in Cleveland, where important work has been done on PVC applications (7). In Africa photovoltaic panels have been installed in Mali, Senegal and Upper Volta in the past two years. At the outset there were some minor problems with the resins and lamination of panels in Senegal and Mali, respectively, but these have been corrected. Whether the panels now used for pumping water (and grinding grain in Upper Volta) will still be performing well 10 to 15 years from now remains to be seen. The rigors of the African climate may or may not have their effect.

The question of cost is an important one. PVC systems incur heavy costs at the beginning, relatively few thereafter. The desirable features of photovoltaic power sources, however, are such that in many rural areas of developing countries they may soon prove themselves preferable to their alternatives. The desirable features, spelled out in a NASA Lewis report, are: "modularity (therefore scalable in size); no moving parts; low maintenance; and a potentially long life" ( 8 ). The alternatives are usually hand, foot, diesel or gasoline-driven pumps. If the application is for irrigation rathern than human or animal consumption, the alternatives are apt to be diesel or gasoline pumps.

Hand and foot pumps are far less costly than a PVC pump. The Vergnet foot and Briau hand pumps being installed in the four northernmost Departments of Cameroon by FSAR cost 200,000 CFA ($930) and 300,000 CFA ($1,395) respectively. The PVC panels for a solar pump can cost ten times as much. But the hand and foot pumps have moving parts subject to constantly varying stress and their life expectancy is not long. The Mali Aqua Viva program of Father Verspieren installs both hand/foot and solar pumps. Its experience has been that the former have breakdowns about once a month and at most once every two months ( 9 ). The cost of repairs, if a qualified technician has to visit the site to make them, can be extremely high (10). The Guinard PVC pumps installed in Mali and Senegal, on the other hand, have to the best of my knowledge had no breakdowns.

The cost of photovoltaic cells is falling. There is no need to repeat the oft-cited projections for price reduction. As a general order of magnitude, it is expected that the cost of a peak watt (11) will fall from about $10-12, ex-factory 1979, to about 60-70¢ in constant dollars by 1986. These costs are for the PVC modules themselves. A number of other costs are incurred before a complete system is installed. These other costs, called balance-of-system costs (BOS), cover such things as electrical components, mounting frames and supports, installation, and storage, either of electricity or of water. NASA Lewis believes that BOS cost reductions will not be easy but that they will probably be cut by 1986 to one-third of their 1978 level (12). Others consider that in making PVC applications in Africa, more so than elsewhere, BOS costs need to be and can be significantly reduced (13).

Meanwhile, the operational costs of diesel and gasoline powered systems increase as oil prices rise. At the pump in Maroua in June 1979, diesel was $1.68 a gallon (95.2 CFA/liter) and regular gasoline $1.87 a gallon (106 CFA/liter). These prices are likely to rise, even though Cameroon is now producing oil. Using an assumption of $2/gallon for diesel (as well as others not spelled out here), NASA Lewis projects that in 1981 a photovoltaic system consuming less than 17,000 kWh annually will be less expensive over its lifetime than a diesel alternative. Again using NASA Lewis assumptions, this means that PVC pumps rated at less than 10.6 kW (peak) should soon be competitive. The pumps installed to date in Africa have been in the 1 kW (peak) range.

What does this mean for northern Cameroon and for a possible solar energy program there? In the first place, because of high current costs - of PVC panels, of BOS for African installations, and as a result of the novelty of the technology - the PVC pumps now planned by France, FED and the UN will clearly be uncompetitive with alternatives. If their performance can be monitored by ERU, however, they will provide valuable operating experience under local conditions.

Given that there should be three PVC pumps functioning in the north, it would be prudent to wait three or four years before installing additional ones. It is more important that the initial installations be studied closely from an economic and social as well as a technical point of view. At the same time one could look into the possibility of a solar component in the second stage of the FSAR project, due to begin in two years. This would avoid overextending ERU's responsibilities while allowing time for careful integration of any solar pumping effort into the structures operating in the north. A French conseiller technique at the Ministry of Agriculture in Yaoundé (Mr. Audebert) has been mentioned as the planner in charge of developing the elements that will go into the second phase of the FSAR project.

Another reason for waiting before getting involved in village water supply is the fact that BOS costs in Africa are now much higher than they need to be. Local talent (e.g. blacksmiths and carpenters) and local materials (e.g. fencing) should be substituted wherever possible for imported goods and services. It is almost a certainty that the three initial PVC pumps will not accomplish this. In three or four years' time, however, when the cost of the photovoltaic panels will have fallen appreciably on the one hand, serious thought can have been given to reducing BOS costs on the other. The ERU could make this an important objective and could accomplish it through study of the first generation of pumps in collaboration with Gênie Rural and other rural development agencies. If funding were available, prototypes of some support structures could be built and tested in the absence of the panels, motor and pump. Technicians could be trained in wiring procedures and in pump installation. Some of the personnel to be trained might be among those now working for FSAR.

It has been suggested that FSAR II might have an important irrigation component. In some ways this is the most promising of the photovoltaic applications. For irrigation of small parcels where the water table is close to the surface and for drip irrigation where modest pressures are required, PVC pumps have definite advantages. The modularity of photovoltaics gives them great flexibility. We are talking about rather small units. Smith's study of micro-irrigation is couched in terms of 200-400 $W_p$ units, capable of irrigating one hectare with a lift of 4.5 meters (14). A NASA Lewis memorandum on markets for PVC pumps estimated that it would take only 200 $W_p$ to lift enough water 6 meters to irrigate one acre (0.4 ha) by the drip method.

Drip irrigation may or may not have been introduced in northern Cameroon, but there are areas on the plain near river beds where the water table is close to the surface. The bed of the Mayo Tsanaga, which passes just south of Maroua, is a case in point. Vegetable and particularly onion production takes place now along its banks. Some farmers use the traditional chadouf to draw water by hand. Others use gasoline pumps. Some have shared the use of diesels. The disadvantage of the chadouf is that it can cover so little land. Difficulties with the Honda and Bernard motorpumps now being used are that they require constant attention (e.g. clogged gas lines), spare parts are usually obtained in Nigeria after some delay, and the price of gasoline is rising.

The market for the produce of the vegetable farmers appears to be a good one. They have two crops a year in the off-season, beginning right after the rains. Production of onions has reached 300-400 metric tons, according to an FSAR official. He estimates that farmers cultivating one hectare can clear 300-400,000 CFA ($1,395-1,860) over two crops. Much of their onion production is shipped south. Other vegetables are sold locally, and officials would like to encourage more production. The head of the IRAF center at Maroua estimates that with 25 to 30 kilometers of flat land along the Tsanaga, vegetable production may be possible in a number of locations.

Beginning in October FSAR will provide four-year loans at 10 percent to farmers to permit them to dig a shallow well and buy a gasoline pump for between 150 and 360,000 CFA ($700-$1,675). This is in advance of any larger involvement in irrigation during FSAR II.

The onion farmers of Meskin have shown their sense of initiative and their dynamism. Some are doing well. The introduction of three or four small-head, low-volume pumps powered by small PVC arrays could be an extremely exciting innovation. The farmers who use them should probably be asked to repay on the same terms (and in comparable amounts) as those who buy gasoline pumps on credit. Ideally, the farmers chosen to take the PVC pumps would be ones who have had to use the chadouf up to now, though they may not be able to meet the credit terms. On the other hand, it will be of some importance to be able to compare the results obtained from the solar pumps with those of the gasoline pumps, most other things (e.g. the ability and dedication of the farmer) being similar. FSAR might be asked to manage the program in conjunction with its gasoline pump loans, with the proviso that ERU and the Institut des Sciences Humaines be permitted regular access to observe and measure performance. In fact, researchers from either of these institutes might be assigned to the local IRAF center and operate under the aegis of this sister institute.

Another photovoltaic application to agriculture, more modest but of interest, could be considered. Ultra-low volume insecticide and herbicide sprayers using flashlight batteries have been developed for use on crops such as cotton and rice. Regular batteries are expensive in African countries and are quickly used up in spraying operations. Small PVC panels could be used with sprayers equipped with nickel-cadmium batteries, either to charge them between applications or in a portable set-up. Dr. Ray Wijewardene of the International Institute of Tropical Agriculture (IITA) in Ibadan has written an article on the successful testing of a portable PVC panel-and-sprayer at IITA (15). The IRAF center at Maroua might be interested in experimental use of a few of these sprayers within the context of its programs to increase production of textile and food crops. Owen Gwathmey, assigned to the Maroua Center under the SAFGRAD program, knows Dr. Wijewardene and has discussed the PVC sprayer with him.

