ENVIRONMENTALLY SOUND SMALL-SCALE ENERGY PROJECTS

GUIDELINES FOR PLANNING

by

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Preface

This manual is the fourth volume of the Guidelines for Planning Series. The series was originally suggested by representatives of private development agencies to provide paratechnical information for their field staff and counterpart personnel in Third World countries for use in planning environmentally sound small-scale projects. Titles of other volumes in the series are listed on the opposite page.

The CODEL Environment and Development Committee has guided the development of the Guidelines for Planning Series. CODEL acknowledges the contribution of the Committee to this volume. Those members who reviewed drafts of the manual are indicated by an asterisk.

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Margaret Crouch, VITA publications office, has served as liaison with CODEL and technical adviser to CODEL for several of the volumes in the series. CODEL takes this opportunity to thank Ms. Crouch for her past assistance and special contributions to this volume.

Ms. Molly Kux, AID Office of Forestry, Environment, and Natural Resources, has encouraged and supported the preparation of each of the volumes in the series. She has played an important role in assisting with identifying authors and reviewers and personally reviewing the books. Mr. Albert Printz, AID Environmental Coordinator, reviewed and commented on the text.
CODEL acknowledges with thanks the continued support and encouragement for the Environment and Development Program from both Ms. Kux and Mr. Printz.

The AID Office of Private and Voluntary Cooperation has supported the development of the CODEL Environment and Development Program. CODEL gratefully acknowledges the contribution of that office and the support of Mr. Paul Bisek, Project Officer, for the Program as a whole.

CODEL is pleased to publish this booklet written by Elizabeth

Bessan in collaboration with Dr. Timothy Wood, Technical Editor. During the preparation of this volume Ms. Bassan served with the Sierra Club International Earth Care Center and subsequently with the American Council of Voluntary Agencies in Foreign Service. Dr. Timothy Wood recently spent two years in West Africa as a consultant for VITA, returning to his former position as Director of Environmental Studies, Wright State University, Dayton, Ohio. Brief biographies of the author and technical editor can be found at the end of the book.

Ms. Wynta Boynes, American Council of Voluntary Agencies in Foreign Service, did an excellent job of editing the text.

Finally, CODEL acknowledges with thanks the cooperative services of Ms. Rosa Marsala, Ms. Gwen Dantzler, and Ms. Betty Wynn of the Unified Information System, of the Support Agency of the Presbyterian Church (U.S.A.).

We welcome comments from readers of the book. A questionnaire is enclosed for your convenience. Please share your reactions with us.

Rev. Boyd Lowry, Executive Director, CODEL

Ms. Helen L. Vukasin and Sr. Mary Ann Smith
Environment and Development Program, CODEL

ABOUT CODEL

Coordination in Development (CODEL) is a private, not-for-profit consortium of 38 development agencies working in developing countries. CODEL funds community development activities that are locally initiated and ecumenically implemented. These activities include health, agriculture, water, appropriate technology, and training projects, among others.

The Environment and Development Program of CODEL serves the private and voluntary development community by providing workshops, information, and materials designed to document the urgency, feasibility, and potential of an approach to small-scale development that stresses the interdependence of human and natural resources. This manual is one of several materials developed under the Program to assist development workers in taking the physical environment into account during project planning, implementation, and evaluation. For more information, contact CODEL Environment and Development Program at 79 Madison Avenue, New York, New York 10016 USA.

ABOUT VITA

Volunteers in Technical Assistance (VITA) is a private nonprofit international development organization. It makes available to individuals and groups in developing countries a variety of information and technical resources aimed at fostering self-sufficiency: needs assessment and program development support; by-mail and on-site consulting services; information systems training; and management of field projects. VITA promotes the use of appropriate small-scale technologies, especially in the area

of renewable energy. VITA's extensive documentation center and worldwide roster of volunteer technical experts enable it to respond to thousands of technical inquiries each year. It also publishes a quarterly newsletter and a variety of technical manuals and bulletins. For more information, contact VITA at 1815 N. Lynn Street Suite 200, Arlington, Virginia 22209 USA.

Chapter I

USES AND USERS OF THIS MANUAL

What is the purpose of this manual?

The purpose of this manual is to help development workers and others to become aware of the environmental factors that should be considered in planning small-scale energy projects that are environmentally sound and therefore more likely to be sustained.

Environmentally sound planning includes the physical environmental factors as well as the socioeconomic and cultural factors. This approach helps assure the protection of the renewable natural resources that supply most of the energy used in the Third World.

Traditional sources--dung, crop and forest residues, fuelwood, and human and animal energy--make up a very significant amount of the energy used in developing countries. Estimates of how much traditional fuels are used vary, largely because of the difficulty in measuring non-commercial fuel use. Recent estimates indicate that in Asia these fuels account for about 65 percent of total energy use, in Africa, about 85 percent, and in Latin America, about 20 percent. This masks the enormous variation both between and within countries.

It is not likely that the situation will change dramatically in the near future. Because of supply and cost factors many energy specialists doubt that developing countries will make the transition to fossil fuels as has occurred in developed countries. From an environmental point of view, this may be good. For development, the challenge is to provide energy essential for socioeconomic development, and to promote resource use that will allow for sustainable, reliable supplies of energy.

Traditional, renewable fuels have long been considered the most environmentally sound. Practice has shown that this is true if they are not used beyond their ability to replace themselves. Environmental damage occurs when "renewable" resources are treated as a product that is used faster than it can be replaced. This can damage the ecological system, leading to soil erosion and degradation, loss of watersheds, increased flooding, and desertification. This destroys the ability of the land to produce.
Agricultural productivity and energy availability--that is, having food to cook and fuel with which to cook--depend on the ecological well-being of the physical environment.

Energy is critical to development. Energy is necessary for cooking and for pursuing productive activities that generate income and provide employment. This is as true of the twigs and leaves for village fires as for the relatively small amounts of fossil fuels that represent the life-blood of market town activities. Energy can improve the quality of life by providing drinking water, light, and heat. It can be used in devices that lead directly to added income, or free up time that can be used for other purposes.

When planning projects that involve the use of energy, there is a tendency to deal with energy and environmental questions in isolation and so to ignore their relationships to other issues. In examining these questions, planners must consider the relevant social and economic factors as well as the technical. Finally, they should appraise administrative and/or implementing capabilities. For regardless of the size of the effort, good energy planning requires more than merely a technology, a source of funds, and sound development intentions. The purpose of this manual then, is to aid development workers in thinking through how to use natural resources for energy in a way that maintains ecological well-being--the lifeline for survival.

What does the manual provide?

It provides:

* an introduction to ecological concepts, their relevance to energy development, and their interaction with the broader socioeconomic environment in which energy

development takes place

* a guide to planning small-scale energy projects in which environmental costs and benefits are incorporated

* guidelines for making an informed decision on the most enviroamentally sound energy project alternative

* an overview of the environmental considerations in using various energy sources

* background information for choosing an environmentally sound strategy to provide for specific energy end-uses, in households, agriculture, small-scale industry, and transportation

* a useful reference to commonly used energy and environmental terms

* a look at alternative solutions to addressing energy development within the broader framework of environmental and economic considerations.

Who should use this manual?

This manual was prepared for development workers and project planners in Third World countries who are assisting the urban and rural poor to plan and implement small-scale energy projects. It has been written for those who lack technical training in the area of energy, but require some general guidelines for planning projects that will help to meet pressing energy needs and at the same time protect and even increase the renewable resources.

Chapter II

ECOLOGY FOR SUSTAINABLE ENERGY DEVELOPMENT

Ecology is the study of the relationships among all living things and their surroundings, or environment. Generally the environment is thought to include such things as land, vegetation, climate, shelter and animals. In this manual a concept of human environment is expanded to include cultural, economic, social, and political factors.

This chapter will introduce a few ecological principles that are important to the planning of sound energy projects. A more detailed treatment of ecological processes can be found in any basic ecology text.

What are ecosystems and biological communities?

A central theme of ecology is the concept of an ecosystem. Common examples include forests, mangrove swamps, grasslands, and oceans. The plants and animals in an ecosystem form biological communities. Members of the communities are like interwoven threads of a fabric, each performing an important role that helps the whole community to function. Some of the "threads" may be energy and minerals that combine in complex ways to form a "food web." Other "threads" may involve activities that aerate and fertilize the soil, help the soil retain moisture, pollinate flowers, and aid in seed dispersal, to name just a few.

Although no two ecosystems are identical, all have the same fundamental structure. Two basic processes of all ecosystems are: (1) the one-way flow of energy, and (2) the cyclical flow of mineral nutrients. These processes are strongly influenced by such physical factors as sunlight, water, and temperature. Energy is expended and nutrients are recycled through eating. Eating links all plants and animals to each other. The way in which the linking takes place is called a "food chain."

How does an ecosystem work?

Ecosystems tend to be self-regulating. In well-functioning ecosystems processes of growth and decomposition occur at a rate and in a manner to maintain a balance or equilibrium. A development project that introduces a new component to the ecosystem (for example, waterpower) or diverts resources useful to the ecosystem (for example, organic wastes) may change the balance or equilibrium. Sometimes a new equilibrium can be quickly achieved. In other cases, the ability of the ecosystem to foster growth is changed.

There are four "actors" in any ecosystem through which energy and nutrients flow:

1. Producers -- green plants such as algae in a pond, grass in

a field, or trees and undergrowth in a forest. The producers make life possible through their ability to convert radiant energy from the sun to chemical energy using carbon dioxide and water. The process is called photosynthesis. Other living things, including people, can use this energy for food and fuel. About 100 billion tons of organic matter are produced annually through photosynthesis. Eventually, most of this is changed back to carbon dioxide and water. Some is left temporarily in vegetation, and some becomes cell tissue in people and other animals.

2. Consumers--animals (including people) that eat plants and/or other animals. Part of what is eaten becomes energy stored in cell tissue. The energy is used for growth, movement, reproduction, and the maintenance of the body (respiration, digestion, etc.).

3. Decomposers--bacteria and fungi. These produce enzymes that break down dead plant and animal material. This releases essential nutrients, which may be reused by producers. It may also provide organic materials that bind soil particles and thus help protect the soil from erosion.

