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ENERGY FOR THE VILLAGES OF AFRICA

February 25, 1977

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Recommendations for African Governments

and

Outside Donors

by

James W. Howe and Staff of

The Overseas Development Council

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FOREWORD

There are nearly three hundred million people in the countries of tropical Africa that we discuss in this paper.[1] More than 250 million or about 85% of them live in rural areas including importantly the villages of Africa. Only about 4% of these rural Africans live in areas that have access to electricity. The rest live out their lives without more than occasionally being touched by modern energy--for example when a bus or truck passes by and delivers or picks up an item they buy or sell. Even the less modern energy in the form of animal traction is not common. The chief sources of energy for most of these people are human muscle power, wood, and the rays of the sun. Prescriptions for reaching these people with energy that is generated centrally and distributed through an electrical grid confront the twin problems that the pace of the grid's spread is agonizingly slow and that most sources of energy for the grid--oil, gas and nuclear fission--will one day dry up. This paper inquires whether by contrast, it might be possible to bring energy to these rural people with less delay using renewable local sources such as sun, wind, wood, waste, and flowing water harnessed by technologies that are now on the shelf or emerging from the laboratory.

Until well into the 1960's there was a near consensus that the developing countries of Africa, Asia, and Latin America should follow a development path modelled after that in Europe, North America, and Japan. That path emphasized urban areas more than rural, capital rather than labor, industry more than agriculture. It was a growth path which put resources in at the top of the economic pyramid and counted on them to trickle down to the city slums and eventually to the countryside. Within the past decade doubts about this development strategy have grown. U.S. foreign aid legislation beginning with the Foreign Assistance Act of 1973 has both reflected and stimulated these doubts. That act gave priority to three fields--(1) agriculture, rural development and nutrition; (2) health and population; and (3) education and human resource development--in an effort to force U.S. aid to address directly the problems of the poor majority, with particular emphasis on poor people living in small towns and outlying rural areas. The Congress in 1975 included a specific mandate to the President to launch "programs to help developing countries alleviate their energy problems through such means as research and development of suitable energy sources and conservation methods, collection and analysis of information concerning countries' potential supplies of and needs for energy, and pilot projects to test new methods of production or conservation of energy." (Section 106[2]) In the same Act the Congress initiated a new program of "intermediate technology." There is very little doubt where the U.S. Congress stands on the development strategy it hopes developing countries follow, and it is also clear Congress favors energy to meet the needs of poor people in rural areas. This paper, written with a grant from A.I.D., is directly responsive to the repeated Congressional views.

The energy policy of the Nixon and to a lesser extent of the Ford

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[1] The countries covered in this paper are those African countries South of the Sahara including the Sudan but excluding South Africa.

Administration saw the struggle to meet U.S. energy needs as a "zero sum game": if we gained, it was at someone else's expense and vice versa. Thus, the initial--unsuccessful--effort was to make the U.S. independent of oil imports and to break up the oil cartel. To the tension over oil prices and supplies has been added the problem of the proliferation of nuclear technology carrying with it the threat of proliferating nuclear weapons as well as of environmental hazards. A more promising course of action than seeking independence would be to treat energy as a "positive sum game" where all participants can benefit if they cooperate internationally to meet the energy needs of all nations; in other words a policy of making energy interdependence work. The proposals in this paper are a small part of such a policy.

The new Administration of President Carter will soon face a need to respond to the mounting demands from the developing countries for reforms in the international economic order to meet their needs for more resources. To a major extent this will require improvements in such international commercial systems as trade and investment. But it will also require more aid. In fact aid may be easier from a U.S. political point of view than trade and investment--at least in the short run. And it is easier to target aid directly to the needs of poorest countries and poorest people than trade and investment. If there is more aid in the next few years, the course of action proposed in this paper is all the more urgent: to learn how to spend money wisely in the field of energy for rural areas.

Of all the people in the world, those whose energy needs are farthest from being met are those in the rural areas of developing continents such as Africa. The energy needs of the villages of Africa are to be distinguished from their current economic demand for energy. As defined by economists and energy engineers, their demand is notoriously low. As is clear from the deficit in meeting the basic human needs of these people, their needs for non-human energy are high, especially in rural areas; to grow more food as well as to harvest, grind, and cook it; to light and sometimes heat their homes; to provide water for people and animals to drink and for basic sanitation; and to transport supplies and people. Meeting those needs is a goal that is worth great effort, for if it should prove possible to do so, the burdens of one quarter of a billion Africans could be immeasurably lightened and their lives dramatically enriched by it.

It would be poetic justice if the villagers of Africa--long among the most deprived of modern amenities of any people in the world--should benefit from the very latest renewable energy technologies ahead of people in the modern areas of the world, who will be late to acquire such technology precisely because of the heavy investments they have made in the obsolescing energy facilities we now consider modern.

James P. Grant, President
Overseas Development Council

EXECUTIVE SUMMARY

This paper examines the subject of village source energy for the villages and farms of Sub-Saharan African and recommends a course of action for African policy makers and outside donors. Village source energy includes those forms of primary energy found in the villages and farms (sun, wind, flowing water, animal and crop waste, and wood).

Assuming that bringing more energy to rural Africa is a high priority (which some people dispute), the first question for Africans to resolve is whether village source energy is a feasible approach or whether rural Africans must wait the decades that will elapse before a power grid brings them reliable centrally generated electricity. This paper does not answer the question--indeed the question cannot be answered with the present information base, chiefly because there are so few cases where village source energy technology has been tested in African villages. Instead this paper outlines a course of action for developing the information needed for Africans to make two decisions: first, whether village-source energy warrants use on a wide scale and, if so, second, what system to use to match energy hardware with village needs and to install it in villages together with a support system that will maintain it, provide repairs and spare parts, and generally keep it operating.

The course of action consists of three parts.

First, African governments, perhaps working with outside donors, should conduct certain research which we call "software" (to distinguish it from the actual design and development of energy hardware). Software research includes three simultaneous activities followed by three more steps to be conducted sequentially in an adequate sample of villages in any interested country:

1. Help villagers identify tasks they want performed by non-human energy (e.g., grinding, pumping, lighting, cooking, tilling) and select appropriate hardware devices, taking into account local energy sources and community aptitudes, values, and enthusiasms.

2. Evaluate the primary energy available to each village (e.g., measure wind velocities, stream flows, insolation (sunshine), organic waste materials, potential for work animals, etc.).

3. In a smaller sample of villages record base measures of the quality of life (e.g., income, yields per acre, migration to cities, employment, health, fertility, etc.) so that later, when new sources of energy come to the village, its impact on these quality of life indicators can be accurately gauged.

4. Install, operate, and keep records on pre-tested hardware devices in each village that so chooses. (This could as logically be called "hardware," but we have included it as "software" because it is testing the interaction of hardware and village life.)

5. Evaluate the performance, local acceptance, and costs of such hardware, and

6. Examine how best to extend village source energy to the villages of a region or of the nation. This consists of examining what role can be played by the private sector, by existing agricultural extension systems, or by a wholly new energy extension system. This would include a survey of the market potential for various kinds of energy hardware.

This software research would be designed and managed by an African national institution such as a university or a ministry of energy or of rural development, perhaps with the assistance of an outside consulting group financed by a donor.

Second, create or strengthen energy-related institutions.[1] This includes training African energy experts and providing support to African national energy institutions. It also includes helping to create new international institutions including an international lead agency to help make a more coherent network of the rapidly proliferating solar research (over 120 institutions now so engaged) throughout the world, and perhaps doing the same for wind and bioconversion. The lead agency would not attempt to supervise the work of participants in the network but would have much the same relationship to them that CIMMYT does to the 200 corn research stations around the world. The advisability of an International Energy Institute remains to be demonstrated.

Third, in the field of hardware research, three things are called for: (1) Industrialized countries' domestic energy and research programs should devote more attention to small scale renewable energy; (2) Aid programs should strengthen their help to African research on hardware both to apply and adapt energy technologies developed elsewhere and to develop indigenous technologies and (3) Aid programs should provide more help to African institutions--including the private sector--to design and build cheap, reliable tools, implements and appliances (e.g., stoves, grinders, pumps, tillers, decorticators, etc.) which can be used by hand or powered by village source energy to perform village tasks.

The paper recommends a relatively inexpensive project for undertaking the first four steps in the software research (up to and including site testing of hardware) involving the cooperation of qualified persons who are living in African villages--African school teachers, secondary school graduates, African volunteer corps, health workers, agricultural extension agents, etc. In addition, where African authorities so desire, non-African volunteers living in villages might be used, such as volunteers of the Peace Corps, the U.N. volunteers, and private voluntary agencies. It also recommends a project to take from existing U.S. government computer tapes data on wind and insolation in Africa to identify those few villages where hardware site testing could begin at once, bypassing the time consuming step two (gathering data on village

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1 Approximately 30 of such institutions now exist in the countries being discussed in this paper.

energy sources).

These proposed actions are not intended to substitute for vigorous action to develop the conventional energy (oil, hydroelectric, natural gas and coal) sector of African nations' economies. Indeed, increased support for fossil fuel exploration, construction of hydroelectric facilities and electric transmission lines and for generalized energy training and energy policy-making within national governments is and will remain vital to national development in Africa. If small scale decentralized energy should prove to be viable, this will in all likelihood not pose a challenge to the continued need for large scale centralized energy. Rather the two are likely to be complementary parts of a sound approach to development.

Nor are these proposals intended to suggest the substitution of a new intellectual discipline or government organization of village energy separate from and in competition with general rural development. Quite the contrary, if village source energy proves to be feasible, it will be given validation only as it fits into and gives support to comprehensive rural development.

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CHAPTER ONE

Village Source Energy: Romance or Reality?

I. Energy and Rural Development

The physicist's definition of energy is "the ability to do work." In human terms, energy is also the ability to play, to create, and to destroy. In terms of economic development, increased energy means increased ability to produce the necessities and amenities of life--food, shelter, clothing, communication, health care, education, transportation, leisure, and so forth. In fact economic development consists in large part of harnessing increasing amounts of energy for productive purposes. This can occur either by tapping increased amounts of energy resources (including previously unused or new sources) or by making more efficient use of available energy resources through use of appropriate tools and machines or conservation techniques. The relationship between energy and economic development is a dynamic one, in which the amount, type, and speed of economic growth are mutually dependent variables of the quantity, kind, and price of energy available.

For developing nations the present international situation is ominous: they are unlikely to ever again have access--as the world did for a quarter century before 1974--to energy fuels priced at less than two dollars a barrel of crude oil equivalent. This constitutes an additional hurdle to overcome in their struggle for economic advancement, a barrier that arises just as a major reassessment of strategies of economic development is underway by many Third and Fourth World governments and concerned outsiders. It has become distressingly obvious that the development strategies of the 1950s and 1960s, patterned on the large-scale urban industrial models apparently so successful in the North, are being overwhelmed by rapid population growth, urban migration, environmental degradation, and global inflation, and that whatever gains are being made in GNP do not simply "trickle down" to the poor majority of the population.

There is a growing consensus that successful development requires a firm agricultural foundation; that the basic quality of life must be improved for--and with the participation of--the poor majority of people living in the countryside. If this can be done--and no one suggests that it can be done either easily or quickly--then the rural poor may have reason and ability to reduce their birthrates, may increase their food production and consumption, and may no longer be forced to flee to already overcrowded cities. Carefully and persistently pursued, a fully integrated rural development program could provide a sound basis for the manufacturing and service sectors of a self-reliant and thriving national economy.

Increasing energy supply and efficiency of energy use will be important aspects of any such comprehensive rural development strategy. Indeed, the present vicious cycle of overpopulation/overconsumption of

available firewood/deforestation/siltation, flooding, and reduced agricultural productivity, will make meeting even existing fuel needs in rural areas a considerable task.

II. The African Village[1]

Villages are probably the world's single most common form of settlement containing perhaps as much as 60% of all people in the world. This is especially true of Africa, where as much as 90-95% of the population lives in villages which range in size from 75 to 3,000 people. The village is an ancient social, cultural, and political mechanism dating back as much as 3,000 years in Africa. There has been an uncountable amount of human experimentation adapting this particular social form to a variety of historic, economic, geographic, environmental, and cultural conditions and traditions.

African villages vary tremendously according to local culture and conditions. Some are densely populated (up to 2000 persons per square mile among the Kikuyu societies of Kenya). Others are widely dispersed or composed of dispersed compounds, with each compound having 20-30 inhabitants. Clearly their needs and potential can vary widely, but in focussing on village level technology in Africa, especially in the form of renewable energy resources, one is working with a time-tested, essential form of social organization.

III. Do Villages Need More Energy?

The first rural energy question for African policy makers to resolve is whether increasing non-human energy in African villages is a high priority. There are those who believe it is not—that health, education, roads, and improved agricultural practices, for example, are so much more important that villages can wait until their incomes have risen to the point where they can afford to pay for the capital costs of installing a village scale generator or of hooking into the national grid, and then can pay for the recurring costs of using that energy. Others—including the authors of this report—believe that village energy is a high priority now, in part because it is an essential ingredient of these other goals of health, education, and increased production.

The case for increased village energy rests on three propositions. First, it improves the quality of life. A decade ago, this would not have been widely accepted as a valid goal unless it also contributed to Gross National Product, but today it is considered by most scholars and practitioners of development to be a worthwhile objective in itself—indeed it is regarded as the ultimate purpose of development. How does it improve the quality of life? An increase in energy relieves people of very onerous physical tasks such as those described in Section V of this chapter and at greater length in Appendices I and II. More energy may

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1 This section was adapted from an informal memorandum of January 31, 1977 from Dr. Priscilla Reining, International Office, The American Association for the Advancement of Science.

also improve the quality of life by providing clean drinking water, lights to read or work or play by at night, and warm rooms when the weather is cold (as it frequently is at high altitudes). It may also provide clean, hot burning fuel (e.g., charcoal, charoil or methane gas) in lieu of slow burning unsanitary cow dung, and finally it can provide hot water to wash clothes and to bathe, which is an improvement over the present practice of washing in cold streams.

The second proposition is that more village energy will increase production. To begin with, it releases human energy for use on other purposes. A village adult may spend three or more hours daily on such tasks as gathering wood, hauling water, and pounding grain into a coarse flour. If this time were released by mechanical devices, some of it might be devoted to more intensive cropping, more acreage, better care of livestock, greater efforts to store grain, thereby avoiding losses to rot, diseases and pests, or to non-agricultural productive activities such as handicrafts. Such new energy might also increase production by providing heat needed to dry crops better and machines to cultivate, thresh, winnow and shell or decorticate more effectively. It could pump enough water to irrigate. By furnishing a better means of cooking it could release cow dung to be used for fertilizer. It could power a lathe or other tools for small industry in the village or furnish intense heat needed by a village blacksmith, and it could transport the increased crop production from the fields to market towns or truck loading points.

The third proposition is that a new source of energy can help save the terrain surrounding the villages from being stripped of vegetation as villagers seek woody material to use for cooking, crop drying or other purposes. An alternative source of energy to meet such needs could stop or reduce wood gathering, thus permitting trees, brush or other vegetation to grow. This would reduce erosion and in some areas would stop, slow or even reverse the spreading of the desert.

These three factors—improved quality of life, increased production, and improvement of the environment—constitute a strong case for making new sources of non-human energy available to the villages and farms of Africa. To those African governments that are determined to follow a development strategy that gives increased emphasis to the rural areas, to agriculture, to labor-intensive, capital-saving investments and to meeting the basic needs of the poorest people, the case for energizing the rural areas will be especially appealing.

IV. Village Source Versus Outside Sources

If village energy is needed now, the second rural energy question for African policymakers is whether energy must be delivered to the village from the outside through power lines or a fuel delivery system, or whether technology exists that can draw useable energy from renewable sources available to the village on site, such as wind, sun, flowing water, and organic wastes. The weight of conventional energy expertise is on the side of outside energy sources, and with good reason. Hundreds of millions of people are served satisfactorily by such large scale sources. Thousands of engineers study such technology in scores of engineering schools. Vast sums spent on research (e.g., on oil, coal, and

nuclear fission) are making large scale technology progressively more modern. By contrast, village source energy as a modern technology is almost untried in Africa and is virtually ignored in most engineering schools. Relatively little research and development is being devoted to it. Many professionals doubt whether it is to be taken seriously as a potential source to solve African village energy problems.

The answer turns on two unknowns: (1) whether village-source energy can achieve reasonably high performance specifications, and (2) what are the costs of village-source energy compared with energy from a power grid or a petrol distribution system. We know of no cost-benefits comparisons between village source energy and large scale conventional energy. There have been comparisons of a power grid with village scale diesel generation in such places as Brazil and the Philippine Islands, but this does not help with the problem of comparing village scale, village-source energy (e.g., wind, waste, wood, water, sun) with energy from the grid. We doubt that very good cost comparisons of the grid and village-source energy could be made until there has been more testing of the latter under actual conditions of an African village. Solar cookers, biodigesters and solar pumps and the like are being tested at research centers, but the missing ingredient is a deliberate comprehensive program of tests of such devices under actual African village conditions. In the absence of such tests it is likewise not possible to judge the performance characteristics of village source energy.

Thus, we do not have an answer to the question whether village-source energy is to be taken seriously. However, three facts suggest that answering the question warrants a considerable effort. First, there are several small scale energy technologies (e.g., windmachines) which reliably produce energy that could be used to perform village tasks, and their costs, although currently high, are declining and will decline further if a mass market develops. Hence village source energy is not without some promise.

An outstanding example of the potential for successful use of decentralized small scale alternative energy technology for rural development can be found in the recent windmill irrigation project conducted by the American Presbyterian Mission at their Omo River Station in an isolated, semi-arid area of southwestern Ethiopia on behalf of the local Geleb people. The Gelebs are semi-nomadic stock raisers who manage to grow one harvest out of the annual flood waters of the Omo River near Lake Rudolf; food is always in short supply during the six months prior to harvest. During 1973-74, the Gelebs received emergency air drops of food in order to avoid mass starvation during the drought. With funding from Ox-Fam, meteorological equipment from the Government of Ethiopia, and the cooperation of the village leaders, the missionaries tested a number of alternative designs, developed an appropriate design adapted from indigenous ancient windmills from the isle of Crete, used modern durable materials for the windmill construction, fabricated the windmills in a nearby town, located suitable sites in the village, and trained a local village handyman to assemble the fabricated parts, install the windmills, and maintain them in the village. Over the last 2 1/2 years, some forty windmills have entered into use, resulting in a doubling to quadrupling of the number of harvests per year, a host of new crops, and higher cash

incomes and living standards for the Geleb farmers. This project is described more fully in Appendix III.

The second reason for seriously investigating the potential of village source energy is that the pace at which power grids are being extended to rural areas in Africa is at best glacial. The World Bank estimates that in 1971 only 4% of the rural and village people of Africa lived in areas served by electricity and that by 1985 the figure will not have reached 10%.[1] Since these estimates were made before the prices of fossil fuels (which provide about 45% of African electricity) began to escalate in 1974, the prospects for reaching rural areas may be even more bleak than the Bank's estimate. Thus, rural Africans are in for a long wait if they must rely on the grid or village diesel generators.

A third reason is the recognition that a fossil-fuel economy is ultimately a dead-end street. Even if significant additional oils, gas, and coal reserves are located in Africa--as they almost certainly will be[2] --those fossil fuel reserves will be finite, and they will be highly valued for industrial and perhaps export purposes. To the degree that rural agricultural development can proceed without them, they will be available for those other purposes. For these reasons, and because of the expense (both financial and environmental-social) of massive hydroelectric projects and the expense and uncertainties of nuclear power, it seems prudent to explore the village source alternative to see whether it can at least help make some village tasks less burdensome and more productive during the long wait for the grid, and at best be a permanent alternative to centralized energy systems.

V. Energy in the Villages of Africa: A Description of the Current Scene[3]

This summary will focus on the specific energy-using tasks at the village level recognizing that, of course, needs and tasks vary widely with local conditions and resources. These village scale energy needs and tasks will be examined under four broad categories of use: production, processing, marketing and services.

A. Production

In the area of production, agriculture in African villages is the predominant activity by far, accounting for up to 56% of GDP in the African countries south of the Sahara (excluding South Africa). The following tasks and their energy implications can be delineated: Preparation of earth and plowing is a major time-consuming operation, dependent on

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1 World Bank, Rural Electrification (Washington, D.C., 1975), p. 17. The 10% estimate was supplied informally by World Bank officials.

2 See Appendix IV.

3 For a detailed description of the energy regimes of two African villages, see Appendices I and II.

conditions such as climate and rainfall regimes, terrain, existing vegetation and the types of crops to be planted. In arid land areas, multiple plowing may be necessary to soften the earth, break up clods, and turn under seed. In wet, tropical areas, thin nutrient-poor laterite soils are difficult to work, and the clearing of rampant vegetation growth is a problem in itself. One method is two-oxen plowing with a steel-tipped plow. Sowing seed is predominantly done by broadcast dispersion. In some areas stipple farming is practiced--that is, planting of seeds or roots by hand in individual holes made by a hoe or stick. This is used for most tree crops as well. In some areas, such as in the Sahel, stipple agriculture is practiced to reduce wind erosion. In tropical areas, this kind of planting is preceded by extensive slash and burn preparation of land (including laborious uprooting where possible). In areas practicing shifting cultivation, the clearing of vegetation consumes the greatest amount of the planting time. Hand hoeing is the chief method of soil preparation, especially in countries where animal traction is not used, such as those in the Sahel or in tse tse fly-ridden areas.

The hoe also plays a significant part in weeding throughout much of Africa, although it is usually done by hand. Hence weeding is highly dependent on manpower availability since it competes with planting and harvesting of other crops. In some areas, intercropping is practiced to reduce weeds and to provide other complementary needs, such as shade and pest control. In many parts, especially at harvest time, children or scarecrows are used to discourage birds. Fertilizing crops--in the few areas where it is practiced--is most commonly done with animal manure, nightsoil and ash, which are usually applied by hand. Some traditional use is made of crop rotation or fallow field rotation in all areas. Likewise, sometimes leguminous crops (which are nitrogen-fixing) are planted on a traditional farm. Irrigation varies with crop needs, availability of water, and knowledge of technique. Most ditch irrigation is constructed with hand tools and used for small garden plots for vegetable or certain cash crops. The most common sources of ditch irrigation are through diversion of stream water and the tapping of lakes and other natural water bodies. Other irrigating devices of a traditional sort include waterwheels and low-level dams (barrages). Harvesting is usually done by hand using scythes or machetes. There is little use of harvesting machinery at the village level.

B. Processing

Processing of agricultural production involves a wide number of tasks, each requiring energy. Threshing of grain is done chiefly through animal or human means, both using pounding methods as described in the case studies in the appendix. Other tasks include winnowing grains, usually with sifters; drying foods (normally by the sun); roasting (by fire); and grinding grain. Commercial grinding mills depend greatly on the size of the market and availability and price of fuel; thus much grain is ground at home on stones, or it is pounded and mashed in mortar and pestle. Animals are slaughtered either in village abattoirs or at home (depending upon custom and religion). Milk is churned into butter, either using a wooden agitator in a gourd or shaking it in a waterproof basket or other container, and cheese is made using natural fermentation. Cooking is a major task: this is usually done over a fire that is fed

by wood, charcoal, tree litter or (less often) dried cow dung. "Stoves" vary from depressions in dirt floors, ringstands for pots, small charcoal braziers and various-sized pans. A supply of several gallons of water is necessary for cleaning and cooking the food each day.

Preserving food is an especially complicated energy task. At the village level, refrigeration techniques or equipment are nearly unknown. The problem of spoilage is solved by all-at-once consumption (e.g., eating meat chiefly on feast days), drying, or salt-curing. Butter may be preserved, like other spoilable semi-liquids, by spicing it heavily. Depending upon distance from market, customs, and local organization, grain may be stored in individual barns or in village "warehouses." Produce and grain may be stored in pottery, jute or burlap sacks, sown-leather hides, buried underground and, much less often, modern containers. Normally, the containers are made by individual households.

Non-food agricultural and livestock processing, especially of cotton, wool, gourds, reeds (for baskets, mats, thatch, papyrus, boats, etc.), animal or vegetable oil and other products, are very important in the African village context. Livestock uses of hides, cowhorns (stretched over a fire into cups or bowls) and the use of ground bones for fertilizer are other examples. Many of these activities are labor-intensive and performed by women as an important source of market income. Competition from modern competing manufactures must impinge on these activities (as well as on homemade non-agricultural goods discussed in the next paragraph), although to what extent is difficult to measure. Despite this trend, much clothing is still made at home, the cotton or wool hand-spun, woven, sewn together, dyed and embroidered with the use of simple tools. House-building is a major use of non-food materials, including wood, mud, reeds, hay, rocks and living trees. Most house-building involves simple tools combined with a high degree of skill in manipulating relatively unprocessed materials.

C. Non-Agricultural Production

Energy-related tasks in production of non-agricultural goods within the village include the refining, shaping and repair of metal objects such as horseshoes, lanterns and tools, often from scrap metal; sewing and weaving; pottery and charcoal-making; the production and modification of building materials (wood, thatch, adobe) and additional associated operations such as smithing, carpentry, tailoring, etc. Much of this is hand-done or with the use of simple, traditional tools, often in ways that use scarce energy resources inefficiently.

Light and heat are produced chiefly through direct combustion. Light is provided by a variety of forms including hearth fires, oil lamps (vegetable oils), candles, sunlight (the use of outdoor facilities), and kerosene lanterns among others. Modern light sources are far less common, even rare, in the village setting. Heat is provided by using wood, charcoal, dried dung, tree litter, and the sun as fuel. Insulation, for example from thick stone walls or the use of earth in charcoal making, is significant. Work schedules and activities in African villages are usually structured so as to preserve or dispel heat in accordance with need.

Transport of grain and produce is either by human, animal, or automotive means; or a combination of all of them. Choice of method varies with the prevalence and kinds of roads (field to field; household to market; market to market). In many parts, a lack of draft animals due to insufficient fodder or the prevalence of disease places distinct limits on marketing and storage. This is compounded by the tremendous lack of roads, especially feeder roads. Water-born transport is significant in a few areas such as Mali, Senegal River states, and Zaire, but it is marginal or non-existent in many parts of Africa. Transport of agricultural production is generally stratified inefficiently; better and more rapid means exist between markets than from field to market.

D. Marketing

Transport is perhaps the chief aspect of marketing African village products. As mentioned above, roads play a critical role here. Those facilitating market to market trade are increasingly important. The open-bed truck and small bus are crucial elements of marketing goods and moving people. Other aspects of marketing are connected with services. Small grocery stalls and kiosks as well as tea houses, grills, hotels, and many other establishments are dependent on energy of all kinds.

E. Services

To the extent that modern services such as health clinics, schools, and the like arise in larger villages, their needs for refrigeration, heat and power require conventional energy sources. Not surprisingly, then, many of these seek to move towards more conventional commercial energy sources very quickly and are often in the vanguard to push for electricity or plumbing.

F. Energy Use in Transition

Many tasks at the village level in this sector are in a transitional state between traditional and modern modes. Weavers using simple hand looms may work side by side with tailors using treadle sewing machines. Pan bread baked over a wood fire may be served with eggs fried on a gas-fired hot plate. Energy source choices along the traditional-modern continuum are based primarily on availability, cost and knowledge, rather than being inflexibly bound by tradition. Most traditional tasks now done by human muscles could be done more effectively with better techniques or tools or with a small addition of inanimate energy. As already noted, only about one in twenty African villagers presently has access to electricity. The proportion with effective access to gas, oil or other modern commercial fuels is probably not much greater. Few figures are available, but calculations for Tanzania and Nigeria suggest that better than 95% of African rural energy still comes from traditional non-commercial sources.[1]

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1 Arjun Makhijani and Alan Poole, Energy and Agriculture in the Third World (Cambridge, Mass.: Ballinger Publishing Company, 1975), p. 46; Roger Revelle, "Energy Use in Rural India," Science, Vol. 192, (June 4, 1976), p. 969.

G. Efficiency of Energy Use

Likewise, traditional tasks often waste energy resources and could be done more efficiently with improved tools and technology. Both commercial and non-commercial energy sectors in rural areas are characterized by very low efficiency of conversion to actual useful work, probably on the order of 5 - 20%.[1] Thus, a major challenge for African villages is rationalizing traditional energy sources and adapting new source technologies with a minimum of displacement and cultural disturbance in order to improve the ability of those societies to accomplish their goals.

VI. Perspective and Focus of this Report

A. Conventional Energy Development

Although this paper deals exclusively with one alternative for increasing energy in the villages of Africa, namely technologies that use village source energy (e.g., the sun, wind, running water and waste), it is important to keep our perspective: conventional large scale energy is vital to the continued development of the modern sectors of African countries--especially urban areas--and in turn to the pace of economic growth. Conventional rural electrification--gradual link-up with centralized grids or interim installation of dieselautogenerators--should also be continued at full pace. Even though that pace may be agonizingly slow, it remains a proven method of significantly increasing village energy. The recommendations in this paper with respect to small scale energy are in no sense to be interpreted as suggesting a reduction in attention to the critical area of conventional energy.

B. The Village-Source Option

Despite the continued and increasing importance to African countries of conventional energy development, we believe that African energy policy makers, with the support of the development assistance programs of the industrialized countries and OPEC, should launch a vigorous research effort to explore the merits of the village source alternative. It appears likely that some aspects of rural energy development, such as development of more efficient wood-burning stoves, would be relatively inexpensive to develop and disseminate widely now with considerable benefit. Other aspects, such as solar water pumps or solar or wind electrical generators are unlikely to be economic under a strict financial analysis in the early future, although they seem promising in the long run--particularly when non-monetary benefits in terms of quality of life, productivity increases, and environmental quality are factored in.

If it should prove that local sources can meet local energy needs at low cost, high reliability and with little damage to the environment, it would be a breakthrough without parallel since the green revolution. If it should turn out to be impractical, the cost of learning that fact would not be high, and the entire development community as well as the energy community would be greatly benefited by having a firm answer.

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1 Arjun Makhijani, Energy Policy of the Rural Third World, (London and Washington, D.C.: International Institute for Environment and Development, 1976), p.7.

Therefore we outline in this paper a basic strategy--adaptable to individual national circumstances--for (a) encouraging development of technologies to harness village-source energy resources, and of inexpensive tools and techniques that can help African villagers make better use of whatever energy resources they may already use, (b) gathering the information which will be necessary for African policy makers (and outside donors) to determine whether, and if so, where and how to introduce such new technologies, and (c) encouraging and supporting African institutions that can carry out such a strategy. In Chapters Two, Three, and Five, we take up each of these three means of investigating and supporting village energy.

CHAPTER TWO

Village Source Energy Hardware Research

Introduction

In this chapter we distinguish three kinds of hardware research. First we identify those presently available tools to increase the efficiency with which village tasks are performed without introducing a new energy generating technology. These tools generally are low in cost and have been used successfully in other parts of the world (or even other parts of the same country). Research in this area is required primarily to adapt these existing devices to particular local situations and to facilitate local commercial production.

The second category consists of devices that tap and make available "new," "alternative" energy sources such as the sun, wind, and biogas. Some, though not all of these are very expensive, and in some cases are still emerging from the laboratory. Research in this area is needed at all levels, but primarily at the field testing stage, to gain experience for practical application and commercial production.

Finally, there will be a whole range of tools and machines to be developed or adapted to use such new energy sources for particular village needs.

Introduction of new tools and technologies inherently implies changes in existing life-style patterns. A special concern arises regarding change of traditional roles of women: since women often play a major role, or the major role, in traditional agricultural production and processing, the introduction of new tools frequently has particular impact on their economic activities and social relationships. Too frequently in the past, new agricultural tools and technologies have either been transferred only to the men in a village, in nearly total ignorance of women's roles and contributions, or they have been transferred to a village with little forethought to the implications of greatly increased amounts of free time or sudden productivity increases by one group or another. Perhaps adverse impacts of technology development and transfer can never be entirely anticipated or ameliorated, but with adequate software research, as discussed in Chapter Three, new tools and technologies could be made much more likely to "fit" and therefore to succeed than they have in the past.

I. Presently Available Tools to Increase the Efficiency of Village Energy Use

The essence of a tool is the ability to apply and direct energy to accomplish useful ends. Some are specific to one task; others are multipurpose. Tools and energy-using devices already exist in traditional

African villages. However, they are often crudely made and inefficient. More importantly, other tools, often simple but quite effective, may have been developed by clever individuals or communities in other parts of the world (or even in neighboring villages) which could readily be adapted to use in many traditional African villages. With increased international interest in appropriate, or intermediate, technologies, the vast collective experience and genius of mankind can now be tapped more effectively in this area. Combined with even minimal support in scientific research, appropriately developed and introduced tools could yield significant improvements in village productivity and quality of life in the immediate future, at very modest cost.

Especially in the agricultural context, new kinds of tools should meet certain criteria. Such tools should: 1) be easily incorporated into small-scale, labor-intensive farming; 2) complement and enhance the existing technological level of the village; 3) be amenable to local manufacture and easy to repair, maintain, and replace; and 4) not unduly displace or overburden traditional cultural, social, or economic patterns.

With the exception of fire and sunshine (which are inanimate energy sources), virtually all energy in a traditional African village comes from animate sources, i.e., human or animal muscle power; therefore this section will concentrate on tools that can enable a given amount of animate energy to accomplish an increased amount of useful work. Yet even animal power is not a traditional energy source in much of Africa, so we will first briefly examine some of the potentials and constraints of greater use of animal traction.

Expanded and Improved Animal Traction

In North Africa, bullocks, camels, horses and donkeys have been used for ages as beasts of burden and convenient means of transport. South of the Sahara, however, widespread infestation by tsetse fly (vectors of Trypanosomiasis—sleeping sickness) has limited the raising of livestock largely to a narrow stretch of wooded and grassland steppe areas comprising the northern parts of West African coastal countries, southern parts of the Sahelian countries from Mauritania to Sudan, large parts of Ethiopia, and grassland steppe areas of Tanzania, Kenya, and Uganda. Most African livestock consists of cattle used by nomadic or semi-nomadic peoples and rarely used as beasts of burden for hauling or other tasks.