A last photovoltaic application to be suggested is in the field of public health. Sacha Lainovic, an engineering student at Lyon, after discussions with the Ministry of Public Health, recommended the idea of PVC-powered refrigeration units in rural dispensaries. He pointed out that most of the rural dispensaries in the north have no vaccines. They are almost certainly short of medicines as well. There would be some risk in providing refrigerated vaccines and medicines to medical personnel in remote locations who have not been trained in their use. It would thus be imperative to be selective about the sites and to link a solar refrigeration component with provisions for proper training of personnel and adequate safeguards.

One of the constraints on using photovoltaics for refrigeration has been the problem of using direct current. Marine refrigeration units use DC, however. A manufacturer of marine refrigerators developed a custom design for the Schuchuli village photovoltaic power system in southwestern Arizona (16). Experience gained from this project may be helpful in deciding whether it is technically and economically practical to envisage PVC refrigeration units in rural dispensaries.

Recommendations for a project design team:

1. Verify the extent to which ERU has been successful in monitoring the performance of the photovoltaic pumps scheduled for installation in the north. If necessary, suggest ways in which ERU can participate more effectively in the testing of these pumps.

2. Examine the desirability of providing three or four small-head, low-volume PVC-powered pumps to onion/vegetable farmers at Meskin or at a similar location nearby. If desirable, see whether FSAR would administer the loan part of the program while permitting ERU to measure and test. Before going to Cameroon it would be worthwhile to learn about the availability of appropriate DC pumps from such suppliers as the Jenson Pump Co. of Kansas and Shurflo of California.

3. Look for drip-irrigation and small-head irrigation projects elsewhere in the north where PVC pumps could be used.

4. Explore the possibility of providing some PVC-powered ULV sprayers to the IRAF center at Maroua for experimentation.

5. Look into the desirability of installing one or two photovoltaic village water pumps at some later date for comparison with hand and foot pumps to be provided under FSAR II. Initial contact should be made with Mr. Audebert at the Ministry of Agriculture. If it were deemed desirable to proceed, one objective should be to reduce BOS costs by using local talent and materials wherever possible. Funding could be provided to ERU to enable it to begin working right away with provincial agencies on the development of inexpensive support structures.

6. Consider the feasibility of supplying a limited number of rural dispensaries in the north with photovoltaic refrigeration units. Magna Kold, Inc. of 1760 Monrovia Ave., Costa Mesa, CA 92627 is one possible source of technical and price information.

## Pyrolysis

Pyrolysis is the process by which waste materials from agriculture and forestry are converted into high energy fuels: char, oil and gas. A feasibility study of pyrolytic conversion was conducted recently in Ghana for AID by Tze Chiang and John Tatom of Georgia Tech's Engineering Experiment Station and others. The results were published in July 1976 (17). Tatom and Chiang subsequently did a similar and more detailed study in Indonesia (18).

Charcoal production is in fact a pyrolytic conversion. As traditionally done in many African countries, it is a batch process that does not permit recovery of oils and gas. A continuous process such as the one recommended in the Ghana study allows recovery of these fuels but, as the study points out, is vulnerable to shutdowns for lack of spare parts and requires preprocessing of the waste feed. The system recommended for Ghana is of rugged, simple design but requires about $26,000 in capital outlay and up to $43,000 annually in operating expenses for two or three shifts of 11 workers each. There would be a high level of return on the investment, however. The plant would have to be located next to a steady supply of waste material: sawdust at a sawmill or rice husks at a rice mill, for example. A two-shift operation requires four to eight tons of waste material a day, depending on the moisture content.

There may be some differences between Ghana and Cameroon which make the latter a less likely candidate for such a plant. In the first place, production and consumption of charcoal are estimated at high levels in Ghana. Annual domestic demand was estimated by Ghanaian sources at 250 to 300,000 tons in 1975, according to the Georgia Tech study. Almost all Ghanaian charcoal is produced by earthmound kilns. There is a small amount of production by improved kiln (19). Ghana also imports coal--24,000 metric tons in 1975--to use in boilers in factories, trains and ferries.

In Cameroon, by way on contrast, we were unable to obtain data on charcoal production and consumption. Neither the Forestry Service nor the Forestry and Fisheries Fund had any information to give us. Our SNI contact, who is interested in charcoal, said that one works in the dark. When queried, Cameroonians replied that charcoal production is scattered and artisanal; there is no organized form of production. Further inquiry is undoubtedly needed and may reveal that there is significant consumption, but we found no evidence for it. Nor do we have any data on the extent of coal imports. Whatever volume there may be is hidden under a general term in the published import statistics.

To be used for domestic cooking and heating purposes, the powdered char produced by the continuous process has to be turned into briquettes. If not, it is suitable only for industrial purposes as is the oil. The gas that is produced is usually used on the spot since storage and transport could pose serious problems. If the goal of a possible renewable energy program for Cameroon were rural development applications, the type of pyrolysis plant recommended for Ghana would probably not be suitable.

What could be more appropriate is the improved production of charcoal for domestic use in the northern part of the country where forest resources are nowhere near as abundant as they are in the south. Cameroon has in fact some 20 million hectares of forest, one of the largest reserves in the world. A very small fraction of it is comercially exploited, but there are still some 60 sawmills in the country, the largest of which produce up to 88,000 cubic meters of sawn logs per year (20). Small scale charcoal production from sawmill trimmings and sawdust might be worth supporting. Ed Karch, a Peace Corps Volunteer working at a sawmill in southern Senegal under UNDP/FAO auspices, has been experimenting for the past two years with a Jamaica retort and other methods of improved charcoal production. He has also worked on using local materials as binders for charcoal briquettes. If available, he would be well qualified to assess the possibility of including a pyrolysis component in a possible project.

Recommendations for a project design team:

1. Obtain information on where, how and how much charcoal is produced and consumed in order to assess the desirability of a pyrolysis component. SNI (Mr. Ngassa Batonga) is a possible source of information. See whether SNI has pursued its interest in charcoal production.

2. Look at current disposition of sawdust and trimmings by sawmills and of rice husks by the SEMRY rice mill at Yagoua so as to determine the availability of waste matter.

3. Consider how an effort to turn forest and agricultural wastes into charcoal for domestic use might be organized and supported.

## Biodigestion

The production of methane gas by anaerobic fermentation of animal dung, kitchen scraps and grass cuttings is one form of renewable energy activity now being tried in Cameroon. Professor Morabin on the Faculty of Sciences at the University of Yaoundé has been an advocate of biodigestion in southern Cameroon as a way of providing energy to dispersed households while at the same time providing a more hygienic fertilizer and cutting the bilharzia cycle.

In April 1978 Jean-Gérard Galvez, a teacher at the Polytechnical

School, and a student named Fotso built a small 800 liter biodigester in which cow, hog and chicken dung gathered at the Nkolbisson Agriculture School were fermented along with grass clippings. Gas was produced after four days and the cycle was completed after 40 days. The model cost 30,000 CFA ($140) to build. Galvez calculated that it could produce 550 liters of gas per day when filled to the top each day with 11.5 kg of dung and 10 liters of water (21). The digester worked continuously for over a year, then was damaged while being cleaned out. A larger (3 cubic meter) digester had been built and was ready to be started up in late June 1979. Unfortunately, both Galvez and Fotso were leaving ENSP in July, and it was uncertain who would look after the new model.

More extensive experimentation is going on in and around Douala under the supervision of West German advisor Rainer Wesenberg, who is assigned to CENEEMA (22). He has directed the construction of seven biodigesters of different types and hopes to determine by the end of the year which is most promising. The installations to date:

1. Bamenda: 12 $m^3$, about 2 years old.

2. Village 40 km from Douala: model using 3 interconnected 200-liter drums. A fourth drum, inverted, is used as a bell to collect the gas. The fermenting matter inside is stirred periodically with a crank running the length of the digester. The device is initially charged with 600 liters of raw material, then 20 liters are added each day after one month. Production: 1 $m^3$ of gas per day. Wesenberg considers this model to be the most promising so far.

3. Douala: at an individual's house, 9 $m^3$, in a rectangular shape which was used in Germany at the end of WWII. Has three compartments and a crank to turn the material inside. Uses an inverted metal drum inside another set apart for a bell. The bottom drum will have rust-inhibitor added to the water. The raw material is one-year-old hardwood sawdust litter from chicken coops. Cost: about 300,000 CFA ($1,395).

4. Douala: at Wesenberg's house in Bonaberi. This model is also rectangular. It produces a lot of gas from household scraps and the effluent of an adjacent latrine. There have been problems with gas escaping.

5. Douala: a circular 12 $m^3$ installation next to an individual's

chicken coops. Had been operating about two months. Cost: about 300,000 CFA, half of which went for a 6 $m^3$ bell forged in a workshop under the direction of a Dutch volunteer. Unless the bell is given a few shakes/turns each day, it will stick in the sludge and not descend, thereby lowering the gas pressure. When observed, part of the masonry had broken away because the hole around the inlet pipe had not been filled with earth as suggested by Wesenberg and had been eroded further by rainwater run-off.