4. Non-Living Environment--basic elements, combinations of elements, and climate. Basic elements include carbon, phosphorus, nitrogen, and sulphur, among others. Combinations of elements include proteins, carbohydrates, and

fats. The climate, which affects the rate of growth and decomposition, includes temperature, moisture, and sunlight.

As noted, the components of an ecosystem are complex and interwoven. Each performs an essential role that fosters the growth of the living parts and maintains the entire system. And changes in one component will affect not only its own functions, but also its relationship with the others--and the functioning of the system as a whole.

How are energy and the environment related?

In less advantaged countries much of the energy consumed is derived from organic matter, such as crop residues, animal dung, trees, and shrubs. These same materials may also be used for fertilizer or construction. They may be needed by plants and animals for food, nutrients, and shelter. Such competition for resources can have a far-reaching impact that may not be apparent immediately.

A more obvious environmental impact occurs whenever any energy resources are exploited and used by man. Inevitably, water, air, and soil pollution are the result. Currently in many developing countries, for example, wood for charcoal is being cut faster than it can be replaced. Proper management techniques, such as timely replanting, more efficient charcoal production methods, and controlled harvest rates, are not being adequately practiced. Exploiting the wood energy resource can become an

important contributing cause of deforestation.

The results of deforestation include exposing soils to direct sunlight, heavy rains, and nutrient loss. Soils become dry, compacted, and unproductive. Soil erosion leads to huge silt deposits in streams, creating dry stream beds and reducing the effectiveness of dams and irrigation channels. As the wood supply diminishes, the price of fuelwood increases, either in cash amounts or in the time and effort required to bring it in from more distant areas. Eventually, people may begin to use alternative fuels such as cow dung, which precludes its use as an important soil conditioner and fertilizer.

The purpose of understanding ecology in relation to development projects is to project the effect a proposed project may have on an ecosystem, to learn what mitigating measures may be required, and to monitor changes in the ecosystem as the project is implemented.

This manual addresses the conflicts between the uses of energy and the natural resources that provide energy. We are as concerned with the impact energy use may have on the environment as with the impact that environmental degradation may have on the potential energy supply. Development planners who can see beyond the technical limitations of energy technologies to view the relationship between economic development and resource management will have developed one additional method for assessing project feasibility and promoting economically viable, sustainable projects.

What is energy flow?

All life depends on energy to grow and reproduce. The ultimate source of energy on earth is the sun, which transmits its energy in the form of radiation. Green plants make life possible because they are able to convert radiant solar energy to a chemical form, using carbon dioxide and water. This process is called photosynthesis. Chemical energy is passed along as food to plant-eating animals, such as some insects, birds, rodents, wild and domestic animals, and people. These animals use much of the energy for their own activities, then transfer the rest--again as food--to predators or to decomposing bacteria and fungi. (See diagram page 8.)

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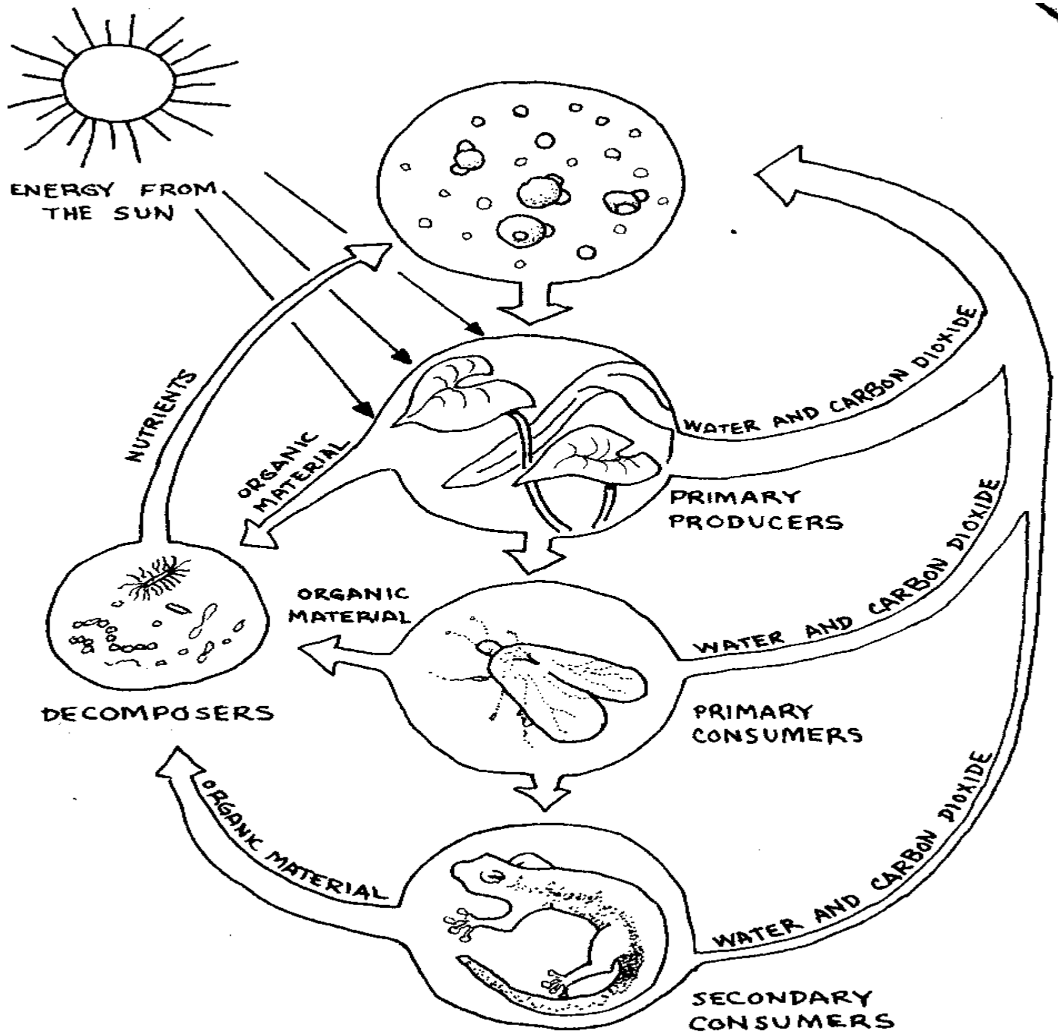

THE CYCLE OF NUTRIENTS AND ENERGY IN THE FOOD CHAIN

The diagrams on the following pages show how solar energy is

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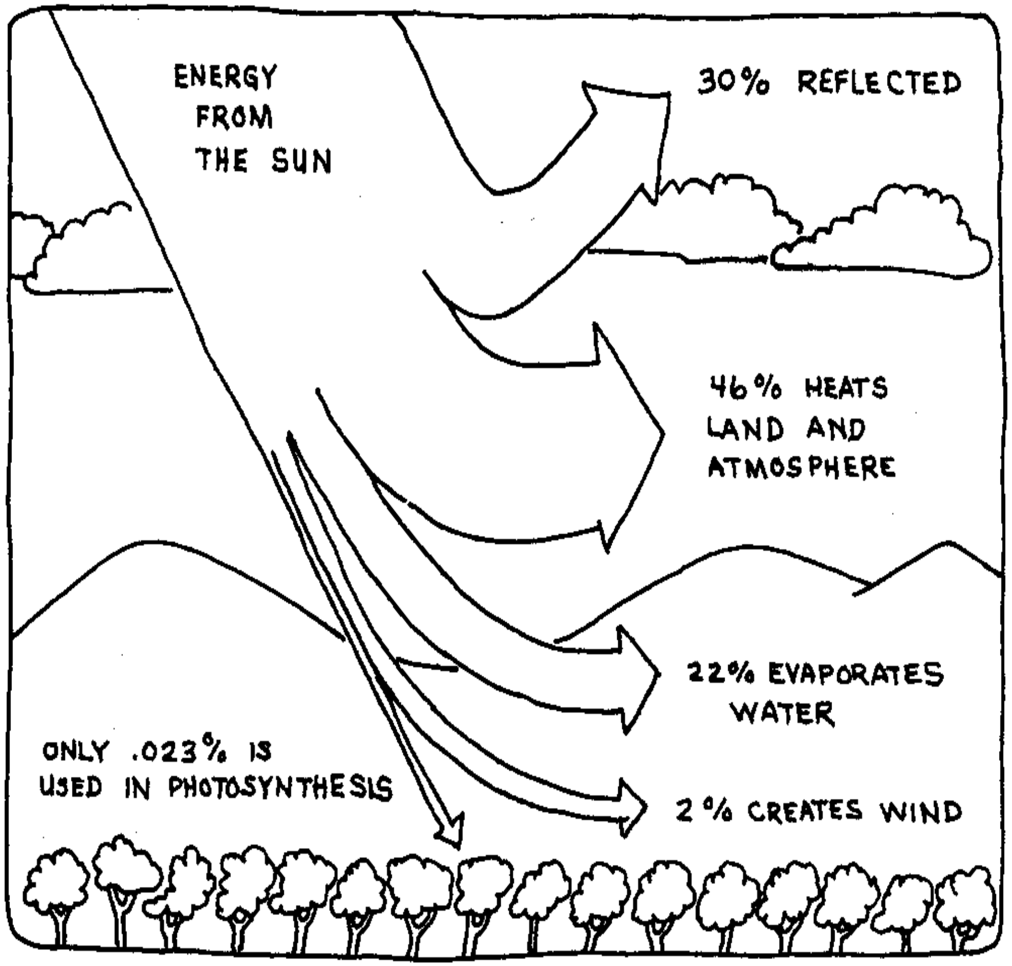
THE FLOW OF SOLAR ENERGY



photosynthesis. Smaller and smaller amounts of energy are passed along from the plants to others in the food chain. This is because a lot of food energy is used in heat-producing activities, and this heat energy is dissipated into space. Only a small amount of the initial energy is stored in chemical form, which becomes food in the food chain.

All forms of energy undergo the processes of conversion and

dissipation like that just described for solar energy. These two characteristics of energy are the first and second laws of thermodynamics: (1) energy cannot be created nor destroyed, but only converted to other forms, and (2) as energy flows through an ecosystem, it is degraded and eventually dissipated into heat, a non-usable form. This means that a continuous supply of solar energy is required to support life.