Experience with animal traction has demonstrated that a healthy draft animal can contribute upwards of one third to one half horsepower capacity for 300 to 1,000 hrs. per year.[1] This enables the farmer to either use his land more intensively, relieve peak labor problems, or expand the area of cultivation by as much as 100% for small holdings

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Arjun Makhijani and Alan Poole, Energy and Agriculture in the Third World (Cambridge: Balliner, 1975), p.75; informal U.S. Dep't. of Agriculture estimates.

of a few acres.[1]

The bullock, mule, horse and camel have been proven over the millenia to be appropriate forms of technology for the peasant farmer who has abundant arable land but no tools or power for cultivation but his own and his family's hands and the arm-length hoe. With proper care, feeding, and watering, the draft animal represents a reliable form of power which is mobile and can be used in a diverse number of ways. These include plowing, discing and cultivating the soil, clearing the land of rocks and stumps for new planting, grain grinding, root crop pulverizing, water lifting for irrigation, and (along with the donkey) transporting people and goods to and from market. Furthermore, the draft animal represents a mobile form of wealth and a renewable form of small scale power if proper animal husbandry is practiced. Finally, the draft animal yields regular amounts of dung, useable as fertilizer, building material, cooking fuel, or as an input into the new bio-gasification process (explained in Section II)--and as a last resort, the draft animal is a source of leather and meat.

Draft animals are not a simple technology for people who have never used them before. They require proper care, feeding and vaccinations. Farmers must be trained how to use the animals for the various tasks involved. For example, it is more efficient to attach a yoke to the powerful shoulders rather than (as is currently practiced in some areas) to the horns. Farmers or village craftsmen (blacksmiths, leathersmiths) must be trained how to build the necessary accompanying implements and equipment (plows, yokes, etc.). Finally, it must be remembered that for every acre or so that may be cultivated by a draft animal, perhaps a third of an acre (including fallow land, stubble, and non-cultivable hillsides) must be set aside to feed the animal.

Nor should it be assumed that just because an area is not infested with tsetse, or has been newly rid of tsetse, that animal traction will automatically develop. For example, in a tsetse-free central area of Togo in West Africa, fifty progressive farmers are being introduced to bullock driven animal traction techniques--to them a wholly new technology..

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1 A recent report (African Rural Employment Study -- Paper No. 1, by Derek Byerlee and Carl K. Eicher, September 1972, Department of Agriculture Economics, Michigan State University) maintains that considerable potential exists for use of animal power, as well as selective mechanization, for specific agricultural operations for which labor bottlenecks exist. The report mentions other researchers' experiences in which use of oxen-power increased both cultivated area and yields in Ivory Coast and were found to be more economic than hand labor or tractors in Northern Nigeria. The report also mentioned results for Malawi, however, (where man/land ratios are much higher) in which oxen power did not significantly increase yields, cropping intensity, or area sown, and thus did not prove economic.

Tools

Agricultural production tools which could be improved or introduced include replacement of the crude, steel-tipped wooden plow with one that plows deeper and more efficiently and one capable of being used with or without cattle. Such a plow is being developed by the Intermediate Technology Group in the United Kingdom. Stronger and better made hoes, axes, weed cutters, and seeders are not only important in terms of improving the efficiency of land use for cropping, but also go a long way to reducing demand for labor at critical steps, including weeding and harvesting. Improved grain scythes and sickles and, where appropriate, use of animal-drawn McCormack reapers or human-operated reapers and pickers could also be helpful. Machetes and improved digging tools would be useful for cultivating and harvesting vegetables and wet tropical crops and for digging irrigation ditches.

A major area of improvement in agricultural production lies in the increased use of wheeled vehicles. The range of these employing animate energy is wide. Human-operated wheelbarrows, bicycles, and bicycle-style (chain drive) carts and rickshaw type vehicles have proved effective even on dirt roads (as in China). For larger loads, ox-carts and wagons could replace or at least supplement similar human roles (porters and farm laborers) with the prospect of increased production. Although most transport mechanisms require some kind of road, all have the advantage of being multi-purpose and not dependent on conventional fuels. They can be used equally well for carrying farm inputs and output, people, building materials (for terracing and fencing material, for example) and many other tasks.

Processing of agricultural production is a critical area in which animate energy tools can play a significant part. The kinds of tools using animate energy in processing is significant and could, if properly introduced, reduce the often exhausting and time-consuming traditional methods now employed. Shellers, huskers, decorticators, grain mills, improved knives, palm oil and other kinds of presses, small-scale grinders and others would be especially useful.

With respect to water pumping and hauling, a few design improvements and attachments could lead to much greater time and energy savings: 1) Building deeper and better constructed wells (bore wells, artesian wells, cement and stone-lined wells, for example).[1] 2) Attaching simple, easily maintained extraction devices such as traditional cross-bar and pulley systems and hand or foot-pedal pumps over a sealed well. 3) Developing a better means of distribution. At present, most village water supplies are carried by people or on the backs of animals to the using area. Increased frequency of wells would help alleviate the distance problem, but also, lighter, stronger and larger containers would help. Adaptation of existing storage facilities like the "water granaries" of the Dogon would also help to alleviate dry-season shortages. Also, where appropriate, animal-drawn carts or human-operated pushcarts would be useful. Where roads do not exist, using modified wheelbarrows could be considered.

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[1] In semi-arid areas increased use of wells has led to environmental degradation and lowering water tables and hence is a course of action that needs to be carefully weighed.

For irrigation in flat areas, ditch irrigation could be expanded or improved by introduction or increased use of Archimedes' screws, foot-pedal pumps, or shaduffs (water scoops employing counter-weights) and through use of plastic tubing (as in drip irrigation), lined canals, and tile drainage pipes (although perhaps too costly for most villages) to prevent salinization of the soil.

In construction of buildings, smaller structures and furniture, the efficiency and efficacy of human energy is tremendously increased with the use of simple hand tools and techniques, many of which, however, are not available or known in African villages. Tools such as well-made hammers and axes, saws, planes, lathes, strong nails, and chisels could make great impacts. Techniques employing levering, ropes and pulleys and inclined planes could be developed along with new or improved materials, like ferro-cement.

Cottage crafts, another vital area of the village economy, is particularly susceptible to change and improvement of tools and techniques. It is also the area in which competition from costly imports has made its biggest impact. Improving this area not only might enable villagers to diversify their economies, but also help the nation's balance of payments.

Better tools for cottage crafts may include improved and better constructed looms, treadle sewing machines, pottery wheels, blacksmith's bellows, and a whole range of tools for making tools. Many of these can be treadle operated using belts and gears to transfer animate energy more efficiently. Other devices include spindles and simple spinning-wheels (like Ghandhi's famous one) and new techniques such as the use of vegetable oils, not only for cooking, but also as fuels, lubricants or processed into soap. This kind of improvement could save households money and increase output that can be marketed to earn cash.

The major traditional village use of inanimate energy is in cooking. Present-day stoves and ovens are often inefficient. Improving the heat retention of charcoal braziers or developing a multi-purpose clay stove-oven would help to conserve existing traditional organic fuels. Building more efficient stoves such as the Norwegian two-chamber stove which burns both the wood and the gases released from the initial combustion would also conserve supplies.

A number of AID-supported projects incorporate hand tools and intermediate technology along with an agricultural extension service such as the MIDAS Program for Small Farmer Development in Ghana and the Upper Lofa Co. Rural Development Program in Liberia. One of the more elaborate is the Kongolo Intermediate Technology Center, part of the proposed North Shaba Maize Production Program of AID in Zaire. Aiming to increase small farmer production through economic incentives, the Center's role is to utilize existing trained manpower (blacksmiths, authomobile and electrical repairmen) and abandoned production facilities of the colonial Great Lakes Railroad Company to manufacture and sell a variety of hand tools and simple machines, including hoes, knives, axes, a variety of shellers and grinders, decorticators and

the like. The goal is to refine and expand the use (through cheaper, local manufacture) of simple, labor-saving devices while attempting to minimize capital costs (using existing abandoned facilities) and work displacement by creating multi-purpose tools that will expand the amount and kinds of products to be processed.

II. Technologies that Tap New Energy Sources

This discussion will review briefly the several village energy sources and the leading technology for converting them into useable form.

A. Direct Solar Energy

For millenia the direct rays of the sun have been used for open air drying of crops, hides, and meat. The small scale technologies of fairly recent invention all use the same heat or light energy of the sun as before, but in such a fashion as to collect it, concentrate it, or convert it into electricity, a form useable for a wide variety of applications. Climatically, many African countries are in favorable geographical locations for use of direct solar radiation, being located in tropical areas of seasonal or slight cloud cover and intense solar radiation on clear days. (See map on P.116). As with the wind, any technology using direct solar radiation requires energy storage facilities or a back-up system if it is necessary to have energy on demand. Solar technologies range from relatively unsophisticated simple solar heat collectors to fairly capital intensive, complex and expensive solar concentrators, photo-chemical arrays, and combinations thereof.

1. Flat-Plat Collector

The collector consists of black metal tubing or flat sheet, covered by clear glass or plastic, between or through which flows either water or air. The black metal absorbs the solar heat radiation, which is kept from escaping by the glass or plastic cover. The air or water flows through the structure, carrying away the heat--hot water or hot dry air for many uses, such as space heating, agriculture crop drying, driving Rankine cycle engines. Hot water may be stored in insulated tanks and heat from air can be transferred to rocks below ground for later use. Such technologies are tested, reliable, and certain parts of them are amenable to local manufacture even at the village community level. Solar water heating is in widespread use in Israel, Japan, and Australia, and in scattered use in parts of West Africa for private, commercial use (e.g., hotels). Solar crop dryers offer a promising means for quickly drying crops in a more efficient fashion than air drying and less environmentally damaging than using scarce firewood, while reducing harvest loss from pests and spoilage.

Collectors may also be used to produce potable water for villagers and livestock through distillation of brackish, muddy, or polluted water by evaporation, moisture condensation, and collection. Constructed of concrete and glass, and other durable materials, such plants can deliver clean water for a few dollars per 1,000 gallons, and last up to

20 years.[1] Located near the watering hole or river bank, such an operation could become part of a daily routine--providing clean drinking water at very low cost.

A series of solar water pumps has been developed by a French firm, SOFRETES[2] (in cooperation with a Senegalese researcher, Mr. H. Masson) that use flat-plate water heaters to vaporize butane or another intermediary liquid, which in turn operates a reciprocating engine. Currently ranging up to 50kW in size, these units are capable of pumping, from a depth of 25 meters, between 14 and 2,400 cubic meters of water per day. Since 1968, they have been installed in more than a dozen developing countries (mostly in Africa) and have proven highly successful; although at a present cost of at least $10,000 per installation, they are acceptable for village use only with large government or donor subsidy.

2. Solar Concentrator

The solar concentrator involves intense concentration of solar radiation by means of either parabolic mirrors or mirror arrays. These may be aimed onto a boiler, which in turn produces steam to operate electric generators or steam engines. High costs and complexity of operation render the latter technology unacceptable for use in most developing countries for the time being.

Efforts to introduce solar cookers for village use in the form of mirror parabolas which focus radiation onto a flat metal burner plate or pot have had little success. This is due as much to the obstacles of culture, taste of food, and to the fact it can only be used for the noonday meal, as to the cost and clumsiness of the apparatus as well. Attempts by VITA to design an acid storage cell which could absorb solar energy, store it, and then release the heat energy when inverted, are still in the experimental stage. There appear to be many technical obstacles to overcome, not the least of which is the necessity to use sulfuric acid, a highly toxic and dangerous substance, as the base material. Other solar cooker field tests are under way in Haiti by AID.

3. Photo-chemical

Photo-chemical or photo-voltaic fuel cells transform solar radiation in the form of photons of light into electricity. The most popular and best developed are silicon solar cells, although cadmium sulfide and others are available and in moderate use. The fragile, wafer thin cells are usually arranged in arrays of up to 1 kw, for a variety of specialized uses ranging from power for outer space technology to buoy lights in Japan, remote TV reception in Niger, and highway emergency signal units on certain U.S. highways. Estimates by the World Bank demonstrate solar cells to actually be cost competitive with regular dry cell storage batteries for use in Ivory Coast for remote TV reception. Current costs for solar arrays approximate $15,000 to $70,000 per peak KWe, and $120,000+ for an average

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1 National Academy of Sciences, Energy For Rural Development (Washington D.C.: NAS, 1976), p. 76.

2 Societe Francaise d"Etudes Thermiques et D'Energie Solaire

KWe. Crystal ribbon growth techniques currently in progress may well result in solar arrays beneath $1,000 per average KWe within the next decade, a figure that may go as low as $500 - $825. For the time being, solar cells offer interesting alternatives to batteries in remote areas for high value uses such as radio and T.V. with low loads of between 1 to 100 watts.[1]

C. Small-Scale Hydropower

Flowing water (in conjunction with suitable dams and controlled sluices) can be used to operate water wheels or rams for mechanical power or water turbines for either mechanical or electrical power.

Waterwheels, which can be built in a variety of styles, have been used for thousands of years by various cultures, primarily to grind grain. They represent known, reliable technologies, capable of being constructed of local wood by local craftsmen. Indigenous water wheels are still reported in fairly wide use today in mountainous areas of Afghanistan and central and eastern Turkey. At one time, waterwheels were in wide use in Europe and the United States, both for grinding grain and operating machinery.

The advent of the more sophisticated water turbine, with much higher rpm and much higher efficiency than water wheels, helped provide mechanical power for the Industrial Revolution of Europe and America, and is best known for its use in hydroelectric generation.

The hydraulic ram is a little-known device (with only two moving parts) that uses the power of flowing water to pump part of that water to heights even above the level of the original head. One of its greatest potential uses is for irrigation pumping.

Although flowing water is, of course, an intermittent source of energy depending upon rainfall and season, the building of dams or penstocks and sluice gates to channel part of a stream or river to the turbine can help to adjust for variations in stream flow and fall and contribute to a much more controlled source of power than other intermittent sources such as wind or sunshine.

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1 National Academy of Sciences, Energy for Rural Development, pp. 97-106.

The potential for using such small hydropower devices in sub-Saharan Africa has, suffice it to say, been largely overlooked and under-researched. The use of water wheels or small hydroelectric (1-10 kW) units in sub-Saharan Africa is reported to be virtually non-existent, despite the fact that the watersheds of Africa contain the streams that contribute to what is thought to be the world's largest hydroelectric potential. One problem, of course, is the extreme seasonality of rainfall, particularly in West Africa and the Sahel, where entire rivers, let alone streams, often dry up in the dry season and flood whole river valleys in the rainy season.

Nevertheless, there are undoubtedly a number of villages where nearby stream flow and fall are sufficient to warrant use of waterwheels, small hydroelectric units, or hydraulic rams. The problem is that little is known about small stream gauge data (both stream discharge and stage). Stream discharge data describe the speed with which water flows while stage data define the steepness of the fall of the stream. For the Sahel, for example, continuous records of river discharge are made at 44 stations in Niger, Senegal, and Chad, while river stage measurements are made at over 250 stations in the six countries, but small streams are ignored.[1]

It is likely that similar data exist for other African countries as well. A careful investigation of this data, with on-site visits and studies of villages alongside the streams that feed the watershed for these rivers, should yield a better picture of the applicability of small-scale hydropower for these areas. Once the discharge and stage data are known for a particular village, and the energy need is calculated, then it is possible to select or design the appropriate hydropower device. For example, for those villages of sub-Saharan Africa with demands for 1/2 kW - 10 kW of power, and nearby access to sufficient seasonal or regular streams capable of generating falls of 8 - 25 feet and flows of 70 - 1,000 cubic feet per minute, hydroelectric generating turbines exist commercially from around $3,500 - $4,500 for the smallest units to $12,500 - $15,000 for the largest units to meet these needs. (James Leffel Co., Ohio)

Likewise, hydraulic rams for water pumping and irrigation are marketed in the U.S. (by the Rife Hydraulic Engine Manufacturing Company of Millburn, New Jersey) which can adapt to falls of 2 - 12 feet or more, ranging in cost from $300 - $2,600, and capable of lifting from 5 - 25% of the flowing water to use for irrigation.

The potential impact of wide-scale use of hydropower should not be underestimated. As mentioned before, much of the early Industrial Revolution was powered by mechanical hydropower. In the People's Republic of China, more recently, the use of small hydropwer stations less than

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1 Source: A Survey of Meteorological and Hydrological Data Available in Six Sahelian Countries in West Africa, by the World Meteorological Organization, Geneva, 1974, pp. 6-8.

100 kW, according to various reports, numbers in the tens of thousands. Press reports indicate the operation of between 20,000 - 35,000 small hydropower units in 1973 averaging 34 kW. For the Chinese villages involved, the use of such small-scale hydropower, which represents some 20% of total Chinese hydropower capacity, is significant for irrigation, lighting, machine operation, and electrical grid equipment. Their contribution to the national output is calculated at something like 7.5 billion kwh in 1974, representing more than 50% of rural electric power consumption.[1]

D. Bioconversion

Bioconversion, the direct transformation of biological material into energy by burning or fermentation, is perhaps the oldest of man's energy technologies. Aerobic burning of wood and other plant material has been known to humans almost since their appearance on earth to be a useful source of both heat and light. With the use of domesticated animals came the use of dung for fuel (and fertilizer) in some cultures. In the late 1700s, wood burning was used to generate steam for the steam engine, which gave impetus to the Industrial Revolution. More recently, there have developed anaerobic burning techniques (pyrolysis) of woody material and urban and industrial organic wastes to produce alcohols and charcoal and anaerobic fermentation techniques to process dung, nightsoil, agricultural residues, and farm wastes into methane gas leaving a useful residue of fertilizer slurry. Other methods of processing biological material currently being experimented with include hydrolysis and distillation techniques applied to algae to yield fuel alcohols.

1. Burning (Aerobic)

For much of Africa, firewood and woody debris constitute the major fuel for cooking, household uses, and cottage crafts. However, in many areas, especially the Sahel, supplies of firewood and woody underbrush are dwindling so rapidly that the lands are being devegetated causing soil erosion. More efficient indigenous cooking stoves, oven facilities, and charcoal production techniques would reduce the amount of wood needed per task. Reforestation of already badly affected areas and of areas currently undergoing deforestation would both provide firewood for future generations and help arrest soil erosion and shifting sand.

2. Solar Farming

This involves the deliberate growth and harvesting of plants on land or sea for the express purpose of processing them through burning, pyrolysis, methane generation, or other chemical distillation to produce energy. Solar farming experiments using water hyacinths and algae are currently ongoing in Israel, Canada, Japan, and U.S., among other countries. As conversion techniques become more developed, solar farming may offer some potential for decentralized energy supplies in the humid, tropical rainforests and forest areas of Africa.

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[1] Thomas Rawski (private communication, June 10, 1976)

3. Biogasification

This involves the anaerobic fermentation of animal dung, human night soil, and organic farm and household debris and wastes in relatively air tight tanks, to produce methane gas for fuel to serve farm, household, and cottage craft purposes and a liquid fertilizer in partially sterilized form. The technology is known and reliable, particularly where livestock are abundant, and has been used by thousands of well-to-do individual farmers in Korea, Taiwan, China, and India. Although there are problems with consistency of output during the cold season in high latitude or high altitude countries, and with costs for construction materials like steel, cement, tubing, gas appliance fixtures and adapted equipment, (or plastic or rubber instead of steel and cement), biogas is one of the more promising of the whole host of small scale technologies, particularly if applied as a village biogas unit.

For Africa, the degree to which biogasification can be accepted and used will depend heavily on both the number of sedentary cattle from which dung can be collected and the willingness of African villagers to collect and handle dung. For most family size biogas units, dung from a minimum of five head of cattle is usually necessary for the process. For village scale use, of course there would have to be a substantial degree of cooperation involved, both in collection of dung and in distribution of gas and fertilizer by-products. Biogasification has some promise for those cultures with domesticated sedentary cattle, particularly if animals are penned or corralled (a practice which facilitates collection), and provided the people are accustomed to using dung (to build mud walls for homes, for example) or are otherwise willing to handle dung. It would require some careful investigation of cultural habits for each village or community to ascertain this potential.

4. Pyrolysis (Anaerobic)

Woody cellulose matter can also be processed by a technique of anaerobic burning to yield not only charcoal but also various forms of alcohol fuels, charoil, and chargas as well. Known as pyrolysis, this technique has been used for some time in OECD nations, and has come to be of more interest recently for urban organic waste processing. It is historically an advanced, fairly complex, capital intensive process, although recent AID-assisted efforts by Ghana, in cooperation with the Georgia Institute of Technology Engineering Experiment Station (EES), appear to be on the way to yielding much more manageable and affordable small scale units, (e.g., one ton per day continuous batch feeders) which may show promise for large parts of Africa where charcoal is used.

Feasibility studies of pyrolitic conversion for use in Ghana by Georgia Tech. estimate that their 6-ton (dry feedstock) per day continuous feeding pyrolitic converter produces charcoal yield up to twice that of the indigenous charcoal production methods. In a traditional charcoal production (a pit covered with earth) both charoil and chargas are lost. The BTU value of the traditional charcoal pit might produce only 25% of that

in the original woody material, while that of the charcoal, oil and gas in a modern plant might yield as much as 90%. Chargas can be used on site for such purposes as crop drying, and charoil may be used for example in boilers, cooking stoves and lamps (though not for combustion engines). Pyrolysis may have significant potential for African areas with adequate woody material.

D. Windmill Potential

For villages of sub-Saharan Africa with suitable wind regimes, wind represents one of the most promising sources of energy for water pumping, certain agricultural tasks and cottage craft industries, and low load, high value electrical demands such as lighting and telecommunications. Historically, there seems to have been no indigenous development of windmachines in sub-Saharan Africa, as there have been in China, Persia, Northern Europe, and the European Mediterranean islands. Efforts in the past to introduce Western windmachines for use by Africans for pumping water in sub-Saharan Africa have met time and again with resounding failure. Furthermore, much of the conventional wisdom of Western wind experts is that average wind speeds in most of Africa are so low (5-6 mph, they maintain) that widescale use of windmachines is effectively precluded and that it would be better to look for other energy sources.

A more careful look at the potential for wind energy in sub-Saharan Africa indicates that further investigation is indeed warranted. This conclusion is based on the fact that: 1) Most of the Western attempts to create windpower projects for use by Africans have suffered either from lack of sufficient extension, training, and maintenance programs, improper siting, or selection of inappropriate windmachines, and not from the failure of the windmachines to function technically or the lack of sufficient wind. Indeed, there are scattered reports of windmachines used successfully by European farmers or missionaries for 40 years in Africa (to generate electricity or pump water). It is reported that these machines were kept well maintained. 2) There has as yet been no systematic analysis of available wind data, nor any widespread intensive collection of data, to be able to judge that there are not many villages in various parts of Africa which could in fact use commercially available windmachines designed for 10 mph+ average winds. 3) There has as yet been only marginal effort to adapt Western conventional windmachines, windmachines from other parts of the world, or new windmachines under development, to be able to better utilize those winds which do average only 6-10 mph. Such adaptive research might render windmachines much more useful to large numbers of villages. Almost all commercial windmachines have been designed for use in the temperate climates, with their significantly higher average wind speeds of 10-15 mph.

In order to proceed further with a discussion of wind potential for sub-Saharan Africa, it is important to describe some of the characteristics of wind as a natural phenomenon and power source, the technologies capable of using the wind to generate useable power, and an overview of commercial manufacturers of windmachines.

1. Characteristics of the Wind

Average conditions in the summer and winter result in two belts of high pressure between the temperate latitudes of approximately 30°N and 40°N and 30°S and 40°S and low pressure in the tropical latitudes between 23°N and 23°S. This results in the "trade winds" (so-called because their reliability made them very popular for sailing trade ships of older times) in the belts 10° - 20°N and 10° - 20°S but relatively very little generalized wind activity between 10°N and 10°S surrounding the equator (although there naturally exist some localized wind activity.) These conditions also give rise to the "westerly winds" between 40°N and 60°N and 40°S and 60°S.

Locally, within 100 feet of the surface, wind is even further affected by topographical features such as trees, which slow it down, hills and valleys, which create turbulence effects, or large bodies of water (wide rivers, lakes), which absorb heat differently from the land giving rise to the familiar "sea breeze" (wind from sea to land) during the day and "land breeze" (wind from land to sea) at night. Because of this susceptibility to influence by local topographical features, it is entirely possible for wind speeds to vary significantly between one site and another, as close as a few miles or even a few hundred yards away from each other, especially in hilly terrain. For the same reason, wind speed tends to increase with altitude (in general greater on tops of ridges than in valleys.)

Furthermore, wind displays strong seasonal fluctuations in direction and velocity, the latter often roughly correlated to periods of high sun (lower velocities) and low sun (higher velocities). Wind also fluctuates diurnally (daily) such that velocities and direction may differ significantly between morning, afternoon, evening and night.

Finally, although wind speed and direction may indicate a particular average velocity and direction (when recorded over a period of years) for any particular hour of the day or any month, there is no way to guarantee at any given moment of time what the speed, duration, or direction of the wind will be. (See wind data Pages 106-114.)

2. Power in the Wind and Windmachines

Power in the wind can be calculated by a formula in which power varies directly with the vertical cross-sectional area of wind intersected by the blades of the wind machine and with the cube of the wind speed. Thus, if the cross section area is kept constant, the power derived from a 6 mph wind is 73% greater than a 5 mph wind, 7 mph is 175% greater, 8 mph is 300% greater, 9 mph is 480% greater, and 10 mph is 700% greater (doubling wind speed results in cubing power.) Thus, it can be seen how important it can be to locate windmachines in areas of greatest average wind velocity. Selecting a site with 10 mph average wind over a site with 8 mph average wind may result in a power difference of 100%! This also, of course, means that it is important to know the nature of the wind speeds that give rise to a certain average windspeed. If these speeds tend to display a wide range of wind speeds that produce

a given average, then this may very well result in more power from this average wind speed than an even slightly higher average wind elsewhere which is not so variable. It is also important to know the variation in wind direction for given wind speeds and the maximum wind speed that the windmachines is likely to encounter, for purposes of the engineering design of the windmachine.

The vertical windmachine may be powered by wind coming from any direction; however it is capable of powering only relatively low torque loads and some designs require supplemental starting. The horizontal design, such as the familiar American windpumper, may serve either high or low torque loads.

Within each of these two broad classifications of windmachines are found windmills (mechanical power) and windgenerators (electrical generation). The former is capable of doing slow, high torque work, and likely any faster activity would create such mechanical and heat stresses as to endanger or ruin the equipment. The latter is capable of producing very high rpm's sufficient to satisfy the requirements of low torque electrical generators to which the windgenerator must be carefully matched, or the generator may be damaged. Except for shallow water pumping, for example, requiring only low torque, these are not designed to be able to be productively adjusted by means of gears to be able to do high torque tasks, such as pumping deeper water.

Basic tried-and-true windmachine designs are as follows:

Horizontal Axis

Sailmill - typical of the windpumpers used in the Greek isles, these windmachines may have up to eight large triangular or jib sails capture the wind. In order to capture more energy at lower wind speeds, more sails are left on, while as the wind increases, fewer sails are needed to produce the necessary torque such that at high speeds, only one or two sails may remain on the head of the machine.

Multiblade "fan" windmachine - Typically up to 16 metal blades are shaped such that the appearance of the head is similar to that of a fan. The famous American windpumper of the 1800's and 1900's is characteristic of this variety.

Propeller windgenerator - Typically two or three propeller shaped blades of metal on wood, for generating electricity. The famous Jacobs "windplant" of the 1930's - 1950's falls within this category.

Hybrids - A number of hybrid designs have been developed or are in the prototype stage. Among them are the "bicycle wheel" turbine, so named because it is shaped like a bicycle wheel, with thin strip blades like spokes connecting a hub to a rim. A belt is attached to the rim, which drives a shaft, alleviating the need for gears.

Vertical Axis

Savonius-rotor (S-rotor) - Descendant of a windmachine developed and used in ancient times by the Persians, this S-rotor is so named because of the shape of its S-shaped or hour-glass shaped twisted wind capturing surface. It is capable of carrying out light to moderate mechanical loads.

Darrieus - Commonly described as the "egg-beater," this new windgenerator design consists of two or three thin metal convex blades connected at the top and bottom. It is used strictly for electrical generation and is one of the newest windgenerators to become commercialized.

Other Designs

There existed a great deal of ongoing research and development on windmachine design. Suffice it to say at this point that the aim of this research is largely to accomplish the following:

a.) Improve the efficiency of the design so as to approach the theoretical 59.3% figure. The bicycle wheel turbine is a result of this kind of work.

b.) Augment the power available from a given wind regime by artificially creating stronger wind, either by shrouds, channels, or tornado/cyclone cylinders.

c) Enlarge the cross-section area intersecting the wind, e.g., by means of using lift-augmentors such as the "continuous venetian blind belt" design of the D.J. Schneider Lift Augmentor Company, which is currently investigating the technology in Texas.

3. A Sampling of Commercially Available Windmachines [1]

There already exists a whole range of smaller scale windmills suitable for use by individual farmer, village, or other user for either mechanical shaft power or electricity generation of commercial design available on the market or of indigenous variety--both of course subject to local modification. The U.S. has conventional commercial windpump units for irrigation available for $500 - $4,500 excluding tower (produced in Argentina by Aeromotor, Inc.) or $700 with tower (Dempster, Inc.) and the Germans sell varieties in the $250 - $3,500 range without tower or $2,500 including tower. American models range up to 20 KW units.

Conventional commercial windelectric units are available for as little as $500 - 2000/KW in 5 - 15 KW capacities and $3,000 - 6,000/KW up to 5 KW capacities. Wincharger Inc. units produce .2 KW at maximum windspeeds of 23 mph and costs $450. American Energy Alternatives, Inc. cost $1,500/KW up to 1.5KW and $600/KW up to 5KW, while Independent

[1] National Academy of Sciences, Energy for Rural Development, pp. 114-35.

Power Developers, Inc. has 15 - 18 KW units for $500 - 600/KW (without towers). Such units may be used either in conjunction with diesel-electric generators to cut fuel costs, as units integrated into local power grids, or in conjunction with expensive battery storage.

Finally, for farmers who cannot afford to buy or maintain such units, North American and European research institutes and development workers are active in helping to develop or improve low cost appropriate technology alternatives, such as those found in the Omo River Project described in Appendix III.

III. Tools for New Energy Sources

Some of the village-source energy devices, such as solar crop dryers or solar water pumps, both harness the previously untapped energy resources and perform specific work. Others of these devices, such as biogas digesters or wind generators, simply convert the raw energy into useable intermediate forms, such as methane gas or electricity. These new intermediate energy forms can then be applied, through use of tools and machines, to perform work.

The tools and machines that will be powered by these new intermediate energy sources will generally be for the same purposes as those discussed in Section I of this chapter. Indeed, they are generally likely to be modifications of the same tools and devices, simply substituting the new inanimate energy sources for the traditional sources (e.g., stoves that use methane instead of firewood in cooking). But, depending on the amount and type of additional energy sources which can be tapped, there may also be new devices or tools (e.g., lightbulbs, grinders, or pumps for using electricity) which would be useful.

As in the case of tools to gain greater utility from traditional energy sources, efforts will primarily be needed in adapting devices already proven elsewhere, and introducing them to particular villages with similar care.

CHAPTER THREE

Software Research in Preparation for Village Source Energy

In Chapter Two we dealt with energy hardware, first with the use of tools in order to improve the efficiency of use of present sources of energy, and later with research on technology to convert village-source primary energy into usable energy and then into work. In this chapter we deal with software—the production of certain information needed to make use of the hardware. The information is of six kinds. First is an inventory of the tasks which the residents of any given village would like to have (and which are most susceptible of being) performed by mechanical (or animal) rather than human energy. The second kind of software research is a survey of the local sources available to any given village (e.g., wind and water). In both cases the information is specific to any given village. Averages or aggregates are of some use for policy makers but they are not actionable. To be actionable the information must reveal, for example, that the residents of village A would like to have more energy for two purposes—to cook their evening meals and to grind millet, and that the energy sources they have available are wind of a certain velocity for an average of so many hours a day during certain seasons of the year, sunshine of a given intensity for a known average number of days in each season, and a supply of organic wastes of a given volume. To get this kind of data for each village in an entire country would require a permanent institution for that country and a great deal of time. (This is discussed in Section VII below.) Thus, we are dealing with building or strengthening African national institutions, rather than with negotiating a contract with a consultant to produce the information, although a contractor might be helpful in conducting pilot studies of how to collect the information and of what information to collect.

The third kind of software research is designed to tell African policy makers something about the impact of village energy on the life of the villagers and ultimately the nation. In order to find out what impact increased energy availability has on village life when it comes, it is necessary to measure accurately and record carefully what life was like in a representative sample of villages before the arrival of the new energy. This research would establish certain base lines against which comparisons could be made. Like the first two kinds of research, this must be begun before the fourth step in software research, namely testing in a number of villages the most promising kinds of village source hardware. The fifth step is to evaluate the cost and performance of the several technologies and compare them with one another and with the alternative of generating electricity in a central facility and distributing it to villages through a centrally managed electricity grid. The sixth step is to study how village source energy technology could be best extended to the entire countryside if the decision were made to do so.

All of this software research is designed to help an African country to decide whether to follow the village source route and if so,

how to do it. We now discuss each of these six components of the kind of software research that are needed to provide information to help African policy makers make decisions on energy for the villages of their nations.

I. Assisting Village Choice of Tasks and Hardware

In Chapter One and in the two case studies that appear as Appendix I and II we have described in some detail the present status of energy use for performing common village tasks.

These illustrate the range of human activities in rural Africa that might be candidates for the use of energy. Not all can be energized at once. The sorting out of which should come first is something each village should do for itself if—as we believe advisable—villagers are to participate in financing, selecting, and installing the technology and keeping it operating. A qualified African agent will be needed to provide expertise to the villagers and to introduce to them the array of possible choices. Those choices will be governed first by the level of skills, technical interests, cultural patterns, values and preferences, in the village, second, by the primary energy sources that are available in the village, third, by the particular tasks these villagers wish to energize, and fourth, by the kind of hardware the villagers prefer. In the final analysis, the purpose of this research is to find out what choices of tasks and technologies will enlist the enthusiasm of the people in a particular village.

II. Measuring Village Raw Energy

The second kind of village information needed is the sources of local energy. It must be very specific for each village, and in some cases it must be measured over time. An inventory of sources might include the following kinds of data:

1. A measure of the flow of water in nearby streams in each season of the year.
2. Wind velocity measured for daily and seasonal variations.
3. Sunshine duration and intensity measured for daily and seasonal variations.