6. Douala: 6 $m^3$ built entirely above ground, with a plug near the bottom to allow easier cleaning.

7. Douala: a similar but smaller model. Neither were observed. One is said to be much better maintained than the other because the owner paid for part of it.

For most of these digesters, West German aid has contributed part of the cost and the Cameroonian who is using it has paid a part. Wesenberg has found individuals who are generally quite interested but he believes that their interest may wane when the novelty wears off and the drudgery of maintaining (and especially cleaning out) the digesters is felt. He has encountered in some quarters the attitude that this is another crazy Western idea being foisted off on Africans by do-gooders.

He has found the wet, humid climate of Douala ideal for producing biogas. Two major problems that he believes have been underemphasized in the literature are the difficulties encountered in cleaning out biodigesters and corrosion of the metal bell. He estimates that the bells used in Douala will rust through in a year and a half at most from contact with gas and from being constantly dipped back into the fermenting goo. Galvanized steel might solve the problem but would be too expensive, and rust-inhibiting paint has not proven very effective. Wesenberg also realizes that the Cameroonians who can afford biodigesters do not need them since they have enough income from chicken raising and other sources to buy bottled butane gas.

He is proceeding nonetheless with a series of interesting and valuable experiments. Additional biodigesters are planned for installation at various locations along the road that leads north to Bafoussam. The differences caused by a change in climate and in other conditions will be observed.

An area which at first blush seemed a possible candidate for simplified digesters, perhaps of the 3-drum type mentioned above (#2), was the Mandara Mountains. It appears that the population there relies on scraps of wood and dried dung to fuel cooking fires and also has the custom of keeping cattle for fattening in enclosures over extended periods so that dung would be easily collectable. There are two problems, however, one possibly not constraining, the other almost assuredly so. The first is that most families in the Mandara keep only one animal for fattening. The second is that water is so scarce that the moist method of anaerobic digestion is probably impractical.

A simpler and much cheaper type of biodigester for family use has been designed and built in China, but relatively little still is known about the method. Clarence Kooi has obtained some interesting information about the Chinese model. A brief description is found in Appendix G.

Recommendations for a project design team:

1. Determine what results Rainer Wesenberg has obtained from his experiments and what recommendations he may have for further work on biodigestion.

2. Explore the possibility of supporting ERU in experimenting with inexpensive, easily maintained biodigesters and in determining what, if any, areas of the country might have (a) enough collectable raw material, (b) enough water, and (c) an economic interest in biogas production.

## Solar Crop and Fish Drying

There is some Cameroonian interest in solar crop drying. Simo Augustin's principal work has been on cocoa drying, and Charles Minka of ENSP intends to work this fall with students on a simple solar collector for drying agricultural products. Minka was given a copy of the Brace Research Institute technical report on solar dryers (T99).

Improved cocoa drying techniques could be used in Cameroon, but there is question whether a solar energy device is the proper means. The solution must be simple and inexpensive yet provide protection from the rain. Two drying methods are used at the present time. One is to dry cocoa in a woodburning oven, a process which is rapid (12-18 hours) but which risks giving the cocoa beans a smoky smell that lowers quality. The other method is to dry the beans in the sun. The natural process takes a week since the moisture content has to be reduced from between 40 and 50 percent after fermentation to only 18 percent. For much of the cocoa harvest this must occur during the period between September and December, when rains are heavy in the production zone, centered on the Center-South Province. One ingenious device for natural drying--called a "sechoir autobus artisanal"--is four trolley trays on wooden rails stretching in four directions from a covered housing unit. The trays are each on different levels, so that when it rains the cocoa farmer can push them all back under shelter. When the sun reappears, they are rolled out again. The system is usually built by the farmer with local materials and his own labor. It is effective, but the farmer has to be on guard against sudden showers and the beans can get wet.

SODECAO, created by the government in 1974 to promote cocoa production through a project reaching 30,000 farmers, considers drying to be a serious problem. It has recently been experimenting with plastic sheets to cover the trolley trays. SODECAO's technical director points out that under their program the cocoa farmer already goes 21,200 CFA into debt to obtain a sprayer, a pod splitter, a sieve and a fermentation box. He does not believe the farmer could afford a dryer that cost more than 10,000 CFA ($46.50). The challenge, then, is to see whether a simple device can respond adequately to the need. Luckily, a method that moves air through or over the cocoa beans at a temperature only slightly above ambient is all that is needed to reduce drying time. Simo intends to continue his work on the cocoa dryer and is looking into the possibility that it may be more practical to introduce a solar dryer at the level of a group of farmers or a cooperative rather than for the individual farmer.

Onion production near Maroua has been discussed. Onions are also produced at Kousseri, across the river from N'Djaména in the far north. Improved preservation of onions is considered desirable because late in the season the market is usually glutted and the price per sack of 80 kg falls from around 11,000 CFA after the first harvest in December to as little as 2,500 CFA after the second in March. Onions are shipped by truck to markets in the south. The successful farmer to whom we talked at Meskin maintained that by separating his onions and drying them carefully in the sun he had no problem with spoilage but that others did have problems. Onion preservation is a candidate for a solar drying application, but it too requires a simple, inexpensive approach.

More costly and more complicated is the need to raise temperatures to 60 degrees C in order to kill insect larvae that usually infest fish when dried in the sun. Losses from insect damage are generally considered to be very high. A prototype fish dryer with 20 square meters of solar collector surface, capable of drying 250 kg of fish a day, is being built at the Institut de Physique Météorologique (soon to become CERER) in Senegal. The cost is still very high at about $4,650, but if IPM has success with the dryer in the next few months and is able to reduce the cost, Cameroon might consider the possibility of adapting the design for use with catch landed from the Logone River. It would be advisable for ERU to establish direct contact with IPM in order to keep up with developments.

Recommendations for a project design team:

1. Determine what progress has been made on adaptation of solar drying techniques at ERU and ENSP. Learn, if possible prior to departure for Cameroon, what developments have occurred in solar fish drying techniques in Senegal.

2. Explore the possibility of providing some support to ERU and/or ENSP for the production and testing of simple cocoa, onion and other crop dryers in a realistic environment.

3. Decide whether enough progress has been made on solar fish drying to warrant support for such a component in a renewable energy program, aimed at fish preservation in the far north.

## REFERENCES


1. The administrative centers in the north will be electrified. A 90 KV high tension line will run between Garoua and Maroua. The 72 MW Lagdo dam now under construction near Garoua is expected to produce power starting in 1981. In the meantime, the Garoua thermal plant will have its capacity increased by 10 MW from the current 13.7 MW. Large villages along the route of high tension lines will receive electricity, but the level of rural electrification in the north is not expected to exceed 5 percent in the year 2000.

2. Lacaze, G., articles in bibliography, Appendix A, page 36.

3. Morabin, A., "Projet d'Etude", in bibliography.

4. Available from the U.S. Government Printing Office, Stock number 061-000-00210-3. $4.75

5. The Unit is supposed to have a budget of 4.5 million CFA ($21,000) for equipment but office rents must also come out of this sum. We were told that ERU had recently placed an order for 1.5 million ($7,000) worth of equipment to measure flows in flat-plate collectors. The International Atomic Energy Agency has furnished the Unit some equipment for analyzing radioactive substances.

6. CILSS/Club du Sahel, Energy in the Development Strategy of the Sahel: Situation, Perspectives, Recommendations. October 1978.

7. Rosenblum, L. et al., reports in bibliography.

8. Rosenblum, L. et al., "Photovoltaic Power Systems," p. 2.

9. Interview with UNDP expert in Mali, published in Afrique Agriculture, February 1979, p. 35.

10. "Over a period of 10 years, one manual pump will cost about $35,000 in repairs, maintenance, and replacement (every two or three years)." The White Fathers of Africa, Washington, D.C., "Missionaries of Africa Report," January/February 1979.

11. A solar panel which produces one watt of power when illuminated with 1000 $W/m^2$ at 28 degrees C is rated at 1 watt (peak).

12. Rosenblum, L. et al., op. cit., p. 14.

13. CRED "Working Papers", in bibliography. Forthcoming revision will include a paper on BOS costs by Clarence Kooi.

14. Smith, D. and Allison, report in bibliography.

15. Wijewardene, R., article in bibliography.

16. Rosenblum, L., *op. cit.*, p. 8.

17. Chiang, T. et al., study in bibliography.

18. Tatom, John W. et al. *Pyrolytic Conversion of Agricultural and Forestry Wastes to Alternate Energy Sources in Indonesia: A Feasibility Study*. Atlanta, Engineering Experiment Station, Georgia Institute of Technology, February 1977.