What is a nutrient cycle?

The cyclic flow of nutrients involves both living and nonliving parts of ecosystems. (See diagram on page 8.) The decomposers play a major role in recycling nutrients by breaking down dead plant and animal material. This makes essential elements available to the soil and to plants. Such elements as carbon, calcium, nitrogen, phosphorus, and sulfur are passed in this way.

No living thing can survive without the basic elements. Removing plant material takes away an important source of nutrients, and will eventually decrease the fertility of the soil. Care must be taken to assure that sufficient ground cover is left.

Unlike energy, the minerals essential to life may be used over and over, constantly recycled within the ecosystem. In land-based ecosystems, minerals are taken from the soil by plant roots. Later they may be passed from plants to grazing animals and then to a chain of predators or parasites. Eventually they are returned to the soil through the action of decomposers, such as bacteria and fungi.

Mineral recycling is seldom perfect, and in fact can be seriously disrupted. For example, wood or cow dung will eventually decompose if left alone, and the nutrients they contain will return to the soil. When wood or cow dung is collected and burned for fuel, however, all of the minerals are released in smoke or ashes. This represents a net loss of nutrients from areas where the fuel was taken, and the soil there may become less fertile. With the nutrient cycle thus broken, the ability of the soil to support plant and animal life is reduced.

What is the hydrologic (water) cycle?

Another important ecological cycle is the water, or hydrologic, cycle. Not only is water necessary for life, it also helps distribute nutrients. Powered by solar energy, the hydrologic cycle is the movement of water from the surface of the earth to the atmosphere and back to the earth again.

As can be seen from the diagram below, forests and other

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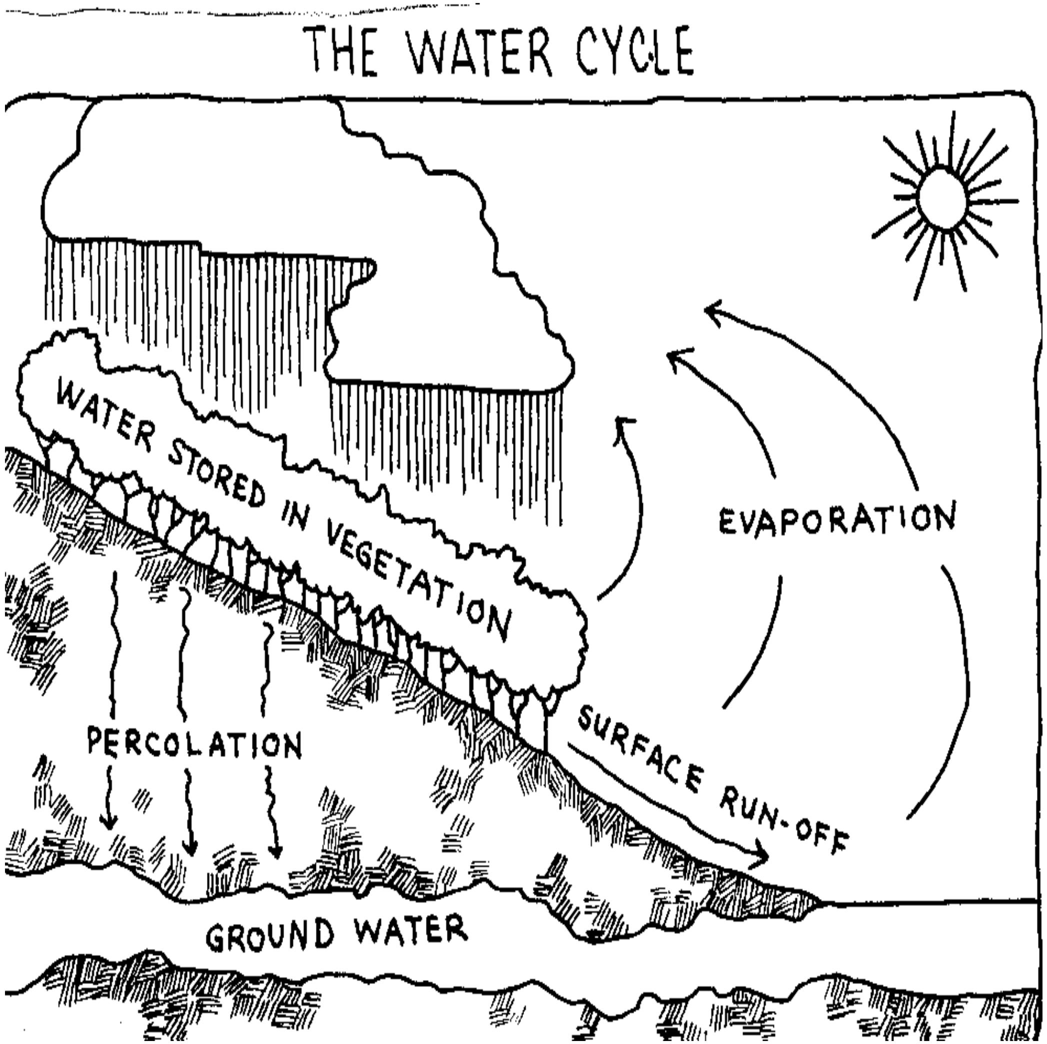

vegetation play very important roles in the hydrologic cycle. Vegetation acts to help slow down and control the flow of water to an open body of water. This keeps nutrients within an area, and prevents flooding and soil erosion. Land clearing can significantly affect the process, and may eventually decrease agricultural productivity.

What are limiting factors?

To thrive in any given situation, plants and animals must have the basic materials for reproduction and growth. These include sunlight, water, a wide variety of minerals, shelter, and protection from parasites and predators. When any one of these factors is present only in amounts approaching the minimum needed for survival, it is known as a limiting factor.

For example, the number of plants and animals that can be supported in a fertile flood plain is greater than in an arid upland of the same area because more water, nutrients, and better soils are available. Nutrients are continually brought into flood plains from upland regions, and flood plain farmers benefit from this transfer of resources. <see image>

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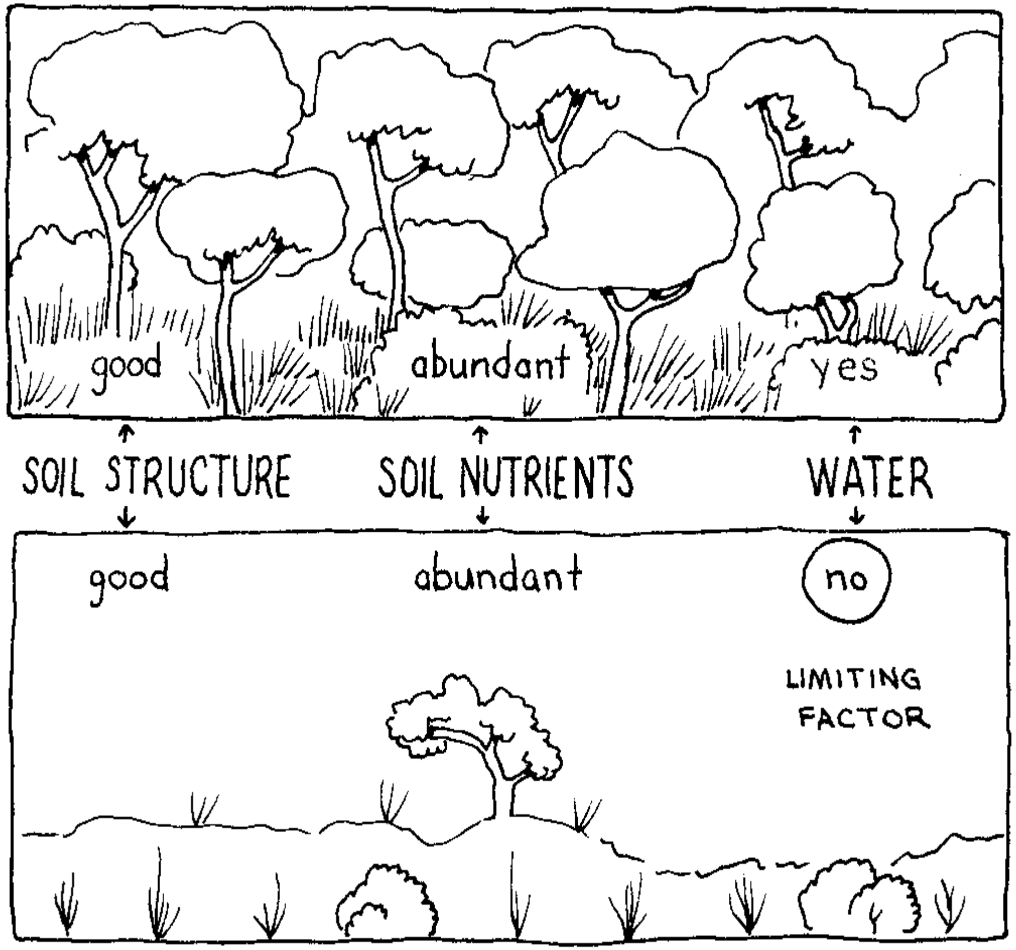

THE LIMITING FACTOR DETERMINES GROWTH IN AN ECOSYSTEM.

However, if the amount of any particular nutrient were reduced below a critical level, the productivity of the flood plain would suffer, even if all other conditions remained the same. This nutrient would be the limiting factor.

Limiting factors will vary from one place to another and from year to year. Temperature, the amount and intensity of

rainfall, soil characteristics, sunlight, and availability of nutrients vary constantly. These variations determine the types of species and number of individual plants and animals that can live in a given area.

The amount of living material an ecosystem produces can be altered, by natural and human interventions. Natural causes include things like violent storms, earthquakes, or drought. Humans can supplement a limiting material, for example, by adding water or fertilizer. However, unintended or unavoidable human interventions also can decrease the amount an ecosystem can produce. For instance, if plant materials that normally fall to the ground and decompose to enrich the soil are instead gathered for fuel, soil fertility will decline.