In each of these three cases the measures should be taken over a period of at least one year and should be supplemented by the judgment of the villagers as to whether flow or the velocity or the intensity in that year was above, below or just about normal.

4. Estimated volume of organic wastes (animal, human and agricultural). Also there should be an evaluation based on discussions with villagers of the cultural and economic problems in collecting such waste and using it for a) communal and b) individual bio-digesters.

5. Estimated sustainable yield wood production with an assessment

of the difficulty of cutting and transporting it to the place of use.

6. Any special energy sources such as a local coal vein or lignite deposit should be described.

7. Animals that might be used for draft power should be counted, and the reasons why they are not now being used and problems in using them should be discussed. The key obstacle to raising animals in Africa has been the tsetse fly which carries sleeping sickness. However, there are tsetse free areas that do not have animals, and areas with animals that are not used for draft purposes. The software research should report on whether conditions for the use of draft animals exist: tsetse free, expandable cultivation; local or nearby blacksmith capabilities; interested farmers or farmers with experience in livestock care; access to occasional visits from a veterinarian; and available supplies of food and water for the animals.

Although the picture on raw energy can normally be pieced together only by the time consuming village by village process described above and detailed further in Chapter Six, it may be possible to get some data on a number of villages from existing computer tapes kept at the National Climatic Center in Asheville, North Carolina. This is included as a recommendation in Chapter Six and described in more detail in Appendix V.

III. Measuring the Impact of Energy on Village Life

The process of bringing energy to the villages of Africa will engage many people and resources over many years. Information gathered about the impact of energy on the life of villages that are newly energized can provide valuable guidance to those who participate in the ongoing process. What is the impact of energy on agricultural production? Is a substantial portion of the labor released from other tasks devoted to raising additional crops or livestock? AID's food energy chain project will attempt to measure this in Upper Volta for example. Does unemployment occur as a result? Are small industry or handicrafts stimulated by the coming of energy to the village? Does the provision of lights for reading improve the pace or quality of education? What effect is there with respect to health services or the incidence of disease (for example from clean drinking water)? What effect is there on the role of women? Is there an increase, a decrease, or no change in the number of babies born each year? The AID-financed Evaluative Study of the MISAMIS Oriental Rural Electric Service Cooperative in the Philippines, (P. 18) concluded that "The sharp decline in the crude birth rates (in the wake of electrification) is one of the most interesting phenomena uncovered by the study." Is there a change in infant mortality? What changes, if any, take place in the patterns of migration? Does energy set up a demand for imported items that drain limited foreign exchange? These and other evidences of the impact of energy on village life should be measured and analyzed in order to better understand the importance of village energy, to anticipate problems and opportunities it may create and to differentiate among the effects of different uses of energy (lighting, clean water, cooking fuel, for example, contrasted with irrigation) and different forms (electricity

versus gas, charcoal or mechanical energy).

These evidences of the impact of energy on village life will be especially useful to African policy makers and to loan officers in donor agencies in determining whether village source energy meets various criteria of economic feasibility. It will help to judge whether the value of the economic product of the village increased by an amount large enough to pay for the capital investment in a reasonably short time. There is some dispute whether small scale renewable energy technology should be required to meet such an economic feasibility test, any more than literacy or health or family planning projects do. However loan officers frequently demand such evidence, and this kind of software research will help to provide it.

In order to make such measures, a given village should be studied for a period of time before new energy technologies arrive, and then studied at certain intervals afterwards to measure changes brought by such energy. Unlike the inventories of energy sources or the analyses of village tasks discussed above, these energy impact studies need not be done for every village that is to be energized. A small sample, if properly selected, should give answers that will provide valid guidance to policy makers.

IV. Implementation of Village Hardware Testing

Two actions are involved in village hardware testing: 1) Careful selection of villages in which hardware devices are to be tested, and 2) Careful selection of the hardware devices to be tested in those test villages. Both of these actions must be conducted in such a way as to achieve the somewhat conflicting goals of two different groups: (1) the test managers who will want to simulate laboratory conditions in order to make the tests of hardware performance and costs as valid as possible and (2) the villagers who will want the hardware being tested in their village to be as valuable to them as possible, whether it fits into the overall design of the testing program or not. Although the test managers will want central control of the tests, they will also want considerable village participation in order to learn as much as possible about the process of village participation in the use of village source energy technology. The question of central control versus village control may very well be resolved differently in different countries.

The managers of the test should, of course, be the African government or an African institution (e.g., a university or a research institution) designated by it. If desired, it could engage a foreign consulting group which might be financed by a donor agency. The African managing institution would design the hardware test within whatever limitations its government specified.[1] It would (1) select a range of hardware from which choices could be made by or for each village (depending on the degree of local control desired); (2) select a representative sample of villages taking into account such factors as the government's regional priorities for rural development, the several agro-climatic regions, the major cultural groupings, and the more important settlement patterns and (3) specify guidelines for the conduct of the test (e.g., whether villagers have to pay a portion of the cost of the hardware) and conduct the tests.

[1] For example, some governments might require that hardware be chosen that could be wholly or partly produced within the country.

In selecting hardware the managing institution and the villagers will need to take into account the impact of the technology on the rich villagers as compared with poor ones. Some technologies tend by their nature to favor rich people. Others may be more neutral. It is not clear whether there are any which favor poor people. Clearly a tractor, even a walking tractor, would tend to favor rich farmers in the African village context. It would cost several hundred dollars even if it were stripped to the bare essentials; and it would call for a degree of sophistication in operation and maintenance that is not commonly found among poor villagers. Similarly a diesel generator that provided a village electric grid would favor those that were rich enough to afford to hook up to the grid and to wire their homes. To begin with, it would favor those that have permanent structures rather than mud and straw composition that disintegrates every few years. Biodigesters for individual households favor those wealthy enough to own several cattle. Biodigesters for a community facility plus plastic tubing to carry gas to individual homes would serve anyone that could afford a small burner. A windpumper that provided drinking water in the village would serve anyone that came to the pump with a carrying utensil.

The conduct of the tests will involve not only the introduction, testing and reporting on hardware devices in villages, but also the three kinds of software research that precede hardware testing. Such tests will require that qualified individuals be found who are residents of the participating villages. We have outlined in the section that follows a procedure for most of the software research sequence that might be followed in those African countries that wish to maximize village participation.

A Proposed Village Energy Research Program

The involvement of the village in developing or improving its own energy economy can be most useful, initially, in the four kinds of software research outlined above (including field testing of hardware). In some cases, source measures must be taken over a period of at least one year and preferably longer. An outside agent might be expensive as well as inappropriate except as a technical backstop to the actual measures taken by a village resident. Fortunately, however, most African villages contain a number of residents capable of undertaking these operations. These people may be part of the modern sector, but their ties to local society, language, and their perspective on the traditional and modern worlds enable them to work with villagers to make energy choices taking into account the limitations of climate, culture, political system, and the indigenous economic infrastructure. They may be local teachers, traders, or health, agricultural extension or veterinary officers, educated farmers or one of the many unemployed secondary school graduates. Likewise one can visualize such African residents working with resident expatriates like Peace Corps or U.N. volunteers, missionaries and others. The greater the degree of village participation and decision-making in these steps, the greater the chance of success. All resident researchers, whether they be country citizens or resident expatriates, would report to and work in coordination with the African national institution in charge of the village energy research program (this may be a university, national ministry, energy institute, etc.)

The village resident researcher would work with those individuals in the community who are the real movers or centers of power and change. In some cases, one of those people might be the resident researcher himself. These "change agents" may or may not be part of the nominal political structure of the village and may be found in various parts of the local economic, social or religious structure. They may be men or women; young or old.

This framework would enable the managing African institution and the participating villagers, perhaps with the support of an interested aid agency, to perform some of the software research much less expensively and with more local sensitivity than outsiders could do.

A brief training course in two phases might be useful for the participating village residents. The first phase would introduce the village resident researchers to the various technologies, measuring techniques, and the use of the instruments for the first three steps in the software research sequence. It would be necessary to equip the training course with questionnaires, sets of instructions appropriate to regional and cultural needs and a supply of instruments for taking measurements. The instruments for measuring energy sources are discussed briefly in the following paragraph and more fully in Appendix VI .

Wind recording instruments cover a wide spectrum of sophistication, quality and cost ranging from $1,000 for an integrated recording cup anemometer to $10 for a hand-held cup anemometer, to a printed sheet with a guide to making visual observations and estimates of wind speed. Solar radiation equipment ranges from $1,000 to $200, but of course resident researchers could improvise by making visual observations of cloud cover and taking temperature readings. Stream flow data are taken with recorders or meters costing from $1,000 to $300. Researchers could improvise by timing the speed of a float in the moving stream and taking depth measurements by hand. The African managing institution would have to work out inexpensive ways of making all of these measures with acceptable accuracy.

Turning to the second, or hardware testing phase, although in some cases researchers might be technically qualified, in most cases they would have to be given a more intensive course in the technology itself than is envisioned in the first phase training course described above. Several weeks of training might be necessary in order for a resident researcher to be able to help villagers select and install a technology. In this stage it is likely that any resident researcher will be involved on more or less a full-time basis in contrast to the part-time work on the software research that precedes hardware testing. The African managing institution would be responsible for putting the contents of the two training courses together and for directing the courses using professional talent and demonstration projects available at the host institution possibly supplemented by an outside consultant.

Ideally there should be a multi-skilled team including engineers, anthropologists, and economists during training and hardware-testing. The consultant would be responsible for advising the African institution on the contents and technical direction of the training program, and perhaps for providing a systems expert to help identify some of the elements required for a successful energy extension system, pinpoint the problems, and help minimize the costs by providing information to help solve these problems.

One of the key functions of the systems analyst would be to develop information to help the African policy makers decide which parts of the energy extension system could best be managed by public institutions and which services the private sector should be encouraged to provide. (See Section VI below.)

Even in those cases where one village resident is an expatriate volunteer or missionary, care should be taken to ensure that a resident with permanent ties to the community be part of the village's research and operating team. Moreover, since the role of women in the African rural communities is an especially key one, it may often be essential to bring them into both the software and hardware phases of the program.

The donor's input to the two-phase village energy research project might consist of (1) a technician or contractor to help the African institution design the questionnaire and write the instructions, to participate in the training sessions and the subsequent field testing of hardware including, (if necessary) being on a standby basis to consult with the African institution managing the project; (2) the cost of instruments and materials for the courses; (3) a follow-up contract or technician to write up the experience and draw from it any lessons that might be useful to African policy makers in deciding whether it is feasible to gather village energy resource data on a widespread basis and (4) the cost of hardware selected for village testing. The Peace Corps and any foreign voluntary agency might participate by offering the cooperation of the volunteers. Resident African researchers would probably need to be paid.

V. Evaluating the Hardware

As soon as an adequate number of energy devices have been given village site tests for a period of from one to two years, sufficient data will hopefully be generated to permit an evaluation of each. The evaluations should be of two types. First, the performance of each device should be assessed for each of the village tasks on which it was used, noting how well it performed the task, whether villages seem to prefer using the old methods of performing the task, how difficult it is to maintain, to repair, how much time it was out of use during the test period, and what revisions, if any, are needed in design or materials. The device should be evaluated also in terms of its capital and recurring costs in foreign exchange and local currency.

Second, with these data in hand, the cost of bringing a certain level of energy to the village of a country (or subdivision of a country) through village source technology can be compared with the cost of using large scale central generation and an electrical grid. For example, the cost of energizing the villages of Upper Volta through a combination of wind, wastes, wood, water, and sun could be compared with a rural electrification grid fed from hydroelectricity from the Volta River.

The question has been raised whether it would be useful to attempt immediately to make a comparison of village source energy with centrally generated electricity or a petrol distribution system. The costs of the central systems could certainly be estimated and compared with decentralized diesel generation because there is an experience base for both of these methods in many places throughout the developing world. However there is no significant experience base with the use of many village source technologies in the villages of the developing countries. Thus we do not see how such technologies could be evaluated either as to performance or costs until such a body of experience has been accumulated as would be done through the course of action described in this chapter and recommended in Chapter Six.

VI. Analyzing Alternative Extension Systems

At this point in the sequence of software research steps, we are nearing the stage where African policy makers must begin to consider the knowledge that has been generated in order to decide to what extent to rely on village source energy to meet the needs of their villages and farms as compared with extending the national electrical grid. However, there remains one further variable for them to ponder in making the decision: what system would they use to distribute and support the village source technology if that is the course they choose?

As part of the initial contract on software research, the consultant should have been asked to help the managing African institution design the software research to be able to help answer this question. Thus, careful records should be kept on each of the first four steps in the sequence described in this chapter (survey of tasks, of village sources, of energy impact, and test installations of hardware) with respect to the costs of such software research, problems encountered in conducting such research, and which research techniques seemed most effective. In short, software research should have been designed not only to help Africans decide whether to use village scale technology to meet village energy needs, but also to decide how to do it.

Before discussing alternative systems for reaching the villages with energy devices, it may be useful to consider briefly why it is necessary to have a system to extend village source energy to the field, and what such a system should be expected to do.

One cannot work long in the area of village source energy without hearing of the many small scale energy projects in LDCs that have been abandoned. Their sponsors have long since returned to Europe or North America, leaving behind the skeletons of windmills and the remains of biodigesters. Although the reasons for these failures are not well documented, they probably include a normal quota of errors on the part of project designers and managers. One may also generalize that a leading cause of failure among development projects in general (not just energy projects) is lack of enthusiastic commitment to the projects on the part of the intended beneficiaries. Unless there is strong local support for a project, it will fall into disuse soon after the departure of the last outside technician.

But more than enthusiasm is needed. A local support system is also required. From the analysis given above of the sequence of software research, one may identify the components of such a system. First, the system must help villagers develop an energy strategy for their particular village, taking into account what their local raw energy sources are, what tasks they would like to use them for, and what devices they would like to employ. Second, the system must provide a qualified person to work with villagers to set in place the chosen technology. This calls for helping villagers to order the necessary equipment and supplies, to find the financing that may be needed. to train local persons for operation, maintenance, and repair and to supervise the actual building of the energy facility. Third, there is a need to monitor the use of the local energy facilities, trouble shooting when there is a physical breakdown, counselling when cultural, personal or political problems arise, arranging for training of additional village people and bringing information from the world of energy researchers that might improve on the local technology. Fourth, there is need for the experience of the village with the energy device to be recorded and made known to the research world so that its work can be kept relevant to the energy needs at the village level. In particular, careful records on energy costs could provide indispensible information to researchers.

In the early stages of a program of installing small scale renewable energy in selected villages, and while nations are gathering experience on which to judge whether village source energy is feasible for nation-wide application, the energy extension system to perform these four steps will of necessity be elementary and somewhat informal. A full scale national extension service would not be warranted. However, once a country becomes convinced of the feasibility of village scale technology, and determines to apply it on a wide scale, it must face the need for some kind of energy extension system.

That system may take one of three forms. First, it is possible to envision a situation in which private manufacturers and distributors would produce and market one or more devices, install them, train local attendants to operate and maintain them, and provide such central servicing as may be necessary. It might be necessary for a government

agency to perform the first of the four functions described above helping villages design an energy strategy). There will be other cases where poor prospects of profits, the ideology of the government, or the fragility of the private sector make it unlikely the private sector can do the job, and thus such countries may require a governmental extension service. The second type of system may be to have the service of extending energy provided by the existing agricultural extension system. Third, in other cases, it may be necessary for a wholly new national energy extension service to be established.

At this point in time we can safely say it will be necessary for all countries to have a system for extending village source energy technology and for supporting that technology if village source energy is to succeed. But we cannot predict which countries, if any, can rely on the private sector, which can turn to an existing agricultural extension system, and which will need to develop a new system for energy.

In order to help African policy makers decide among these three alternatives (or some combination), it may be desirable to engage a consultant to evaluate the experience gained during the entire software research sequence, and in the light of that to carry out one or more of three specific research studies. The first of these studies would be a survey of the prospective market for village source energy technology. The purpose of this survey is to help the private sector and public energy policy makers determine what quantities of each kind of device can be sold to villagers at a given price and what performance specifications each device must meet. That will enable those in the private sector to decide whether such a venture is sufficiently profitable for them to establish a distribution system and a support system to ensure that the device works and is maintained properly and repaired or revised when necessary. It will enable the responsible public officials to estimate the financing requirements of the villagers and to ensure that they are met either by the private sector, through village savings, or through public loans.

The second study would be an evaluation of the existing agricultural extension system to determine whether it could be strengthened to perform some or all of the energy extension function. This study would identify what additions would be needed to the agricultural system and whether such changes seem compatible with the achievement of its original purpose. The third study would be to design a wholly new energy extension system and to predict its costs based on the experience with the village resident research project described in Section Six. In Appendix IX we have illustrated what such an energy extension system might be like.

With the information provided by these six software research steps, African policy makers will be in a position to make two basic decisions: first, whether to rely on village source technology to meet the needs of their rural populace and second, (where the answer is affirmative) what basic system to turn to in order to make the new technologies available.

CHAPTER FOUR

The Status of International and African Small-Scale Renewable Energy RD & D

I. Some Observations on International Energy Research

For this report, energy research and development (R&D) are considered to be those activities involving basic theoretical work, data gathering (both software and hardware data) as defined in Chapters 2 and 3, creation of prototype hardware devices, and experimental testing and refinement of prototype devices. Demonstration (D) covers actual field trial of prototype devices or of devices proven in other regions or conditions. All three types of activities may be carried out simultaneously. Indeed, all are closely inter-related, and it should be stressed that demonstration efforts, to be successful, should be accompanied by adequate R & D preparation and follow-up.

There is as yet no international agency responsible for keeping track of global energy RD&D activity. However, several attempts at identifying various aspects of what has been defined in this paper as small scale, or village scale, renewable energy RD&D have been undertaken recently which include at least most of the significant programs.[1] In drawing upon those compilations as well as our own correspondence with energy researchers and concerned development experts, there is sufficient information to offer at least preliminary support to several observations (See Tables 4-1 and 4-2).

- First, a considerable amount and variety of small-scale renewable energy research is taking place both in industrialized and in developing countries, including a limited, but significant, amount of activity within Africa.

- The bulk of this research, about 75% (measured in numbers of projects) both globally and in Africa, is devoted to various aspects of direct use of solar energy, particularly to water distillation, water and space heating and cooling, and crop drying.

- Almost all of the hardware research is devoted to applied technology (engineering) according to energy source. That is, most researchers are attempting to develop better solar heating devices, better windmills, etc. Relatively little research is based upon a general task orientation, for example attempting to examine all of the methods available for pumping water or cooking.

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1 National Academy of Sciences, Energy for Rural Development, (Washington, D.C.: 1976); F. de Winter and J.W. de Winter, eds., Description of the Solar Energy R&D Programs in Many Nations, published for Energy Research and Development Administration (Washington, D.C.:1976); Hittman Associates, Compendium of Energy-Technology-Related Assistance Programs for Less Developed Countries, Final Report, Prepared for U.S. Department of State (Columbia Maryland: September, 1976); Organization for Economic Co-operation and Development, Energy R&D (Paris: OECD, 1975).

TABLE IV.1

KNOWN SMALL-SCALE ENERGY RD&D RESEARCH PROGRAMS [1, 2]

	World Total	Industrialized Countries (including USSR)	Developing Countries (including Africa)	Africa (Sub-Saharan)
Researchers	278	170	108	29
Research Institutions or Departments	194	115	79	28
Countries with such Programs	49	15	34	15

Footnotes to Tables IV.1 and IV.2

1 Compiled from the NAS, Energy for Rural Development, 1976; ERDA, Description of the Solar Energy R&D Programs in Many Nations, 1976; and Overseas Development Council correspondence, 1975-76. Includes information from more than 150 institutions in more than 45 countries.

2 An energy researcher is defined here as a person who has been identified by name or position as either a director or a principal technical assistant in an energy research or development program. An energy research or development program may be composed of one or more energy research or development projects. An energy research and development institution is a discrete organization composed of one or more energy researchers carrying out a specific energy research program. Thus, a university is counted as one energy research institution if there is only one known energy program or researcher present, but if two or more departments of the same university have separate R&D programs, each department is counted as a research institution. The same is true of governments or international organizations with more than one agency or branch conducting energy research. Unfortunately, such distinctions are not always clear-cut; classifications are frequently arbitrary.

3 Based upon program emphasis; some programs conduct projects that clearly include two or even all three areas and are counted accordingly; therefore totals more than 100%.

4 See text for definitions.

5 Since most research is conducted within universities, most programs provide training. But only programs primarily concerned with training are counted here under the heading "training."

6 Virtually all source surveys are insolation measurements only.

NOTE: This is a compilation of our available data. Hopefully, it reflects the general orders of magnitude and spread of present programs, but it should not be considered a definitive or final summation.

TABLE IV.2

An Approximate Breakdown of Small-Scale Energy RD&D Programs [1, 2]
World Wide

LOCATION OF PROGRAM	Percentage	Number
developed countries	59%	115
developing countries (non-African)	26%	51
developing African countries	14%	28
TYPE OF PROGRAM [3, 4, 5]		
Hardware	87%	169
Software		
source survey [6]	11%	21
need survey	1%	2
village impact	1%	2
hardware field test	.5%	1
hardware evaluation	1%	2
Institutions		
training	-	-
information exchange	5%	10
government organization	1%	1
international organization	-	-
FOCUS OF PROGRAM		
rural LDC	15%	31
general or unspecified	85%	163
SUBJECT		
solar stills	18%	36
all other solar	68%	132
all solar (total of above)	86%	168
wind	16%	31
biogas	10%	20
mini-hydro	2%	4
wood/char/stoves	4%	7
other non-conventional	14%	27
SPONSORING AGENCY		
domestic	81%	157
regional	5%	10
UN or global agency	5%	9
bilateral government	2%	4
bilateral private	4%	8

See footnotes on preceding page.

(This is perhaps simply a reflection of the organization of scientific endeavor, working from a particular background or discipline.)

- Virtually the only software source survey research underway is in solar insolation measurements. (Wind data are fairly widely collected for meteorological purposes.)

- Most of the research is focused on applications of a general nature; very little, probably less than 15% of present research projects, is aimed directly at specific village applications or demonstrations.

- Most of the research, 85% or more, is conducted by national institutions, usually universities--and usually within the mechanical engineering or science faculties of universities. The remainder is done under the auspices of regional or international organizations.

- Most small-scale energy research, about 60% (again, in numbers of projects), is being conducted within industrialized countries. (If private, "backyard" research were included, the proportion would undoubtedly be even greater.) Although detailed budget information is unavailable, it seems likely that more than two-thirds of the money devoted to such research is spent within the industrialized countries.

- Even in the industrialized nations, most of the small-scale projects are funded at a very low level (compared with other kinds of energy research) and without any comprehensive small scale energy RD&D strategy--individual projects are funded on their own merits rather than as part of any long-term commitment to explore decentralized energy systems.

II. RD&D Capacity and Interest in the Industrialized Countries

The United States predominates in almost all areas of energy R&D. Although the 1977 authorization of $290 million for solar and all other renewable energy research is less than 10% of the total U.S. federal energy research budget, it is probably nearly equivalent to the total solar and other renewable energy research expenditures of all other non-Communist developed and developing countries combined.

The industrialized countries recognize that the particular energy problems of developing countries are significant and merit special research attention. This has been expressed to us by a number of officials of international donor agencies, and was the basis of the State Department's International Energy Institute (IEI) proposal.[1] It was also forcefully noted in the final paragraph of the Organization of Economic Cooperation and Development's (OECD) 1975 report on members' energy R&D programs:

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1 See Chapter 6

> "in view of the seriousness of the energy problems of the developing countries which affect not only them but also the developed countries, it is important to undertake a thorough study of the ways in which science and technology can contribute to the solution of these problems, and of the lines along which international cooperation in this field might be initiated and the conditions in which it might be organized." (stress theirs)

Therefore it is not surprising that several of the major donors are presently reassessing their energy assistance policies to developing countries.

III. RD&D Capacity and Interest in Africa

In the course of this study we have corresponded with about thirty institutions within Africa presently conducting research on small-scale renewable energy. Nearly thirty African scientists are presently devoting all or a significant portion of their research efforts to renewable energy technologies. Indeed, several have been working in this area for a decade or more, and are renowned pioneers in their fields. A number of other scientists in Africa have expressed to us considerable interest in renewable energy and suggested that much more such research is needed, but noted that they presently have inadequate resources or trained staff with which to conduct such research. Virtually all of the institutions within Africa presently engaged in such research are part of or closely associated with a university. At many of these places fairly ambitious programs are underway or planned--subject to severe limitations of budget, facilities, and trained manpower.

Several African governments have already established special national renewable (solar usually) energy institutes: Senegal, Niger, Mali, and others are considering doing so. A number of governments (Senegal, Mali, Niger, Upper Volta, Ghana, Tanzania, Kenya, Sudan, Cape Verde Islands) have also expressed specific interest in cooperating with outside donor agencies to demonstrate village scale renewable energy technologies within their countries.

The Economic Commission for Africa has recently been promoting intra-African cooperation in energy development generally, and has included wind, solar, and other potentially village-scale sources in its recent studies and conferences. There has also been discussion within UNESCO of establishing a regional African solar energy institute. But the UNESCO proposal is still in the preliminary discussion stage and such a center appears to be at best several years away from being established. Meanwhile, the UN Environment Program is working with the government of Senegal to establish an operating village-scale solar-wind-biogas energy system there.

IV. Donor Activity

Energy and power development projects have been an important part of most foreign development assistance programs, in Africa and elsewhere, since their inception. Last year (1975-76), energy and power development projects comprised about 15% of all World Bank (both hard and

soft) lending. In Africa, however, it only constituted about 6% of World Bank lending. No small-scale energy projects have yet been funded by the Bank. For several of the OECD's Development Assistance Committee (DAC) members, energy development assistance projects have comprised 15-20% of total assistance in recent years. While most development assistance in energy and power has been related to centralized electrification, hydroelectric projects, and fuel resource exploration, and has been aimed at the countries' commercial and industrial population centers, there have been a handful of village-scale, non-conventional energy technology projects internationally, including several which have been located in Africa.

Those small-scale energy projects which have been funded have been approved without a comprehensive plan or strategy for small-scale rural energy development on the part of either the donors or the recipient countries. Furthermore, they have generally been conducted in isolation from whatever energy R&D program the donor government itself is conducting. And, as a final limitation, such projects have generally been conducted without built-in mechanisms either for assessing the sociological and other impacts of the project in such a manner that others might learn from the experience gained, or for continued maintenance of and potential extension of otherwise successful projects.

Present Donor Projects

The French Ministere de la Cooperation has probably devoted more attention to small-scale energy applications in rural Africa than any other donor to date.

Since 1968, France has supported a program to power educational television with solar batteries in areas of the Niger without access to the electricity. Presently some 22 rural classrooms have solar-powered televisions, compared with 214 classroom televisions in areas with electricity.

The Ministere is presently completing a study, to be available in 1977, of potential alternative sources of energy in Africa. The study is focusing on use of agricultural wastes, wood and sawdust, solar energy, and wind, and will include an assessment of the present and anticipated technology developments for each of these, an analysis of pilot projects and experiments already underway, and an examination of the potential in two African countries, one on the coast and the other in the interior.

In cooperation with the "Delegation aux Energies Nouvelles" of the Ministry of Industry, the Ministere de la Cooperation has embarked on a three-year "new energy for the Sahel" program. Begun in 1976, the program is concentrating on use of solar and wind power for water pumping and for telecommunications. Considerable attention is being paid to the problems of integrating the new energy technologies into the existing socio-economic situation and existing rural development projects.

A number of French firms and research institutes are working on

various aspects of appropriate R&D, at least partly with the expectation that one or more of the new energy technologies (such as solar pumps) may find a considerable market in a number of African countries.[1]

The Ministry of Overseas Development of the United Kingdom, in addition to supporting several domestic studies of small-scale energy technologies that might be applicable in developing countries, has recently made a research grant (about $2,200) to test a prototype solar water heater in Sierra Leone. Programs of the Swedish, Dutch, and Canadian governments are comparable. The Germans are presently making a major reassessment of their aid to energy development and may be expected to place a considerable emphasis on small-scale energy technology assistance in the future.

The U.S. Agency for International Development (AID) is presently sponsoring some work on charcoal pyrolysis in Ghana, has recently begun a several-year study of the effects of increased energy in the food system of various rural villages, and is also sponsoring an energy advisor to ECA, who will be carrying out village scale hardware experiments in East Africa.

Within the United Nations, the United Nations Environmental Program and United Nations Industrial Development Organization are each sponsoring research or demonstration projects within Africa. UNEP, as mentioned before, has developed a system based upon combined utilization of locally available solar, wind, and biogas (SWB) resources, which will be applied to a rural village of about 500 persons in Senegal. UNIDO is presently sponsoring an evaluation and manufacturing feasibility study of solar pumps within Senegal, a study of a possible solar energy laboratory in Mali, evaluation of a prototype windmill for water pumping in Kenya, a study of the potential for exploiting peat as a fuel to replace wood in Burundi and in Rwanda, and an evaluation of two solar sea water distillation plants in Somalia. UNICEF has recently launched a village appropriate technology demonstration unit near Nairobi.

Most notable has been SOFRETES (Societe Francaise d'Etudes Thermiques et D'Energie Solaire) in cooperation with Renault Moteurs International and other partners, which has developed and installed the solar water pumps mentioned above and on Page 17.

CHAPTER FIVE

Institution Building

I. Building African National Institutions

The best way outside agencies can help build African energy institutions is to conduct as much of their hardware research as possible and all of their software research in Africa, and to do so jointly with, or in support of, work by African institutions. In some cases they will be existing institutions; in other cases the work described in the chapters above will require newly created institutions.

In addition, donor agencies may be able to help build African institutions in at least four other ways. First, they can help by training Africans in the subject of village source energy. This training could take place in the industrialized countries at appropriate institutions. Even more appropriately, one or more African institutions might be selected as potential regional training sites and given the support necessary to develop that potential. Second, existing African research institutes could be given support including funds, supplies, major equipment, and technical and professional assistance to enable them to do such things as research, teach, perform analyses, run special training programs, and in some instances, conduct programs of energy extension to villages. Third, appropriate African ministries will need technical assistance in the form of surveys, advisory personnel, written materials, professional staff from abroad, and funding for promising activities in the area of village source energy. One useful activity that could be supported by donors would be the establishment of national systems to collect data on the kinds and quantities of energy produced and consumed. Finally, private African commercial institutions could play a more useful role in extending energy to African villages if they were given appropriate support by outside agencies. Such support, however, should await completion of the kind of software research described in Chapter Three and a decision by African policy makers whether to go ahead with village source energy and what role, if any, is to be played by the private sector in extending such energy to the villages.

II. The Configuration of International Institutions

A. A Global Comprehensive Institution

Former Secretary of State Kissinger has proposed that an International Energy Institute (IEI) be created whose basic purpose would be to help developing countries on their energy problems. The State Department version of the IEI would have four major functions. First, it would help LDCs identify their chief energy options so that they can better determine an energy strategy. Second, it would facilitate and arrange training for LDC personnel in energy topics with the training or advice to take place either in the LDC or abroad. Third, it would help LDCs find their own oil, coal and other energy resources by furnishing ex-

Economies could be achieved and time saved if everything known to every energy researcher were known to every other one. But that is impractical already and will become more so as research produces more knowledge. However, it might be possible for essentially everything known to every researcher on (say) photo-voltaic production of electricity to be known by every other. And the loss to each of them from not learning of breakthroughs on wind or biogasification would not be great. Hence, it may be practical and would certainly be useful to bring the knowledge of all researchers on a given energy sub topic together. Although it would not be practical to locate all such research in one place, some of the advantages of such a concentration might be achieved by the loosely coordinated network of researchers described in Section C above.

2. Software Research

Software research, by contrast, is probably best organized along geographic rather than topical lines, as is indicated by the following brief look at each step in the software research sequence: (1) Research on village preferences or village sources must be village specific, (2) Research on energy impact on a given village is more applicable to a nearby village than to one in a totally different climate, culture, and economy. Such differences probably grow greater as geographic distance increases. (4) Research on performance and cost effectiveness of specific hardware devices, although calling for some topical expertise, also requires familiarity with the villages where the test installations are made. (5) Comparisons of the costs of village-source technology with the costs of centralized generation together with an electrical grid also are facilitated by understanding of the area being studied, though they could be performed by visiting consultants from a topical institute located abroad. (6) The same is true of market surveys and surveys of alternative extension systems.

3. Trade-off

In the African context some of the advantages of subject matter and geographic expertise might be achieved by helping some of the more promising national energy research institutions develop a specialized capacity to serve regional needs in Africa. A consortium of donors might agree with such African institutions that in return for donor support they will offer such services to other African nations as (a) training students and experts in energy, (b) consulting with and advising African governments on their small scale energy research and (c) liaison with and coordination of related research in other African nations including (d) keeping the latter abreast of developments in such research throughout the world.

4. The Global Comprehensive Institute Proposed by the United States

The advantages of a global comprehensive institute such as the IEI proposed by Dr. Kissinger are not directly apparent from the point of view of village energy. Although it could be useful in the early stages of small scale energy research, after that research gets beyond its infancy, such an institution is likely soon to be outgrown, much as the FAO would be incapable of knitting together all of agricultural research. The

perts to advise them on exploration and development of such resources and on how to stimulate private exploration. Fourth, it would encourage the transfer of energy technologies and actual hardware to the LDCs as well as the adaptation of northern technology to the needs of LDCs. This fourth activity would be limited to studies and to encouraging others' activities rather than itself financing such activities.

The United Nations also has under consideration a proposed International Energy Institute (same name but somewhat different functions) which focuses on the subject of technology for LDCs. A report has been turned in to the General Assembly and is now being given further study, to be completed in the fall of 1977, by an ad hoc committee involving those U.N. agencies that have an active role in the subject of energy.

B. Regional Topical Institutions

UNESCO has proposed an African regional solar research institute, which is now in the discussion stage. It is not yet clear how comprehensively the term "solar" is to be treated in this institute. Nevertheless, one or more regional African institutions dealing with one or more small scale renewable energy technologies could play a role both in hardware research and especially in software research, including testing hardware in the African village context.