19. The Forest Products Research Institute at the University of Science and Technology, Kumasi, Ghana, appears to be a much better source of information on charcoal production in Ghana than any we found in Cameroon.

20. *Afrique Agriculture*, June 1979, p. 13.

21. Galvez, J-G., "Production de Bio-Gaz", in bibliography.

22. Wesenberg has no telephone. He can be reached in person by going to his house in Bonaberi. Go to the Centre Equestre, which is off the main road, take an immediate left on a narrow street, then first right. The house is the third on the righthand side.

# APPENDIX A

# BIBLIOGRAPHY

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________. "Variations Géographiques et Saisonnières du 'Gisement' Solaire au Cameroun: I - Evaluation par la Durée d'Insolation" and "L'Insolation dans la Region de Yaoundé: II - Premières Mesures de Rayonnement Global: Comparison et Corrélation avec la Durée d'Insolation." To be published in Annales de la Faculté des Sciences de Yaoundé, no. 25.

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________. Photovoltaic Power Systems for Rural Areas of Developing Countries. NASA Technical Memorandum 79097 (Revised), February 1979.

Smith, Douglas V. and Allison, Stephen V. Micro Irrigation with Photovoltaics. MIT Energy Laboratory Report - MIT-EL-78-006, April 1978.

Wijewardene, Ray. "Solar Energy Powers Light Crop Sprayer." in Appropriate Technology, vol. 4, no. 4, February 1978, p. 9.

## APPENDIX B

## ABBREVIATIONS

| | |
|---|---|
| CENEEMA | Centre National d'Etudes et d'Expérimentation du Machinisme Agricole (National Center for Studies and Experimentation in Agricultural Mechanisation) Under ONAREST/IRTISS. B.P. 1040, Yaoundé. Tel. 22-32-50. |
| CRESS | Centre de Recherches sur le Sol et le Sous-Sol. Under ONAREST/IRTISS. B.P. 333, Garoua. |
| ENSP | Ecole Nationale Supérieure Polytechnique. Part of the University of Yaoundé. B.P. 728, Yaoundé. |
| ERU | Energy Research Unit (Unité de Recherche sur les Energies). Under ONAREST/IRTISS/CRESS. B.P. 4110, Yaoundé. |
| FSAR | Fonds Spécial d'Action Rurale. B.P. 201, Maroua. |
| GREEP | Groupe de Recherche en Electrotechnique et Electronique de Puissance. At the Ecole Polytechnique. |
| IRAF | Institute of Agriculture and Forestry Research. One of the five ONAREST Institutes. Headquarters at Ekona, near Buea. The Institute's Center for Textiles and Food Crops is at Maroua. |
| IRTISS | Institut de Recherches sur les Techniques, l'Industrie et le Sous-Sol. One of the five ONAREST Institutes. B.P. 4110, Yaoundé. Tel. 22-00-08. |
| ISH | Institut des Sciences Humaines. One of the five ONAREST Institutes. B.P. 193, Yaoundé. |
| ONAREST | Office National de la Recherche Scientifique et Technique. B.P. 1457, Yaoundé. Tel. 22-44-92. |
| SODECAO | Société de Développement du Cacao. |
| SNI | Société Nationale d'Investissement du Cameroun. B.P. 423, Yaoundé. Tel 22-44-22. |
| SONEL | Société Nationale d'Electricité du Cameroun. B.P. 4077, Douala. |
| SOFRETES | Société Française d'Etudes Thermiques et d'Energie Solaire, Montargis, France. |

## APPENDIX C

### List of Officials and Others Met, June 7 - 21, 1979

ONAREST

Dr. F.A. Gandji, Director General

Mr. Nelle, Deputy Director General

IRTISS

Soba Djallo, Director of IRTISS

Ebenezer Epié, Chef du Centre, CRESS

Melende Abate, Coordinateur des Recherches Energétiques, ERU

Simo Augustin, Attaché de Recherche/Chercheur, ERU

Mr. Henke, Construction Section, CENEEMA

Emmanuel Mofor, Construction Section, CENEEMA

Institut des Sciences Humaines

Samuel Ndoumbe-Manga, Director

Université de Yaoundé

Faculté des Sciences

Armand Morabin, Professeur

Guy Lacaze, Laboratoire de Météorologie

Ecole Nationale Superieure Polytechnique

Charles Minka (Ph.D., University of Pennsylvania)

Gérard Capolino, Responsable, GREEP

Jean-Gérard Galvez, Assistant

Alain Lefevre, Directeur Technique, Projet Chauffe Eau Solaire

Ministry of Mines and Power

Samuel Mbakop, Sous-Directeur de l'Energie

SODECAO

Daniel Assoumou Mba, Directeur Technique

Société Nationale d'Investissement

Ngassa Batonga Louis-B., Département des Etudes

United Nations Development Programme

Mr. Coppens

Community Development Foundation

Alan Miller, Director

Météorologie Nationale

E. Bibiang, Chef de Station Météo Principal de Yaoundé

DOUALA

Rainer Wesenberg, attached to CENEFMA, B.P. 9172
Martin Pokam, Ingénieur d'Application de la Météorologie

GAROUA

Theophile Mba Mpondo, Chef de Service Hydrogéologique, Ministry of Mines and Power

Medjo Salomon-Félix, Chef de Service Provincial du Génie Rural du Nord

Deborah Coates, Peace Corps Volunteer, Service du Génie Rural

Mr. Gourlemond, Délégué Provincial de l'Agriculture

Mr. Mohamadou, Délégation Regionale du Nord, SONEL

Mme. Bourgeat, US-AID, Seed Multiplication Project Manager

MAROUA

Chau Minh Thien, Chef de Division des Operations, FSAR

Pius Massok, Ingénieur Agronome, FSAR (livestock, onion production)

Joseph Bindzi-Tsala, Ingénieur Agronome/Pédologue, Chief of the Center for Textiles and Food Crops, IRAF

Gérard Pellegri, Garage du Génie Rural

Mr. Bouecke, Chef du Centre Technique de Maroua

Richard Carron, US-AID livestock project

Kate Farnsworth, Peace Corps Volunteer, Délégation Départementale de l'Agriculture

Bud Laue, US-AID, IRAF

Boubu, onion farmer, Meskin

Rick Embry, Community Development Foundation, B.P. 216

Owen Gwathmey, SAFGRAD program, IRAF

# APPENDIX D

## SOLAR MEASUREMENT DATA

### Sunshine Duration Measurements

Monthly Averages, 1961-70
(hours per month)

| | Batouri | Garoua | Koundja | Ngaoundéré | Maroua | Yaoundé |
|---|---|---|---|---|---|---|
| JANUARY | 161.1 | 285.5 | 260.9 | 285.5 | 288.5 | 179.1 |
| FEBRUARY | 177.4 | 276.0 | 241.5 | 258.2 | 274.2 | 180.6 |
| MARCH | 174.4 | 273.5 | 215.5 | 225.3 | 263.1 | 165.0 |
| APRIL | 184.1 | 240.2 | 197.1 | 169.3 | 223.5 | 168.7 |
| MAY | 205.7 | 255.4 | 209.5 | 180.6 | 238.7 | 172.0 |
| JUNE | 145.5 | 210.0 | 177.8 | 148.2 | 207.1 | 126.5 |
| JULY | 104.3 | 191.4 | 118.8 | 118.2 | 185.7 | 103.7 |
| AUGUST | 83.0 | 172.9 | 117.8 | 102.7 | 164.8 | 81.8 |
| SEPTEMBER | 113.8 | 193.6 | 129.5 | 124.5 | 194.5 | 101.7 |
| OCTOBER | 141.0 | 267.7 | 183.7 | 166.6 | 255.9 | 129.6 |
| NOVEMBER | 184.4 | 287.4 | 138.3 | 260.0 | 282.8 | 177.0 |
| DECEMBER | 176.6 | 301.1 | 270.9 | 296.9 | 303.3 | 188.8 |

Source: Direction de la Météorologie Nationale, Douala

Yaoundé data covers the years 1967-76 and was obtained from the Station Météo Principal de Yaoundé.