Often, biological potential and productivity can be improved by adjusting the availability of limiting factors. For example, agricultural production can often be increased by adding whatever is missing or in limited supply to the area. This addition might be fertilizers, organic matter, water, or pest management.

The limiting factors should be considered in any project in which energy may be derived from biomass sources that may have agricultural uses. For example, obtaining energy by burning agricultural residues diverts the amount of nutrients that can be returned to the soils. When nutrients are the limiting factor, this practice may have serious effects on long-term agricultural productivity. However, if these nutrients are not a limiting factor because agricultural productivity is relatively high and there is an excess of agricultural residues, then use of these residues for energy can be extremely beneficial to people who need fuel.

When considering limiting factors, remember:

* Satisfying the most obvious limiting factor may not solve the problem. In fact, satisfying one limiting factor may reveal yet another. For example, when nitrogen is lacking in a corn field, farmers may add a nitrogenous fertilizer. They may find that crop growth then is limited by a lack of phosphorus.

* Changing existing conditions by altering the limiting factors may upset the relationships among organisms. Changes in the system may favor organisms that previously were less competitive. These changes can be beneficial for energy production. The degree of adverse impact can be affected by the natural resource management planning in the original project design.

What is renewability?

Resources are renewable if they can reproduce themselves (for example, plants) or if they are unlimited in supply (for example, wind and sunlight). All plant-based resources have the ability to reproduce. However, their reproduction depends on the presence of suitable soil, sunlight, water, and favorable temperature.

These limiting factors must be maintained if the resource is to remain renewable.

An ecosystem can be degraded in several ways that will hinder its ability to provide the conditions necessary for its parts to reproduce. For example, dung plays a major role in recycling nutrients when left on the soil. When burned as dung cakes for fuel, many of its nutrients are lost. Although dung is renewable, its use as energy may affect its alternative use to improve soil fertility. If the soil is less fertile, less fodder will be produced. This will eventually also reduce the production of dung.

One way to avoid this would be to use the dung in biogas digesters, where sludge by-product can be an excellent fertilizer. The availability of other renewable energy sources should also be investigated. Perhaps another energy source would relieve the need to use as much dung for fuel. <see image>

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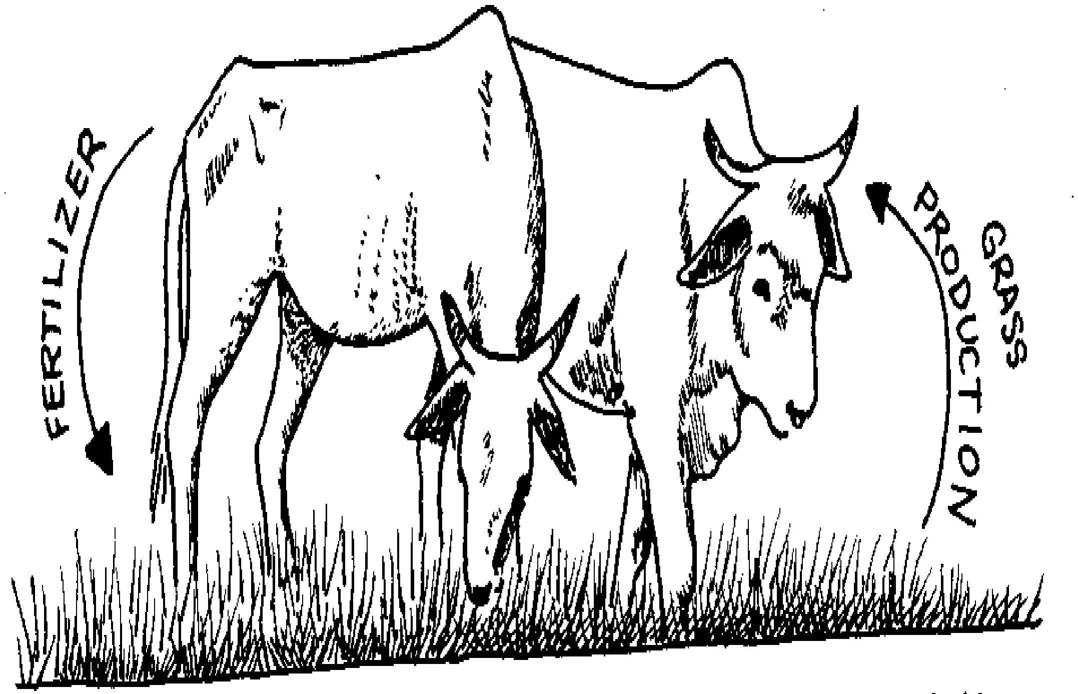

ANIMAL WASTE CONTRIBUTES TO GRASS PRODUCTION

Renewability also depends on how much time one has for planning.

For example, population growth and development pressures may require that the natural capacity for renewability of trees be supplemented with forest management practices. The time for planning must be sufficient for forest growth.

Energy, ecology, and the tropics

Ecological differences occur among tropical arid, tropical

moist, temperate, or other types of climate. These variations affect the availability of energy resources and the environmental impact of their use. We cannot cover the range of possible variations of ecosystems and energy resources in this manual. Some of the major regional systems that might affect tailoring the discussion in this manual to your particular surroundings are examined in Appendix C.

In general, solar radiation in the tropics is more abundant and harsh. Rainfall is usually more variable and concentrated. Natural rates of soil erosion are higher. The growth of plants is faster (except in the more arid areas) and often not interrupted seasonally. Differences [within the tropics are due to: the quantity and seasonal variation of rainfall; soil characteristics and erosion potential; insolation (the rate of delivery of solar radiation); and wind patterns. These characteristics of the tropics as related to the subject matter of this manual are further explored in Appendix C.

What are environmental effects?

Environmental effects are changes in the environment caused by human activities or natural processes. Determining the potential effects of a particular project requires looking at economic, cultural, and social factors, in addition to those factors that make up the natural environment. Some of these factors are explored in Chapter VI. The development planner as well as the ecologist needs to be concerned with determining the amount of pressure that populations, communites, and ecosystems can withstand without being seriously damaged.

Small-scale energy projects can have both positive and negative effects. The impact of any project may be smaller or much larger than the scope of the project itself. Changes caused by a project may not be seen for several years. It is important to know current energy use patterns in an area to determine how development projects may help solve the problems of acquiring and using energy. It is also important to find the relationships between current energy sources and the natural resource base of the project area. Once those linkages are known the planner must decide whether:

* small-scale energy projects will relieve shortages in local energy supply

* the potential source of energy (flowing streams, fuelwood, etc.) has other uses that would compete with energy production

* the uses competing with energy production can be provided for in some other way without additional pressure on the ecosystem

* small-scale energy projects in the area will have negative environmental effects

* environmental damage that may limit energy supply can be halted by developing projects that improve the

management of natural resources

Charcoal production provides a useful example of the way energy production can adversely affect the environment, and the way environmental quality can affect energy production. The increased use of charcoal, especially in urban areas, is often one of the few ways that large numbers of people can cope with rising petroleum prices.

In many places (Haiti, for example), wood for charcoal is being culled beyond a sustainable point. Trees are being cut down faster than they can grow back. The result is fewer trees, and therefore less wood for charcoal-making.

At the same time, deforestation leaves the soil unprotected from hard rain, leading to nutrient loss and soil erosion. As the environmental quality declines, the ability of the ecosystem to grow trees at all is undermined, further reducing the wood available for charcoal-making.

This illustrates the interrelationship between the effects on the environment and the balance of the ecosystem as energy is produced and used.

The link between the well-being of people and the availability of energy is very strong. This is especially evident in places where energy is scarce and great efforts or large proportions of income are spent to obtain it. Examination of the relationships between natural resources, energy, and economics will help to find the options for dealing with shortages. Increasing energy sources is only one possible solution. Others may include institutional changes, improvements in marketing, or the promotion of soil and water conservation practices. In all cases, however, natural resource implications must be realized and provisions made for careful advance planning and long-term subsequent monitoring.

Chapter III

SOCIOECONOMIC CONSIDERATIONS OF ENERGY USE

Energy, the capacity to do work, is the motive force underlying all activity. Like a tool, it is always used to do something else--to cook food, light a room, supply power to a piece of equipment, operate a factory. Like any tool, it has little value except when in use.

How energy is used by people and communities and for what it is used vary by region, culture, and income group. Determining how and for what energy is used, as well as what it could be used for, and who controls the sources are critical steps in energy planning. In most communities, women can play a central role in developing answers to these questions.

There is also a whole range of variables that need to be recognized. Some of these are:

-- who determines access to energy

-- where energy is produced

-- where energy is consumed

-- use patterns to which people presently conform

-- myths

-- demographic trends

This chapter will explore some of these issues.

Energy use in developing countries

Developing countries produce and use energy, especially from renewable energy resources, in different ways. <see image> Some villages

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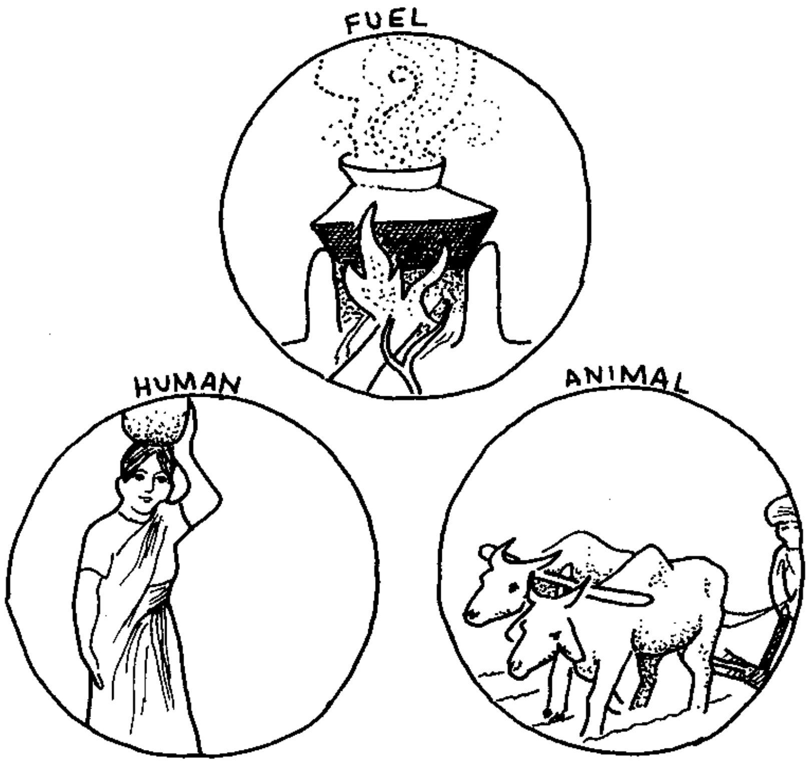

ENERGY IN USE

mostly use crop residues. Other villages are more dependent on fuelwood. Still other villages depend heavily on dung, charcoal, and biogas. This is because the resources that provide energy are available in different amounts around the world. Also, because the resources that provide energy can be used for a variety of other purposes, people may choose differently on the final use of a resource.