C. Networks of Topical Research Institutes

Already topical energy institutes exist and are proliferating rapidly. For example, our own files include the names of more than 140 institutions in more than 40 countries throughout the world that specialize in solar energy. Research in wind and bioconversion is also expanding. Thus a third possible evolution of the international energy research scene might be toward topical research networks. There is probably already enough research in solar energy at enough widely scattered points to justify some coordination efforts including perhaps a lead agency for solar research (much as the International Center for the Improvement of Corn and Wheat in Mexico City --CIMMYT--is the lead agency for research on those grains.) The role played by the solar lead agency might include keeping informed on all solar research efforts, notifying all solar researchers of similar efforts elsewhere, informing all members of the network of significant breakthroughs, preparing and circulating analyses of promising but neglected areas for further research, arranging the exchange of people, arranging technical workshops and, if financially capable, supplying seed money to initiate or strengthen needed research at appropriate points in the network. It would not, of course, be in a supervisory relationship with respect to the solar research centers throughout the world, any more than CIMMYT attempts to supervise work in the 200 corn research stations that are part of its network.

D. Some Observations With Respect to Alternative International Configurations

1. Hardware Research

Hardware research is undoubtedly improved by topical specialization.

field of energy is too large, the number of professional specialties too numerous, and the methodology of research too varied for one organization to play the intimate leadership role required to make a major contribution. It is worth examining briefly whether the other functions of the U.S. proposed IEI (advising LDCs on energy strategy, arranging training programs and technical assistance and stimulating the development of local energy reserves) would be useful. With respect to the first task, advice to LDCs on basic energy strategy would certainly be more balanced if it came from a comprehensive institute than from a topical specialist. The latter might tend to view their particular specialty (e.g., photo voltaic cells or wind generators or pyrolitic converters) as the answer to most situations, whereas a comprehensive institution would be more likely to be objective as among the several technologies.

With respect to the second task of the proposed IEI, arranging training and technical advisors, the need for a new international body needs to be further articulated. There might be considerable utility in establishing a new global training center on alternative energy sources or a series of training centers for energy in developing countries, but that is not what is contemplated. Rather, it appears the IEI would sponsor and help to design training programs to be conducted elsewhere which still would be useful but less so than one or more new centers. If the IEI develops a highly qualified staff, their assignment from time to time as advisors to individual LDCs should also be of modest use though probably not very significant at the levels of support now being discussed.

The third task of helping LDCs find and develop their oil, gas, coal and perhaps other stored energy resources is very important. However, it is a very large task which will call for a great deal of resources to provide significant help. It is almost totally unrelated to the problems of village-source energy and not very closely associated with the training and advisory functions identified above as part of the U.S. proposed IEI. The tasks of helping LDCs plan their exploration programs and stimulate private investment call for professional skills quite different from those needed for the use of technology to get energy from renewable sources and those needed to advise countries on their basic energy strategy. If there is an International Resources Bank with a guarantee fund to promote exploration and development of fossil fuels, that is probably the place to locate the highly specialized experts on fossil fuels rather than including them in the proposed IEI.

CHAPTER SIX

Recommendations: Priorities for Africans and Outside Aid Agencies

I. General Recommendations

Our review of work under way and work needed leads us to make three general recommendations. First, much higher priority should be given to research on software: finding out more about villages--what kinds of devices might be appropriate to their level of sophistication and will enlist their enthusiastic support for which village tasks, and what their energy sources are; research on the impact of energy on village and national life, evaluating the costs and performance of village source hardware and comparing it with central energy systems; and analyzing potential energy extension systems. Research on hardware has commanded much more attention than software, which has been neglected almost altogether. The amount of research on village source energy actually taking place in African villages is meager. There are some village energy projects in Africa, particularly those sponsored by French aid, but the point is that there are very few. The World Bank has none. UNEP has one (Senegal: solar, wind biogas), etc. But all together these activities add up to a story of relative neglect of a vital area. Yet there are a number of technologies that are now ready for village testing. This deserves much higher priority.

Second, more research needs to be done on small-scale renewable energy hardware throughout the world but especially in Africa. Our review indicates that work on small-scale renewable energy technology is beginning to proliferate, but most of it is located in the industrialized countries. The pace of this kind of research in Africa, while relatively neglected, is picking up, most of it being centered at research institutes.

Third, major efforts are need to help build African energy institutions. All work on hardware and software in villages, at African research centers, or even in industrialized countries should, wherever possible, be so conducted as to train African people and build African institutions.

II. Resume of Research Alternatives

With these general principles in mind we turn now to a brief resume of the six specific kinds of software research that should be undertaken perhaps with the help of outside agencies--public (such as AID or CIDA or SIDA or private (such as VITA or ITDG). Following the resume of software research we will continue with hardware research.

A. Software Research Sequence

Are efforts is needed on the three kinds of research that precede actual installation of hardware in the villages.

First, it is very important to work with African villagers to help

them determine what village tasks they would like to energize and what technologies to use in light of (1) the tasks chosen, (2) the local energy sources, (3) their native talents and aptitudes, and (4) which approaches they are most likely to support enthusiastically. Like the second step of measuring village raw energy, this must be done village by village. Outside agencies cannot do either job, but they can work with African institutions to learn something about how to do them as effectively and inexpensively as possible.

Second, research is needed on primary sources of energy available in each village.

Third, outside agencies should help African institutions measure the impact of energy on village life as well as on the economy of the country. This need not be done for each village. A sample might yield enough information to be helpful to African energy policy makers.

Fourth, and very important, there should be a major effort to field test all promising technologies in an adequate sample of actual village sites.

We do not attempt to set a sequence of priorities among these four activities. We recommend that all of the first three be undertaken without any further delay. Where existing data permit a sensible matching of device and village (for example from the computer project described in Section C below) we recommend that the fourth also proceed at once, and as soon as data from the first three are developed that the field testing of hardware be extended to other villages. Meanwhile to help the African policy makers select among technologies, we recommend a study of the "rich-prone" and "poor prone" characteristics of hardware devices. (See Chapter Three). No one step is more important than others, since all are needed (step three only selectively). But donors and African experts should guard against a temptation to spend too long on the first three steps. Those steps simply provide information to select the right technology and install it in the right village to perform the right tasks.

Step five, the evaluation of technology, will not be possible until enough devices have been tested long enough to make such an evaluation possible. As soon as it is possible, we recommend that such evaluations be undertaken. Again, donors and African institutions are advised not to linger too long on steps four and five (field testing and technology evaluation) in the hopes of finding "the perfect" technology. Grain storage technology has been undergoing field testing in LDCs for more than a decade and still the professionals are searching for a better storage facility in many cases before making a decision to go ahead with widespread installations. Decision makers should guard against this search for perfection in the case of energy.

We recommend that step six, systems research, be undertaken at two stages. First, the managers of the very first software research should design their projects to learn as much as possible about the best way to extend village source energy on a nationwide scale. Second, after stage five, technology evaluation, African agencies and donors, should commission systems research including market surveys to guide African policy makers in their choice of a system.

B. Village Research Program

This software research and hardware testing in village sites will require a degree of intimate knowledge of the villages being tested that only a resident of the village will have. At the same time the residents must be sufficiently educated to be able to conduct the tests so that they will be valid. Fortunately many qualified Africans and some qualified foreigners are village residents.

We recommend that African governments and donors undertake a Village Energy Research Program with the cooperation of qualified village residents as described in Chapter Three (pages 31 to 33) in order to obtain information that African policy makers can use in deciding to what extent village source energy technology can be useful in helping develop their rural areas.

C. A Proposal for Quickly Identifying Raw Energy Sources in a Few Villages

At the National Climatic Center in Asheville, North Carolina, data are recorded on computer tapes or computer read-outs that may permit installation of hardware in a few villages without going through the time-consuming process of measuring it over one or more years in the village. Included are data for wind and insolation in great detail for some 260 sites in sub-Saharan Africa. A contractor could be engaged to put together a computer program to read out those villages where raw energy sources appear to warrant test installation of hardware. These villages could become candidates for the software research described in Chapter Three. If the research on village choice of tasks and technologies warranted, hardware could be installed much earlier than without the use of these computer data. We recommend that use of the National Climatic Center be explored. This is described further in Appendix V.

D. Research and Development of Energy Hardware

The vast bulk of R&D on hardware is financed and controlled by industrialized countries. Most of it is devoted to accelerating the pace at which the remaining stocks of stored energy (oil, coal, uranium) can be depleted (about 85% in the case of the United States). Of that which is devoted to research on renewable energy, most of it is on large scale forms.

We recommend that industrialized countries devote more of their R&D resources to small scale, renewable energy technology. In the case of the United States, with whose budget structure we are familiar, one would expect that this would be financed by energy research budgets rather than by foreign aid budgets--the latter being reserved for work within the developing countries.

We recommend that donors provide more support for research by African institutions on small-scale renewable energy hardware. Nearly thirty African institutions have been identified that have considerable interest in small-scale energy research, at least ten of which have significant programs under way. Support should be provided to these institutions

and to other promising ones to enable them to undertake additional research. As appropriate, energy research agencies in industrialized countries should farm out some of their research on small scale renewable energy to research institutions in Africa. This could be done by contract or by grants. In addition, aid agencies should provide support to African research on tools and implements (e.g., pumps, grinders, shellers, etc.) of the kind described in Chapter Two.

III. Help Build Energy Institutions

A. African National Institutions

We recommend that donors be alert to opportunities--where African policy makers desire it--to support promising African national energy institutions including not only public ones but also any parts of the African private sector that might play a role in bringing energy to the villages of Africa.

B. International Institutions

We recommend that one or more African national energy institutions be strengthened to perform regional services in Africa and that it (they) be given the resources to perform the following tasks:

1. Assist African governments with software research.
2. Perform research on the most promising hardware.
3. Participate in village site testing of hardware.
4. As soon as enough knowledge is generated, advise African governments when to use village source and when to use large-scale source energy to meet the needs of villages and farms.
5. Advise those African governments that elect the village source route what extension system to use.
6. Serve as a center for training African small scale renewable energy professionals.
7. Provide other technical assistance as needed to African governments and African energy institutions.
8. Serve as a link between energy research in other continents (including the solar network recommended below) and energy research and the applications of that research in Africa.

We recommend that an international lead agency be created at least for solar energy research. The purpose of the lead agency would be to knit together into a global network the work now going on in solar research projects. Whether that network should include all direct solar work (photo voltaic; thermal electric; solar heating, cooling, drying and distilling) or only some portion should be decided after intensive consultations with researchers in the field. The functions of the lead agency would not be to direct or supervise, but to inform, perform liaison, coordinate and stimulate.

We recommend that as soon as the amount of research under way appears to warrant, additional lead agencies be established (or existing agencies designated) to create additional networks, for example for bioconversion and windmachines. This will depend on how soon research on these topics has proliferated to the point where formalizing a newly created network would be useful. Already there is a newly created private association of bio researchers called "The Council on Solar Biofuels." It may be that a few years hence the networks will have grown to the point where there would be some value in establishing an energy network coordinating body analogous to the Consultative Group on International Agricultural Research.

We recommend that further work be devoted to articulating the purposes of the United States' proposed IEI including the work now under way in the United Nations before governments attempt to decide whether such a global comprehensive body should be established.

IV. Matching Resources and Needs

These several suggestions on research offer a cafeteria of choices for African policy makers and outside donors. It is beyond the purview of this paper to attempt to suggest for any African nation and any donor which activity it should choose. Each of these activities will be necessary to enable Africans to make the best choices. It will be up to Africans and donors to get together in such a way that all resources are put to best use and that there are no major areas neglected and no steps postponed so long that subsequent action on other steps is delayed awaiting essential information, or compelled to go ahead in the dark without it. It may be that the entire enterprise of bringing energy to African villages would be stimulated and guided if interested Africans and donors could be brought together to discuss and debate some of the concepts, assumptions and ideas outlined in this paper.

APPENDICES

APPENDIX I

Energy Needs and Tasks in Debarek, Ethiopia [1]

I. General Background and Setting

Debarek is a village-town perched at the edge of the northern escarpment of the Semien Mountains in Northwest Ethiopia. Numbering 5,190 souls in 1970 (of whom 2,140 were male; 3,050 female), its existence is based on a district-wide, agricultural market, administrative and educational facilities for the awradja (district or county), and water. For hundreds of years, its prosperity was due primarily to its location at the summit of the Wolkefit Pass, the only passage up the great northern escarpment for many miles around. Thus, in the feudal "Age of the Princes" it was the seat of petty chieftains who maintained themselves by the extraction of tolls from travellers journeying from the Red Sea Coast in the north (500 km.) to Gondar, the medieval Ethiopian "capital" (100 km.) in the south.

Debarek's geography not only strongly influenced its socio-political history, but determines its economy and lifestyle, today, as well. The town lies in a slight depression, some five kilometers before the precipitous edge of the escarpment at an altitude of 3,020 meters (about 10,000 feet). (At that altitude, clouds come at you, not over you.) The topography is characterized by gently rolling hills, gradually rising to steep "ambas" or buttes several hundred to a thousand feet in height above the surrounding hills. Very little flat land exists and fewer perennial streams.

Like the rest of Ethiopia, the climate is composed of two seasons: dry and wet. However, there is also a period of the "little rains" which comes towards the end of the dry season, but whose main characteristic is its irregularity. The mean annual rainfall is between 1300 and 1500 mm. (55-60 in.) Due to the altitude and rainfall regime, the natural vegetation tends to be temperate grassland and montane varieties. However, the road winding up the escarpment climbs from an altitude of about 4,500 feet to 10,000 feet in about 20-30 miles. Hence, a range of vegetation from tropical to temperate exists, nearby, albeit with difficult accessibility. Winds are fairly constant all year averaging about 8 - 10 mph, except for March and April when daytime winds are very weak. Vertical drafts from the many canyons and escarpments lead to much local variation. The coldest months are July and August (in the rainy season) with average lows of 40-50°F; the warmest are March and April with average highs of 75-80°F. There are likely to be about four times as many cool (59°F or less) days than hot days (77°F or above).

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[1] Written by James J. Tarrant, former Peace Corps volunteer in Ethiopia, who lived in this village as a secondary school teacher from September, 1972 to June, 1974.

Debarek is a market village-town. It is fairly typical of Beghemdir Province in which there are 4.41 persons/ km^2 in rural areas and 3.30 persons/km^2 in urban areas (1970). The population density in this part of Ethiopia is 17.4 persons/km^2. Probably half of the people living in it are not peasants though a number are petty landlords and farmers. Holding such jobs as teachers, bureaucrats, traders and merchants, these people belong to a transitional category, with monthly incomes ranging from about $30 Eth./mon to $600 Eth./mon. On the other hand, all around Debarek, and closely identified with it are numerous family or sub-village groupings called "mender" (Ethiopian word for village) in almost all cases numbering less than a few hundred people and usually less than 50. Nevertheless, these "mender" are not far from each other and provide an agricultural network for the town itself, looking to it primarily as a market, but also, marginally, for its judicial, protective and educational facilities (primary and secondary school).

Most of the people of Debarek and the environs are of the Amhara tribe, many of whom are Christian and predominantly pastoral and agricultural. Due to the north-south trade and existence of a government road (improved gravel surface) through the town, there are sizeable numbers of Tigre people from the north (speaking a different mother tongue) who may be Moslems or Christians. In addition, there are, nearby in the mountains, the Falasha or Ethiopian Jews, also of Amharic extraction as well as some lowland Galla tribesmen who have migrated to the highlands but live mostly in the town as laborers.

II. Agricultural Tasks and Needs

Despite its trading, administrative and educational aspects, Debarek is predominantly an agricultural community. Without the weekly market which, it is said, doubles the population of the town for one day, Debarek would perhaps have deteriorated to the level of some other towns on the main road whose markets are not large.

The environs around the town produce a variety of crops, though the altitude and rainfall regime limit the preponderance of production to grain and ruminant animals. The leading grain crops include wheat, barley, oats and teff, in addition to lentils, chickpeas, beans and smaller amounts of other crops. Most farmers also raise sheep, cattle, donkeys, horses and a few goats. Mules are also bred. Except for oxen used in plow-pulling, cattle are not treated as commercial items, in fact, they are not often eaten. Nevertheless they are a traditional sign of wealth and security. Sheep (the fat-tailed variety), on the other hand, are widely eaten, at least on feast days,[1] and their skins and wool are important trading items. Donkeys, horses and mules, of course, have a critical transport role in a region devoid of almost any roads.

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[1] Dietary restrictions are important for both Christians and Moslems. Ethiopian Coptic Church observes 254 fast days a year. Moslems observe the month of Ramadan. Both groups of traditionalists pride themselves on their fasting stamina.

Beyond the individual family level, there is some pooling of agricultural tasks and needs. Oxen are few and are usually shared, in one of three ways: 1) Either a farmer will hire a man (perhaps a relative) who has oxen to plow his field, usually helping him in return; 2) oxen and plowing schedules may be organized on the basis of the "mehaber" (a traditional village association); and 3) oxen may be provided by the landlord for the people who farm the land, on a scheduled basis.[1] Of course, a few peasants own and use their own oxen. Plowing is invariably done with a crude, wooden plow, of ancient design, with an iron-tipped point. The process is very slow and the furrows are shallow. As the ground must be moist enough to plow, the timing of the small rains in relation to the regular rainy season is important, and thus plowing time becomes quite frenetic (often causing many students to become suddenly "sick" and miss school to help out back home.) Cooperative or village efforts at coordinating irrigation or fertilizing (cow dung and night soil) are apparently little, if any.

Again, at harvest, there is a sudden bulge in the workload, and there exists some sharing in this task.[1] However, the grass in the public fields (for example, the school and the compound of the local governor) are commonly reaped by local prisoners. The work schedule is generally somewhat staggered due to different harvest times for different crops and some variance in the time of the original planting. Again, oxen are usually shared, as in the above arrangement, for threshing purposes. Most of the crop, after harvesting and threshing, is brought quickly to market for sale to traders who take it to larger cities by truck. Storage facilities on a cooperative or village-level are non-existent.

Energy use in agricultural tasks in Debarek is characterized by almost exclusive reliance on human and animal power. There are no tractors or harvesting machinery, no pumps or mills of any kind in the area. There is one grinding mill in the town capable of grinding to a number of different degrees of fineness. Its capacity is not large but sufficient for the area, and it runs on a diesel motor. Occasionally one comes across a crude irrigation scheme based on diverting stream water through small ditches to a hillside plot with a gentle grade. These are almost always used during the time of the little rains to squeeze out a marginal vegetable crop, or they are cultivated after the rainy season. However, the volume of stream water is small, the time employed in constructing and maintaining the canals (from wandering cattle) is great, and the area-extent of irrigation very small. Of course, irrigation is unnecessary during the rainy season. This community grows only one crop a year (1 1/2 if the little rains are good).

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[1] This may lead into the very complex land tenure system. Suffice it to say that both peasants and lords have rights (rist) but that the peasants are bound to the soil to a significant extent, by many legal or traditional restrictions.

Human energy use in plowing is great. While the soils are generally deep and volcanic in origin (lithomorphic soils developed on calcareous and igneous rocks, and organic soils; there are no laterite soils in this region), the ground is very hard after six to seven months of totally dry weather. In addition, there is little flat land, and the grade of the hills varies constantly. It is not uncommon to see unterraced plowed slopes of at least 60 degrees from the horizontal. Erosion is a serious and endemic problem. Oxen, as mentioned, are not common but used when available. Ordinary cattle don't appear to be used as substitutes, but occasionally horses were. In some places, fields are burned to prepare them for plowing and to make ash fertilizer. However, this is not a widespread practice around Debarek. Some rotation of fields or crops exist, but this is influenced by land tenure relationships which are very complex. Also, a farmer's fields are often separated, and so cannot be plowed at the same time. The great preponderance of land is farmed by tenants of absentee landlords, although some petty landlords live in the town along with a good number of peasant families. Only men plow the land. Young boys and sometimes girls almost always take care of the flocks (with varying degrees of reliability), although occasionally they help with the sowing and harvesting. Women take no part in these activities although they play a large part in storing and processing for home consumption and the growing and selling of vegetables. In addition, women usually take care of milking and butter making, the selling of these and eggs and whatever fruit might be had. Usually, the men take their own grain to be ground or traded.

Reaping (of which barley and oats are the most common, closely followed by wheat and lentils) is done with scythes. Bundles of cut grain are left in small piles and upon the completion of a field, gathered into one big haystack. The haystacks are left uncovered. Later, usually after several weeks, the grain is threshed by throwing it on the ground in a circle and having cattle tread on it. The grain is then placed in hide sacks for transport to market by donkeys or men. Beans and chickpeas are processed by hand by men and women.

Family storage facilities for grain consist of either heavy, hardened mud pots, of perhaps 10 kg. capacity and tall (four or five feet) thin-walled, tube-like dried-mud containers of perhaps 50 kg. capacity. Straw is usually kept outside uncovered or in a crude lean-to-type barn or in a tukul (a small round grass and mud hut also used as a dwelling). Meat is preserved, occasionally, by drying it and hanging it in strips in the house. The preserved strip, which seems to rot as often as it dries, can then be most palatably used as flavoring in a stew. Little else is stored for long periods other than potatoes and maize (which is procured through trade with lowland people.) These items are stored in covered baskets. Any modern container whatsoever is recycled and used until it disintegrates. Indeed, glass jars, plastic bags and containers, large tins, cardboard and wooden crate boxes, and the lowly tin can are important trading items for sale in the market.

Agricultural implements are few and made either at home or procured from the few artisans or farm trading shops. These include plow tips, the mortuaylow bret which is a combination crowbar and hammer which frequently has a hoe-like chopping blade, as well as axes, chisels and knives.

However, most agricultural-related items are made at home, including leather harnesses, wooden plow parts, baskets and pottery of all kinds, and mortar and pestle containers (the "pounders" are usually large chisels or wooden clubs). There is little or no use of labor-saving devices, such as pulleys, and no use of devices such as watermills or well crank-lifts.

Since wheeled transport is rare (there exists only one cart in the entire town and environs) and roads non-existent, human and animal transport is well-developed. Leverage is used in carrying heavy objects. For example, a carrier will extend a long, stout stave backwards from one shoulder across and underneath the large, bulky load extending from the other shoulder, thus balancing the load and relieving the strain on one side. Using this method, bundles of hay, firewood, large boxes and other loads can be carried by one man. In the Debarek area, it is rare for people to carry things on their head, although carrying loads on the back in a bent-over stance is very common with women (carrying loads of wood, household effects and especially pots of water). Donkeys are the most common means of animal transport of goods such as grains, dry vegetables, firewood, and bulky objects. Horses and mules are the most common form of personal transport, other than by foot. In fact, most peasants are too poor to buy a horse (average price: 1973-74 $20 - $30 U.S.).

III. Household Energy Needs and Tasks

A. Buildings

In a community such as Debarek, almost all economic tasks take place on the farm and in the house. Thus, household tasks play a far greater role in the economic life of the village than do market shops or artisans.

Perhaps the most basic and certainly the first household task is that of building the house. Except for a few modern structures made of mortar and stone (usually public offices or a few rich men's houses), structures fall into two types, both constructed by individual families or other informal groupings. One kind of house, most common within the town proper, is the chika bet style (mud house). Rectangular in shape and usually one or two rooms in size, this kind of house is characterized by a wooden skeleton (perhaps, 25 feet by 35 feet) covered with a skin composed of mud and straw. Sometimes, the house may have a separate cook-king house, similarly constructed. A corrugated tin or thatched roof completes the structure. The floors are of hard-packed dirt with a small depression at one end where the cooking is done. If the homeowner can afford it, the outside of the house is covered by a lime-based whitewash, very coarse and crumbly in nature, which doesn't last many years. Oc-casionally, a farmer will have the inside whitewashed if he can afford it. If the latter is done, lighting, through the reflection off the white walls, is improved. The houses tend to be poor insulators of heat. Aside from cracking after time, especially at the corners, the tin roof allows heat to penetrate during the day and cold to come in at night. If the house has a window, it is small, paneless, and closed by a hinged shutter which rarely is flush with the window frame. The same is true with the doors. If the house has a backyard, it usually has a back door.

Houses are constructed of eucalyptus poles. These are fashioned to fit, either with an axe (which is rare) or by a mortuaylow. Saws are almost unknown. Most of the time the wooden frame is put together with nails, especially in houses near the town, but occasionally bark strips are used to tie the poles together; dried mud later provides "permanent" support. These houses are expected to hold together for about ten years. They eventually either collapse by sagging off to one side, or coming apart at the seams. In either case, the main culprit is the rotting of the poles at the base of the ground (the "foundation" is a rectangular ditch in which the poles are set and supported with packed rocks and dirt). Nevertheless, if the owner can afford it, two-story houses of this nature are built. Some even have attached balconies.

The other kind of house is a tukul. This is the traditional Ethiopian structure, resembling the kind of hut found in other parts of East Africa. In many parts of Ethiopia, it is commonly constructed of close-set poles, arranged in a circle and interwoven with straw or heavy reeds of some sort. However, in Debarek and other highland areas, it commonly has the kind of mud walls described above, although still circular in shape. Moreover, it always has some sort of thatched roof, well-layered and "glued together" in layers with a mud mixture which effectively keeps even heavy rains out (though requiring at least yearly maintenance). Rarely attaining the size of the rectangular (mud houses), a well-constructed "tukul" is nevertheless not cramped. In the countryside, where most tukuls are found, they are often grouped together in a small circle with the peasants' fields laid out "in back" of them. Within, the floors are of packed dirt with a cooking hole in the center of the house (which is one large room). Ranged around the wall are ledges of packed earth for sitting and sleeping, giving a slightly "sunken living-room" effect to the interior.

Modern buildings in Debarek are of two types: those built by the occupying Italian army and those built since. The buildings built by the Italians in World War II are similar to those in small towns in Italy. Stone and mortar with plaster-covered surfaces constitute the frame, and a corrugated tin roof completes the structure. Arches, round windows, modern doors and ironwork are also characteristic. There are only about a half-dozen of these structures--all for administrative use now. The other Post World War II structures consist of a few rectangular stone and mortar houses, almost all of which have some part using mud and wood, usually the latrine or servant's quarters. The secondary school, serving half the province, was financed by the World Bank and built by the Swedish International Development Authority. Consisting of three long buildings, two modern latrines, and a small electric generator house, it is the most modern structure in the district. The walls are made of concrete block and mortar. One half of one wall, though, has windows which are arranged as small, rectangular rows of panes (about 4" by 18") which can be opened and closed in groups of four. The latrines are built for a plumbing system that doesn't exist, and so are used for storing hay. An electric generating unit has recently been installed, with wires buried in metal pipe leading from the generator house to each school building. There are, however, no operating funds for fuel or lights, so the generator isn't used.

B. Lighting

In Debarek, lighting needs are, for most of the people, not a great problem. For students of peasant families who need to study in the evening, the lack of poor quality of light is an important barrier to their progress. Likewise, lack of portable lights or streetlights make night-travelling hazardous due to the rough terrain and the possibility of robbery (not very common except on market day). However, most people "turn in" at about 9:00 or 10:00 in the evening, arising before dawn at 5:00 or 6:00 (or earlier, depending upon the season and their crops). There was no electricity in the village until the spring of 1974.

There is now electricity for lighting from 7 p.m. to 11 p.m. each day. The electricity comes from a diesel generator provided by the government (through direct taxes levied on the town residents and countryside, some years before, for this purpose). The generator is located immediately outside the town proper in a very large corrugated tin shed. For the people living in the town, installation costs vary directly with the house's distance from the main road. Electric wires for street lights were strung at government expense only along the main road. Individual house lines, however, are payable before installation, and utility rates are assessed on the basis of a flat fee calculated on the number of outlets per house. There is no metering, and lights come on and go off automatically. (The only way to turn off the light before 11 p.m. is to unscrew the bulb.) The electricity is as often as not inoperable, and electricity is not available outside of the immediate town. Within the town, few people can afford it or need it, and it is confined chiefly to hotels, groceries, and "coffee houses" (bars).

Flashlights (made in China) are fairly common, but usually just with town-dwellers, and batteries present a chronic replacement problem. Only one or two groceries stock them (usually Everready-type) and are not consistent about restocking. Candles are also widely used in the town. They have the disadvantage of not being terribly cost-efficient. A relatively great number would be needed to light a room sufficiently for reading, for example. Candles (made in Ethiopia) come six to a box for $.40 U.S. (1973-74). They also tend to burn down very fast. Other sources of light include pressure lamps, using kerosene (East German and Chinese kerosene-wick lamps, with or without a small, round mirror fixed on the back to augment the light, bottled-gas lights (very rare), storm lanterns (kerosene), and for outside use, torches made of twisted straw and a flammable substance at the top. Almost all of these forms of lighting are expensive by peasant standards and only a small proportion of the town population uses them. Kerosene-wick lamps are actually more common in the town. Some metal varieties are made in towns the size of Debarek, but apparently not in Debarek itself. Most peasants use torches, or the light from cooking fires, or, less often, candles. However one occasionally finds people using wick lamps based on animal fat or vegetable oil.

Lighting, even during the day, in most peasants' households is rarely sufficient to read by, particularly in "tukuls," which almost never have windows. However, lighting from the doorway and cracks is sufficient for cooking, food preparation, cotton spinning and other such activities. In town, most houses do not have glassed windows, merely shutters. Those that do have glass are windows of the sash and pane type with latch fasteners.

C. Heating

Heating is rarely ever a function in itself. It is usually combined with cooking or is part of the purpose of clothing. This is not to say it isn't warranted. Overnight temperatures in December and January frequently go down to 8 - 10 degrees centigrade in early morning, rising only to about 18 degrees centigrade during the day. At even higher altitudes, such as the village of Sancober (13,000 feet and some 20 km. east), temperatures in early morning may drop to -5 to -7 degrees centigrade. Heating as well as cooking is done with either firewood (or tree litter), charcoal, dried dung, kerosene pressure stoves, or as a result of heat given off from cooking with bottled-gas stoves. The latter are found strictly in the town and mostly in commercial buildings. Most portable for heating and cooking are the square, enclosed metal charcoal braziers. These have windows on two sides and a top grate which can be removed. They are usually about a foot wide on each side, and when not used as "one-burner" stoves, can be utilized as space-heaters.

Charcoal is either made at home (usually by peasants) or bought in roughly 15 kg. bags for $1.50 U.S. (1973-74) in the town. Charcoal made by peasants is processed by burying smoldering wood under a cover of earth. Charcoal does not appear to be used very often by the peasants, and then primarily during the harvest season out in the fields to keep farmers warm while guarding the crop, and, it is said, to restore ash (as fertilizer to the soil).

Long before the turn of the century, almost all virgin forests in the highland areas had been cut down for fuel or building without replacement. Native species in Debarek were mostly cedar, pine, juniper and several species of acacia. Around the turn of the century, Emperor Menelik II introduced the Australian eucalyptus to Ethiopia, expressly for reforestation which was a critical problem even at that time. It has since spread throughout the country and provides the principal fuel for heating and cooking as well as the principal building material. It is very rapid-growing, is apparently unappetizing to free-wandering goats and sheep, and is easily burned, although Ethiopians consider it a poor choice for building use because of its tendency to split and to expand (thus loosening nails) when it dries out. But if it is used after drying out, it is extremely tough and difficult to nail. The tree also develops knots and has a tendency to grow in a twisted fashion, making it poor material for furniture as well. Nevertheless, the peasants widely perceive its utility and it is planted as a crop, although not nearly sufficient for needs (except in the immediate environs of the town). Eucalyptus trees are also used as wind shelters in fields and cut to build fences. However, population pressure and cropping patterns severely constrain areas of tree-growing, in general. Another problem is the cutting of trees before they are fully grown. As a result, eucalyptus groves tend to be clumped in non-tillable, or very steep areas (which is good in preventing erosion but not widespread enough), or grown by those who can afford to give up crop land to long-term tree-growing. Thus, dung and tree litter are actually more important sources of fuel for the average peasant while purchases of firewood, relatively expensive, are occasionally made as reserves.

Firewood in Debarek is rarely purchased already cut. An individual usually picks out his tree, pays the owner a price, and hires a common laborer to chop it down (or he cuts it down himself). This is true of the town-dweller as well as the peasant. In 1974, a roughly 50 foot eucalyptus tree, bought, felled, and cut up into firewood size (a two-day task) would cost about $6 - 8 U.S. Judiciously used, such an amount might last more than half a year.

D. Water

Water is obtained in one of three ways and usually a combination of them: wells, stream water, and water catchments. Within the town, some nieghborhoods have primitive wells with restricted access (to the family or neighbors). These wells are rarely, if ever, lined with stones or cement, and probably no more than a few are operable. Occasionally, they might have a wooden top. They tend not to be deep and are found in the lower parts of the town. Several years ago the U.N. built some deep cement-lined wells (three or four) in the town. All but one are now sealed over, reportedly having "dried-up." In any case, no well, no matter its depth, operates under a crank-life arrangement or a pump system (manual or otherwise). Usually the hired laborer or the woman will straddle the edge of the well and haul the water out by the buketful. Five-gallon metal buckets (Polish) are the only manufactured water-carrying device used in Debarek. They are highly prized and fairly expensive for the average peasant.

By far, the preponderance of the town's water supply comes from two perennial (barely) streams that flow just outside the town proper. Water-carrying is the exclusive job of women. They make journeys down to the streams with large, heavy pots strapped to their backs. These pots, empty, weigh about 15 - 20 kgs., and have a capacity of 7 - 10 gallons. Of course, the distance from the stream varies but seems to average between several hundred meters to about a kilometer at most. Virtually all water is carried from the stream on the backs of women. Occasionally, a peasant might procure empty 10-gallon tins (from cooking oil or gasoline, etc.) or sew-up animal skins and strap these to a donkey (no more than two containers/trip) for water-carrying. But for some reason, this practice is very unusual.

The third source of water supply is catchments in the form of rain barrels. If the building has a gutter spout, the barrel is located at one end. However, gutters are extremely unusual in Debarek (only the two schools and a few administrative buildings have them). Nevertheless, during the rainy season, a rain barrel the size of an oil drum fills up in a few weeks. They rarely cost less than $8 U.S. and thus are out of the reach of most people and certainly of the peasants (who mostly have thatched roofs anyway). Partly this is due to their low marginal cost/benefit relationship. They are only available as a source during the rainy season (4 months/year) and impractical for long-term water storage (they tend to rust).

Water uses in Debarek are probably similar to those in any society: drinking, cooking, cleaning, and irrigating.