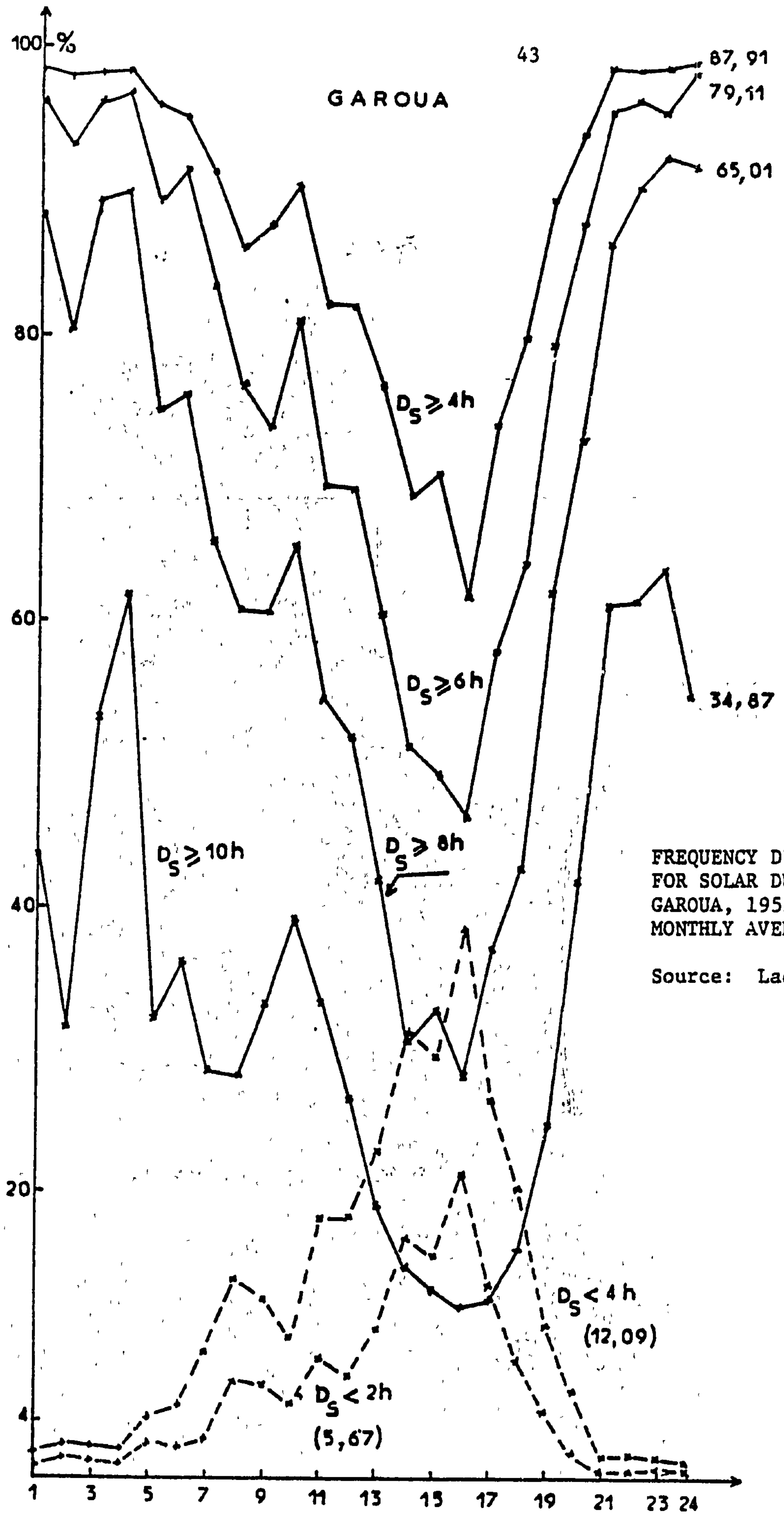
SOLAR DURATION OBSERVATIONS AT 8 STATIONS, 1955-74: STATION CHARACTERISTICS, MEAN SOLAR DURATION AND FREQUENCY DISTRIBUTION

| Stations | latitude N | longitude E | altitude (m) | $\bar{D}_S$(h). | $D_S=0$ | $0\leq D_S<2h$ | $2\leq D_S<4$ | $4\leq D_S<6$ | $6\leq D_S<8$ | $8\leq D_S\leq 10h$ | $10h\leq$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DOUALA | 4°01' | 9°43' | 13 | 4,4 | 7.95 | 27,23 | 16,38 | 1[illegible],39 | 24,30 | 11,55 | 1,15 |
| YAOUNDE | 3°52' | 11°32' | 760 | 4,6 | 2,38 | 17,66 | 23,02 | 25,93 | 22,70 | 10,00 | 0,69 |
| BATOURI | 4°25' | 14°24' | 665 | 5,2 | 4,78 | 17,42 | 18,13 | 20,65 | 20,70 | 18,17 | 4,93 |
| YOKO | 5°33' | 10°22' | 1031 | 6,3 | 1,40 | 10,58 | 14,15 | 17,41 | 20,96 | 25,01 | 11,89 |
| NKOUNDJA | 5°37' | 10°45' | 1217 | 6.5 | 0,67 | 9,42 | 13,81 | 16,41 | 18,54 | 30,43 | 11,49 |
| NGAOUNDERE | 7°17' | 13°19' | 1119 | 6,6 | 1,55 | 9,33 | 14,47 | 17,67 | 18,05 | 22,04 | 18,44 |
| GAROUA | 9°20' | 13°25' | 249 | 8,1 | 1,35 | 5,67 | 6,42 | 8,80 | 14,10 | 30,14 | 34,87 |
| MAROUA | 10°28' | 14°16' | 404 | 8,0 | 1,62 | 5,65 | 6,43 | 9,68 | 15,49 | 28,86 | 33,95 |

KEY: $D_s$ = Daily hours of sunshine at ground level

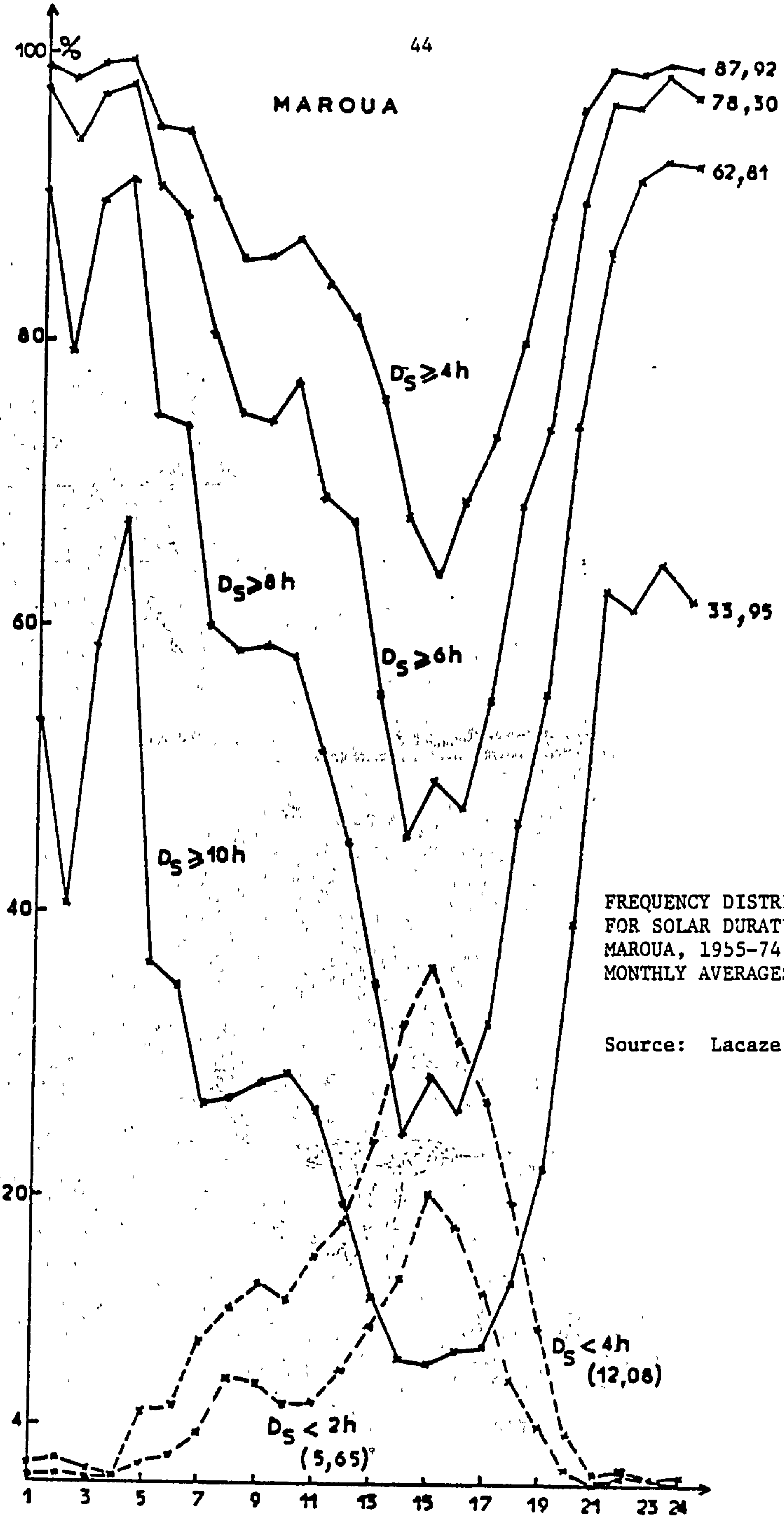
$\bar{D}_s$ = Mean Daily hours of sunshine at ground level

Source: Lacaze, G. "Variations Géographiques et Saisonnières du 'Gisement' Solaire au Cameroun."