DAILY ENERGY USE PER CAPITA: AN INDIAN VILLAGE (population, 500)
Activities (Kilocalories/per capita/day)

Energy Agriculture Domestic Lighting Transport Manufacturing Total
Sources (mostly
cooking)

Human Labor 370 250 -- 50 10 670

Animal Power 840 0 0 160 0 1000

Fuelwood, Dung 0 4220 0 0 470 4690
Agric. Wastes ___ ____ ___ ___ ___ ____

Total
Non-Commercial 1210 4470 0 210 480 6360

Oil 50 0 260 0 0 310

Coal 0 90 0 0 0 90

Electricity 90 0 40 0 0 130

___ ___ ___ ___ ___ ____
Total
Commercial Energy 140 90 300 0 0 530

Total 1350 4560 300 210 480 6890

Percentage that is
Non-commercial 89% 98% 0% 100% 100% 92%

Source: Holland, et al (1980).

In general, however, energy use in developing countries, especially in rural areas, relies heavily on `traditional' sources--human and animal energy, fuelwood and wood scraps, charcoal, dung, and crop residues. This is true for about 200 million people.

The table opposite shows energy use in an Indian village, which is one example of how energy is used in the developing world. In this village, human labor, animal power, fuelwood, dung, and agricultural wastes provide 92 percent of the energy. The bulk of this, or 70 percent, is for cooking.

Reaching participant groups

The table opposite does not show how energy is distributed among income groups. Since energy projects affect particular groups in different ways, this is important information for helping the group with which you are working--the participant group--and for ensuring that other groups are not adversely affected. This information will also help avoid environmental damage, since groups that are hurt might be forced to collect energy sources beyond a sustainable point.

For example, when biogas digesters were widely distributed in India, middle-income groups benefited, but poorer groups were often worse off than before. The poorer families did not own enough cattle to produce the dung necessary for the digesters. These same families had relied on free dung for fuel. When the biogas digesters were introduced, dung suddenly became valuable and could no longer be collected for free. This forced the poor to find other energy sources or to reduce their energy consumption. Finding other sources of energy often resulted in the over utilization of resources. Making do with less energy can also result in nutritional and health problems.

Information on the use of energy by families and income groups was collected in a study of the village of Ulipur, in Bangladesh (Briscoe, 1979). This study (discussed in detail in Chapter V) illustrates that when the socioeconomic structure of a community leaves some families in poverty, those families may create environmental problems in the struggle to survive.

Social, cultural, and economic aspects of energy

The way energy is obtained and used in households, for farming, and in small-scale industries is related to social, cultural, and economic considerations. There is often an imbalance among these considerations. For instance, the use of human waste in biogas digesters often depends more on cultural traditions, social organization, and living patterns than economic considerations. There may be taboos against using human wastes, in which case a central latrine or carting human wastes to a central point may be unacceptable.

Cultural habits affecting the use of energy are sometimes

related to environmental factors. In some places, especially hot, humid areas, smoke from indoor cookstoves is perceived to be a good thing because it discourages harmful insects. In such areas, stoves with chimneys should be coupled with housing improvements or stove adaptations to keep insects away. In other places, especially in highland areas, where respiratory ailments and eye inflammation from smoke are more of a problem than insects, stoves with chimneys can be an improvement.

The value of a new technology is often closely related to its ability to suit or adapt to sociocultural habits. For instance, Lorena (sand and clay) stoves in some parts of Honduras were altered to suit particular cooking styles and fuelwood lengths to the point of sacrificing energy efficiency. (NAS, 1982) The economic and environmental benefits--using less wood--were less important to the users than maintaining customary cooking styles. Apparently, even the most efficient wood-burning stoves can be rejected (and environmentally problematic) if they cannot be adapted to local cooking practices.

Similarly, social, cultural, and economic factors may help explain the differences in experience with biogas in China and India. The rural Chinese are more willing to sacrifice private gain for the good of the community. Technology is viewed as useful when it serves community needs. Consequently, biogas digesters are widely used in a collective way, thereby benefiting the whole community.

In contrast, where a rigid caste system still exists in parts of

India, and energy-producing resources are controlled by a small group, individuals work for private gain. Technical solutions are sometimes given high priority even when benefits are marginal In this case, biogas digesters are acquired by a few wealthy families for private use partly for the satisfaction of using something new and "modern."

The social, cultural, and economic factors create boundaries within which energy technologies and projects must be developed. For example, stoves need to be adapted to the requirements of cooking styles (e.g., frying, simmering, and boiling), and to accommodate to the kind of fuel used. Where new charcoal stoves were introduced in Upper Volta, women used these stoves for cooking small amounts of food quickly, but for large amounts of slow-cooked foods the women continued to use the traditional three-stone fire (NAS, 1982). This may have been to obtain the right kind of heat, or because charcoal is too expensive for extended usage. Both considerations would be important in designing an acceptable energy project.

What is the role of women in energy production?

Women are key people in the collection and use of energy in developing countries. However, this does not mean that women are therefore in control of the sources of energy. Up to 85 percent of non-commercial energy sources in developing countries are used in households for cooking, heating, and lighting. It is the women who usually fetch water, collect wood, prepare grains and vegetables, make the fire, and cook the food.

Recent surveys have been made of the expenditure of energy by men as compared with women in various parts of the world. The following table indicates that in subsistence economies women work longer hours than men, and, in most cases, spend a substantial amount of their working hours on processing and preparation of food, gathering fuel, and carrying water. Introducing energy projects to reduce the use of human energy in these activities will have a substantial impact but will affect men and women differently.

The greater contribution of women to survival tasks that draw directly on local resources means that women have a special understanding of the extent, potential, and changes in the natural resources in their area. Other activities that bring women into constant contact with their environment include raising vegetables and fruit in home gardens, raising small animals that graze nearby, assisting in home construction, preparing a variety of medicines, as well as fashioning tools, handicrafts, cloth, and dyes from local vegetation and other local materials. Where fertile land has been replaced by deserts or where soil has been degraded in both semi-arid and humid regions, there is a serious shortage of resources to sustain these activities.

TIME SPENT ON RURAL ACTIVITIES BY WOMEN AND MEN

Country Average hours of Food for human Firewood Water
work/day (in hrs.) consumption

Female Male Female Male Female Male Female Male
(in hours) (in hrs) (in hrs) (in minutes) (in minutes) (in minutes)

JAVA 11.1 8.7 2.7 hrs. 6.26 min. 5.25 12.5 - -
NEPAL 10.8 7.5 3.0 27 minutes 22.8 14.4 40.2 4.2
hours

UPPER
VOLTA 9.8 7.55 2.2 10.0 6.0 2.0 38.0 -
hours minutes

INDIA 9.69 5.68 3.65 18.0 39 34 74 2.4
hours minutes

Source: Tinker (1982) based on time-budget studies by following: Java: White, 1976; Nepal:
Achrya and Bennett, 1981; Upper Volta: McSweeney, 1980; India: A. K. Reddy, 1980.
Tinker provides additional data based on fuelwood-gathering studies, which frequently
indicate longer times due to shorter period, seasonality, and other factors.
South India - daily - men .72, women .84, children .6 = 2.16 hours/day
Tanzania - weekly - 12 hours on the average
Kenya - daily - 1/2 - 1 hour/day
Tinker has observed the critical fuel crisis is in urban not rural areas.

A social forester described the situation in a Senegalese village where much of the surrounding wood was cleared for raising groundnuts, a cash crop (Hoskins, 1979). The distance and

time required to collect wood increased. More people were drawn into the activity to decrease the number of trips and leave enough time for all the other household work. Women began to use other fuels and more crop residues. They used green wood even though they knew it gave less heat and would damage the forest resource over time. They began to use dung even though they were aware that it was needed to fertilize their gardens. They were also forced to purchase wood.

Clearing land for cash crops forced a change in fuel sources and uses that affected many aspects of daily living in the Senegalese village. Less fuel and more time spent gathering meant that the quality and quantity of food changed. To save fuel, women switched from cooking two hot meals a day to one a day, or one every other day. They also turned to rapidly-cooked foods and to serving raw food. Fewer vegetables were served because the women had less time to tend their gardens and also found that their gardens grew less food--they complained of loss of ground cover that had provided natural fertilizers. Buying fuelwood left less money to buy food. Changes in diet affect health and nutrition, which affect the life-long productivity of people.

When developing energy projects, it is important that women participate from beginning to end. Their unique knowledge of the available natural resources is essential to a good project. Only they truly know their needs, the time they can devote to a project, whether it will benefit them (an absolute necessity for continued participation), and whether project ideas are compatible with environmental, social, cultural, and ownership conditions in their community.

Energy and general welfare

Fuel availability affects many other facets of life, such as education and employment. Children may be kept home from school because mothers cannot both travel the longer distances necessary to collect fuel and also take care of other household tasks. Income-producing activities such as pottery-making and processing food for sale must be abandoned where fuel becomes too expensive. As land becomes cleared of vegetation, soils degrade, ponds silt up, and valuable plants are lost. When plants are lost, traditional medicines based on this vegetation are lost. When the soil is less fertile, home gardens have lower yields. When ponds and lakes silt up, fish do not reproduce. Without nearby forage, small animals cannot be raised. All of these factors affect the ability of an area to sustain life.