1. Drinking

Though certainly necessary in the dry season when water supplies are low and often stagnant, water purification is necessary during the rainy season as well. However, this practice is rare because of ignorance as to its health benefits and because the techniques or equipment necessary are not known or readily available at reasonable cost. Many, though certainly not all, "educated" Ethiopians at least boil their water before drinking it. Few filter it because of the expense required for purchase of a device for doing so (which is available only in provincial capitals). Drinking plain water is not so common anyway. Most drinking water is converted into tea, homemade beer and wine (tedj), coffee, or used in cooking.

2. Cooking and Food Preparation

As the national dish, injera na wat (very similar to Indian curry and chapati) requires water for the various stews as well as water for flour batter, it is used accordingly. This usually amounts to a pot a day or less. (Water pots, called gumboas, were described above.)

3. Cleaning

In Debarek, as well as in most other rural areas of Ethiopia, washing of one's clothes or person takes place down at the stream. Clothes-washing is an integral social task as well as a personal one, although not done nearly as frequently as in modern societies. Although in the family setting women usually wash the clothes, it is not uncommon for a man to do so when necessary--and especially if he is paid to do so. Women go down in groups of neighbors and wash their clothes by pounding them with smooth rocks on rock slabs, rinsing and squeezing in the stream. Many townspeople use special detergent bars ($.05 Eth./bar). Peasants often do not, distinctly considering soap a luxury. In the dry season, this use of soap and detergent in low-level streams becomes a real pollution problem in the vicinity. Newly woven cloth is bleached white with the juice from the berries of a bush (called endod (Phytolacca dodecandra) which has the additional advantage of being a molluscide, capable of killing schistosomiasis-bearing snails. Clothes are dried by spreading them upon the grassy banks of the stream. With near-constant dry winds available, clothes-drying is effortless (or nearly so). Personal bathing is not common, due, at least in part, to the cool climate. People bathe down at the stream as well, except for some of the better-off towndwellers. Certainly, bathing or cleaning with heated water is not practical and is not available even on request in the small town hotels. Though a number of houses in the town have outside latrines, this is not a common practice at all, even among many educated people. It was not at all the practice in the countryside. However, as defecation is done in wooded areas, if possible, for privacy, waste removal is not perceived as a problem. Unfortunately hotel latrines are rarely cleaned, either, although lime is used sporadically by some people to aid in waste decomposition i latrines.

The extent of irrigation has beem referred to. Where there are no canals, occasionally people will carry water from stream to garden beds themselves.

4. Livestock and Other Animals

Livestock and other animals are all watered at the stream. If pasture lands abut a stream, and most do, this is not a specific round-up activity but a casual one taking place all day long. But for those farther away, herding to the water's edge is done at least once a day. Herding is a fairly difficult job in itself when done by small boys and girls without the benefit of sheep dogs (although occasionally a boy rides herd bareback on a pony, cowboy-style). As the amount of water runs low during the latter part of the rainy season, simultaneous animal watering and water-filling for humans, occasionally leads to quarrels. Watering the animals at the river's edge of course means that the animals frequently relieve themselves, as well, in or near the stream, raising a health problem.

E. Cooking and Food Processing

Processing of food has at least two different aspects: a) processing for immediate use and b) processing for long-term use. The first involves preparation of the food in an easily manageable or edible form including activities such as threshing, winnowing, grinding, pounding, killing and skinning, and of course, cooking. The second involves various ways of preserving and storing food. The relationship between organic combustible fuel and cooking is very important traditionally. Ethiopians believe that adding smoke will drive out impurities. Thus, various things such as dried meat, milk, butter, and even beer and home-distilled liquor is smoky-flavored.

The threshing process has already been described above. There are no machines utilizing inanimate energy for food processing in the village other than the grinding mill. Vegetables and fruit are prepared by hand in a straightforward fashion. Some kinds of food must be dried before they are used, most notably chile peppers (a vital ingredient in Ethiopian cuisine) and gaysho (Rhamnus prinoides), an ingredient in beer-making. Normally, it is sufficient to spread these out on skins or clothes in the sun. Some kinds of food are ground before using, including grains of all kinds, although roasted grains are a common snack as well. This is normally done on a smooth rock approximately two feet in diameter, possessing a slight slant as well as a slight depression in the middle. This is to keep the grain on the rock. Another stone is pushed and pulled across the grains to grind them. Other kinds of food are pounded, including coffee beans, spices and a number of other grains such as sorghum and millet. These are placed in a kind of wooden mortar resembling a small cannon piece (perhaps four feet high but hollow only about one-third of the way down). The food is pounded to a pulp with a heavy wooden club (or less commonly a kind of blunted crow bar or long spike). For small jobs, there are also small pounding vessels.

Winnowing is an important step in the processing of nearly all grains. After the grain has been lightly ground initially to remove the husk, it is placed on a large round mat of woven straw and winnowed through the process of tossing it in the air and allowing the wind to carry off the chaff. For small snacks, the same preliminary process is repeated. The actual separating of the chaff from the grain is accomplished by taking

a handful and rubbing it briskly between one's palms. Then the hands are cupped and by lightly blowing into them grain is sifted and the snack ready to be eaten. Mashing such things as bananas or soft vegetables is not done except with regards to the making of homemade beer. Here, the barley grain is first mashed lightly, then soaked and scooped together for the beer mash.

The eating of wild animals as well as pigs is prohibited by all the local religions. Fish is not eaten in this area by tradition. All other animals, including cattle, sheep, goats and chickens are killed according to the Judaic Law by cutting the throat and draining the blood. All operations are performed with a knife. No woman is ever permitted to kill an animal, but they almost invariably cut it up and cook it (unless the man is a servant). The meat is usually boiled or fried but occasionally roasted on a spit. Virtually all parts of the animal are eaten with the exception of the colon. All animal skins (except chicken) are either sold or dried and stretched at home. The skin may amount to as much as 30 - 40% of the total price of the animal.

The staple dish injera na wat is a stew-curry and pancake or chapati combination. In a town like Debarek, little else is eaten. The stew can be made from anything, meat or vegetable, but rarely both at the same time. The pancake is made from wheat, teff, barley, or maize. The most highly-prized injera (pancake) is made from teff - an indigenous Ethiopian grain (Eragrostis teff). Due to the high demand for teff, it is the most expensive grain.

Injeras can be made very rapidly and are done so in the same way as crepes. Briefly, first a large (18") heavy, black lipped pottery disk is carefully rubbed until glossy with linseed or other vegetable oil and placed directly over the fire (which in a peasant's hut is encircled with rocks similar to American campfires, and in a town dweller's house is surrounded by a metal ring). The batter is poured thinly and very quickly in a circular fashion, then covered for about 30 seconds. The pancake is flipped off, the dish quickly re-rubbed and the process started over for the next injera.

The wat or stew is made by first roasting the spices lightly. Then water is added to make a paste. This is mixed with the meat or vegetables and sauteed. After adding more water, the mixture is cooked for a very long time, as long as a half a day on a low fire until ready. However, a batch made in this fashion will not usually be consumed all in one sitting unless there are many people present.

Eating and drinking utensils are an unusual combination. With rare exceptions, the custom is for meals to be eaten collectively. Thus, the injeras are laid in a shallow basket and the wat is poured on top. The food is eaten without utensils. If a cold liquid is consumed before or after the meal, any container may be used, including tin cans or jars, and less often glasses. In the countryside, peasants often make their own cups by hollowing out cow's horns and stretching them over heat, which creates a satisfactory container. Usually tea and coffee are drunk out of

a findja, a very small demi-tasse-like cup which even peasants try to procure (occasionally even as wedding gifts). Most townsfolk have cooking pans similar to the Western type of steel or tin manufacture. Most peasants also have metal cooking pots. A few use heavy pottery, although this appears to be fairly uncommon for cooking.

Preservation and storage of food can be a real problem. Characteristically, the quantity and variety of diets noticeably improves immediately after harvest, as compared to the end of the dry season when one may find spot shortages even in the big cities. This is at least partly due to the inability to store much of the harvest for a long period of time. Neither peasant families nor town dwellers consciously employ any techniques of preservation using cold temperatures even though, given the climate, such is definitely possible. (For example, due to the generally cool weather, creamery butter can be preserved for from three weeks to nearly a month by merely keeping it wrapped in a wet cloth in a dark place. This capability drops to only two weeks during April, the last month before the cooler wet season arrives, when the sun is at its zenith--just north of the equator.)

Most commonly, potentially spoilable food is preserved by drying. An example of this method is the aforementioned dried meat which was hung up in the house on a line in the form of bacon-sized strips. This form of preserving seems to have a high failure rate. Butter is always preserved, that is, it is never consumed fresh unless it is Western-style creamery butter from the larger cities (very little of which is sold). This is partly because of culinary reasons and partly because of the lack of refrigeration (although which came first is hard to say). The butter is usually melted and mixed with hot spices which presumably destroys any microbes. It is then poured into a container, either a gourd (in the traditional fashion), or a pint beer bottle (increasingly common and an example of recycling). Spiced butter is an important ingredient in making quality wat. However, because Ethiopian cows give little milk (an average of 2 litres per day and then only briefly after calving, butter is very expensive. Indeed, many peasants smear it on their babies as a sign of wealth (attracting a horde of flies in the process which further leads to the high incidence of trachoma).

As mentioned before, grains and vegetables are stored in mud-hardened pots and baskets of all shapes and sizes. Some are covered with leather while others are plain. Basket-weaving is a fair art in the country and styles vary widely from district to district. Debarek favors leather-covered baskets which can be used to hold ready-made meals to be taken on journeys. Pottery, in terms of variety and quality, seem to be much less developed. All pots seem to be made in the coil fashion. Each of several coils is allowed to begin drying and then is smoothed and toughened by hand with water before a new layer is added. Finally, the completed pot is dried out and sun-baked. As a final measure, the pot is given repeated coats of linseed oil both inside and out which are rubbed in by hand until it assumes a near-permanent glossy finish. This is presumably to prevent cracking and crumbling, because the tall cone-shaped

storage pots, alluded to above, are rarely "finished" in this fashion and have a tendency to disintegrate after a while.

Some farmsteads have crude barns--little more than an elaborate "lean-to" or an occasional extra tukul to keep animals sheltered. However, the vast majority of people keep their animals in their houses with them. This is true of some town dwellers as well who own farm animals or else buy their meat "on the hoof" but are not ready to consume it yet. This practice is partly due to the need for protection from predators and the lack of guards as well as the cool climate. It also has the advantage of keeping both men and animals warmer by having them under one roof.

The chief menace in Debarek, in terms of preservation and storage, is rodents (the ubiquitous field mice and rats) and to a lesser extent--flies. The former are of a very determined variety. Cardboard, for example, presents little challenge to their abilities. Hence, the added necessity of keeping everything in pots and baskets.

F. Clothing

This aspect of energy use is increasingly dominated by the trade and manufacture of artisans. Nevertheless, for most peasants, the bulk of their clothing is homemade. In fact, a peasant woman can turn raw cotton into a fairly complex garment, as part of her regular housework, in a few weeks. Both cotton and woolen fabrics are made at home.

Raw cotton brought from the lowlands can be purchased at the weekly market. This cotton is then spun into threads by wrapping a piece of cotton around the needle end of a hand-held bobbin and spinning it between thumb and finger, gradually adding on clump after clump of fiber. This spun cotton is then usually taken to a village weaver who (as opposed to a larger town weaver) weaves it on a simple, traditional wooden loom. The owner then either sews the fabric into a garment or takes it to the town tailor or some other person who does this work by hand. Both men and women sew. Sewing machines are operated almost exlusively by men who also traditionally tend to knit more than women. Embroidery is common on some kinds of garments, notably women's dresses and veils. Wool is sheared with a knive but usually only after the animal has been killed. The wool is roughly twisted by hand and woven into a variety of objects; mostly brimless hats, belts, shoulder bags, rugs and blankets. An item the size of a rug or blanket, however, is almost always woven on a loom rather than knit by hand. Woolen garments, considered crude by everyone except foreigners, are rarely worn by town dwellers unless they are laborers or small farmers living in town.

Wardrobes are not extensive. The women living in town wear Western-style long frocks, often as many as three or four at a time, rotating them inside to outside as a change of dress every few days or so. Men and women both wear "shammas," an all-purpose, heavy cotton cloak that functions as coat, blanket, pillow, disguise, and according to its quality, an indicator of wealth. Depending on how it is worn, it can even signal

a certain mood or emotion (grief or anger, for example). One odd form of protective "clothing" is the umbrella used by peasants or shepherds during the rainy season. Woven out of reeds or straw, this cone-shaped umbrella completely covers the individual like a grass poncho but without openings for either head or arms. The effect is a goblin-like appearance.

Most Ethiopians never wear shoes or boots at all. This is particularly true in the countryside, although increasingly some of the peasants as well as more of the town dwellers are wearing sandals (made from leather, old rubber tires or manufactured plastic types). Less common are western-style shoes and gumboots, although both exist in a town such as Debarek. Gumboots are relatively expensive (about $1.50 U.S.) and tend to wear out quickly in the rough and rocky terrain. Ethiopian-made tennis shoes are increasingly popular, especially with students.

IV. Transport

In traditional Ethiopia, the wheel, as a basis of transport, was unknown. Thus, no roads exist outside of the ones built during the twentieth century. These are limited to city and town streets and the major "highways" linking the fourteen provinces together and joining them with the capital. Addis Ababa is clearly the hub of the national road transport system.

In Debarek, one of two highways linking Addis Ababa with Asmara (the capital of Eritrea) runs through the town. The road is approximately 15 - 18 feet wide and was constructed by the Italian Army during World War II (with local labor). It has an "improved gravel surface" (Michelin's classification) which nevertheless is extremely dusty in the dry season. There are no other roads within the town, though at both ends of the town on the east side, two crude dirt roads extend about a quarter mile in from the highway. In the dry season, only, they are traversable by four-wheeled transport (leading to the market and the district governor's house respectively). No other roads exist except for horse-trails and cowpaths. Given the terrain of Ethiopia, particularly in the mountain regions, it would seem extremely difficult and costly to build and maintain any kind of extensive road network. Two Land-Rovers are the only automotive transport owned by town residents. One belongs to the district governor; the other to the district veterinarian.

Bus service is the principal public means of transport. Two kinds of buses stop in Debarek for two kinds of journeys. Long distance buses as large as Greyhound buses, but with large baggage racks on the roof, ply the distance between Addis Ababa and Asmara, stopping usually once a day in Debarek in each direction. The other kind of bus, known as Lonchinoes are much smaller. This kind of bus runs shorter trips, usually of a maximum of 100 km. or so, one way. Thus Debarek is the terminus of a Debarek-Gondar (the provincial capital) run. The trip takes about two and a half to three hours each way. At least two such runs a day in both directions are available.

Generally speaking, the cross-country buses are highly professional, well-maintained operations. Again, generally the Lonchinoes prove a risky deal, but they offer the incentive of cheaper rates for the same distance.

The principal problems of Lonchinoes are extreme over-crowding, occasional "sharp" practices (over-charging of fares), frequent mechanical breakdowns, and very casual schedules (planning one's schedule is generally a worthless endeavor). Nevertheless, the Lonchinoes are very important, because peasants wishing to market surplus produce and grain in other towns and cities (where they might get a better price) and petty traders going from one weekly market to another rely on them for transport. Appropriately, Lonchino operators (invariably privately owned) do not charge for personal baggage, but do so for marketable cargo (which usually weighs more anyway).

Much more rarely, a jitney-type service comes through Debarek, usually in the form of a Land Rover or panel truck. However, this is too infrequent to have much impact.

For most peasants, certainly, transportation for themselves and their goods is by foot or hoof. Moreover, except where it proves convenient, walking or horseback travellers rarely go by the main roads when there exist many trails and paths more direct and safer (from buses). Given Debarek's terrain, development and climate, horses and mules for transport are rather common. In consequence, they also take up a fair degree of land for grazing. But it is uncertain whether this land would have been given over to cropping in the event of other means of transport. In Ethiopia, as in the U.S. West, mules, donkeys and horses are highly prized (although ill-treated by modern American standards).

In terms of load-bearing, horses are much less efficient than donkeys or mules. Whether this is because of the more sure-footed nature and better temperament of the latter, or because of different needs (riding as opposed to bearing) is uncertain. Normally burdens are tied on with leather straps (peasants rarely own rope or wire). Wooden saddles with cloths and a cutting bit are trappings for horse-riding, although bareback riding is not uncommon for youngsters.

Much short-term hauling is done by people. A grown man, unless he is a servant or hired laborer, rarely shoulders burdens (this includes peasants). Most loads are hefted by women and children. Women clearly do the lion's share of drudgery work, carrying water, large bundles of firewood or other bulky loads. This is almost always done by strapping the load in question to the woman's back. Nothing is carried on the head. On the other hand, men usually carry burdens on their shoulders, very rarely carrying something on their backs.

V. Commerce and Crafts

The business section of the town is grouped around the open market and straddles the sides of the main road. Businesses are of three broad varieties: service, trade and crafts. Service enterprises include tea houses, coffee houses (which are also bars) and hotels. Trade, broadly speaking, includes traders of specific goods and "grocery-store" owners. Crafts include enterprises making things for sale. "Manufacturers" would be too grandiose a term.

In the service trade, tea houses are the most numerous. This isn't surprising, when it is considered that they are merely a house that serves tea and bread, both home-made, to the public. Usually run on a family-scale by a widow, the tea is brewed in successive batches on a wooden fire in a large tea-kettle. In Debarek, the bread is heavy, unleavened and made from coarse-ground grain. Tea houses are the chief social spot for peasants and traditional townfolk. Related to them are the "tedj" houses. Tedj is a homemade honey wine (very potent) and is the national traditional alcoholic beverage. (Moslems drink a similar non-alcoholic form of this drink.) Barley beer is also served here. ("Keeping" honeybees and collecting and selling the product is an important rural side-occupation.) Coffee houses are also bars and, in Debarek, are invariably part of a hotel. They are somewhat more modern, usually having cooking facilities as well (not usually modern stoves, however). There are five bars and thus five hotels in Debarek. The hotel section of the bar rarely has more than six rooms and usually less. Thus, Debarek cannot handle large numbers of visitors at once (even though it is the entrance to a national park). The average hotel room is small, usually about five by eight feet most of the time, without a window and capable of holding little else save one small bed. Candles are usually available for lighting. In general, the hotels have very much the character associated with medieval inns--which is really what they are (most even have stables and none have parking).

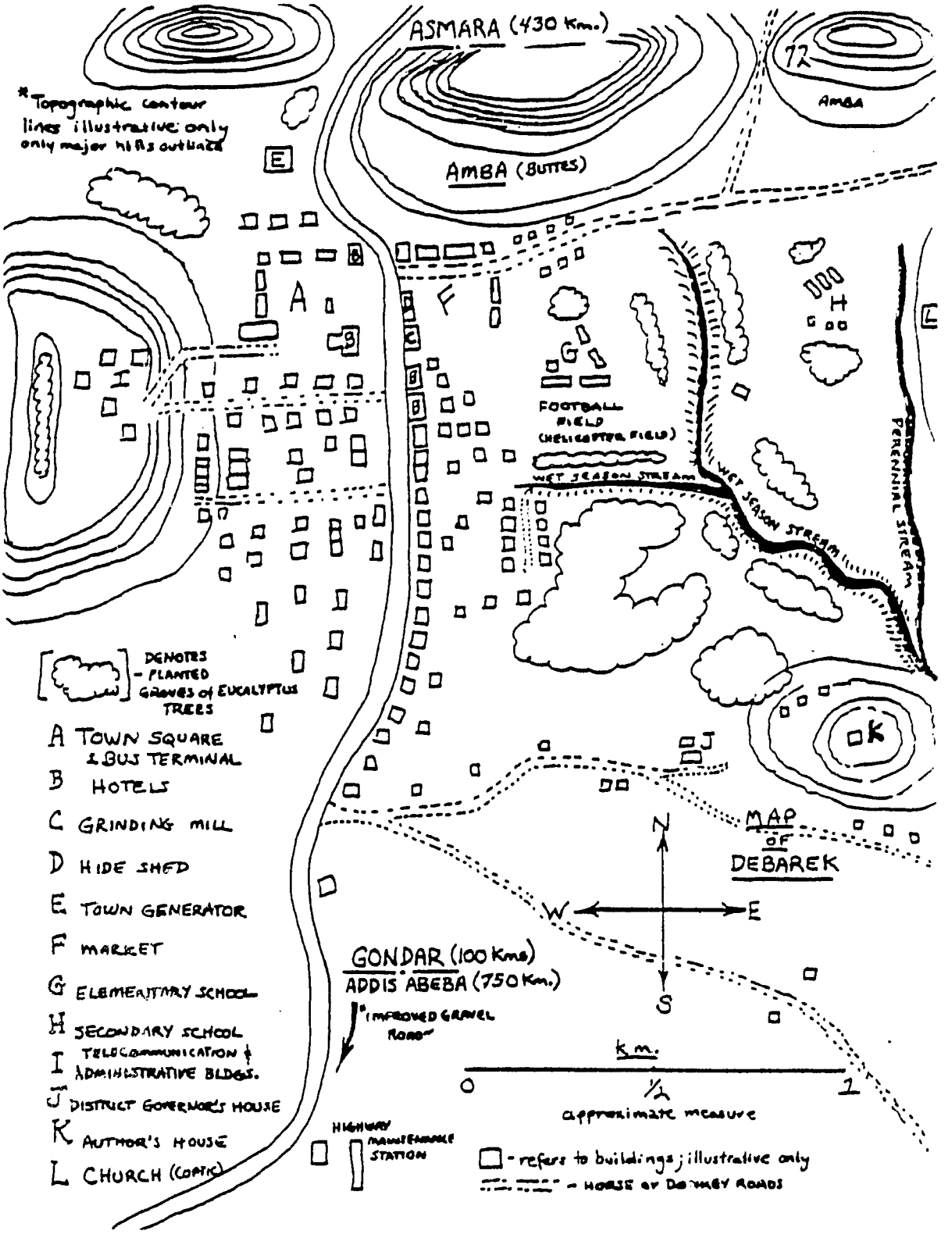
Traders do not usually have offices of their own. Only one or two in the whole town have storage sheds, and even these are of small capacity. Normally, they work out of hotels (if they are not residents) or even the tea houses and load trucks with whatever load of produce and grain is available on that market day. Debarek traders do not seem to be commodity-specific, except in the case of a very rich gentleman who owns the government sugar franchise for the region. There are also many small traders, but their activities would be hard to describe coherently.

Grocery-store owners are few and their stock of goods are meager and eclectic. Rarely numbering a few of each item, imported goods run the gamut from Australian canned pineapple to Italian cold cream. As a practical matter, the only significant items are matches, sugar, salt, ground grains, dry vegetables, legumes and lemons. Thus, for the most part, groceries are in direct competition with the market and seem mainly to offer convenience (e.g. ground grains and longer hours) or easy availability (e.g., salt and sugar).

The crafts industry in Debarek is quite small. For the most part, it consists of tailors who seem to be in direct competition with one another (yet, evidently thriving). In addition, there is at least one blacksmith and an occasional weaver.

The tailors all have treadle-style, Singer sewing machines of turn-of-the-century vintage. These seem quite efficient for the job and require no electricity. The tailors usually deal in commercial cloth but also do sewing work on traditional home-made cloth as well. Blacksmiths use charcoal fires for the most part and do traditional work with horse trappings, plow tips and repair of tools. However, at least one

does some reprocessing of recycled metal, e.g., turning tin cans into candle holders. As noted above, weavers use a crude-looking but evidently efficient loom for their purposes. Finally, a large shed in one corner of the market is solely devoted to the drying and stretching of hides. This shed, perhaps 20 feet by 40 feet has a tin roof but open, slatted sides. The hides are taken from the sheep (usually killed at home or some other place). they are cleaned by scraping a sharp-edged knife along the inside. Holes are punched in four or five corners (the four extremities and sometimes the tail). The skins are then strung up and pulled tight with ropes and leather thongs, to a wooden framework. In the drying shed this is one large framework. The wind and dry air quickly dry the hides. A truck comes to market on a regular basis and takes away the dried and completely stiff hides (fur still attached).


ASMARA (430 Km.)
AMBA (BUTTES)
AMBA
*Topographic contour lines illustrative only only major hills outlined
FOOTBALL FIELD (HELICOPTER FIELD)
WET SEASON STREAM
WET SEASON STREAM
PERENNIAL STREAM
DENOTES - PLANTED GROVES of EUCALYPTUS TREES
A TOWN SQUARE & BUS TERMINAL
B HOTELS
C GRINDING MILL
D HIDE SHED
E TOWN GENERATOR
F MARKET
G ELEMENTARY SCHOOL
H SECONDARY SCHOOL
I TELECOMMUNICATION & ADMINISTRATIVE BLDGS.
J DISTRICT GOVERNOR'S HOUSE
K AUTHOR'S HOUSE
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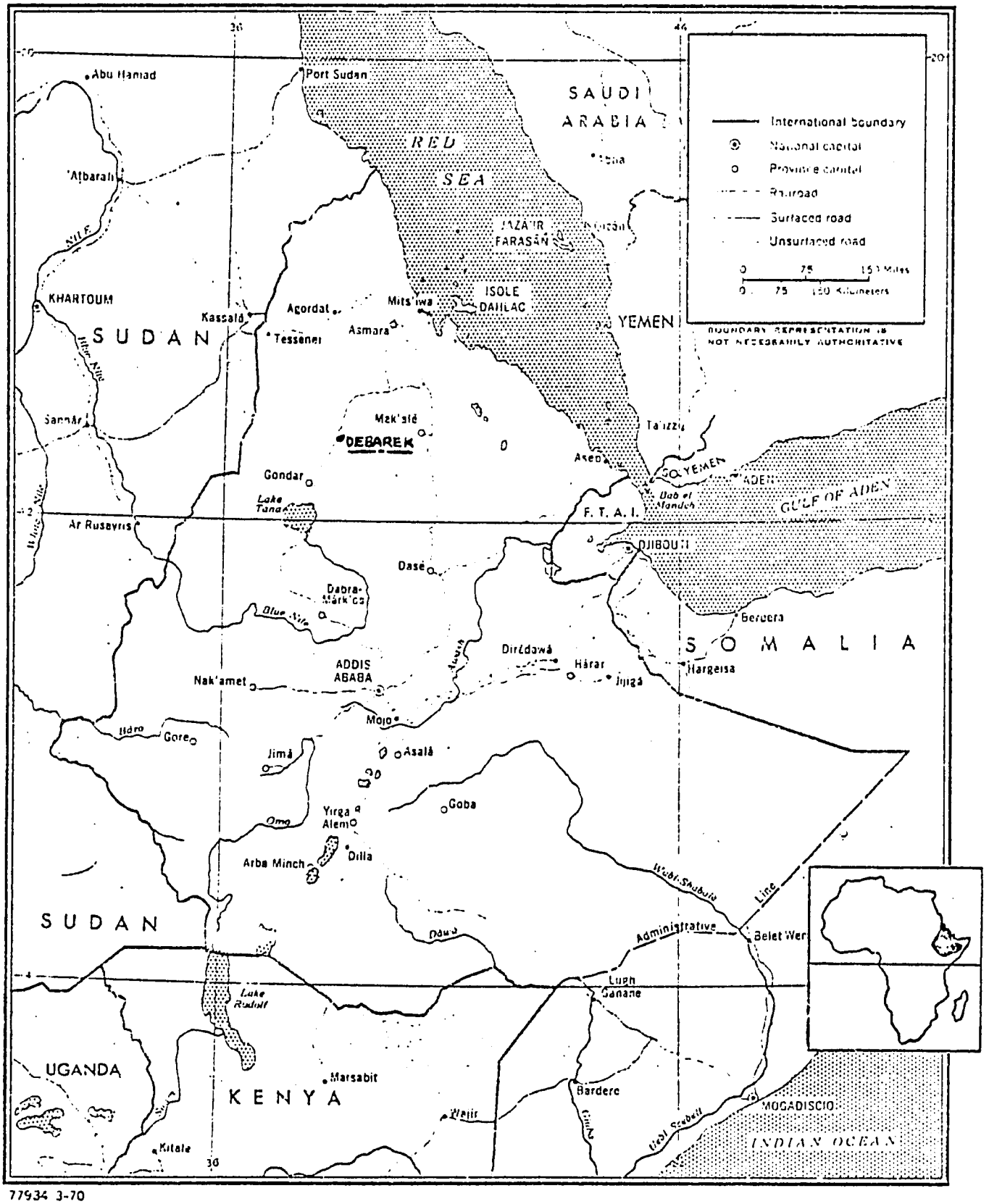
HIGHWAY MAINTENANCE STATION
- refers to buildings; illustrative only
- HORSE or DONKEY ROADS

ETHIOPIA



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APPENDIX II

Energy Needs and Tasks in a Sahelian Village[1]

I. The Milieu

The Sahel is a vast expanse of arid land south of the Sahara Desert, stretching across Africa from Senegal to Sudan. It extends southward from the sandy fringe of the Sahara to the more densely vegetated and watered regions of the savanna. The Sahelian climate is generally hot and dry, although there is a rainy season of several months duration, which lasts and hence limits the growing season from June through September. During the other months of the year there is little or no rain although a fairly abundant water supply can be found beneath the surface at depths of ten to seventy meters.

A more detailed breakdown of the dry season is as follows. October is a hot month (with average daily maximum temperatures ranging from 100° to 105°) which gives way to the relatively cool and pleasant months of November through February or sometimes mid-March. The local inhabitants refer to this period as the cold season, although the maximum daily temperature seldom falls below 80° on any given day. During the dry season, especially between December and March, harmattan winds laden with sand and dust sweep across the Sahara from the north and northeast and penetrate the savanna to the south. A torrid two month hot season precedes the first rains of mid to late May, during which the maximum daily temperature rarely drops below 100°.

On account of the paucity of rainfall and the prevalence of sandy soils, the vegetation in the Sahel is sparse, consisting of weeds, small bushes and occasional trees, usually of the neem, gao and baobab varieties. Most of the land in the Sahel can be cultivated, although perhaps 20% of it is lateritic cuirass, which is uncultivatable. A large percent of the soils in the Sahel, perhaps a bit over 50%, are classified as tropical feruginous. These soils are slightly leached, low in humus and exchangeable bases, lacking in phosphorous, and generally of low fertility. They are suited to the cultivation of millet, cowpeas, sorghum and other grains which do not require much water nor fertile soils of high phosphorous and humus content.

The village which will be described in this paper represents a composite of Sahelian villages visited by the writer in the course of a two-year stay in Niger. It could be any one of several villages around Ouallam, a town 100 kilmeters north of Niamey. This village could have a population of anywhere from 1500 to 4000 people, who inhabit a collection of mud brick houses and straw huts clustered about a permanent water source (either wells or mares). The village can be reached by

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[1] Written by John S. Holtzman, former Peace Corps volunteer in Niger who taught on the secondary school level from September 1974 through June 1976.

large market trucks (Mercedes, Savieum or Berliet), Land Rovers, panel trucks or durable smaller vehicles (such as the Peugeot 404) via access routes ranging in quality from tracks in the sand to all-weather laterite roads. A produce market is held weekly, at which grain, beef, some vegetables, animals (camels, horses, sheep, goats and cows), clothing, handicrafts, and a variety of luxury items (batteries, soap, razor blades, cigarettes, sugar, tea, etc.) can be purchased. This market will usually attract a large number of nomads and farmers from the surrounding bush, who may come from as far away as 25 kilometers on foot or on the back of a donkey, camel or horse.

The people in the village perform virtually all of their daily tasks by hand. The drawing of water, construction of houses, processing and preparation of foodstuffs, and farming are all done manually. There are one or two resident merchants who stock the village with goods from the larger towns and a handful of artisans, usually leather works, basket and cloth weavers, potters and tailors. The vast majority of the villagers are, however, subsistence farmers who have not changed their methods of cultivation for generations. They cultivate millet or one of the other basic grains and may have a small plot of spices and vegetables. Each family owns several goats and chickens and perhaps a sheep, a horse or cattle, though certainly not all three of the latter.

In many respects life in the village has been going on unchanged for centuries. People get around the village or out to their fields on foot. In addition, the village is not electrified, although kerosene lamps and flashlights are widely used. The villagers practice Islam and various forms of indigenous religion, and their family structure has been relatively untouched by time and French colonialism. Unlike the coastal areas, the Sahel was not subject to intensive colonization and the educational systems, missionary activity and economic exploitation which invariably accompany it.

Men, particularly heads of households and the older members of the community, make the important decisions concerning land use, the planting, weeding and harvesting schedule, marriage and divorce, and the division of labor among different members of the family. Women are generally excluded from the decision-making process even though they perform a good number of the daily tasks, such as preparing food, gathering firewood, drawing water, gardening, helping with planting, and caring for the family's chickens, sheep and goats. Formal decision-making bodies do exist, for there are traditional chiefs who consult the village elders on important matters, but this group does not meet on any regular basis. Rather, decisions taken by the village chief or by a collective body are made in response to conflicts which might arise, such as land disputes or quarrels over proper compensation in the event of divorce.

Although the village has in many ways retained its traditions, there are signs of change. There may be a government representative, such as an agricultural extension agent, health worker or teacher. The increasing availability of primary education, through which children learn the official language (French), has created new expectations among students and parents alike. A primary school certificate may lead to a clerical or teaching position and hence a regular income, with its attendant host of family obligations. Many villagers own radios which receive broadcasts in local languages which have expanded their limited horizons. In addition, the construction and improvement of roads have linked villages to urban centers and led to extensions of the market economy into the bush. Easier access to commercial centers has encouraged males to migrate in search of employment, especially during the long dry season when little is to be done. It has been estimated that about 50% of the able-bodied males have, at one point or another, lived and worked in one of the larger towns of the interior or less often in one of the large coastal cities or on a plantation in a coastal country. Finally, some cash crop production may have been introduced, for the government has encouraged the peasants to grow peanuts, rice, cotton and vegetables.

Thus, the former permanence and immutability of village life has been shaken. Farmers living at the margin are, of course, highly skeptical of change and not always receptive to new methods of agricultural or livestock production, for these represent risk. Opportunities for increasing income and greater availability of western amenities (radios, flashlights, shoes, sugar and the like) bode well, however, for further change.