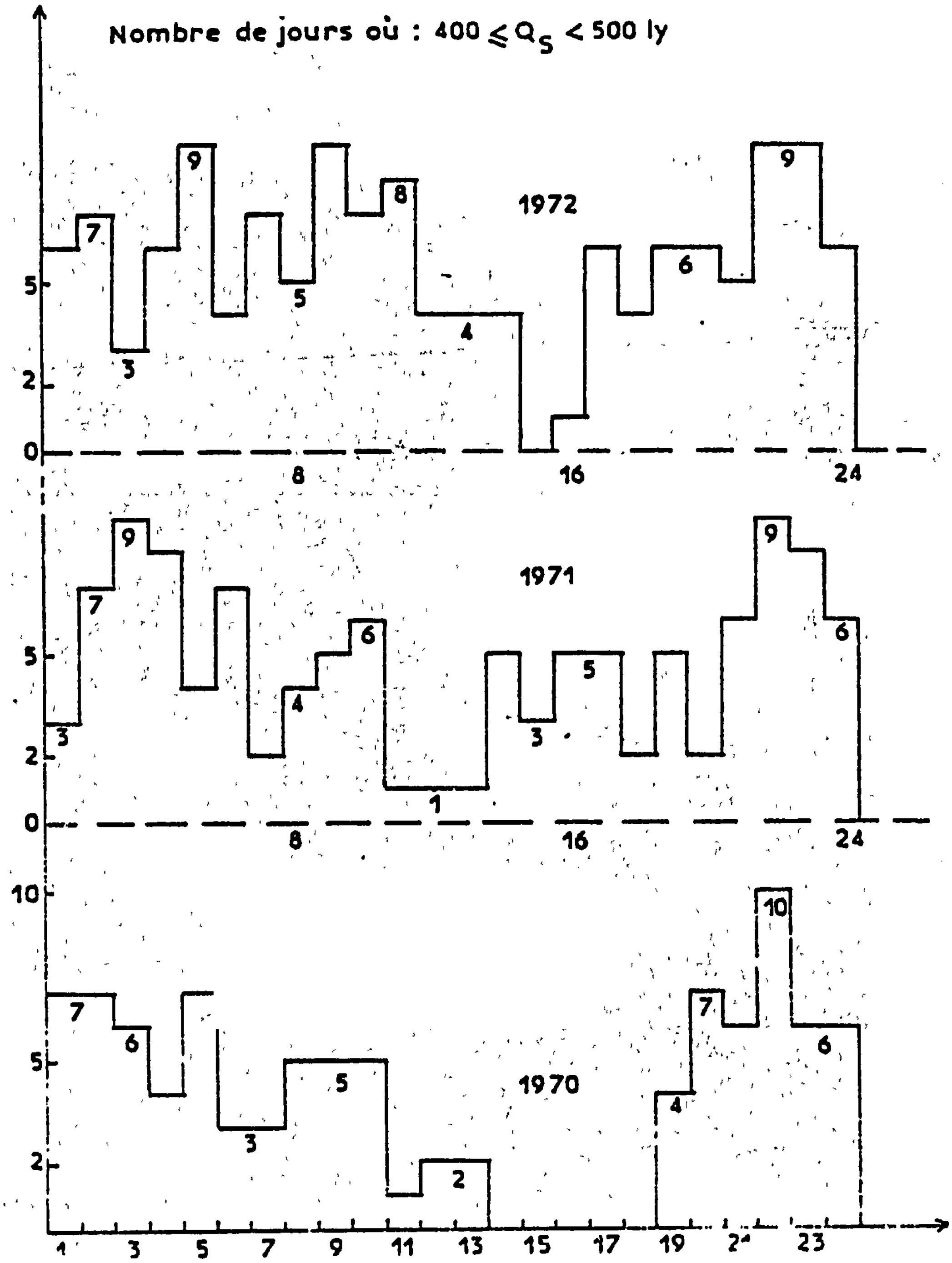

FREQUENCY DISTRIBUTION FOR SOLAR DURATION AT GAROUA, 1955-74: SEMI-MONTHLY AVERAGES

Source: Lacaze, G. op. cit.




FREQUENCY DISTRIBUTION FOR SOLAR DURATION AT MAROUA, 1955-74: SEMI-MONTHLY AVERAGES

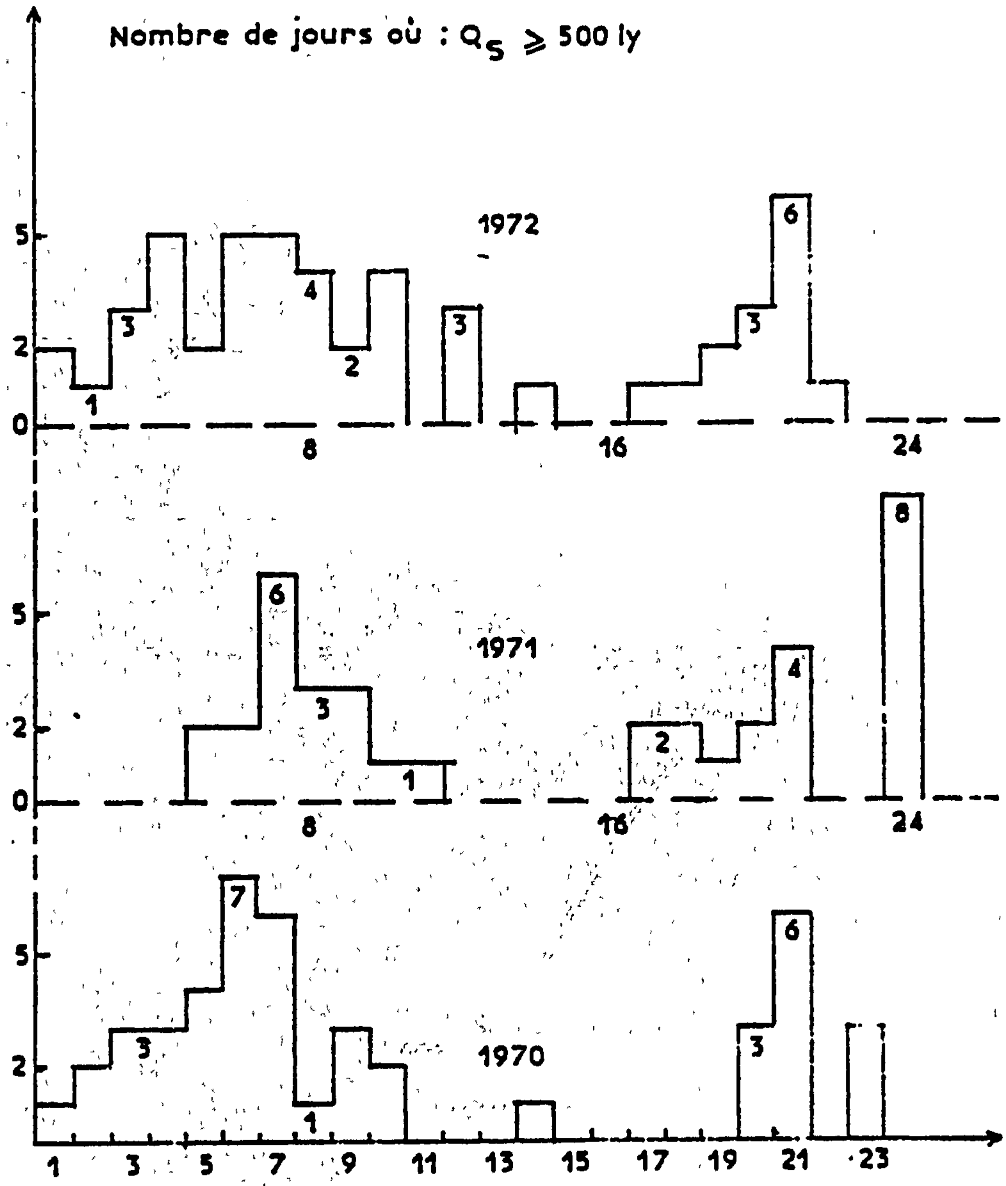
Source: Lacaze, G. <u>op</u>. <u>cit</u>.




FREQUENCY DISTRIBUTION FOR GLOBAL SOLAR RADIATION AT YAOUNDE, 1970-72: NUMBER OF DAYS PER SEMI-MONTHLY PERIOD WHEN $400 \leq Q_s < 500$ cal/cm$^2$

KEY: $Q_s$ = cal/cm$^2$/day

Source: Lacaze, G. "L'Insolation dans la Region de Yaoundé: II-Premières Measures de Rayonnement Global."