Factors affecting the adoption of energy technologies

The political as well as the social, economic, and cultural characteristics of a society affect whether new energy technologies are feasible and will be accepted. These characteristics are often more influential in the adoption or rejection of an energy technology than technical soundness.

A National Academy of Sciences study of the primary factors affecting the acceptance of biomass-related technologies found the following conditions to be most important (NAS, 1982):

How well the technology adjusts to the economic and financial structures in a society:

*** Who owns the resources the technology will use?**

*** What are the sources of capital for financing a technology and who has access to them, either directly or indirectly?**

*** What is the economic rate of return?**

*** Is the economic rate of return greater for this use than for alternative uses of this resource?**

*** What are attitudes toward risk and how can the risk involved in adopting a technology be minimized?**

Even if a technology is "given" to project participants as part of the project, a long-term commitment to use the technology depends on the availability of natural resources to fuel the technology, financing to maintain and repair it, and the amount of risk involved in changing. (See also French, 1979.) The economic rate of return for the use as compared with alternative uses should be considered, although other factors such as social value may outweigh the economics.

How compatible the technology is to the existing organization of work:

* What is the division of labor within the family or social unit (by age, sex, ethnic group, etc.) affected?

* How will the division of labor be affected by a proposed technology?

These factors affect whether the people who presently perform the task involved will be likely to find the technology beneficial in terms of its effect on time, the patterns and pace of work, and the social organization related to this work. A technology that disrupts the division of labor among men, women, and children is likely to be resisted, especially if it changes the access of sex or income groups to productive resources.

How well the technology can be integrated with the existing social structure and value system:

* What social customs, moral values, and religious beliefs determine the way energy is used?

* How can change accommodate these customs?

Traditional lifestyles and ways of thinking can be threatened by new energy technologies. For example, displacing the traditional three-stone stove in the Sahel requires sensitivity to it as a symbol of harmony between a husband and wife.

How well the technology adapts to the local political system and the decision-making process:

*** How are decisions made and enforced in the community?**

*** How are disputes settled?**

Obviously, the answers to these questions will define a hierarchy in the community that in itself may reinforce the poverty of a participant group. Knowledge of the system may for this reason be all the more important, because open conflict between a participant group and the local political structure may be too great a risk for the participant group. Minimizing the conflict will help mobilize the support of participants.

There are many examples of the relevance to the political structure of an energy project. A successful agroforestry project depends on the structure that assures the land-tenure system; a charcoal project depends on those who set prices and regulate distribution. Those that control the credit structure will affect the viability of almost all energy projects.

This is not an exhaustive list of the various factors that influence the adoption of an energy technology, nor are each of the factors listed necessarily of equal importance. You may find other factors in your community and some may be more important than others. (This discussion has not included the environmental

factors that affect the adoption of energy technologies since t his is covered elsewhere in the booklet.)

Who pays for environmental problems?

Individuals or groups that misuse resources may not be those that experience the consequences. Some individuals may realize that they are engaged in practices that lead to degradation of resources that will directly or indirectly decrease land productivity over a period of time, but continue with the same practices in order to survive from day to day. When degradation of resources does not affect the people who cause this degradation or when poverty allows no other alternative, it is difficult to modify environmentally unsound practices.

In many areas, energy resources are collected free of charge, often on public lands. This includes crop residues, twigs, wood scraps, and dung. When this collection adversely affects resources, it is the community as a whole that bears the cost, not the individual. A charcoal-production example illustrates this. Charcoal-makers often use inefficient, inexpensive kilns, and migrate in search of wood. The incentive for them to invest in more efficient kilns is minimal because they do not bear the costs of the deforestation they may be causing.

Environmental problems or benefits generated by one group may be experienced by another group. For example, siltation results from the dispersal of topsoil and nutrients from land (often due to deforestation). The most direct and dramatic effect is to alter downstream watersheds. Reforestation to remedy that problem may be perceived locally as loss of land, but it can result in benefits to downstream farmers.

The interrelationships within and between ecosystems are responsible for the fact that those who cause environmental degradation may be different from those affected. Remedies, however, usually require a change in the practices of people who initiate the act that triggers a chain reaction in the ecological setting. It is important to develop acceptable incentives for change. When the poor are forced by socioeconomic circumstances both to cause and suffer from environmental degradation, income-producing activities are needed to modify practices.

One example of a project that is providing income-producing activities is located in the Horn of Africa. Training, seeds, and materials are offered to individual refugees to encourage them to grow tree seedlings. The seedlings of a prescribed height are purchased from the trainees. Thus the project provides both income potential and the opportunity to assist in reducing the environmental degradation to which the large numbers of refugees are inadvertently contributing.

Chapter IV

ENERGY PLANNING FOR SUSTAINABLE DEVELOPMENT

Energy planning for sustainable development is a process for devising projects that use natural resources to meet local energy

needs in a way that is socially and culturally acceptable, environmentally sound, and economically feasible. The purpose of such planning is to avoid the pitfalls of energy projects that are not accepted by the people meant to benefit from them, that use inappropriate technologies, that ignore the environmental constraints of the natural resource base to provide energy and other resources in the future, and that are not economically feasible.

Why plan?

The planning process can serve a variety of purposes:

* **Identify potential community problems.**

* **Help community develop solutions.**

* **Uncover difficulties and benefits that might arise through a given solution.**

* **Set up a system for adjusting to unforeseen effects that may occur.**

Good planning creates a consensus among those affected by the problem and the solution--the participant group. It is essential that this group participate in the entire planning process. This is particularly critical for small-scale energy projects since they are very localized and draw upon resources that local people use and know intimately, and that directly affect their day-to-day survival. Because the value of energy is

in the work it can perform, the tasks must be defined by those who will benefit from the work to be done.

Ineffective planning may cause environmental problems by not taking into account new pressures on resources that the project itself can create. For example, dung used for fuel may be diverted from its use as fertilizer and deprive the soil of nutrients. Energy diverted from other uses for an income-generating project such as food processing may require gathering more energy resources than are locally available on a sustainable basis. Poor planning may also hurt the poorer groups, by reducing their access to various energy sources.

Special considerations in meeting energy needs

Energy needs are for heat, light, and mechanical power. Supplying these needs can be accomplished in several ways:

* Managing and increasing the supply of energy sources. This can be accomplished by tree planting on marginal lands, managing or creating village woodlots, or introducing integrated home gardening approaches to farmers. Additional energy based on the wind, the sun, and water can be developed. In situations where the supply of a resource is being depleted by non-energy use activities, the planner could attempt to introduce actions that reduce this loss. Deforestation losses as a result of agricultural expansion are an example. <see image>

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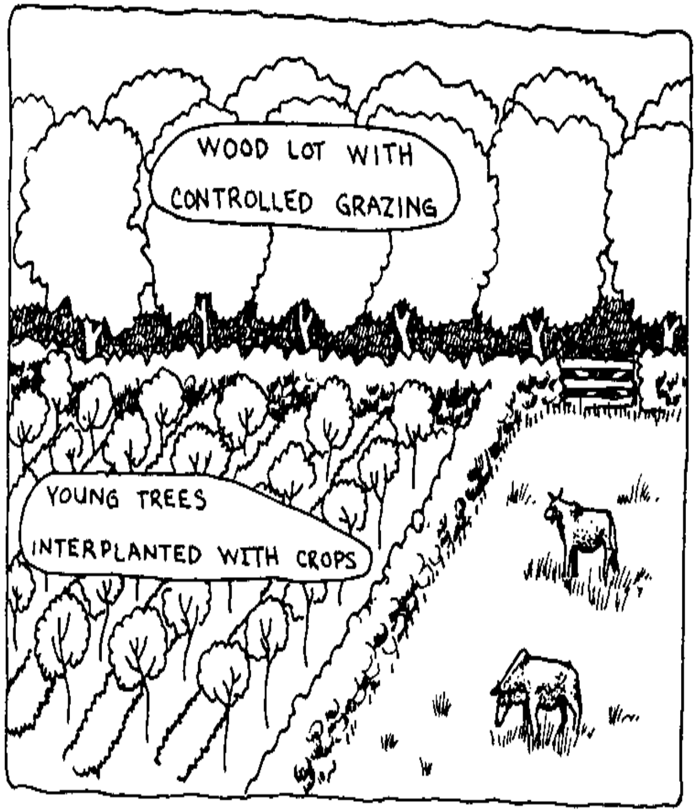

BIOMASS CAN BE INCREASED BY COMBINING AGRICULTURE AND FORESTRY

* Developing new conversion technologies: Conversion technologies include solar and wind devices, small-scale hydro installations, and biogas digesters. These technologies can open up new sources of energy or increase the efficiency of tapping existing sources.

* Improving the efficiency of end-use devices: The

efficiency of devices that utilize energy can often be improved substantially. Cookstoves are a good example.

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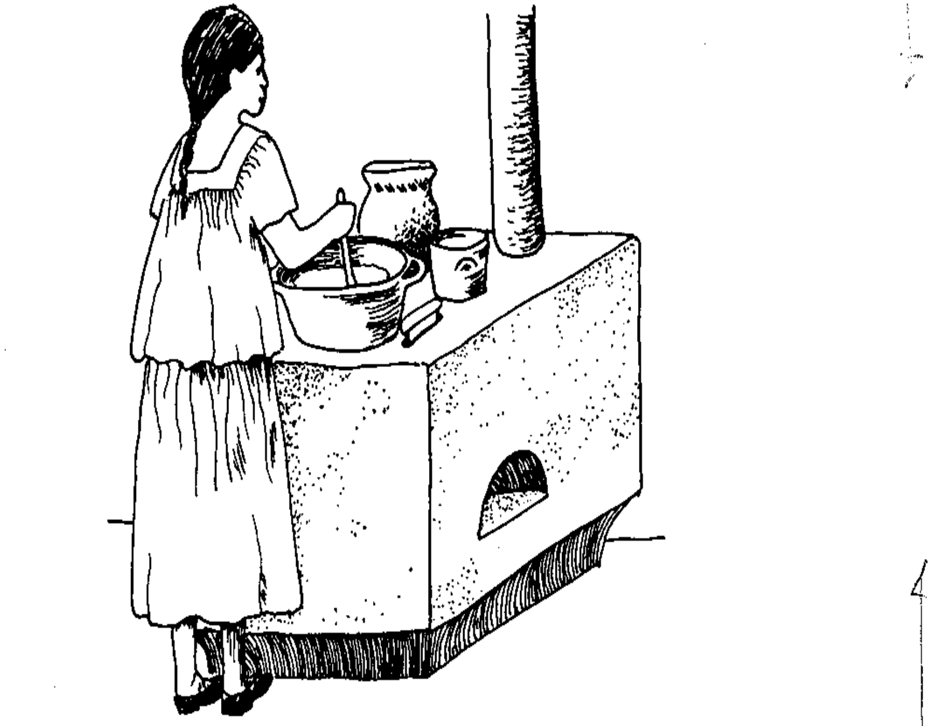

ENERGY-EFFICIENT COOKSTOVES CAN DECREASE FUEL NEEDS

By developing more efficient designs, less energy is required. The overall impact on energy consumption from the introduction of more efficient stoves and which models are more efficient are still being studied. This will be discussed more fully in a later chapter.