II. Economic Activity: Primary Production

A. Agriculture

The principal crops produced by village farmers in the neighborhood of Ouallam are millet, sorghum, cowpeas and to a lesser extent manioc, sweet potatoes, groundnuts, maize and rice. Land holdings average about six hectares and they are cultivated by family units. In Niger land tenure varies depending on the ethnic group, but it is generally held in one of two ways, which correspond to those systems practiced by the two principal ethnic groups, the Djerma and Hausa. In the first system (Djerma) all the land surrounding a village is individually owned, whether or not it is actually being farmed. A farmer's prospects for expanding the area under cultivation in such a system are limited, unless he is willing to walk considerable distances to new, unclaimed lands which are not contiguous to his original holdings. In the other system of land tenure (Hausa), land belongs to whoever is willing to farm it. Each extended family traditionally cultivate certain plots, but none of them has any permanent claim to land. Instead, ownership is established and perpetuated through usage.

Although village chiefs in the Ouallam area may have substantial holdings, most of the farms are small, subsistence units. Cultivation can be extensive, particularly in the sandier areas closer to the desert, or intensive, as one moves south into areas where soils and rainfall are superior. Cash crops are farmed in larger villages, villages where there is access to an extension agent, or in villages with ready access to large urban markets. Peanuts, cotton and vegetables have had some success as cash crops on a fairly widespread basis, whereas wheat, rice and maize are cultivated to a lesser extent.

Given the general absence of surface water in the Sahel, there is limited irrigation. The little irrigation that does take place is done alongside the Niger River and near small lakes and ponds. The beds of streams which flow only during the rainy season and those of semi-permanent ponds which dry up during the dry season are cultivated intensively, for the soil remains moist even after the surface water has evaporated and pockets of water can be found beneath the surface. Invariably the topsoil which has been washed into these semi-permanent bodies is far superior to the sandier soils of higher and drier areas. This permits cultivation of vegetables rather than low-protein grains.

A kilometer to the west of Ouallam, there is a permanent pond which extends about 8-9 kilometers on a north-south axis. It never reaches a width of more than 100 meters, nor a depth of greater than two meters. During the dry season, the water level drops a meter or so, but there is always sufficient water for irrigation purposes. Alongside this pond, progressive farmers grow manioc, vegetables and sorghum for sale. They carry water from the pond to their fenced-in plots by calabash, metal can, or less often by watering-can. Calabash bowls and containers and metal cans are carried on one's head or by using a shoulder yoke. The water from this pond is not generally used for drinking. Villagers in Ouallam draw their drinking water from three cement-lined wells (of 20-30 meters in depth) at the outskirts of town.

Irrigation is done by means of mechnical pumps along the Niger River, but it is done manually in other places, with the aid of watering cans, calabashes, gourds, or weighted, rotating scoops. This last device is made out of wood, and it acts as a lever with a weighted end and a leather water contained at the other end. The weighted end allows the farmer to raise the water (usually about five gallons) from the permanent water source to the irrigation channels with little difficulty. At this point the device is swivelled around 180° so as to enable its operator to pour the water into the irrigation canals.

Villagers around Ouallam farm exclusively by hand, with the use of rudimentary implements. They clear their fields before the rains by burning off brush and cutting down trees with small hatchets. Planting is performed with either long or short handled hoes, and farmers employing the latter type are required to bend at the waist in order to dig

holes for the seed. Animal traction for pulling plows is virtually nonexistent. Holes are generally dug about two steps apart in rows, and a small handful of seed is dropped into each hole before it is covered over. When farmers weed they use a long-handled tool with a semi-circular blade, which is highly effective in loose, sandy soils. When harvesting the grain, farmers use one to two foot long knives to cut the millet stalks. These stalks are bound together in sheaves, which are then carried from the fields to the farmer's compound. Sometimes donkeys carry the millet sheaves from the fields, but it is more common for farmers to carry sheaves on their heads. In Ouallam there might be as many as 100 donkeys.

Millet seeds are stored in above-ground grainaries made from millet stalks or mud bricks and covered with millet thatch. Thorn fences designed to prevent rats and mice from entering are only partially successful. The seeds, many of which lose their germinating power during the dry season, are planted by everyone available after the first major rain. This usually occurs some time in late May or early June. The entire family assists in the planting. While the men and older boys work with the hoes, the women and children drop the seeds in the holes and then cover them over with soil. The first weeding takes place about fifteen days after the planting, or before the weeds reach ten centimeters in height. Farmers can then plant cowpeas between the rows of millet, a method known as intercropping, for the young millet plants have sufficiently matured by this point. A second weeding takes place about two weeks after the first one. As in the weeding, the men and boys of the family harvest the millet, although some of the boys may, by that time, already be in school and unable to assist. The initial clearing of the fields is also a male activity, though women and children can help by carrying away loose brush.

Almost all of the farmers allow nomads to graze their animals on the stubble of their fields after the harvest. This is a symbiotic relationship in which the nomads borrow pasture for their animals, while sedentary farmers benefit from the manure droppings and milk and cheese furnished by the nomads' cows. Of course farmers also graze their few animals on the millet stubble. This traditional use of manure is not wholly effective, for much of its value is lost as it lies exposed on the surface. Few farmers know how to use manure as compost or as a feritilizer which is put under the ground before and during the planting. Moreover, few farmers have access to chemical fertilizers or pesticides, both because of their cost and inadequate supply and distribution.

A small percentage of the farmers in the village can be classified as progressive. This 10% to 15% may use fertilizer, pesticides, an anti-rodent treatment or improved seed strains. Or a progressive farmer may prevent erosion by planting rows of trees (from which goats are kept away through the use of fences), employing "live" fencing, or setting up a series of millet stalk barriers which serve as windbreaks. He might also irrigate small plots near or within his compound which serve as an additional source of income or as a dietary supplement. And certainly

the progressive farmer is more receptive to larger-scale cash crop production than his less progressive counterparts. If his holdings are quite extensive, there is a good chance that he hires wage laborers to help him during peak periods of planting and weeding, when the work must be accomplished as quickly as possible. In rare instances, a progressive farmer might experiment with animal traction or irrigation, assuming that he farms land near a standing body of water or near water which is just beneath the surface.

B. Livestock

Many of the villagers own livestock, although only the wealthiest are able to raise even one head of cattle or more than a handful of goats, sheep and chickens. Chickens and goats are allowed to forage at will. Unimpeded movement of goats presents a problem with serious ecological implications, for goats destroy trees and bushes as they devour their roots and leaves. Children tend sheep and any cattle that the family might own. Small groups of goats, sheep and cattle are led to outlying fields or to fields lying fallow for grazing so that they do not damage crops under cultivation.

If a farmer owns more than one or two head of cattle, he is either very wealthy or semi-sedentary. Larger herds require greater pasture, which cannot be found near the village where land is heavily cultivated. Hence, the younger males in the family have to migrate to fresh, uncultivated pastures during the growing season, while the senior member of the family manages the homestead. Or it is possible that a wealthy sedentary farmer pays nomads to look after his cattle during the growing season. Any negligence in closely supervising cattle which allows freely roaming beasts to damage other villagers' crops is dealt with harshly, usually through fines levied by the village chief or body of elders upon the owner of the transgressing beasts.

Sedentary farmers in the village regard cattle, sheep and goats as a form of investment. They are reluctant to sell their animals or kill and consume them, for their animals are insurance against inevitable bad years. Animals are also valuable property which can be transferred from one family to another on the occasion of marriage, given as gifts, or slaughtered for religious holidays (sheep are sacrificed for the Moslem festivals). When villagers need beef, they generally buy it at the weekly market from nomads. The nomads sell their cattle only as they need to in order to acquire cash for purchasing grain, tea, sugar, other staples and clothing. Nomads' cows and goats also furnish the villagers with milk and cheese.

There are several cattle ranches and cattle-breeding stations spread throughout the Sahel, but their impact on most cattle-raising practices is minimal. The Livestock Service of the Government of Niger vaccinates some of the cattle, treats hoof and mouth disease, and inspects beef sold at the principal meat markets, but their efforts to regulate the predominantly nomadic activity of livestock raising are futile. There are never enough agents and the nomads' wanderings make supervision virtually impossible.

Herds were, of course, decimated during the recent five year drought. Restocking of herds is taking place, but nomads and farmers are understandably hesitant to expand their herds rapidly in light of the recent disaster and in such an uncertain environment. The balance between herd size and the zone's capacity to support greater numbers of animals is a precarious one. Certainly unchecked expansion of herds is undesirable, but the introduction of animal traction and on-the-farm fattening of beef, in response to higher beef prices, will require increased supplies of water and food. The quantity of available pasture is too highly dependent upon rainfall, which varies greatly from year to year. Moreover, it is shrinking due to the southward drift of the Sahara and increased cultivation of land which hasn't been cultivated traditionally or which should be lying fallow on account of population pressures.

C. Handicrafts

Individuals and families who have become specialists perform basic crafts in the village, usually during the dry season when they are essentially idle. The larger the village, the more apt it is to be able to support craftsmen who work all year long. Artisans construct houses and traditional wells and produce leather goods, blankets, clothing, furniture, iron goods, pots, gourds, mats, baskets and calabashes.

The chief leather goods produced are sandals, bags, small sacks, and wallets for carrying money and valuables, saddles, switches and ornamental objects. Leather is obtained locally from cattle and goats. Skins are left to dry in the sun, or when the animal's fur is removed, the bare hide can be coated with a mud compact which facilities the drying. Stones are placed on skins and hides to prevent them from rolling up while they are drying. They can also be tied to wooden stakes for stretching purposes. Dried hides acquire a sheen when the craftsmen rub peanut oil into them. In the larger towns leather workers may obtain leather from a tannery which treats hides for export. Almost all of the leather used in the villages is, however, treated in the aforementioned fashion. Then it is cut with knives and sewn by hand, using a heavy, durable thread. Men, rather than women, generally produce leather goods, and it is not unusual for a leather worker to train one or more apprentices.

Colorful blankets, used for warmth during the cool nights of the dry season and for decoration, are woven by hand. The various threads, which are acquired from outside markets, are fixed at a point some ten to twelve feet from the weaver. He sits and manipulates the thread with his toes or by operating a small footboard and weaves the pattern with a small card composed of a wood frame and metal teeth. This device is, in effect, a small loom. The process is entirely manual and very time-consuming, but blankets are valuable commodities which bring in substantial revenue. They are often presented as gifts, particularly by a young man to the family of his prospective bride.

The fabrics and thread used in making clothes are generally imported or produced in the large towns. Some thread is produced locally, however. The villagers reduce clumps of carded cotton into threads by attaching a thin piece of cotton to a stick. This is spun back and forth in such a way, while simultaneously passing the cotton between one's thumb and index finger, that the clump is transformed into a ball of thread which forms at the bottom of the stock. Villagers dye the thread with brilliant colors obtained sometimes from commercial dyes sold in the market-place but also from local berries, nuts, and herbs.

Each village has at least one tailor who has acquired a foot-operated sewing machine. He is able to make loose, flowing garments for men and long robes and blouses for women. The latter may not often need his services, however, for they wrap themselves in large pieces of cloth (called pagnes). In addition, many of the clothes worn in the village are used (and often tattered) ones having originally come from the larger towns or ironically, from the U.S.

Other skilled craftsmen in the village are the smith and the carpenter. The smith forges and mends bits for horses, iron agricultural instruments axes, knives and other iron implements. He procures his iron from outside the village, often in the form of scrap, and he must heat and shape it against a large rock or rudimentary anvil by wielding a hammer. The carpenter makes furniture (chairs, stands, and tables) and door and window frames. The doors and windows themselves are of corrugated iron, which is imported, along with the hewn lumber, nails, saws, and hammers required for carpentry.

Specialized craftsmen are not usually needed to produce baskets, mats, millet stalk fences, thatch roofs, gourds, calabash water containers and pots, although decorative skills are applied to the production of household items. Most adults in the village are able to fabricate enough of these goods in order to meet family needs. They weave baskets, mats and straw partitions by hand with millet stalks and fibers. Roofs and fences are also made from millet stalks which are tied together with an indigenously produced rope. Calabashes are grown in moist regions, hollowed out and used for carrying water and preparing food. The villagers also use five-liter aluminum cans for holding liquids, and in general, the villagers make use of whatever castoffs from industrial societies (rubber, tin, aluminum and iron products) they come across. Pots and vases can be fabricated by almost anyone without a potter's wheel, as long as there is clay available. The villagers bake pottery in homemade kilns fired by wood and then leave it to dry in the sun. Simple pots and vases are often merely placed in the sun to harden and are consequently quite flimsy. An artistic villager might occasionally paint pots and gourds with henna, a reddish-orange dye introduced from the orient, or a white substance obtained from local herbs.

Whereas handicrafts are performed individually or by craftsmen working with one or two apprentices, houses and wells are constructed in teams. Teams of masons construct one-story brick houses during the dry season. Or communal work groups pool labor in order to accomplish time-consuming tasks quickly. The masons are paid, while those who labor together are not, except that the group builds each man's house along with the others or tackles other individual projects requiring a lot of labor. In sum, everyone profits from this communal arrangement.

D. Housing and Wells

The mud bricks used in building have a high clay content. They are formed in wooden molds and left to dry in the sun for long periods. These wooden molds are planks laid on edge on flat dry surfaces and divided by small pieces of wood. Once the bricks have hardened, the masons (or communal laborers) construct walls by cementing the bricks together with the same clay-mud mixture of which they are formed. Unhewn beams, which are usually small tree trunks or large branches from which the smaller branches have been removed, support the roof. This is composed of small sticks and branches and a millet thatch, all of which is finally covered with a mud-brick layer. Needless to say, these structures do not last more than a year or so, for the roofs cave in and the walls are washed away under the pounding of heavy rains. Millet stalk huts which are covered with thatch roofs are even less permanent. Thus, villagers expend a good deal of energy in patching up and rebuilding dwellings.

In small villages untouched by the market economy, which are not connected to larger agglomerations by access roads, communal teams of villagers dig traditional wells. They scoop the sandy soil out of the ground with crude shovels or by hand; then the sides of the well are reinforced by tree trunks and branches. This temporarily forestalls the sliding of loose soil back into the shaft. These wells never reach a depth of more than five to six meters (usually they are only about three meters deep), and hence they dry up quickly. In addition, they fall in often and get clogged with sand and loose soil.

In most villages the government has put in at least one cement well. Government officials send masons and their supervisors, along with cement, iron supporting rods, shovels and large steel supports, out from the larger towns to a village. Locally-recruited labor helps by hauling away soil and bringing water and sand to the well site, both of which are used in mixing the cement. Sometimes the contributing villagers are offered food for their services, but more often than not their reward is the acquisition of an additional water source. On the other hand, the government teams are invariably well-paid.

Most cement wells are constructed at the rate of one meter a day and reach depths of anywhere from ten to seventy meters. The masons form one to two meter high cement pipes around webs of horizontal and vertical iron rods. This iron is of small diameter (one to one and a half inches) and it reinforces the cement. The interior diameter of the pipes measures approximately two meters. Each pipe has a slightly smaller diameter than the previous one, so that it can be lowered into place inside

of the sections above it. An overhead steel support with pulley and steel wires is set up and used to lower the sections into the well, as well as workers who must dig out deeper soil.

III. Village Tasks

In the previous section the various forms of economic production in the village were outlined. This section will direct greater attention to the performance of daily tasks not directly related to primary production. These tasks include processing food, drawing water, and obtaining fuel for cooking and heating.

A. Processing of Foodstuffs

The diet of a villager in the Sahel is monotonous. It consists basically of millet, prepared either as a paste, as a semi-liquid, or less commonly as a coarse bread. The villager also consumes quite a bit of meat, milk and cheese, but not many fruits or vegetables, although sweet potatoes, peanuts, manioc, corn and rice are included more and more often in his diet. The staple, however, is millet.

Village women spend about one and a half to two hours a day pounding millet grain into an edible mash. They use wooden shafts of 3 1/2 to 5 feet in length (which weigh five to ten pounds), mashing the grain in a hollowed-out wooden mortar, which is about ten inches wide and one foot deep. This exhausting labor drains the women, who are already saddled with a variety of other time-consuming tasks. Often the women pound millet in groups, usually for social reasons. As they pound they chat and their infants doze on their backs.

One labor saving device which has been introduced in the larger towns and a few of the villages is a two-horsepower, diesel-powered mill. Wealthy women in such towns are able to taken their grain to entrepreneurs who have invested in a mill and have them process it into flour in a fraction of the time that it takes to pound it. Drawbacks to expanded use of these mills are the relatively enormous initial cost of investment, high recurring costs of maintenance and fuel, and the need for a prosperous clientele able to afford such a luxury.

After the millet is pounded, it is cooked in a metal pot along with spices, herbs, and a tomato or peanut oil-based sauce. A good amount of firewood is, of course, consumed. It is not needlessly wasted, though, for only the ends of the logs and branches are lit. They are placed like spokes of a wheel so that the food is cooked at the center by heat generated from the burning inner ends of the "spokes." The cooking pot is usually placed on top of a six to eight inch cylindrical tripod made of cast or scrap iron and having an open bottom. In cruder arrangements the pots are placed on rocks. The millet can also be eaten cold, mixed with sour milk and sugar. Villagers eat with their hands out of communal pots and employ knives and ladles in food preparation.

Before the grain can be pounded into a paste, two operations must take place: threshing and winnowing. After the millet has been cut and tied in sheaves, farmers have to husk the millet to separate the grain from the chaff. They thresh the millet by placing the sheaves on mats or on raised mounds and then flailing them with sticks. Each man has a flail of two large sticks tied together with leather cord. He holds on to the larger of the two, which is about six feet long. When raised mounds are used, the grain rolls down the slope while the chaff blows away. In the second operation, winnowing, the grain is further separated from the chaff when the two are tossed into the air from flat trays. Threshing takes place at the end of the harvest, when teams of farmers spend long days processing all the grain. The women do not participate in this very vigorous activity, although they usually do the winnowing.

Consumption of meat is somewhat irregular, yet it serves to supplement a nearly all-millet diet. Most villages have an outdoor slaughter cage, in which goats, sheep and cattle are sliced up with cleavers and hung prior to sale. These cages consist of a cement floor, iron supports and beams, a corrugated iron roof and iron grid walls which prevent predators like jackals from entering. Once purchased, meat is usually cooked, requiring large quantities of a scarce resource, firewood, in its preparation.

B. Drawing of Water

Although some rainwater is caught and stored in oil drums or large pots, virtually all of the drinking water in the Sahel comes from beneath the surface. It is drawn from the water table, which is replenished annually by rains. Both men and women draw water, although men do more so than women. Most of the drawing, an exhausting activity, is done early in the day before the onset of the debilitating mid-day heat. Three or four people are able to draw simultaneously from a large bore well. The drawers raise three to four gallons of water each time they lower their leather pourches, which are attached to thick imported ropes. Water can also be raised in old inner tube sections, which are sewn with leather cord in the form of a sack capable of carrying two to three gallons.

Each family in the villages around Ouallam spends about an hour a day drawing and transporting water. Drawers lower the leather water pouch at least twice in order to satisfy daily family needs. Generally, family members carry the water back to their compound in calabashes on their heads or by using shoulder yokes which have metal or calabash containers at each end. The larger the town, the more likely there is to be commercial drawing and hauling of water. Teams of men work the wells for most of the village in return for cash.

In areas where water must be drawn from depths of over 30 meters, it is not uncommon to see villagers (or nomads) using donkeys or cattle to do the work. This operation requires more coordination than regular hand drawing, for someone must guide the beasts while another man stays at the edge of the well, waiting for the water to reach the top. The rope attached to the leather pouch passes through a pulley which is fixed to a wooden support directly over the center of the well. This support consists of two vertical logs, one on either side of the well, which hold up the horizontal crosspiece to which the pulley is affixed.

In a few villages hand pumps have been installed. The pump is fixed to a metal plate, which is placed over the two meter mouth of the well. The operator drops a rubber hose (which is hooked up to the pump) into the well and powers the pump manually. Drawing is facilitated for more water can be drawn in a shorter period of time than with ropes and leather pouches. In rare instances, one finds a motor-driven well which draws water from depths of 75 to 800 meters. These small-bore wells are extremely expensive to install, operate and maintain. They require a clientele able to pay a lot for the water and a mechanic who can repair the mechanical pump in the event of breakdown. A danger in relying on deep wells is that they deplete subterranean water supplies and encourage overgrazing in the area around the well.

C. Gathering of Fuel

Firewood is the main source of fuel in the village. It is used for cooking, heating, working iron, and glazing pots. There have recently been severe problems of deforestation in the Sahel. These have been accentuated by the drought and subsequent advance of the desert and by population pressures leading to increased demand for fuel and increased land-clearing and hence brush-burning. The Government of Niger has enacted laws against gatherers of firewood who chop down trees or pull up living bushes. Loose wood can be collected as long as it is dead and lying on the ground. Enforcement of these regulations is, of course, difficult. Nevertheless, villagers are forced to forage for firewood at greater and greater distances from the village in light of the increased demand and diminishing supply.

Women and children usually collect the wood. They often spend much of the day wandering in the bush in search of this scarce commodity. Along the way they might gather herbs and leaves used in cooking. On long expeditions they would probably take a donkey for transporting the sticks and branches. On shorter trips they carry the firewood on their heads. As wood becomes increasingly scarce, it is shipped to villages (and especially to the larger towns) from the surrounding countryside. Enterprising farmers gather large quantities of wood and stack it in piles at the side of access roads. There they await merchants with vehicles who might be willing to buy the firewood. After a little haggling, the transporter pays the farmer for several bundles of wood (which are tied together with local rope) and loads them on his vehicle and then proceeds to town for the sale. Wood-gathering can also be a cash-earning activity when someone who owns a donkey or camel is willing to use it for commercial foraging. Wood-

procuring operations of this sort are usually concentrated around the larger towns, whereas more leisurely foraging parties predominate in the villages.

D. Other Daily Tasks

Clothes are infrequently washed in the Sahel, on account of a lack of and difficulty in obtaining water. Women do the washing by hand, and they are obliged to draw the additional water for this task or pay others to do it. Soaps produced in Nigeria and France are available for purchase in the local market.

Each family has a latrine in its compound, which is a hole in the ground that must be sealed up once it is filled. New holes must be dug periodically. The villagers do not use this human refuse as fertilizer.

In addition to preparing the family meals, women sweep out the family compound and huts or house with crude millet reed brooms. They care for the animals that stay in or near the compound, as well as milk the family goats and cow(s). Women also cultivate small vegetable plots, from which they can earn a little money. An enterprising woman may earn money preparing food for farmers at work or for less energetic neighbors.

IV. Transportation, Commerce and Communication

A. Transportation

As might be expected, the main means of transportation in and around the village is by foot, or bisa Allah, literally, by Allah, or by the power of Allah, as the peasants jokingly refer to it. It is not unusual for someone to walk 20 to 25 kilometers to a neighboring market in one day. When light to moderately heavy loads (of up to 60 pounds) are transported any distance less than a few miles, they are carried on one's head. Animals are used for carrying goods greater distances. Camels are especially well-adapted for long-range transport, while donkeys serve to carry people and goods over shorter distances. Occasionally one sees a progressive farmer using his donkey to pull a light cart, laden with millet sheaves, bricks or other goods. Horses are ridden only for pleasure by those able to afford them. Actually, they are not well-suited to the sandy soils of the Sahel.

In areas which are not too sandy or in which there are hardpacked tracks or roads, the bicycle serves as a valuable means of transportation Again, a twenty kilometer ride via bicycle to a neighboring village is not unusual, though for the most part, the villagers ride their bicycles in and round the village. Since a bicycle represents a substantial investment (of at least $40 - $50), only a few of the villagers actually own them. The larger the town is, however, the greater the number of bicycles.

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In every village there is at least one motorized vehicle. This may be owned by an administrative official, a teacher, or a wealthy transporter or merchant. Those vehicles serve to connect the village with more diversified markets in the larger towns. They haul passengers, produce and goods which will stock the village stores and concessions. Human porters load and unload the vehicles, straining under the weight of 50 - 100 kilogram sacks of grain, which they balance on their heads. In addition to the driver of a market vehicle (a large diesel truck, panel truck or pickup), there is always an apprentice who repairs deflated tires, cleans out dirty carburetors, and loads the vehicle, with the aid of a host of other porters in the marketplace.

B. Commerce

Motor vehicles enable enterprising individuals in the village to conduct commerce. There may be two or three merchants with large stocks of goods in the village, who sell spices, pasta, dates, tea, coffee, soap, canned sardines, perfume, biscuits, cloth, batteries, kerosene, matches, lamps, tools and utensils, etc. A village merchant is able to procure these goods from the larger towns, and somewhat surprisingly, there is quite a demand for them. In addition to these full-time merchants, there are a number of petty concessionaries who sell some of the cheaper items sold at the general stores. Finally, there are women who cook meat, millet and bean cakes, and other forms of village snack food for sale to other villagers.

The existence of repairmen who maintain machines introduced by the industrial West is another consequence of improved transportation and linkage with urban centers. A repairman in a Sahelian village is usually someone who is handy with basic tools, such as the hammer, screwdriver, wrench, and pliers. He has usually been tutored in a large town, normally as an apprentice under an experienced repairman and is able to repair any number of machines in a trial and error fashion. In most villages there is invariably someone who tinkers with watches and radios, a number of people who can repair bicycles and motorbikes, but very few men who are capable of repairing automobiles. Most of the repairmen are generally stocked with tools and spare parts taken from a variety of models, makes and years. Basically, a village repairman makes do with whatever is available.

C. Communication

Only in the larger towns are there telegraph and telephone lines which work inefficiently at best when they are operating. Villagers can communicate with the outside world by letter, that is, if they can write, an assumption one cannot make in a region where literacy rates seldom exceed 5%. This difficulty is overcome for a nominal fee, however, when the villager dictates his message to itinerant scribes. These men have had some education but not enough of it to qualify for a post in the government bureaucracy.

The mail is carried by government or private commercial vehicles. In the larger towns like Ouallam, mail might be sent out and might arrive two or three times a week, whereas villages have infrequent (once every two weeks) postal service, if any at all. Generally, villagers have to take their letters to post offices in larger towns in order to send them. It is expensive for peasants who earn less than $100 a year to send letters ($.17 per letter in June, 1976), and the cost of sending telegrams and telephoning is prohibitive.

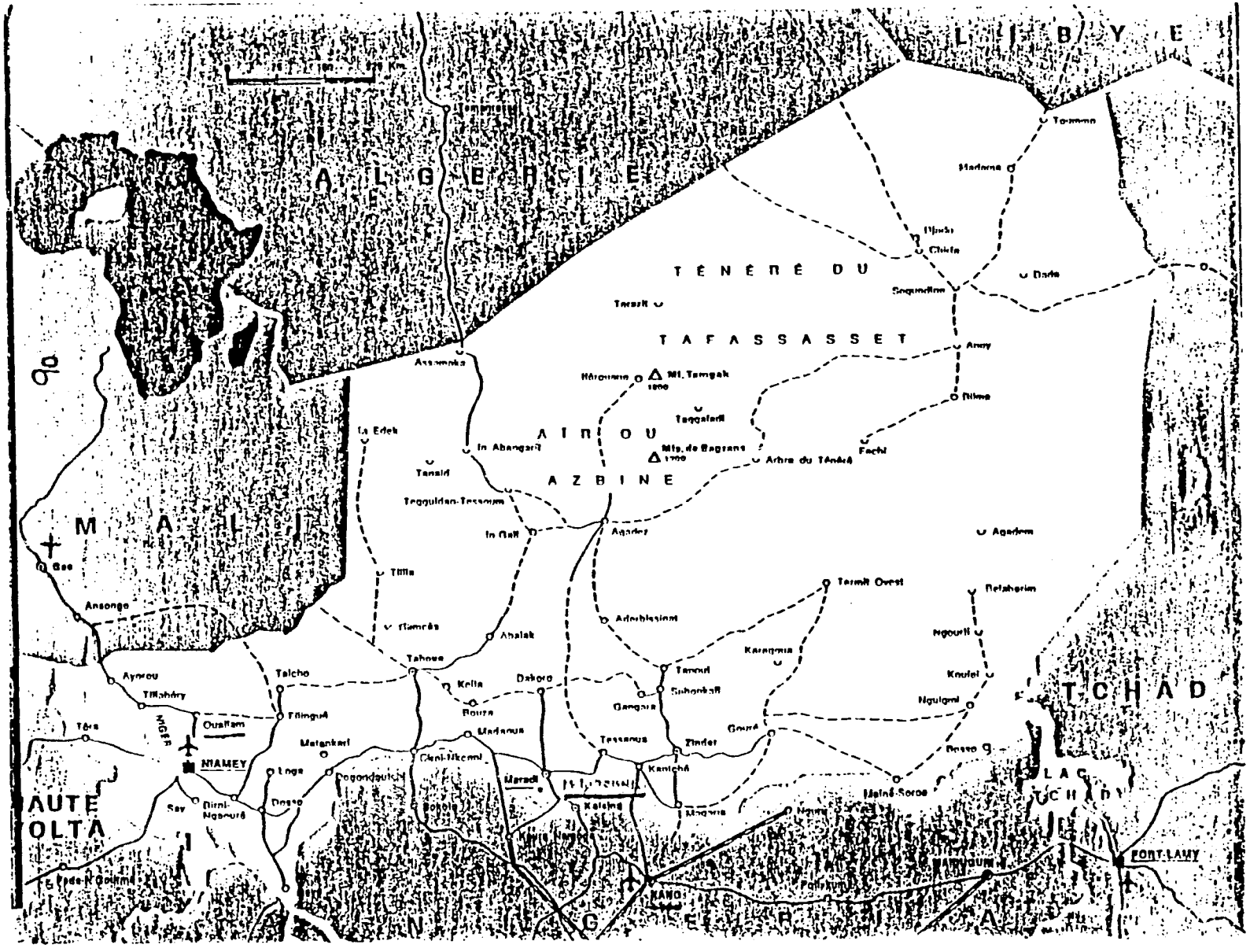
Although villagers may have considerable difficulty in communicating with relatives in larger towns (if they do indeed have any), they can keep up on national and even international events by radio. The radio is one of a peasant's first purchases, towards which he might grow a surplus of millet or a cash crop like peanuts or perform some craft. Radios are operated by batteries, which can be purchased in the merchant's shops or at the weekly market. They are imported from China, France, the U.S. and Japan and they lose much of their power during longer periods of transport and storage, while on the shelves in shops, and when exposed to the sun and heat of the marketplace. Hence, batteries must be replaced often if one desires adequate reception. There are no wireless sets in the villages for getting word out, but there is one in Ouallam (and in other towns). The government-controlled radio stations of Niger and other countries in the Sahel broadcast news, modern and traditional music, plays dramatizing typical daily problems, and instruction in hygiene, agricultural improvements, and a variety of other programs in local languages. These programs are very popular with the villagers, who have few other sources of entertainment (aside from a lively oral tradition and the usual family and religious rites).

V. Electricity in the Sahelian Village

Electricity is a luxury in the Sahel. There are no potential sources of hydroelectric power other than the meandering Niger River and temporary streams. These flow rapidly during the rainy season, but turn dry shortly after the onset of the dry season. Neither has been harnessed for producing electricity. Electricity is made, however, available in the largest towns by employing petrol-powered generators. In smaller towns and a very few villages, petrol-powered generators produce electricity for health facilities, administrative offices and secondary schools.

Petrol based rural electrification is neither feasible nor economical in the Sahel. Costly generators require skilled mechanics for maintenance purposes, not to mention expensive fuel which is already in short supply Even government officials often lack fuel for official vehicles. Yet there are several cases in which large villages have been "electrified," usually in anticipation of a visit by the head of state, hence for showcase purposes or as an example of continuing progress. In these villages electricity is generated on only a handful of occasions each year.

At this point there is little demand for electric lights. Very few villagers are able to read. Those who do, invariably primary school students or functionaries, use cheap kerosene lamps or candles (or bottled gas lamps to a far lesser extent). Although kerosene lamps burn a costly petroleum derivative, they are used universally in the bush. The villagers are able to perform chores and move around at night by using flashlights and torches. However, they arrange their day so as to make maximum use of the daylight. They retire shortly after dark (which varies from 7:00 to 8:30) and rise at dawn (5:30 to 6:30). The length of the day varies less near the equator than athigher latitudes.


ALGERIE
LIBYE
TENERE DU
TAFASSASSET
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AZBINE
MALI
TCHAD
LAC TCHAD
NIGER
NIGERIA
HAUTE VOLTA
NIAMEY
KANO
PORT-LAMY
Tamanrasset
Assamaka
Tessalit
Arlit
Agadez
Termit Ouest
Agadem
Bilma
Dirkou
Fachi
Arbre du Ténéré
Mts. de Bagzane
Mt. Tamgak
Tillia
Tahoua
Ouallam
Tillaberry
Ayrou
Téra
Dosso
Maradi
Zinder
Gouré
Mainé-Soroa
Nguigmi
Koulfi
Ngourti
Bilma
Dirni-Ngaouré
Say
Loga
Talcho
Tillingué
Matankari
Madaoua
Tessaoua
Kantché
Magaria
Kaisina
Dakoro
Bouza
Kelia
Ansongo
Gao
Tessalit
Djanet
Ghat
Ghadames
Sebha
Fort-Lamy
Mao
Nguigmi
Bosso

APPENDIX III

The Gelebs of Ethiopia

Omo River Project

The experience of the American Presbyterian Mission at the Omo River Mission Station with the Geleb people near Lake Rudolf in southwestern Ethiopia provides an excellent case study of use of village source energy to improve the quality of life of the villagers.[1] The missionaries, using windmills of ancient Crete design but modern materials, succeeded in introducing the Gelebs to windpumped irrigation which has now permitted year-round cultivation that was otherwise impossible.

The Omo River area of the Gelebs near Lake Rudolf is a semi-desert arid area which is inaccessible except by 4-wheel vehicle or plane. It receives less than 10 inches of rain a year, most of which falls in April, flooding the Omo River banks. The temperature ranges between 70°F - 104°F. The Geleb people are semi-nomads, living in small villages or clusters. Stock raising is the major economic activity, but enough vegetables, grains and tobacco are grown for one harvest a year after the floodwaters have receded. Food is always in short supply during the six months prior to harvest. During 1973-74, the Gelebs received emergency air drops of food in order to avoid mass starvation during the disastrous drought and famine that hit Ethiopia.