FREQUENCY DISTRIBUTION FOR GLOBAL SOLAR RADIATION AT YAOUNDE, 1970
NUMBER OF DAYS PER SEMI-MONTHLY PERIOD WHEN $Q_s \geq 500$ cal/cm$^2$

Source: Lacaze, G. op. cit.

# APPENDIX E

## SUMMARIES OF PREVIOUS RENEWABLE ENERGY REPORTS ON CAMEROON

1. SAUNIER REPORT:

"Recherche et Developpement en Matière d'Energie Solaire au Cameroun" par G. Saunier, Conseiller régional en énergie solaire, Division des Ressources Naturelles, Commission Economique des Nations Unies pour l'Afrique. B.P. 3005, Addis Ababa, Ethiopia.

Saunier visited Cameroon November 22-29, 1977, for the purpose of assisting the Cameroonian government in the design of a concrete R&D program in solar energy. He made the following proposals:

a. The establishment of a technical committee to set national energy objectives, e.g. solar, wind and biomass (SWB) energy to provide by 1985 15 percent of national consumption of fossil fuels for heat generation.

b. The nomination of a "delegate" for new energy sources whose task would be to:

(1) attend technical meetings on development projects for which energy consumption is planned,

(2) see that the possible use of SWB energy in projects is studied,

(3) monitor SWB projects and measure performance, and

(4) promote SWB use.

c. Support of the ERU as a specialized agency, including:

(1) sending a chemical engineer or agronomist for training in biogas production, i.e. one year studying concrete problems at an African center such as the Centre d'Etude et d'Application de l'Energie au Rwanda, followed by two short training programs of 3-4 months at developed country institutions such as Georgia Tech to learn about latest developments and meet specialists.

(2) sending someone with a B.S. in physics or an electrical engineer for training in photovoltaics: a series of special courses in institutes of technology, followed by short 1-2 month training programs at PVC manufacturing plants. at solar power stations, in Niger (solar television) or in Zaire (telecommunications).

(3) assignment of two expatriate technicians (one in photovoltaics and one in biogas) to ERU during the absence of the trainees.

d. The implimentation of several projects under ERU supervision:

(1) scientific and economic data collection.

(2) study of feasibility of producing methanol from wood trimmings. Pyrolysis of wood in isolated regions to fuel generators and vehicles.

(3) study and fabrication of methane biodigesters in collaboration with the Chemistry Department at the University, Ministry of Agriculture and agronomic research institutes:

(a) 200 liter model as a demonstration,

(b) 10 $m^3$ model

(c) 100-300 $m^3$ model

(4) evaluation of the costs and benefits of solar pumps, e.g. the thermo-dynamic pump at Makari. Donors such as the World Bank should be convinced to install pumps larger than 15 kW in the north for irrigation.

(5) evaluation of the use of photovoltaics for telecommunications:

(a) a mission should visit Niger and Zaire.

(b) a battery charging project.

(6) study of sun and wind energy resources:

(a) every meteorological station should have an anemometer and a heliograph.

(b) 6 or 7 stations should measure direct and diffuse radiation and do statistical analysis to determine the correlation between duration and intensity.

(7) establishment of technical dossiers:

(a) ERU to get in touch with manufacturers.

(b) explore the possibility of making hot water heaters in aluminum.

(c) test the flat plate collectors available on the local market.

(8) surveys to evaluate energy needs:

(a) urban centers that will not be connected to any grid. Identify needs which could be met with solar water heaters and biodigesters.

(b) install biodigesters and distillators at dispensaries.

(c) evaluate cooperatives and state farms where biodigesters and solar pumps could meet needs.

(d) determine what crops could be dried. These surveys could be done as theses by closely supervised students.

2. LAINOVIC REPORT:

"Energie Solaire et Réfrigeration en République Unie du Cameroun." Sacha Lainovic, éleve-ingénieur au Département de Génie Energétique à l'Institut National des Sciences Appliquées de Lyon. Oct. 1978.

Lainovic spent the period from July 14 to September 9, 1978 in Cameroon. He noted the following solar installations:

--the SOFRETES pump at Makari

--water heater at the Lycée Français (now ignored)

--around 10 water heaters fabricated haphazardly,

Mentions two projects underway:

--Guinard PVC pump for Koza

--photovoltaic railway signals and telephone relays between stations on the Douala-Yaoundé line. 600 panels ordered from RTC in France.

Other points:

a. Hydroelectric potential: 31.6 GW

Sanaga dam: 19.7 GW

b. Dams under construction: Lagdo

Song Loulou - 288 MW

c. Centers in the North that have electricity 24 hours: Ngaoundéré, Garoua, Maroua, Kousseri, Yagoua, Kaélé, Mokolo, Mora and Guider.

d. Refrigeration: kerosene refrigerators are not widely used.

(1) in the north fish are either dried in the sun or smoked over wood fires.

(2) there is a problem of vegetable preservation, especially onions and tomatoes.

(3) vegetable production projects:

(a) Maroua perimeter: dam on the Mayo Tsanaga, irrigation of 7,000 ha on the Maroua plain.

(b) Logone and Chari: several irrigated parcels of 1,000 ha each.

(c) SEMRY II: development of 55,000 ha in the region of Pouss.

(4) Ministry of Public Health is particularly interested in the possibility of solar refrigeration for rural dispensaries.

(5) local production of ice: well known and appreciated but water is a precious commodity in the north.

3. BCEOM/BRGM/GEW PROPOSAL

"Proposition d'Implantation d'Equipements Solaires au Nord Cameroun: Etude de Factibilité Régionale--Définition d'Opérations Pilotes." Février 1979.

BCEOM - Bureau Central d'Etudes pour les Equipements d'Outre-Mer

BRGM - Bureau de Recherches Géologiques et Minières

GEW - Guinard - Elf - Wonder

This study appears to have been written in France from material available there. It proposes:

a. To inventory energy needs,

b. To study the adaptation of new energy techniques to satisfy these needs, and

c. To impliment two initial pilot operations.

(1) Garoua: small irrigated perimeter in the Benoué valley - 15 ha for vegetable production. 3 tubewells. Requirement: 60 $m^3$/ha/day.

(2) Northeast Benoué: water supply and electricity for village centers and a dispensary. 80-100 villages to be surveyed. Initial program of pilot operations: pumps for 5 villages and provision of water and electricity for a dispensary (Tchollíré, Sorombeo or Mandingrinn).

d. Second part: water supply and electricity for a dispensary and a campement (campement du Rhinocéros in Doubandjdah National Park).

# APPENDIX F

## LIST OF APPROPRIATE EDUCATIONAL AND TRAINING INSTITUTIONS IN THE UNITED STATES

### Agricultural Drying

Solar Applications Laboratory
STATE UNIVERSITY OF COLORADO
Fort Collins, CO 80521 — Charles C. Smith

Agricultural Engineering Department
CALIFORNIA POLYTECHNIC STATE UNIVERSITY
San Luis Obispo, CA 93407 — E. J. Carnegie

### Biodigestion

OASIS 2000
University of Wisconsin Center - Barron County
Rice Lake, WI 54868 — T. P. Abeles

Department of Civil and Environmental Engineering
CORNELL UNIVERSITY
Ithaca, NY 14850 — R. C. Loehr

New York State College of Agriculture and Life Sciences
CORNELL UNIVERSITY
Ithaca, NY 14853 — W. J. Jewell

Department of Civil Engineering
Sanitary Engineering Research Laboratory
Richmond Field Station
UNIVERSITY OF CALIFORNIA
Richmond, CA 94804 — C. G. Golueke

Agricultural Engineering Department
UNIVERSITY OF CALIFORNIA
Davis, CA 95616 — John Goss, Dave Hill

Department of Agricultural Economics
MICHIGAN STATE UNIVERSITY
East Lansing, MI 48823 — L. J. Connor

Department of Civil Engineering
UNIVERSITY OF ILLINOIS
Urbana, ILL 61801 — J. T. Pfeffer

THE NEW ALCHEMY INSTITUTE - EAST
Box 432
Woods Hole, MASS 02543 — John Fry

Wood Stoves and Combustion

| | |
|---|---|
| Sanitary Engineering Department<br>UNIVERSITY OF CALIFORNIA, DAVIS<br>Davis CA 95616 | Bob Kemmerle |
| APROVECHO INSTITUTE<br>359 Polk Street<br>Eugene, ORE 97402 | Ianto Evans |
| WILLIAMS COLLEGE<br>Williamstown, MASS | Jay W. Shelton |
| GEORGIA INSTITUTE OF TECHNOLOGY<br>Engineering Experiment Station<br>Atlanta, GA 30332 | J. D. Walton |
| VITA<br>3706 Rhode Island Avenue<br>Mt. Ranier, MD 20822 | Henry Norman |