Simple improvements in household and agricultural implements also fall into this category. While often overlooked, such improvements can greatly decrease the amount of time and human energy used.

* Reducing energy losses and economic costs that result from transporting and transmitting energy supplies. In many cases the energy is consumed in the process of converting the energy source to its end use.

The diagram on the following page indicates the relationship

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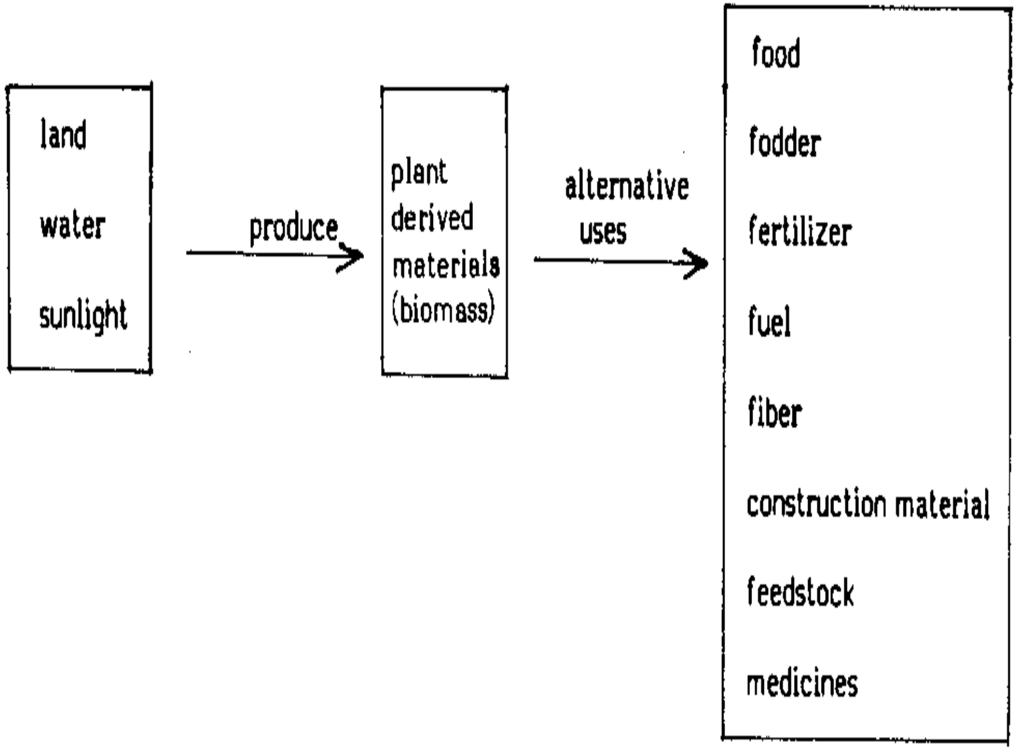
LIMITING FACTORS



)

Which ways are chosen to meet energy needs depends on a number of factors. In the planning process, development workers and communities can collaborate to assess present energy needs and supply resources available for development, and suitable technologies. Decisions will be influenced by what is socially and economically feasible, environmentally sound, and culturally acceptable.

In planning, the different uses of potential energy sources

should be examined carefully. This will bring to light whether shortages will be created in using a resource for energy. The following diagram and set of questions summarize this process for one important source of energy, plant derived materials, commonly called biomass.

*** What biomass resources are available in your community?**

*** How much biomass is used?**

*** Flow is biomass allocated for these different uses?**

*** What are the competing uses for the resource?**

*** How will increasing its use as fuel affect competing uses?**

*** Will increasing its use as fuel mean that the supply of biomass will be collected beyond its ability to regenerate, and thus create environmental problems?**

*** What social or economic groups will be affected by changes in the supply or price of energy?**

*** Are there ways to overcome the environmental and social problems of using more biomass for fuel by creating additional sources, developing appropriate conversion technologies, and/or improving end-use devices? Should other alternatives be considered?**

Clearly, the answers to many of these questions can only be found by talking with people in the community, especially the women and the poor.

What is end use?

Energy is a means to a specific end: to pump water, cook meals, move material. Such tasks are called end uses. Devices that utilize energy are called end-use devices.

One energy source may be able to provide for several end uses. For example, wood can be used to cook a meal, to fire a brick kiln, or to provide light. Each activity involves different costs that determine whether the use of wood is economically feasible. Each use may have different impacts on the environment, if the quantity of wood required or the manner of collection differs. The precise environmental impact will vary with the availability of wood and the condition of the forest ecosystem. It must be viewed within the broader context of all the activities which affect the natural resource base. <see image>

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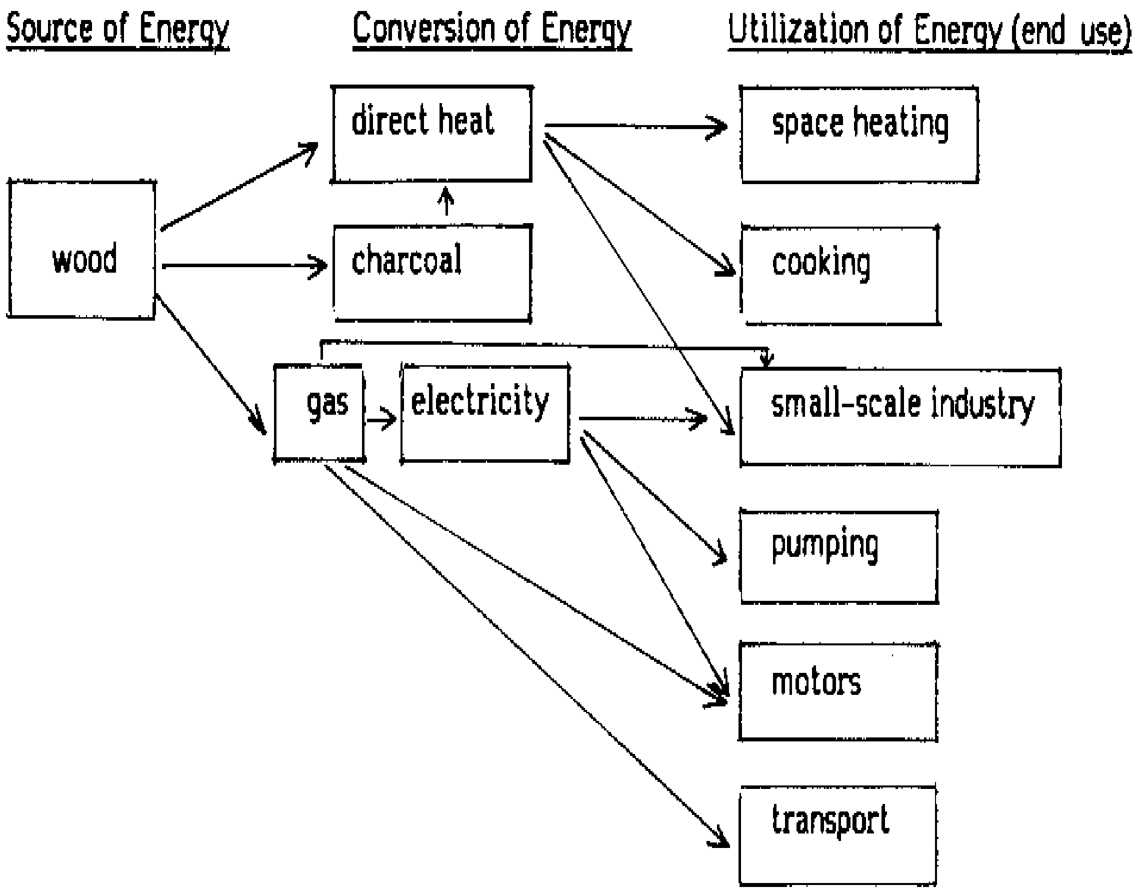
MULTIPLE USES OF AN ENERGY SOURCE



One end use may be powered by a number of energy sources. For instance, transportation can be obtained from vehicles

powered by animals, petroleum-based liquid fuels, electricity, or even gasifiers. Each alternative energy source has different costs, and its use has different impacts on the natural resource base. While similar work can be accomplished, vehicles--and the quality of transportation provided--will vary with the different energy sources. <see image>