The idea to bring windpumps into the area originated in early 1974 with the missionaries who wished to import standard American made Dempster windpumps to replace a diesel-electric pump used for the mission's vegetable and fruit garden that was too difficult and expensive to maintain and fuel. When the windpumps arrived, they found there were too many for their own needs: these were sold on a subsidized basis to a couple of farmers who had expressed interest and curiosity in the ones already operating at the mission. By April, 1974, one of the Dempsters was successfully installed, with missionary assistance, and irrigating 1-1/4 acres of land cultivated by several families. Peter Fraenkel of ITDG relates the outcome:

> "The windmills were an immediate success with the Gelebs, which is perhaps surprising when it is considered that these people are almost completely without any formal education and have had very little contact with outside influences or with machinery of any kind. However, the wind and the machines are relatively reliable and the people very quickly recognized that this could help provide food all the year around and thereby remove their chronic annual food shortage which had caused them great misery in the past."[2]

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[1] Peter Fraenkel, Food from Windmills, (London: Intermediate Technology Publications, Ltd., 1975).

[2] Ibid.

However, the Dempsters, even with the discounts the missionaries managed to receive, cost $1,000 each, much too expensive for wide scale use by the Gelebes. Instead of continuing a search for a cheaper, equally powerful unit in the U.S., which they felt would prove fruitless, the missionaries instead went to the island of Crete. There they found an indigenous windmill design and power capacity using sails instead of blades which could be appropriately modified for the Gelebs. Upon returning to Ethiopia, the missionaries first attempted to build the Cretan design using local driftwood, woven mats, and whatever meager timber was available in the semi-arid region, but the construction, partly affected by termites, proved fragile and unreliable in operation. So steel parts were imported as well as a diesel-powered welding set, drills, a lathe, and other tools which were the only capital investments for the windmills construction operation. Within a couple of months, the first sailmill was erected, and almost one a month has been built since then. During this time other designs were also being investigated on site, among them, the modern vertical Savonius Rotors (S Rotors), but they were not as efficient as the Cretan design because they intersected smaller cross section of wind and needed higher wind speeds to self-start pumping. Furthermore, the Cretan sailmills, costing around $375 each. pumped twice as much water in the same wind and were cheaper to build than the Savonius Rotors. As it turned out, the sailmills also lifted as much or more water than the $1000 American-made Dempster, which required imported spare parts and regular lubrication. One of the Gelebs was taught by the missionaries how to maintain, assemble and install the windmills. Each farmer receiving a windmill also received a package of hand tools and seeds. The missionaries planned the proper loction of the windmill and the layout of the irrigation networks, using simple meteorological equipment on loan from the Ethiopian Government.

Omo is located at 5°N, well within the tropical equatorial belt in which the global wind pattern is considered to be mild and marked by low average annual wind velocities not amenable to the use of windmills. There is only marginal change in climate with the seasons of the year. The primary wind regime is diurnal—a "sea breeze" from Lake Rudolph a few kilometers away during the day which carries 10-15 mph mean wind velocities in the morning that taper off to nothing in the evening, at which time a night "land breeze" arises, tapering off until the morning "sea breeze" the next day. Because the sailmills require careful supervision of the sails to add sails when wind decreases and remove sails as wind increases (in order to avoid damage), all irrigation is done daily in the morning from 7 a.m. to noon while the wind is at its peak. Almost all of the Cretan windmills have 10-11 ft. diameter wind wheels and can pump up to 800 imperial gallons of water per hour in 13 mph winds. The sail mill consists of the following parts:

1) Suction line pipe and foot valve starter pump--both parts made in Ethiopia—represent about 25% of the cost or about $95.

2) Dempster design piston pump and connecting rod--made in Ethiopia at about 50% discount—represents about 10% of the cost or $40.

3) Head assembly and tail unit--made in Ethiopia--for about 5% of the cost or $20.

4) 12 ft. tower, wind wheel, and sails represent remainder of cost, about $120. The tower and wheel are made of metal piping; the sails were made of donated yacht sail material which is impervious to heat and ultra violet damage and are known to minimize material runs, tears, and flapping in gusty winds.

Other costs averaged out over the thirty sailmills add another $125 to each, thus total costs are around $375 for each sailmill. Whereas the missionaries have been charging the Dempster owners $5/year for 20 years for the $1000 machines, the sailmill owners are paying $2.50/year for 20 years for the $375 machines. Such subsidized charges seemed to be enough to establish sincere interest on the part of the Gelebs, who are nevertheless very low on currency, being so isolated from cash markets. Any efforts to reduce capital costs must not sacrifice the simplicity, longevity, or the low cost per gallon water lifted which are what make the sailmills practical and affordable to the Gelebes. Such cost reductions might involve wider diameter windwheels of 16-20 ft. variety with double pumps (and consequently higher towers), which would pump up to twice the water of the 10-11 ft. diameter windwheels.

Approximately twenty such sailmills were in use by Geleb families by August of 1975. Although there were some Gelebes who had difficulty adjusting culturally to the need for more time spent in cultivating the newly irrigated land instead of watching the stock animals, sufficient adjustments were made within the family in most cases to settle such time conflicts. The new opportunity for cultivation not only enabled the well-to-do, land-owning, cattle-owning villager to prosper, but also the landless, cattle-less villager to benefit from the newly arable land and abundant water supplies which the sailmill operators rented out to them. Not only did production of traditional grains like millet and maize increase, but new nitrogen-fixing protein crops like soybean and groundnuts were introduced with success. Surplus grains and beans, as well as new vegetables and fruit like cabbage and papaya were sold for cash at a nearby policy station which enabled some villagers to buy more cattle. The farmers using the sailmills attest to not having been hungry since the introduction of the windmills--one has even succeeded in growing five harvests between April 1974 and August 1975.

The Geleb experience, of course, cannot be duplicated everywhere. It does indicate that in some cases small scale technologies can be successfully transferred and modified to meet local needs, using modern materials if necessary. It shows that such adaptive technology can compete favorably with the best of the tried-and-true or modern designs of the U.S. It is not inconceivable that if such windmills were produced on a mass scale, the fixed capital cost per unit would decline sufficiently, and economies of scale in production would arise, perhaps dropping the cost per unit to as low as $240 or even less. Over a 20 year period, such windmills used five hours a day, 5 days a week, 50 weeks a year would have operating costs around 1¢ an hour or $12 per year, which certainly would put the sailmill within the affordable range, particularly for farmers living within closer proximity to markets and a cash economy.

APPENDIX IV

Africa's Conventional Energy Resources*

In most of the countries of Africa south of the Sahara there are two sharply contrasting worlds of energy: the world of commercial energy--energy that is bought and sold or exchanged, and non-commercial, that is, energy that is used directly by the person or family that gathers it. Commercial energy is dominated by large scale conventional sources such as oil, gas, coal and hydro-electricity. It is distributed to the users through three systems: first, by turning it into electricity and distributing it through city-wide or region-wide power grids; second, in the form of petrol or diesel fuel or kerosene delivered (when roads are passable) in trucks; third, in the form of wood or charcoal distributed in a variety of ways ranging from hand delivery by humans to the use of donkeys, to trucks.

A. Fossil Fuels: Oil, Gas, and Coal

The average per capita consumption of petroleum for energy purposes in the Sub-Saharan African developing countries is barely one barrel per year; of natural gas, less than seven cubic meters; of coal, less than a quarter of a metric ton. These amounts are quite modest by global standards, but consumption in Africa has been growing at about 5.9% per year, somewhat more rapidly than the 5.3% world rate of the past decade. (See Table.) Of the tropical African countries, only the Congo, Gabon, Nigeria, and Rwanda are significant producers of natural gas; only Angola, the Congo, Gabon, and Nigeria are significant producers of oil; and only Zambia, Mozambique, Nigeria, Zaire, and Tanzania are significant producers of coal.

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* Sources:

United Nations, World Energy Supplies, 1950-1974, Department of Economic and Social Affairs, Statistica Papers, Series J. No. 19, U.N. Doc. No. ST/ESA/STAT/SER.J/19), 1976.

United Nations, Electric Energy in Africa: Development and Prospects, Economic Commission for Africa, U.N. Doc. No. E/CN.14/NRSTD/E/3) February, 1976.

United Nations, Energy Resources in Africa, Economic Commission for Africa, U.N. Doc. No. E/CN.14/NRSTD/E/4, March 1976.

United Nations, Environmental Impacts of Energy Production on the African Continent, Economic Commission for Africa (E/CN.14/NRSTD/E/10, February, 1976.

Average Annual Growth Rate in Energy Consumption
1965-1974

	Africa	World
solid fuels (coal)	3.4%	1.2%
liquid fuels (oil)	8.8%	8.2%
natural gas	40.0%	8.8%
hydroelectricity	10.0%	7.7%
per capita total energy	3.1%	3.0%
Total energy	5.9%	5.3%

Data calculated from UN Series J NO. 19, Table 1

1. Oil

Some 40% of total African oil production, or about 4% of total world production, presently comes from the sub-Saharan African countries. Of these, only four countries are significant producers:

(1973 production in millions of tons of crude)

Nigeria	101,765
Angola	8,175
Gabon	7,598
The Congo	2,054
Total	119,592

All of these countries export a significant amount (90-99%) of their production. And a considerable proportion of the production (27-90%) of each of these countries comes from offshore oil areas.

Zaire became a commercial petroleum producer in 1975. Exploration has recently begun, or been stepped up, in Mauritania, Mali, Chad, Guinea, Zaire, Somalia, Ethiopia, Senegal (the Casamance marine basin contains an estimated 100 million tons), Ivory Coast, Ghana, Benin, and the Cameroon. However large new finds may prove, it should be noted that at present rates of production Nigeria's estimated reserves of 2,850 million tons will be depleted about the year 2001, and, at present use rates and known reserves, global stocks would be totally depleted about four years later.

The effects of crude oil exploration, production, transportation, and processing on local communities does not seem to have yet received appreciable study in Africa, although it is of increasing concern in North America and elsewhere. Offshore production may have considerable impact on local environment particularly since most offshore drilling occurs in relatively calm and protected areas near biologically vital coastal areas; thus offshore drilling accidents or discharges can have severe local effects.

Air pollution and effluents in refining and final combustion are also significant pollution problems. And generally inefficient combustion of petroleum fuels, in automobiles in particular, is both a severe source of pollution in urban areas, and a costly waste of valuable fuels.

2. Natural Gas

Natural gas consumption has grown more rapidly than consumption of other fossil fuels in recent years both in Africa and elsewhere, largely because natural gas is relatively pollution-free. Africa as a whole has about 11% of presently known world reserves, and more may be expected to be found.

In 1973 natural gas production in tropical Africa was as follows:

	(in million m^3)
Nigeria	190
Gabon	40
The Congo	16
Rwanda	1
Total	247

Use of natural gas in these countries has been growing more than twice as rapidly as the global rate (probably about 17% per year over the past decade). Considerably more growth may be expected since established reserves are fairly considerable (175 trillion cubic feet for Africa as a whole) and barely 20% of likely areas have been prospected.

One unusual source of methane gas is that of Lake Kivu, on the border of Rwanda and Zaire, which contains an estimated 57 billion cubic meters and is actively producing gas naturally at a sustainable commercial rate. Most natural gas is found in conjunction with oil. It may be transported either through pipelines or liquefied and transported by special tankers. Because of the relative expense of transport and the lack of immediate nearby markets, unknown quantities of natural gas have been and are still being flared, or burned off, during oil production.

In Nigeria and other producing countries, gas has been used in local thermal electric stations or industries. There is only one liquefaction plant in the region presently, at Bonny, Nigeria.

Gas liquefaction plants use power from either steam or gas turbines, with some resulting air pollution. Pipelines for transportation have adverse environmental and social effects particularly during construction. There has been very little experience as yet with shipping of liquefied natural gas by tanker; the operational discharge problems associated with oil shipping would not be a problem in the case of gas, although strict safety precautions would be required to prevent possible explosions. As mentioned above, end use combustion of natural gas poses relatively minor pollution problems, and is in this respect preferable to use of other fossil fuels.

3. Coal and Lignite

Continental Africa probably contains only between 1 and 3% of the known world's potential coal reserves, and of the present estimated recoverable African reserves of 88.5 billion tons, nearly 95% is located in South Africa and Southern Rhodesia.

In 1973, coal production in tropical Africa amounted to about 1.8 million metric tons:

Zambia	940,000 tons
Mozambique	394,000
Nigeria	327,000
Zaire	115,000
Tanzania	3,000
Total	1,779,000

Further deposits have been identified in Benin, Niger (expected to supply electricity to local uranium mines), Zaire (definite reserves of 180 million tons and probable reserves of one billion tons), Malawi, Namibia, Mozambique (estimated reserves of 100 million tons), Swaziland, Lesotho, Botswana, and the Malagasy Republic.

Deep, or underground, mining of coal is one of the most hazardous occupations in any country, both because of accidents and occupational diseases. Environmentally, deep coal mining often leads to significant sulphuric acid leaching from exposure of coal seams to groundwater. Surface, or strip, mining is considerably safer for miners, but may cause destruction of large areas of surface terrain (which can only be partly amended by expensive reclamation efforts) and even worse problems with acid leaching and drainage than in deep mining. Combustion of coal in electrical power stations or for industrial and domestic heating purposes may lead to major pollution problems. Particulates and noxious gases can be controlled somewhat by expensive scrubbing devices or advanced combustion technology, and ash or slag may, in part, be recycled as building materials. But waste disposal and general health effects remain significant, and there is increasing concern about long-term climatic effects

of global increases in carbon dioxide resulting from intensified fossil fuel combustion. An estimated 75 million tons of lignite lie in West Africa, mainly on Madagascar. Present production of lignite is negligible. Peat deposits have been identified in a number of African countries, but except for an estimated 2,226 million tons of peat in Rwanda, amounts have not yet been calculated.

B. Hydro-power

Africa is often said to possess more than a third of the world's exploitable hydroelectric potential. Nearly 80% of this potential is situated within the Sub-Saharan developing countries, largely within or adjacent to regions of heavy equatorial rainfall. Rough figures would be about 160 million kilowatts of potential capacity with a power potential of over 1,300 billion kwh per year (about the same as 160 large [1000 megawatt] nuclear plants--the U.S. now has 55). But comprehensive streamflow and streamfall data necessary for estimating hydro-power potential requires considerable and lengthy research. Present estimates are based upon composites of a number of studies that have each been performed for different purposes in a number of areas. But despite the need for further hydroelectric prospecting and related studies, it is clear that tropical Africa's potential is tremendous, and although hydroelectric production in the region has been growing at roughly 8% a year for the past decade, only a small fraction of the potential has yet been tapped.

Hydro-power in Africa is almost exclusively limited to large hydroelectric dam projects. In Sub-Saharan or tropical Africa about 65% of all electricity is produced from hydroelectric stations. Most of this comes from a dozen dams in the Sudan, Ghana, Nigeria, Ivory Coast, Cameroon, Zaire, Ethiopia, Zambia, and Tanzania.

Among the greatest potential hydroelectric producers are Zaire (an estimated exploitable potential of 530 billion kwh, including the Inga site at an estimated 30 million kwh and 200 billion kwh per year potential--which makes it the largest known site in the world), Angola (230 billion kwh per year), Madagascar (114 billion kwh per year), the Cameroon (about 100 billion kwh per year), and Tanzania (75 billion kwh per year).

As a rough rule, for every dollar invested in the hydroelectric station itself, an additional $1.50 must be invested in the transmission network and about $5 in the machinery that will use the electricity. Installed costs of a hydroelectric plant (including transmission) run two to three times the cost of a conventional thermal plant. This is, of course, compensated by the very low cost of maintenance and fuel after the initial capital investment has been made.

Large hydroelectric projects, although they neither require continuous inputs of fuels nor produce air pollution and waste products, do have significant adverse socio-environmental impacts. In the local

area of the reservoir, villages may need to be relocated, agricultural or wild lands may be destroyed, and diseases related to aquatic environments (malaria, schistosomiasis, onchocerciasis) may spread. Water storage and irrigation benefits may be reduced by infestation of aquatic weeds and evaporation. Downstream areas may benefit from flood control but suffer reduced water quality and decreased biological activity (including loss of nutrient-rich silt). Minor seismic activity has been observed in the vicinity of several large African dams, apparently due to the weight of water in the reservoir. Dam failures, when they occur, generally rank as major disasters. The large capital cost of dam construction usually necessitates heavy foreign financing. And because prime reservoir and dam sites are generally some distance from populated areas, the cost and impact of constructing a transmission network, with significant power losses in transit, must also be considered.

C. Geothermal

Although still a rather unconventional source, geothermal energy is included here because it will be primarily applicable to medium and large-scale centralized steam and electricity production. In fact, where it is available, it is already often competitive with conventional energy sources. Tropical Africa, particularly along the Rift Valley and other volcanically-related areas, may contain a number of favorable geothermal sites. Since 1970 several geothermal exploration and/or commercial development studies have been undertaken in Rwanda, Uganda, Tanzania, Kenya, Ethiopia, Malawi, the Cameroon, Chad, Senegal, and Mali. The most favorable areas appear to be in the French Territory of the Afars and Issas, Kenya, and the Cameroon, but no decisions to begin commercial exploitation have yet been made. There is a small geothermal station (220kw) operating in Zaire, which produces electricity for a nearby tin mining operation.

Exploitation of geothermal energy may require disposal of considerable quantities of hot water containing up to 20% dissolved salts, and noxious gases including hydrogen sulphide, ammonia, hydrofluouric acid and compounds of mercury, selenium, and arsenic. There is also concern about land subsidence resulting from underground steam and water removal; reinjection of waste waters may be a solution. As with large hydroelectric dams, geothermal sites might not be located near urban or potential industrial areas, therefore conversion to electricity and construction of long-distance transmission lines may be necessary.

D. Prospects for Nuclear Power in Sub-Saharan Africa

In 1974, after the initial oil price increases, the IAEA conducted a nuclear market survey of developing countries, assessing their likely

nuclear power needs, and found the following potential nuclear electricity needs for African countries:

	1981-1984	1985	1986	1987	1988	1989	1990	Total
Ghana	-	150MW	-	-	150MW	-	-	300MW
Nigeria	-	-	-	150MW	150MW	-	-	300MW
Uganda	-	-	-	-	-	150MW	-	150MW
Zambia	-	-	-	-	-	150MW	-	150MW
TOTAL	-	150MW	-	150MW	300MW	300MW	-	900MW

The only likely market for a nuclear reactor in Sub-Saharan Africa before the mid or late 1980s would be a regional consortium, most probably Ghana-Togo-Benin-Upper Volta. But this potential market area will probably find it less costly to pursue development of its available hydroelectric resources.

The complexities surrounding a nuclear power program are immense: highly technical manpower training requirements; heavy financial investment--inevitably foreign assisted; considerable dependence on foreign technology and materials, including dependence on fuel processing and on waste reprocessing and disposal; the need to comply with international safeguards and safety requirements; and considerable reliance upon a single, highly centralized and, therefore, vulnerable power source.

The current turmoil among scientists and government policy makers in the nuclear exporting countries suggests that it would be best to wait several more years before making detailed predictions as to the potential of nuclear power in Africa. Regarding rural electrification, since nuclear reactors are presently the largest, and probably the most expensive conventional electric power generating source, it seems safe to assume that nuclear will be a last choice in terms of meeting most of Africa's near and medium-term rural energy needs.

APPENDIX V

Village Raw Energy Data Availability at the National Climatic Center

A general picture of wind and solar radiation data for Africa is shown in the maps below. This does not mean, of course, that any particular village in proximity to these general boundaries and locations will reflect their characteristics. What is needed in order to help pinpoint most favorable locations for field testing of village scale solar, wind and hydro technologies are precise data collected at village sites on cloudiness, temperature, rainfall, wind speeds, and other phenomena such as susceptibility to dust storms, fog, hailstorms, etc.

Fortunately, such data exist, in varying degrees of completeness, for some 240 locations in sub-Saharan Africa. The data are recorded in the form of what is known as an "N Summary" by the U.S. Air Weather Service and kept (mostly on computer tape and partly in printed computer read-out form) at the National Climatic Center in Asheville, North Carolina. The list of data available on the N Summary is illustrated below. (Sample print-outs of such data and a list of the stations are found later in this appendix.)

Such data, giving very detailed monthly and annual information, and occasionally hourly and daily data, could be programmed by a team of computer experts, energy experts, and development experts to read out those sites at which the meteorological phenomena are appropriate for use of certain renewable energy technologies. Such a program could perhaps be designed to the precise specifications of commercially available technologies. It could also select sites favorable for each individual source, e.g., wind or solar, and a combination of each. Furthermore, the program could be designed to select those sites for which wind or sunshine is most favorable at those very times when it is most needed (e.g., favorable wind when rainfall is low to power water pumps, or favorable sunshine when wind is unfavorable). Finally, some general conclusions can also be made from this data as to the likelihood of water flow through streams to power small hydroelectric units--(e.g., flow will tend to parallel or lag slightly behind rainfall, depending upon water balance, and length of stream).

This data could be analyzed in conjunction with other existing data for the area on site (e.g., solar radiation balance data, water balance data, stream gauging data) in order to round out the picture. From such print-outs could come a list of candidate sites, specific for given energy sources and technologies or combinations thereof. If such a computer program proved too expensive or unmanageable, the data could simply be printed out and visually analyzed.

To illustrate the usefulness of such analysis, N Summaries for 110 sites were briefly surveyed to investigate suitability for commercially available windmachines. The survey pinpointed 20 sites with average

annual windspeeds of 10+ mph, and many more sites where 10+ mph average windspeeds existed for certain times of the day or given seasons of the year which might render them useful to satisfy certain rural energy needs. To illustrate the kinds of materials available at the Center, we are including a list of the contents of the N-Type Surface Summary (which includes up to 18 different kinds of climatic information), one wind data sheet from one station and one cloud cover data sheet from another station as examples, and a listing of the posts in Africa for which N Summaries exist.

Solar radiation data that is available from the World Meteorological Organization gives an even more detailed picture of the intensity of solar energy for over seventy sub-Saharan African locations, most of which are also sites for N Summary data. Thus, for many of the N Summary locations, this solar radiation data (cal/cm^2) can be integrated into the information already available in the N Summaries on hours of sunshine, percentage of cloudiness, and temperature, in order to give a more complete solar energy picture.

N-TYPE SURFACE SUMMARY

These standard surface summaries are prepared by the Air Weather Service. A full N-Type Summary is composed of 18 separate summary forms as indicated below.

Summary Form	Title
1	Percentage Frequency of Surface Winds by Month, Hour and Month, to 16 Points of the Compass.
2	Percentage Frequency of Surface Winds (Seasonal and Annual) to 16 Points of the Compass.
3	Precipitation
6	Mean Frequency of Daily Maximum Temperature; Mean Maximum and Extreme Maximum Temperature
7	Mean Frequency of Daily Minimum Temperature; Mean Minimum and Extreme Minimum Temperature plus the Mean Range.
14	Miscellaneous Data
17	Total and Low Cloud Amounts
21	Ceiling Visibility-Terminal Flying Conditions (Revised Form # 18)
22	Relative Humidity Means
24	Percentage Frequency Distribution of Wind Speed and Temperature.
25	Visibility and Various Atmospheric Phenomena
26	Mean Number of Days With Specified Phenomena
27	Mean Cloudiness
28	Snow Depth
29	Percentage Frequency of Surface Winds to 8 Points of the Compass.
30	Percentage Frequency of Surface Winds to 8 Points of the Compass.
31	Sea Level Pressure

NOTE: One or all of the above Summary Forms may be included in N-Type Surface Summaries.

N Summary (cont.)

DATA PROCESSING DIVISION
USAF ETAC
AIR WEATHER SERVICE/MAC

PERCENTAGE FREQUENCY OF SURFACE WINDS
IN KNOTS

N SUMMARY # 2
WINTER

40592 DHALA ARABIA N 13 42 E 044 44 ELEV 4375 FT
JUN 55-APR 59,JUL 59-JUN 61

DIR	WIND SPEED GROUPS 01-03	04-06	07-10	11-16	17-21	22-27	28-33	34-40	>40	TOTAL PCT	TOTAL OBS	MEAN SPEED	DIR
N			.3	.3						.6	6	10.3	N
NNE													NNE
NE	.2	1.3	1.2	2.1	.6					5.3	51	9.6	NE
ENE		.1								.1	1	5.0	ENE
E	.3	1.2	11.4	5.5	2.0	.2				20.6	197	10.2	E
ESE		2.7	9.5	6.1	24.1	1.8			.1	44.2	423	14.7	ESE
SE		.4	8.8	1.7	.2					11.1	106	8.7	SE
SSE	.2	1.6	2.4	1.3	2.9					8.4	80	11.4	SSE
S	.1	.1	1.6	1.5	.1					3.3	32	10.2	S
SSW		.1	.2	.8	.1					1.3	12	11.4	SSW
SW	.1		.2	.1						.4	4	7.0	SW
WSW			.1	.1	.1					.3	3	12.7	WSW
W			.1							.1	1	7.0	W
WNW													WNW
NW		.2	.4	1.2	.1					1.9	18	10.7	NW
NNW	.2	.2	1.4	.3						2.1	20	7.5	NNW
VBL													VBL
CLM										.2	2		CLM
TOT	1.2	7.8	37.6	20.9	30.2	2.0			.1	100.0	956	12.0	TOT

MAXIMUM WIND ESE 44

N Summary (cont.)

AIR WEATHER SERVICE — N SUMMARY # 17

CLIMATIC CENTER — 02 LST

DATA PROCESSING DIVISION

MEAN NUMBER OF DAYS WITH INDICATED TOTAL AND LOW CLOUD AMOUNTS

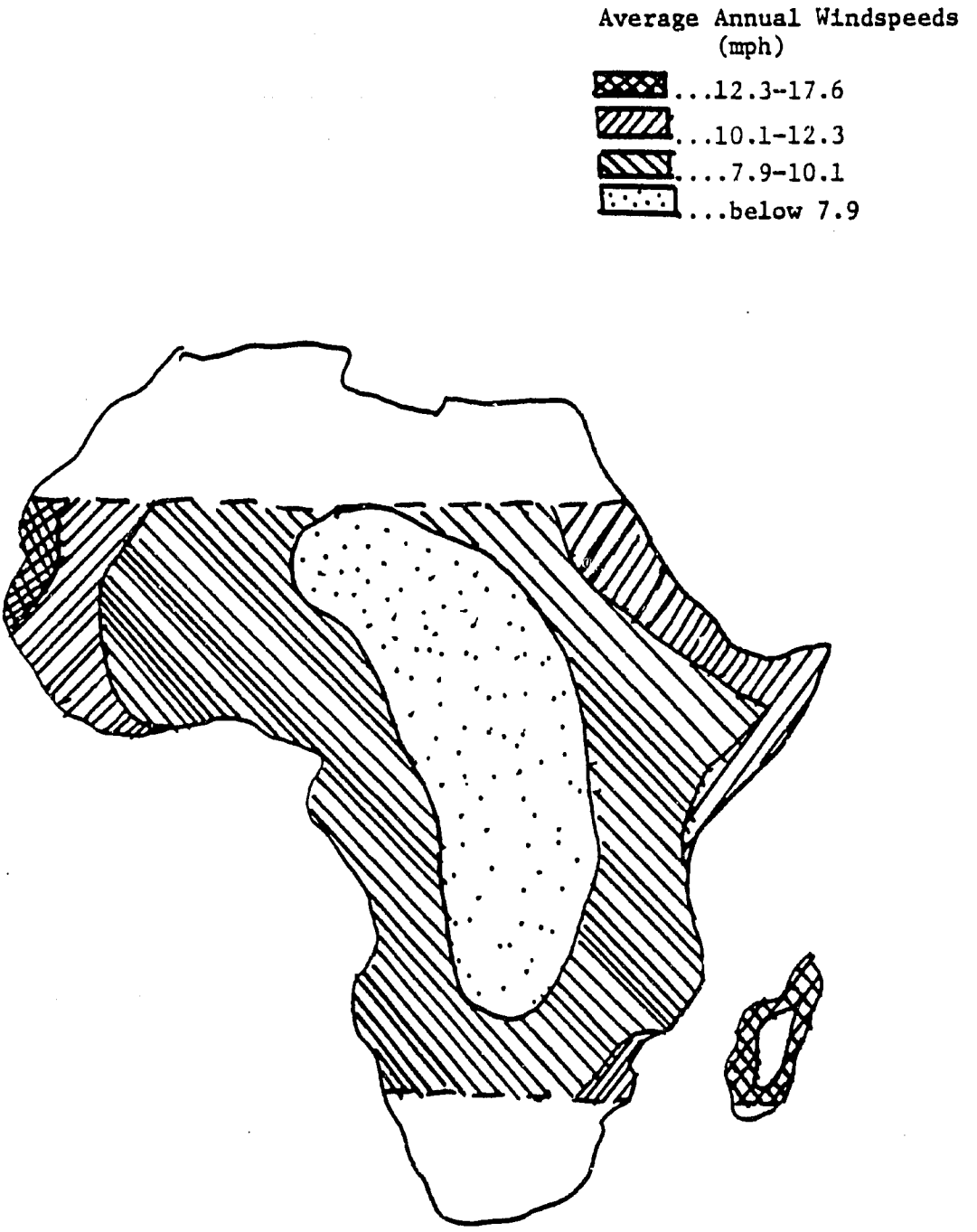
62059 DERNA LIBYA

32 44 N 022 38 E 30 FT

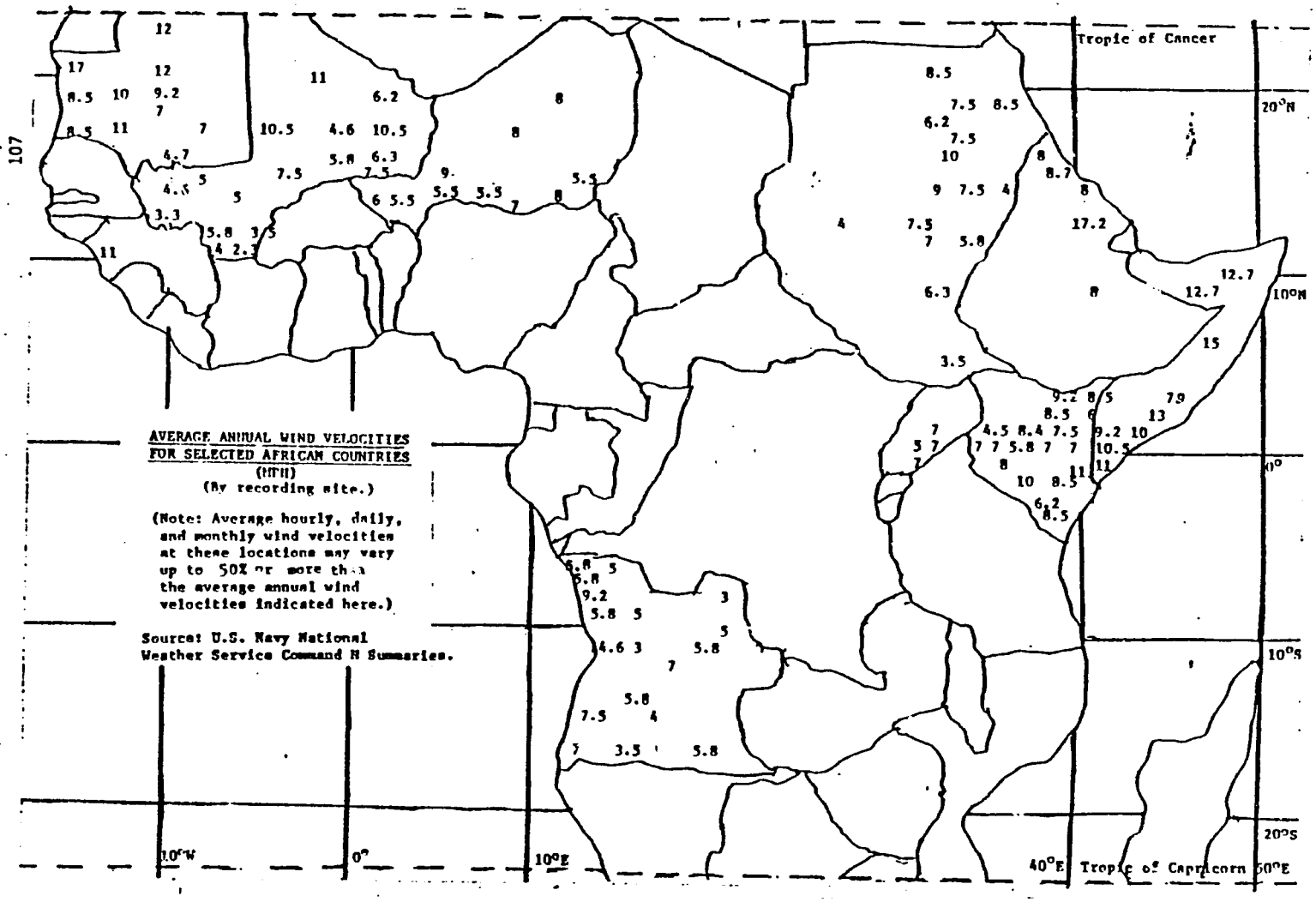
JAN 56-DEC 63

MONTH	MEAN TOTAL CLD IN OKTAS	MEAN NUMBER OF DAYS WITH TOTAL CLOUD AMOUNT 0-1/8	0-2/8	3-5/8	6-8/8	TOTAL OBS	MEAN NUMBER OF DAYS WITH LOW CLOUD AMOUNT* 0-1/8	0-2/8	3-5/8	6-8/8	TOTAL OBS
JAN	3.8	8.3	10.4	10.4	10.2	232	10.3	12.7	10.3	8.0	232
FEB	4.0	7.3	9.0	8.3	10.7	226	9.5	11.3	7.4	9.3	226
MAR	3.3	9.6	12.9	9.9	8.3	248	13.1	15.8	8.9	6.4	248
APR	3.1	11.5	14.3	8.5	7.2	225	13.9	16.7	7.5	5.9	225
MAY	2.2	15.5	18.4	8.0	4.5	232	17.2	20.2	7.2	3.6	232
JUN	1.3	19.0	22.2	6.4	1.4	220	19.9	22.9	6.1	1.0	220
JUL	1.1	20.8	23.5	7.5		235	20.8	23.5	7.5		235
AUG	1.2	19.2	23.3	7.5	.1	247	19.2	23.3	7.5	.1	247
SEP	2.1	12.9	17.6	10.7	1.6	238	13.1	18.0	10.5	1.5	238
OCT	2.9	10.3	12.9	12.9	5.1	247	11.4	14.1	12.4	4.5	247
NOV	3.2	9.8	13.2	9.5	7.3	239	11.9	15.7	9.4	4.9	239
DEC	3.6	7.8	11.2	10.0	9.8	233	11.0	14.1	9.8	7.1	233
ANN	2.7	151.9	189.0	109.7	66.2	2822	171.4	208.1	104.6	52.2	2822

*LOW CLOUD AMOUNT IS FROM THE SYNOPTIC CODE SYMBOL N WITH A LOWER CASE H SUBSCRIPT AND NORMALLY REPRESENTS THE FRACTION OF THE CELESTIAL DOME COVERED BY THE CLOUD TYPE REPORTED FOR THE LOW LAYER OR IF NONE FOR THE MIDDLE LAYER REGARDLESS OF HEIGHT.