Photovoltaic Systems

| | |
|---|---|
| MIT/Lincoln Laboratory<br>P. O. Box 73<br>Lexington, MASS 02173 | M. D. Pope |
| SANDIA LABORATORIES<br>Albuquerque, NM 87185 | K. L. Biringer |
| NEW MEXICO SOLAR ENERGY INSTITUTE<br>Los Cruces, NM 88003 | H. S. Zwibel |
| UNIVERSITY OF DELAWARE<br>Newark, DE 19711 | K. W. Boer |
| ARIZONA STATE UNIVERSITY<br>College of Engineering and Applied Sciences<br>Tempe, AZ 85281 | C. E. Backus |
| UNIVERSITY OF NEW HAMPSHIRE<br>Electrical Engineering Department<br>Dover, NH | F. K. Manasse |
| SOLAR ENERGY RESEARCH INSTITUTE<br>1536 Cole Boulevard<br>Golden, CO 80401 | Sigurd Wagner |
| NASA/Lewis Research Center<br>Cleveland, OHIO 44135 | Bill Bifano |

## APPENDIX G

## THE CHINESE FAMILY-SIZED BIODIGESTER

A considerable amount of work has been done on the development of family-sized biodigesters in developing countries, but, except in China, they are still not widely used. One reason is that the initial cost is too high for an average or poor family. French (Ref. 1) discusses the economics of a three-cubic-meter per day unit of Indian design. It costs $375 and he concludes that only wealthier rural families can afford it. This author's observation of two village biodigesters in Senegal supports this conclusion (Ref. 2).

The family-sized biodigester of Indian design has two relatively costly elements (Ref. 3). These are the cement and construction materials, and the steel gas container which floats on the slurry in the digester pit. How can one reduce these costs?

The Chinese have done it by eliminating costly construction materials and the steel container (Refs. 4,5). The cement is thin and composed of indigenous materials. The gas, instead of raising a steel drum as in the Indian design, raises the water level in an adjoining water chamber. As a consequence of these design changes, the total materials costs are lowered to $30! However, it appears that some skill and knowledge is required for selection and use of the indigenous materials and for the construction of the digester.

The construction, as outlined by Dr. Wu (Ref. 4) commences with excavation of a hole somewhat larger than the hole needed to contain the entire biodigester. This hole is lined with a tamped sand-lime-clay mixture. A brick mold is used to form the cavities and holes. The mold is removed and can be used again. The entire interior surface is covered with a cement, of indigenous materials, of the same type used for construction of buildings. It is composed of about 30% lime, 40% sand, and 30% clay. Salt water is applied to the surface and it is rubbed with a stone. Then "paraffin" is burned inside the cavity. A plastic tube connected to the top to remove the gas is apparently the only manufactured item.

According to Dr. Wu, these digesters have a life of 10 years, material costs of $30.00, and a gas production of 1.5 to 2.0 cubic meters of gas per day (1 cubic meter = 35 cubic feet). This, according to Dr. Wu, is enough for a family of 4-6 people.

The feedstock is typically 10% human feces and urine, 10% animal manure and urine, 30% vegetation, and 50% water. Whether the solids are quoted as dry weight is not known. The large proportion of non-animal material is noteworthy, since it is frequently said that a poor family does not have enough animals to furnish the feedstock for the digester. However, if only one-fifth of the organic feedstock is animal waste, this may not be a difficulty.

The pH of the slurry is adjusted to 7-8.5 by means of lime and control of the feed rate. There are leakage problems, presumably due to cracks in the cement. Clean-out of residues (presumably rocks and dirt at the bottom and undigested scum at the top) takes place once a year. Liquid (slurry) is removed continuously and used as a fertilizer.

According to Dr. Wu, there are 7,000,000 of these digesters in operation in China. In contrast, there are about 36,000 biodigesters in India (Ref. 1) and about 20 in Africa (Ref. 6). Low cost and a national effort to disseminate the not inconsiderable skills and techniques needed to build and operate these digesters appear to be the reason for their widespread use in China. It should be possible to transfer this technology to the rest of the world.

C.F. Kooi, June 1979.

## REFERENCES

1. David French, "The Economics of Renewable Energy Systems for Developing Countries," al Dir'iyyah Institute, Arlington, VA and USAID Washington, D.C. (January 1979).
2. The biodigesters at N'Dioukh Fissel and at Nianing. Neither of these biodigesters was working well at the time of our visit (December 1978).
3. The cost of labor to construct the biodigester can be very low since it can be constructed during the dry non-agricultural season when there is a large surplus of rural labor.
4. The information on the Chinese family-sized biodigesters was obtained from Professor Tseng Tei Wu, Department of Architectural Engineering, Tsinghua University, Peking, China, and Chen Ru-Chen, Head of the Biomass Division, Guangshou Institute of Energy Sources, Chinese Academy of Sciences, 81 Central Martyrs' Road, Guangzhou, China, during their visit to Atlanta in May-June of 1979 (ISES Conference). They have literature in Chinese concerning the biodigester which

they said would be made available to the U.S. Department of Energy.

5. Michael G. McGarry and Jill Stainforth, Compost, Fertilizer, and Biogas Production from Human and Farm Wastes in the People's Republic of China, Report IDRC-TS8e, International Development Research Centre, Ottawa, Canada (1978).

6. Philip Langley, "Utilization du Gas Methane en Afrique en Fin 1978," Environment Africain, No. 21F, (November 1978). Available from International African Institute, 210 High Holborn London WCIV 78W. Reviews biodigesters in Africa--but apparently not in South Africa.

The University of Michigan
CENTER FOR RESEARCH ON ECONOMIC DEVELOPMENT
909 Monroe Street
Ann Arbor, Michigan 48109, U S A
Telephone: (313) 764-9490 Cable Address: CREDMICH

APPENDIX H

Le 19 juillet 1979.

Monsieur Melende Abate
Coordinateur des Recherches Energétiques
IRTISS
B. P. 4110
Yaoundé, United Republic of Cameroon

Cher collègue,

Toujours en train de rédiger mon rapport définitif sur ma mission au Cameroun, je tiens quand même à vous envoyer un peu de documentation sur les énergies renouvables. Vous devez recevoir sous peu, par pli séparé, les articles suivants.

1. extraits du numéro de novembre 1978 d'Industries et Travaux d'Outre-Mer sur l'énergie solaire et éolienne.

2. extraits de la revue anglaise Appropriate Technology sur les séchoirs solaires et la cuisinière à bois "Lorena".

3. extraits du Monde au sujet des recherches françaises sur les piles solaires (décembre 1978) et des énergies nouvelles aux Etats-Unis (avril 1979).

4. "La Grange Solaire d'Illinois" -- Actuel Développement, No. 28, 1979.

5. extraits du numéro de décembre 1978 d'Agecop Liaison sur les énergies nouvelles.

6. "Energie Solaire: de l'eau pour les pays arides" -- Afrique Agriculture du 1er mai 1978.

7. "Energie Solaire: les photopiles" -- Sciences et Avenir, No. 388, juin 1979.

8. "Utilisation du Gaz Méthane en Afrique en Fin 1978" -- Environnement Africain, supplément No. 21F.

9. extrait de Technology for Solar Energy Utilization (ONUDI) sur les séchoirs solaires.

En plus, je me suis permis de suggérer à l'Université des Nations Unies à Tokyo qu'ils vous envoient directement des renseignements sur leur publication mensuelle qui s'intitule Abstracts of Selected Solar Energy Technology. Comme promis, j'ai aussi écrit à Monsieur Bernard Meunier de la SEMA lui demandant s'il peut vous aider à obtenir un exemplaire de l'étude du CILSS portant sur la stratégie énergétique des pays du Sahel. Vous trouverez, ci-inclus, copies de mes lettres.

En ce qui concerne l'ouvrage dont M. Meunier est l'auteur (Evaluation des Energies Nouvelles, SEMA, 1977), il semble que le meilleur procédé serait que vous vous adressiez à la mission d'Aide et de Coopération à Yaoundé. Les exemplaires sont à commander au Service d'Edition, Ministère de la Coopération, Paris.

Je vous serais très reconnaissant de bien vouloir exprimer mes remerciements les plus sincères à Monsieur Soba Djallo pour le dîner d'adieu qu'il eût la gentillesse de m'offrir. Ce fut une réunion très agréable, détendue et amicale, et j'en garde un très bon souvenir.

En vous priant de transmettre mes salutations cordiales à MM. Soba, Epié et Simo, je vous prie de croire, cher collègue, à l'expression de mes sentiments les meilleurs.

C Steedman

Charles Steedman
Directeur Adjoint

CS/ao