Source: Arthur Stodhart, Electrical Research Association, England


Tropic of Cancer
20°N
10°N
0°
10°S
20°S
10°W
0°
10°E
40°E
Tropic of Capricorn
50°E
AVERAGE ANNUAL WIND VELOCITIES
FOR SELECTED AFRICAN COUNTRIES
(MPH)
(By recording site.)
(Note: Average hourly, daily, and monthly wind velocities at these locations may vary up to 50% or more than the average annual wind velocities indicated here.)
Source: U.S. Navy National Weather Service Command H Summaries.

Sub-Saharan African Locations for Which N Summaries Exist (FN)

(and Wind Data for Selected Sites)

		Average Annual Wind Speed (mph)	% of Wind 8-18+ mph
Angola			
	Ambrizete	5.5	24.3
	Cabinda	5.4	24.0
	Carmona	5.0	15.0
	Cela	2.8	10.0
	Dundo	3.0	6.5
	Henrique de Carvalho	5.4	24.0
	Lebito	4.5	18.6
	Luanda	9.0	58.5
	Luso	5.9	22.5
	Malange	5.2	17.5
	Mavinga	5.5	27.0
	Mocamedes	7.5	43.0
	Nova Lisboa	5.9	27.5
	Porto Amboim	5.9	29.0
	Sa da Bandeira	7.0	35.0
	Serpa Pinto	4.3	12.3
	Silva Porto	6.7	33.0
	Vila Rocadas	3.7	15.5
Cameroon			
	Batouri		
	Campo		
	Douala		
	Garoua		
	Ngaounders		
	Tiko		
Central African Republic			
	Bangui		
	Berberati		
	N'Dele		
Chad			
	Fort Archambault		
	Fort Lamy		
Comoro Island			
	Dzaoudzi /Mayotte		

Congo
Brazzaville

Brazzaville/Maya Maya
Djambala
Gamboma
Impfondo
M'Pojya
Ouesso
Pointe Noire

Dahomey

Cotonou
Kandi
Natitingou
Paougnan/Bohicon
Save
Tchaourou

Democratic Republic
of the Congo

Albertville/Kalemi North
Bukava/Costermansville
Buniaville
Buta
Elisabethville
Irumu
Kamina
Baka
Kindu
Leopoldville/Kinshasa
Luluabourg
Mbandaka/Coquilhatville
Stanleyville
Usumbura Ruanda Urundi

Ethiopia

Addis Ababa	5.9	32.0
Agordat	7.4	29.8
Asmara	7.8	51.6
Assab	17.3	80.2
Dire Dawa	8.1	41.6
Massawa	8.7	54.3
Neghelli	8.1	40.8

French
Somaliland

Dikhil
Djibouti
Tadjoura

Gabon

Franceville
Lambarene
Libreville
Mayumba
Mouila
Port Gentil

Ghana

Ada
Ho
Kumasi
Saltpond
Takoradi

Guinea

Boke
Conakry
Kankan
Lare
Macenta

Ivory Coast

Adiake
Bouake
Dimbokro
Ferkessedougou
Man
Port Bouet/Abidjan
Sassandra
Tabou

Kenya, Tanzania
Uganda

Arua	5.2		15.0
Dar Es Salaam			
Eldoret	8.0		40.0
Entebbe Apt.	7.0	(9.0+ more than 30%)	41.0
Fort Portal	6.9		33.0
Garissa	10.5	(12+: Jun-Aug)	78.0
Gulu	7.7		40.0
Isiolo	9.2	(11.5+: July-Sept)	68.0
Kabale	5.8		28.0
Kisumu			
Kitale	6.8	(9: afternoons)	35.0
Lamu	10.8	(13+: Jun- Aug 12+: afternoons)	70.0

Lindi			
Lodwar	8.4		50.0
Magadi	5.5	(11: mornings)	20.0
Makindu	8.6	(11+: evenings)	46.0
Mandera	9.5	(14+: Jun-Aug 11: afternoons)	52.0
Mbarara	6.7	(10+: Sept, Oct 10+: noon)	35.0
Mombasa	8.6	(10+: June 14+: afternoons)	56.0
Moroto	4.5		15.0
Moshi			
Moyale	8.3	(10: August)	57.0
Musama			
Mwanza			
Nairobi/Embakasi Apt.	7.7	(9.5: Dec-Mar 11: afternoons)	45.6
Nakuru	6.9	(10: afternoons)	41.5
Nanyuki	7.5	(9: Jan, Feb, June, July 10+: afternoons)	47.1
Narok	6.4		33.0
Songea			
Tabora			
Tororo	6.0		25.0
Voi	8.0	(10+: Jun-Aug)	45.0
Wajir	10.4	(12+: Jun-Aug 11+: mornings)	78.0

Liberia

Cape Palmas
Roberts Field/Marshall

Malagasy Republic

Europa Ile
Fort Dauphin
Majunga
St. Denis/Reunion Isl.
Tamtave

Mali

Bamako	5.8	28.0
Bougouni	4.0	12.6
Gao	10.4	61.0
Hombori	5.9	33.5
Kayes	4.7	18.0
Kenieba	3.9	10.8
Kidal	6.3	28.0
Kita	5.1	20.0
Koutiala	3.7	15.4

	Menaka	6.1	34.0
	Mopti	7.5	43.0
	Nioro du Sahel	7.1	45.1
	San		
	Segou	5.0	19.0
	Sikasso	2.1	4.6
	Tessalit	11.2	68.0
	Tombouctou	4.4	12.1
	Toukoto		
Mauritania, Senegal			
	Aioun-el-Atrouss	10.9	66.0
	Akjoujt	10.0	68.0
	Atar	9.2	53.0
	Boutilimit		
	Dakar		
	Fort Gouraud	11.9	70.0
	Fort Trinquet	12.3	78.0
	Kiffa	4.8	25.0
	Matam		
	Nema	10.6	55.0
	Nouakchott	8.7	59.0
	Port Etienne	17.3	91.4
	Rosso	9.0	52.0
	St. Louis		
	Tambacounda		
	Tidjikja	6.8	37.0
Mozambique			
	Beira/Sucadura Cabral		
	Lourenco Maurques		
	Mossuril/Lumbo		
	Quelimane		
Niger			
	Adadez	7.9	42.5
	Bilma/Dirkou	8.2	42.0
	Birni N Konni	5.8	29.0
	Maine Soroa	8.3	49.0
	Maradi	6.1	29.0
	N Guigmi	5.7	23.0
	Niamey Aero	6.3	32.0
	Tahoua	9.4	56.0
	Tillabery	7.7	39.0
	Zinder Aero	6.8	35.0

Nigeria

Benin City		
Bida		
Jos		
Kaduna		
Kano		
Katsina		
Lagos/Ikeja		
Maiduguri		
Minna		
Nguru		
Port Harcourt		
Potiskum		
Sokoto		
Yelwa		

Ocean Isles

Ascension		
Diego Garcia		
Mauritius		
Seychelles		

Portuguese Guinea

Buissau		
Bolama		

Somali Republic

Alula		
Belet-Uen	8.1	52.0
Chigimaio	11.0	84.0
Galcayo	15.0	84.0
Gardo	12.5	84.0
Margeisa	13.0	80.0
Iscia Baidoa	9.8	76.5
Mogadiscio	13.5	86.0

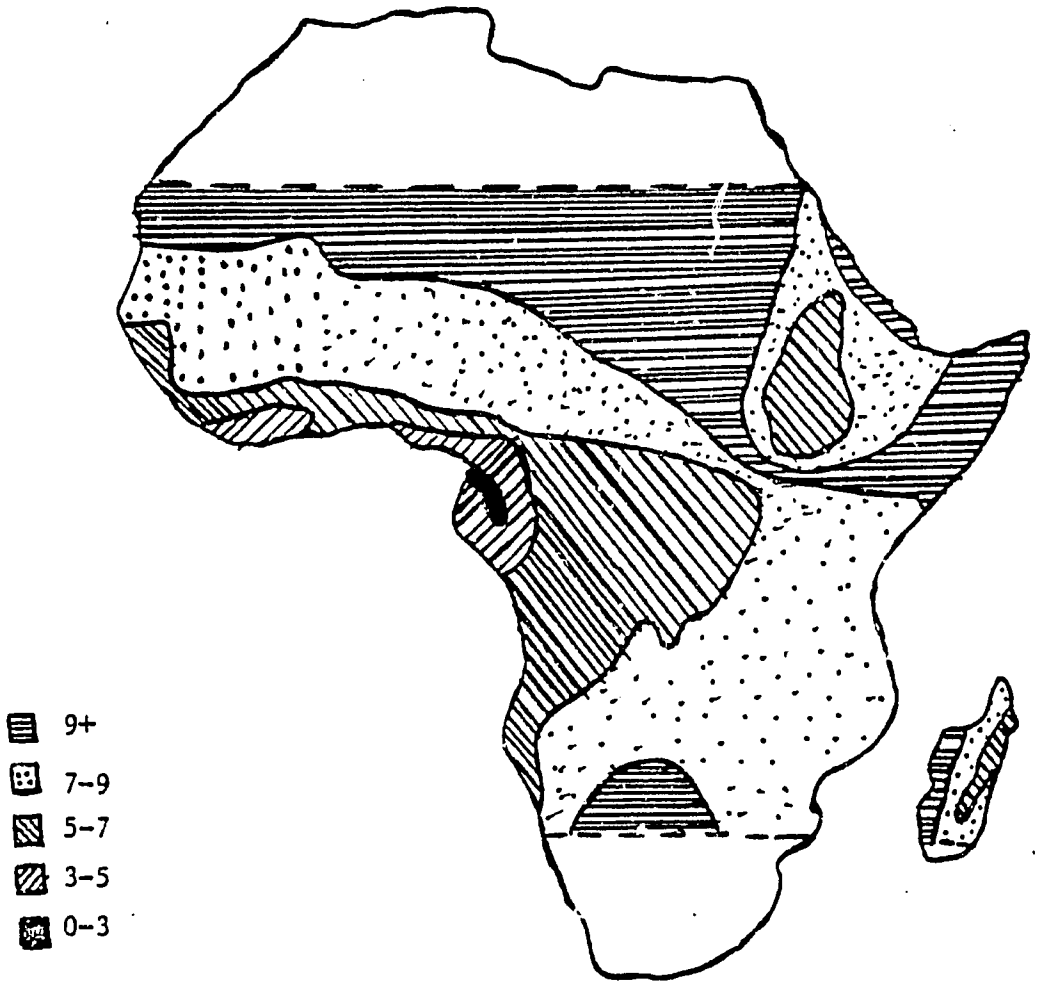
Sudan

Abu Hamed	7.5	
Atabara	7.3	
El Fasher	3.9	
El Geneina	6.1	
El Obeid	7.7	
Juba	3.3	
Karima/Merowe	6.4	
Kassala	3.7	
Khartoum	9.6	
Kosti	6.8	

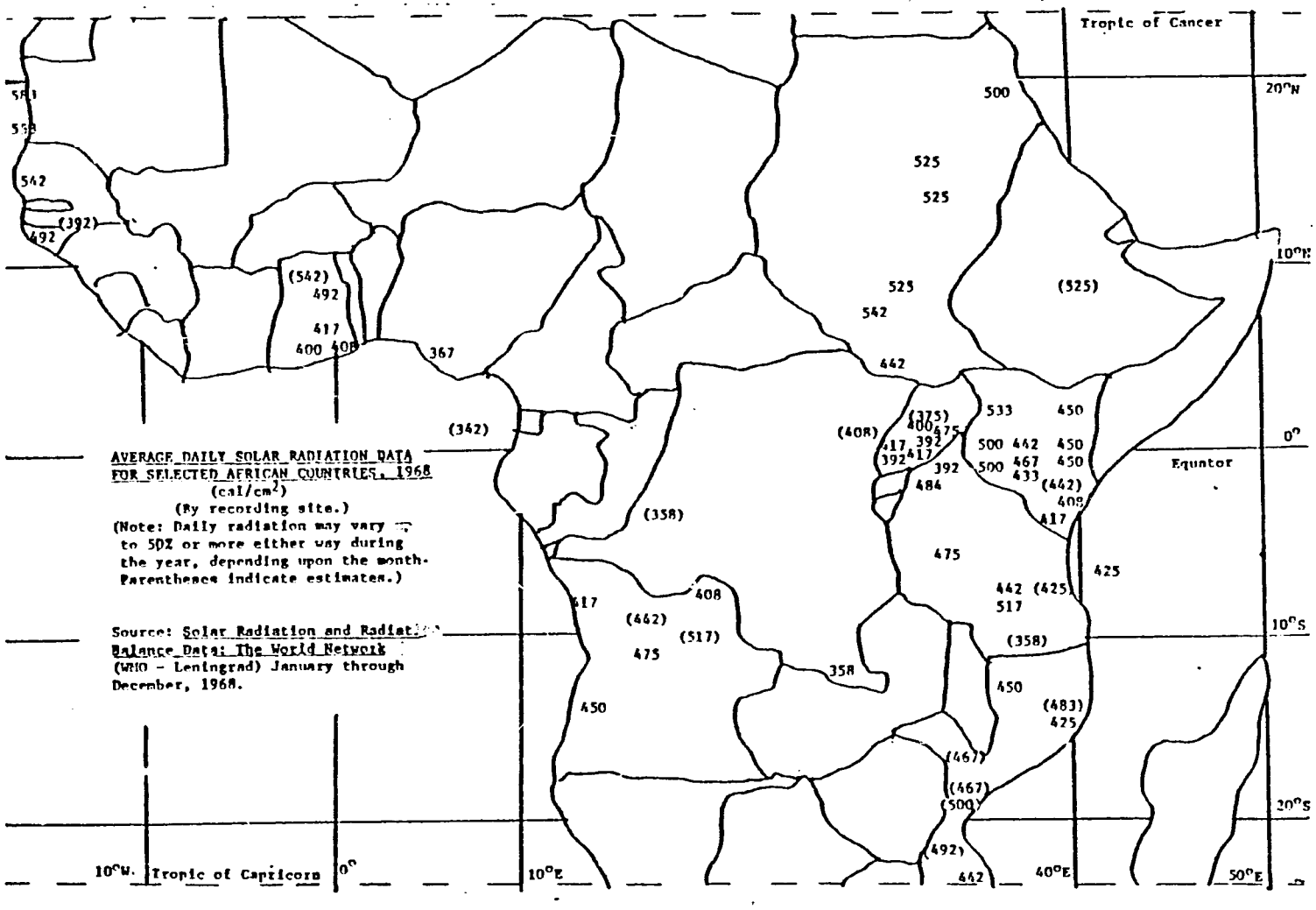
	Port Sudan	8.7
	Wadi Halfa	8.7
	Wau	3.3
Togo		
	Lome	
	Mango	
	Sokode	
Upper Volta		
	Bobo/Dioulasso	
	Boromo	
	Dori	
	Fada N'Gourma	
	Gaoua	
	Ouagadougou	
Zambia, Rhodesia, Malawi		
	Bulawayo	
	Chileka	
	Chipinga	
	Kariba	
	Kasama	
	Livingstone	
	Lusaka	
	Mongu	
	Ndola	
	Salisbury	

(FN) Guide to Standard Weather Summaries and Climatic Services, National Weather Service Command, U.S. Navy, January, 1975.

Mean Annual Sunshine
(Hours/Day)



Source: Oxford Regional Economic Atlas--AFRICA, Clarendon Press, Oxford, 1970.



AVERAGE DAILY SOLAR RADIATION DATA FOR SELECTED AFRICAN COUNTRIES, 1968
(cal/cm²)
(By recording site.)
(Note: Daily radiation may vary to 50% or more either way during the year, depending upon the month. Parentheses indicate estimates.)

Source: Solar Radiation and Radiation Balance Data: The World Network (WMO - Leningrad) January through December, 1968.

Sub-Saharan African Locations for which Daily and Monthly Solar Radiation Data are Available from the World Meteorological Organization (FN)
and
Average Daily Solar Radiation (cal/cm^2) 1968
(Parentheses indicate estimates.)

Angola		
	Dundo	405
	Luanda	415
	Malange	(443)
	Luso	(513)
	Mocamedes	454
	Nova Lisbon	(474)
Cape Verde Islands		
	Mindelo	(590)
	Praia	557
Ethiopia		
	Addis Ababa	(524)
	Wonji	(451)
Ghana		
	Navrongo	(539)
	Tamale	494
	Kumasi	407
	Accra	412
	Takoradi	418
Guinea Bissau		
	Bafata	392
	Bissau	496
	Bolama	(606)
Kenya		
	Mandera	447
	Lodwar	535
	Kitale	501
	Nanyuki	440
	Kisumu	501
	Nakuru	464
	Garissa	454
	Narok	(451)
	Muguga	444
	Nairobi	433
	Malindi	408
	Voi	(445)
	Mombasa	418
Mozambique		
	Vila Cabra	452
	Lumbo	(487)
	Nampula	423

	Tete	(470)
	Vila Pery	467
	Beira	(497)
	Malvernia	(497)
	Inhambane	438
	V. Trigo Morais	422
	Laurenco Marques	441
Nigeria		
	Benin	368
Sao Tome		
	Sao Tome	347
Senegal		
	Dakar	544
Sudan		
	Port Sudan	499
	Shambat	537
	Wad Medani	543
	El Fasher	541
	Abu Naama	602
	Ghazala Gawazat	492
	Malakal	519
	Juba	444
Tanzania		
	Bukoba	393
	Mwanza	485
	Tabora	472
	Dodoma	441
	Zanzabar	422
	Dar-es-Salaam	(425)
	Iringa	521
	Songea	(362)
Uganda		
	Gulu	401
	Masindi	(377)
	Tororo	473
	Namlonge	410
	Jinja	393
	Kasese	414
	Entebbe	419
	Mbarara	390
Zaire		
	Bunia Ruampara	(412)
	Kinshasa	(359)
	Lubumbashi	(478)

(FN) Solar Radiation and Radiation Balance Data: The World Network WMO-Leningrad, U.S.S.R.) January-December 1968.

APPENDIX VI

Instrumentation Equipment

Accurate data collection equipment exist commercially, generally in the range of $400 - 1000. There may be a good case for further research on ultra-cheap improvisations which might substitute for average village use that will give data somewhat close in accuracy to the more sophisticated equipment. Where very accurate data are needed (e.g.-for site selection for more expensive technologies such as wind electric or small hydroelectric, or for field test sites, then use of more accurate, more expensive, more reliable equipment may well be warranted.)

Wind Recording Instruments

Wind recording instruments cover a wide range of sophistication, quality, and cost, depending upon the need:

$1000+ - Integrating recording cup anemometer - this is the most sophisticated instrument, recording the number of feet of air per unit of time continuously for 10-30 days (including wind speed and direction) which passes a given area recorded by the instrument. This instrument allows every calculation of the actual amount of power in the wind for a given period of time--the most useful information for wind machine site investigation.

$650-800 - Recording cup anemometers - capable of recording between 10-30 days of continuous wind speed and direction. Calculation of power must be done by survey of record and a power formula.

$300-400 - Cup anemometers - gives wind speed and direction at instant of observation. Power must be caluclated by reading of meter and power formula.

$10-40 - Hand-held cup anemometers - gives same information as $300-400 cup anemometers, only must use some kind of pole or tower to record the wind at the desired height above the surface (usually 10 meters.)

Improvisation - Beaufort Scale - the chart on the following page gives the Beaufort scale guide for visual observations of wind, which can be supplemented by visual determination of wind direction.

Flags - it would bear further investigation whether a series of differently weighted flags of cloth or other mat material could be devised and standardized such that each flag will fly full for a given specific wind speed range. This would be a very inexpensive way of measuring wind. A similar technique which has been used is that of using a ping-pong ball or similar light object, which can be read against a background similar to a protractor which gives windspeed instead of degrees.

BEAUFORT SCALE OF WIND FORCE
(Compiled by U.S. Weather Bureau, 1955)

Beaufort number	Miles per hour	Knots	Wind effects observed on land	Terms used in USWB forecasts
0	Less than 1	Less than 1	Calm; smoke rises vertically	Light
1	1-3	1-3	Direction of wind shown by smoke drift; but not by wind vanes	
2	4-7	4-6	Wind felt on face; leaves rustle; ordinary vane moved by wind	
3	8-12	7-10	Leaves and small twigs in constant motion; wind extends light flag	Gentle
4	13-18	11-16	Raises dust, loose paper; small branches are moved	Moderate
5	19-24	17-21	Small trees in leaf begin to sway; crested wavelets form on inland waters	Fresh
6	25-31	22-27	Large branches in motion; whistling heard in telegraph wires: umbrellas used with difficulty	Strong
7	32-38	28-33	Whole trees in motion; inconvenience felt walking against wind	
8	39-46	34-40	Breaks twigs off trees; generally impedes progress	Gale
9	47-54	41-47	Slight structural damage occurs; (chimney pots, slates removed)	
10	55-63	48-55	Seldom experienced inland; trees uprooted; considerable structural damage occurs	Whole Gale
11	64-72	56-63	Very rarely experienced; accompanied by widespread damage	
12 or more	73 or more	64 or more	Very rarely experienced; accompanied by widespread damage	Hurricane

Solar Radiation Equipment

$1000-$1200 - Pyranometer - records the total incoming solar radiation (from direct sunlight and indirect reflection from clouds, hillsides, buildings, trees, ground, etc.) The most accurate instrument.

$200-400 - Actinometer or actinograph - records the duration of sunshine (# hours of sunshine per day) but does not measure the intensity of that sunshine.

Improvisation - Technique to estimate solar radiation have so far consisted of visual observations of cloud cover and temperature (from thermometer) - often resulting in test data within 10 or 20% plus or minus the real value. If nearby pyranometer data is available, it may be possible to assume that solar radiation amounts will be similar for a village site with similar typographic and other features.

Stream Flow Data

$400-1000 - Stream Flow Gauge Recorders - Some instruments are similar in structure to cup anemometers in operation, others operate on pressure differentials.

$300-400 - Stream Flow Gauge Meters - No recording equipment - must be read and recorded manually.

Stream Flow Gauge Recorders - Require computer analysis hookup.

Improvisation - There may be room for some improvisation, e.g. a float which can be placed on water at one point, and time recorded for it to cover a given distance. This might be correlated with the height (stage) and width of the stream to give flow data. Once the flow over a wide range of stages is know, then flow can be easily read from a formula or chart.

Training to Operate Instruments

Although some of these instruments are fairly complicated, anyone with a good African secondary school background or good mechanical ability and conscientious work habits can be trained to operate most of them. Indeed, there are numerous reports of African secondary school and college students being successfully trained to operate these instruments, and even reports of African elementary school children successfully taking meteorological measurements on a regular basis, dating in some cases back to the 1940's.

APPENDIX VII

Illustrative Estimate of Costs of Village Resident Energy Research Project

1.	Contractor Expenses	
	First Year:	
	Design and conduct training course and consult during pre-hardware installation research (one man year)	$ 50,000
	Travel and per diem - 4 round trips	10,000
	Supplies, equipment, instruments, etc.	25,000
	Second Year:	
	Design and conduct training course for hardware testing (one man year)	50,000
	Hardware for training course	100,000
	Travel and per diem - 6 round trips	15,000
	Consult during hardware testing stage (one man year)	50,000
		300,000
2.	Cost of Village Hardware to be Installed in 20 Test Villages at $10,000 Each	200,000
3.	Cost of Training One Resident Researcher and One Local Handyman for Each Village 40 X $500 (travel and per diem both years)	20,000
4.	Expenses of One Host African Energy Institution for Two Years	100,000
5.	One Year Stipends for Twenty African Resident Researchers at $1,000 Each	20,000
6.	One Year Stipends of Twenty Village Handymen at $250 Each	5,000
	TOTAL	$645,000

APPENDIX VIII

Village Resident Energy Project

A Sequential Outline of Key Steps

Phase One	Optimum Time Period
1. Consultation with USAIDs and Africans	FY 1977
2. African request for such a project	FY 1977
3. Negotiation of project details; Obligate funds	FY 1978
4. Engage a contractor	FY 1978
5. Begin software research on village energy sources, village choices and energy impact baseline data in a number of villages	FY 1978
6. Installation of hardware in a sample of villages	FY 1979
7. Evaluation of hardware	FY 1980
8. Evaluation of extension systems	FY 1980
9. African decision on whether to use village source energy on wide scale and which extension system	FY 1981

Phase Two	
Implementation of the decisions in Step 9 above (Phase Two was not covered in this paper)	1981-2000

APPENDIX IX

A Hypothetical Village Energy Research and Extension Service

In order that villages can be linked to the research world with a two way flow of information, some African nations may decide to establish a Village Energy Research and Extension Service (VERES). This is an illustrative sketch of what such a service might look like. The experience of the United States with its Cooperative Extension Service (formerly Agricultural Extension Service) may suggest certain components of the proposed Village Energy Research and Extension Service (VERES). At one end of the system would be the village users of energy. In addition to whatever village or tribal officials are involved, the main cadre of the village energy program would be a Resident Energy Technician. This person might typically be a native of the village or at least of the tribe. He or she would be trained in the operation, maintenance, and minor repair of the selected technologies. This might or might not be a full time job. He or she might be on the payroll of the central or provincial government or of the village itself. The Technician would take problems to and receive technical guidance from the Energy Extension Agent. The latter would be the chief link between the village and the outside world of energy research. The Agent should be an energy generalist, familiar with all small scale energy technology, committed to no one source as a universal answer, steeped in a diagnostic approach to energy problems and open to an eclectic solution. Ideally he or she would have engineering training, plus some training in the economics of energy systems and in village culture and politics. He would have responsibility for many villages.

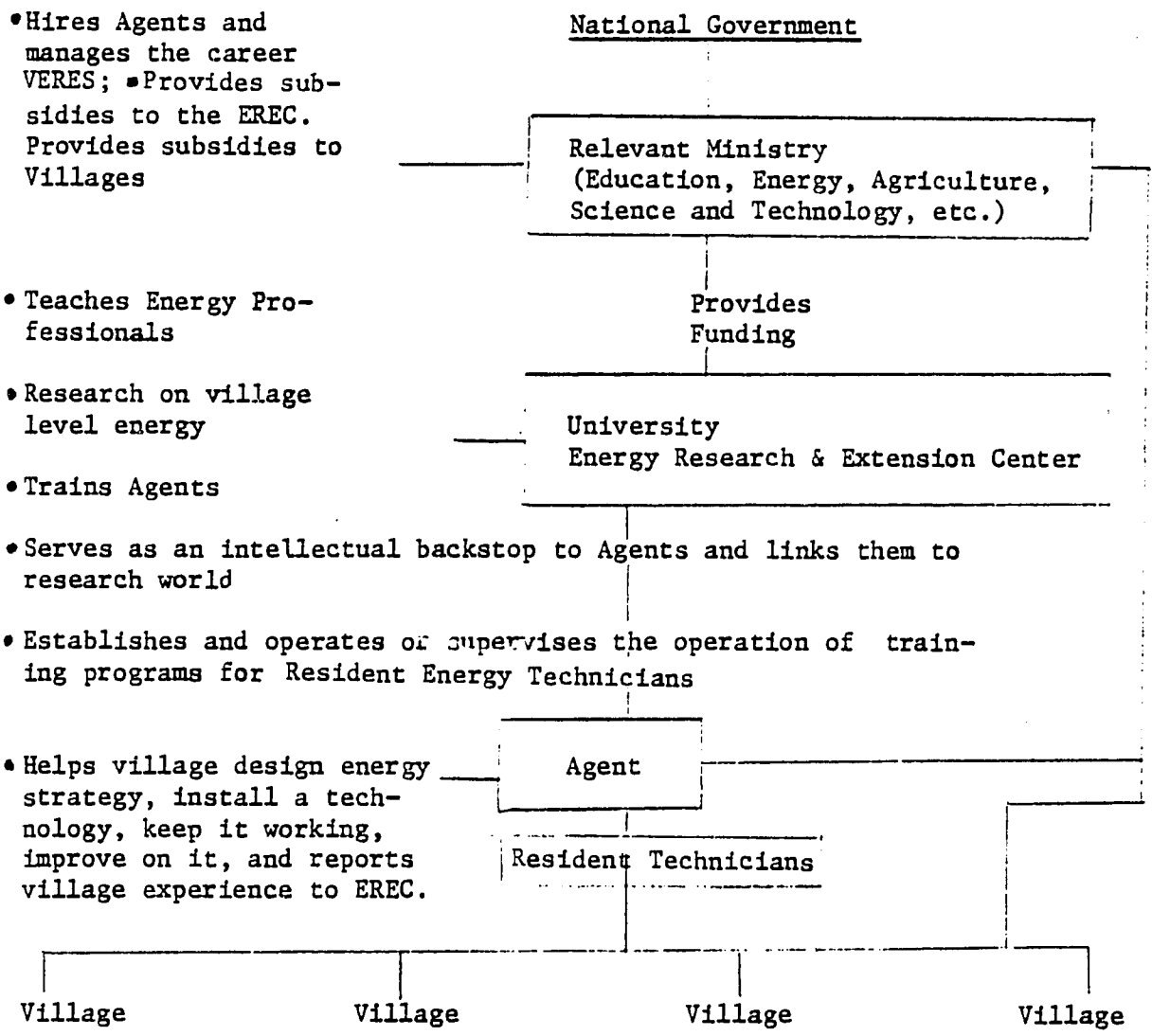
The agent would (1) help villagers work out an energy strategy, (2) install a technology, (3) keep it functioning, working through the Resident Energy Technician and other relevant village officials, (4) bring improvements to the village from the research world, (5) bring to the research world the results of the village experience, and (6) feedback to the RET training programs the results of practical experience at the village level with the technicians.

The agent might be trained at an Energy Research and Extension Center associated with a university, either within the nation, or in some cases, elsewhere in the region. That center, which might be linked to the school of engineering or of Agriculture of the university, would have four tasks: (1) teaching experts in energy for employment inside or outside the Energy Extension Service; (2) research on village level energy technology; (3) the intellectual and technological backstopping of the extension agents; and (4) establishing programs (or supervising their establishment) to train village Resident Energy Technicians. As part of the second and third tasks, it would also collect from the agents information on problems of application in the villages of various technologies and ensure that such information was taken into account by researchers.

The Energy Research and Extension Centers (EREC) would link the national VERES to the outside world of energy research and development. A diagrammatic version of a typical Village Energy Research and Extension Service is provided in Figure 1.

Figure 1

A Typical Village Energy Research and Extension Service



APPENDIX X

Population, GNP and Energy Consumption for 1974

Country	Population (millions)[1]	GNP per capita (U.S.$)[1]	GNP Growth Rate per capita (1965-73) (%)[1]	Commercial Energy Consumption per capita (kg. of coal) equivalent[2]	Electricity Consumption per capita[2] in kwh
Angola	5.8	580	3.2	191	109
Benin	3.0	120	1.5	42	17
Botswana					
Burundi	3.7	80	1.4	13	6
Cameroon	6.3	260	4.9	86	179
Cape Verde Islands	0.3		6.0	90	27
Central African Rep.	1.7	200	1.0	57	30
Chad	4.0	90	-3.3	17	14
Congo	1.2	390	1.9	216	75
Equatorial Guinea	0.3	260	-3.1	87	56
Ethiopia	27.2	90	1.6	31	25
Gabon	0.5	1,560	6.1	1,070	333
Gambia	0.5	170	2.2	73	39
Ghana	9.6	350	0.8	184	379
Guinea	5.4	120	0.1	94	116
Guinea Bissau			5.9	41	39
Ivory Coast	6.1	420	3.0	370	179
Kenya	12.9	200	3.3	177	86
Lesotho					
Liberia	1.5	330	4.7	482	515
Malagasy Republic	8.6	170	0.9	71	44
Malawi	5.0	130	3.7	56	46
Mali	5.5	70	0.5	24	15
Mauritania	1.3	230	1.2	112	74
Mauritius	0.8	480	1.4	275	361
Mozambique	8.5	420	4.1	141	107
Niger	4.5	100	-4.6	31	15
Nigeria	73.0	240	8.3	94	46
Reunion			4.6	484	378
Rwanda	4.1	80	3.2	13	32
Senegal	4.2	320	-2.8	184	92
Sierra Leone	2.9	180	1.5	123	81
Somalia	3.1	80	1.6	40	14
Sudan	17.5	150	-0.6	125	19
Swaziland		@600	@5.0	2,754	2,539
Tanzania	14.4	140	2.6	75	37
Togo	2.2	210	2.5	70	56
Uganda	11.2	160	1.2	51	47
Upper Volta	5.8	80	-1.1	14	3
Zaire	24.1	150	2.9	76	164
Zambia	4.8	480	-0.2	557	
Africa	392	290		359	309
World				2,059	1,613
North America	233	6,133		11,321	9,580

FOOTNOTES ON NEXT PAGE

FOOTNOTES TO APPENDIX X

1 from World Bank Atlas, World Bank, 1975.

2 from World Energy Supplies 1950-74, United Nations, Statistical Papers, Series J, No. 19, Tables 2 and 21.

Notes:

- South African Customs Union includes Botswana, Lesotho, Namibia, and Swaziland; population and GNP figures for those countries have been approximately aggregated here.
- Some data for several countries is tentative; for several countries the per capita GNP growth rate was based upon 1964-73. See original sources.
- "Africa" includes North Africa, South Africa, and Rhodesia.
- Per capita GNP figures for Africa and North America are for 1973.
- Figures for Tanzania are mainland Tanzania only.

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