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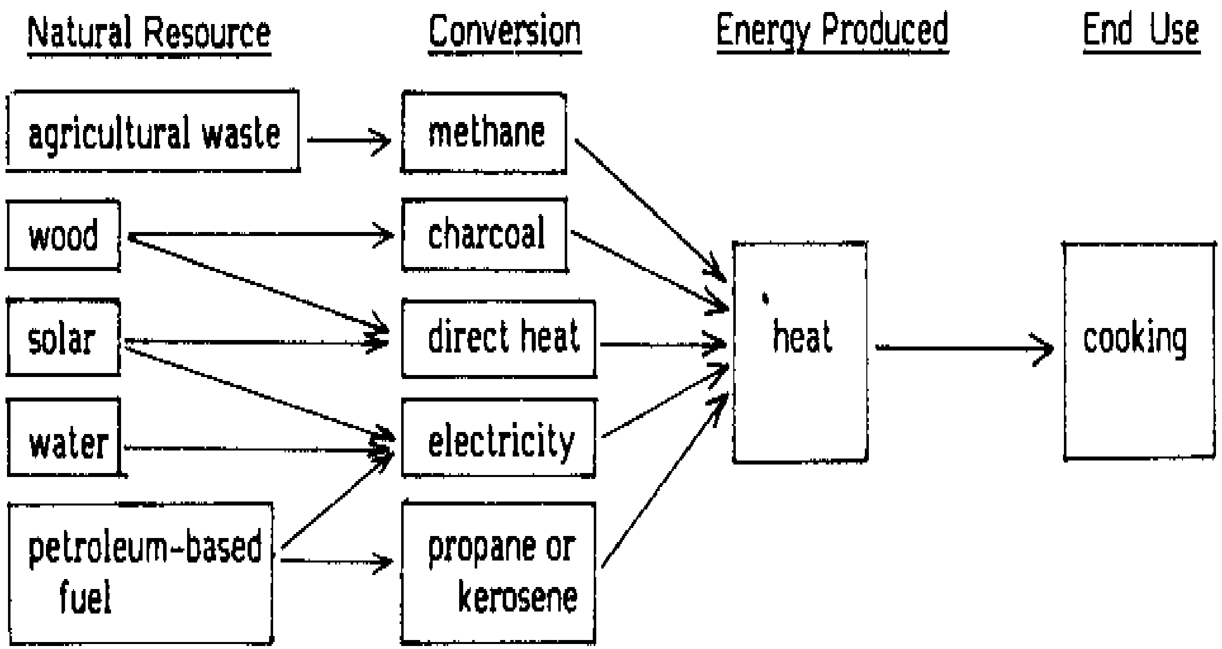
MANY ENERGY SOURCES CAN PROVIDE ONE END USE



How efficiently is energy used?

When one form of energy is converted to another form there is always some energy lost as heat. The relative amount of energy loss may be expressed as a "conversion efficiency," in which the smaller the loss, the greater the efficiency.

Technically, the efficiency of energy conversion can be measured by comparing the amount of useful work done by the amount of energy required to do it. Stated differently,

Energy Efficiency = Useful Energy Output

Energy Input

Since output is never as great as input, this value will always be less than 1 (a fraction).

One of the main reasons to measure energy efficiency is to determine areas where research can be done to increase the effective use of energy from a fuel source. It also permits the planner to measure the effectiveness of alternative technologies if and only if those measurements reflect actual use in the home or industry.

Large losses always occur when heat is transformed into mechanical energy. This happens, for example, in the internal combustion engine or when hot steam is used to turn an electric generator. On the other hand, moving water to generate electricity involves little heat so overall conversion losses are relatively small.

Matching energy sources and technologies with their use (that is, being energy efficient) is economically and environmentally sound. Mismatching energy sources and uses is not only energy inefficient, but if the resource is essential to the ecosystems, the use of an inappropriate source may have a negative effect.

Energy efficiency is only one factor in the selection of energy technologies. The ease of transport, storage and use of the resource; the availability and cost of the end-use devices needed to use the fuel; the amount of government subsidy; cultural taboos; and considerations of cleanliness, smoke content, or other factors all help determine the final selection.

Unfortunately, these other factors often overwhelm any consideration of energy efficiency. This has encouraged, for example, the use of electricity for heating water, or the use of diesel fuel to power irrigation pumps when lower quality and less costly (both to the environment and the consumer) energy sources, such as solar water heaters or windmills, may have been more appropriate.

In matching energy sources with uses, there may still be negative effects on the environment. For example, while methane from a biogas digester is a good source of cooking fuel, methane production has a by-product that is difficult to dispose of and that may cause environmental problems.

Measuring energy output

How does one measure energy? How does one measure different kinds of energy so that they can be compared? Can the energy stored in a tree be measured in the same way as the energy available from a water mill? It is a very important problem, because understanding the linkages between energy, natural resources, and utilization requires that energy be measured and evaluated correctly.

Several energy sources can be compared by converting them into common units such as Btu's and joules (See Appendix A Energy Conversion Table). For example, it is relatively easy to compare gasoline with natural gas with vegetable oil. Technologies like hydroelectric generators or photovoltaic cells can also be compared.

It is difficult, however, to measure sources of energy that are not readily converted into standard units of measurement, such as biomass or human and animal energy. Clearly, there will also be problems in comparing these sources with conventional sources. This poses a real problem at the community level where one is looking at all kinds of energy sources and uses in a community and trying to compare dissimilar things. For example, some produce heat, some produce mechanical energy, and some produce electricity. In some situations measurement can more appropriately be made in terms of the time required to perform certain tasks.

What type of energy data and what level of data should the community planner collect? Following are some general points to

help make such decisions:

1. It is constructive to be as thorough as possible. Find out what data already exist. Data from other surveys on agriculture, public health, forestry, or transport might help to fill in some of the gaps. There is no universal standard regarding what constitutes sufficient data. The best standard is to ask yourself continually whether these data are useful for the purpose at hand.

2. Collect information that allows the planner to:

-- identify the supply or sources of energy

-- quantify the interrelations between the energy sources, the people who use those energy supplies and the environment they live within

-- determine how the energy is being used, the pattern of energy use, pathways of energy flow in the community, and factors that affect present and future energy use.

3. Try to use measurements that allow comparison between energy sources that might substitute for one another, or between end uses that employ similar energy sources. For instance, in comparing the use of charcoal as a replacement for fuelwood, try to calculate both in terms of the amount of wood involved.

4. Testing the efficiency of end-use devices such as cookstoves requires considerable planning and attention to detail. An international committee of woodstove technicians has recently formulated a series of three provisional standard testing methods for wood-burning cookstoves, including water-boiling, controlled cooking, and actual field performance tests. Copies of the test procedures are available from VITA (See Appendix E, Sources of Information).

In all cases, testing should take place under the conditions in which the device will be used, as well as in the laboratory. This should include testing with the kind of fuel to be used, along with the people who will use it and the uses for which it will be required. Testing under laboratory conditions alone may have little practical relevance. For example, wood cut and prepared in ways people who use a device are unlikely to follow may not indicate the same efficiency as a cookstove tested under field conditions.

The following section outlines some of the problems in measuring particular sources and offers some suggestions on how to avoid mistakes that are often made.

Wind: Wind is extremely site-specific and varies with the terrain, season, and range of wind force. Data should be collected at the potential project sites, particularly for electricity generating applications. General data for a region, (for example, information collected at a local airport or weather station) may be helpful but should be supported by site-specific information.

Solar: Seasonal variation caused by cloud cover should be noted. Data should be collected during the season when the energy will be required for the end use. It is not necessary to gather data directly on the project site, as with wind. General data for the area are sufficient.

Water: Three mistakes are commonly made in gathering information on water availability for hydropower:

* gathering data only for part of the season (even if the site has reasonably even rainfall, the river or stream's watershed may not)

* not calculating alternative demand for the water adequately, particularly where, as with irrigation, it is an intermittent but critically important demand

* not estimating sedimentation rates accurately (sedimentation quickly cuts hydro capacity, and therefore blocks its renewability).

Forests and vegetation: Be careful not to equate fuelwood with logs. In rural areas, most wood that is burned is scrap, twigs, or dead wood. Estimates of wood resources and cookstove efficiencies based on tree trunks and large limbs have resulted in grossly inaccurate estimates of wood resources and the potential savings of wood from improved cookstoves.

Similarly, the word "forest" should be used with care. Fuelwood often comes not from forests but from the borders of farmers' fields, from grazing land, shrubs, and from pruned high-value trees in fields around garden plots.

Estimating the rate of fuelwood consumption can be difficult. In urban areas, where wood is purchased, it may be sufficient to find out how much money various families spend for a bundle of wood, and how often they must purchase it. It would then be necessary to measure the average weight of such bundles.

In regions where fuelwood is gathered freely, consumption estimates may be made by weighing the wood supply at the beginning and end of each day. Naturally, it is important always to measure fuelwood use from families representative of the regional population, allowing for market days, religious observances, and any other events that can affect the daily amount of wood consumed. Other useful information includes other uses for fuelwood besides cooking daily meals. When the results are expressed in terms of weight of wood consumed, it is important also to note the species composition, relative age of the tree, whether the tree was cut live or fallen, and average moisture content.

Crop residues: Estimates of crop residues should include a careful calculation of seasonal variation. In some areas of West

Africa, for instance, fuelwood surveys were inaccurate because the method of data collection ignored the four to five months of the year when rice straw and other crop residues were substituted for wood. If possible, the net flow of crop residues should be estimated, and some determination made of the present use of these materials in recycling nutrients back to the soil.

Animal residues: Dung supply can be crudely estimated by calculating the number of animals owned, or available, near the project site. However, there may be considerable differences depending on the health of the animals, the feed, and other variables. Some observation and data collection are essential, especially on the location of the dung (is it distributed over a wide area, are the animals kept in a closed pen, are they brought in at night?)

For information regarding specific questions about data collection write to VITA (See Appendix E, Sources of Information.)

Chapter V

ULIPUR, BANGLADESH: A CASE STUDY(*)

This study shows how energy uses and sources by different income groups in a village setting are interrelated. The way the study was put together may prove useful to planners in thinking through how to present an accurate picture of energy production and use in a dynamic situation. This is an important part of the energy planning process, because it provides the basis for seeing how an energy project may affect the local ecosystem and different income groups.

Of the 2,300 people in Ulipur, 330 were selected for a detailed review of their energy use. Two kinds of information were collected:

* Socioeconomic data: The family structure, resource ownership patterns, and productivity of the land and animals.
* Energy use data: What energy is available, and how it is used by different income groups.

How were socioeconomic data collected?

Field workers talked to families to learn the relationships in the household, the names and ages of family members, their sources of employment, and how much they earned.

The field workers asked about the families' animals: how many they owned and the size of their animals. The researchers

(*) See Briscoe, 1979 and deLucia, 1982.

measured the amount of land owned by each family, and found out how much was farmed by the family itself, how much was farmed by non-family members, and how this was arranged. They also asked how a family was compensated for letting their land be used by someone else. <see image>

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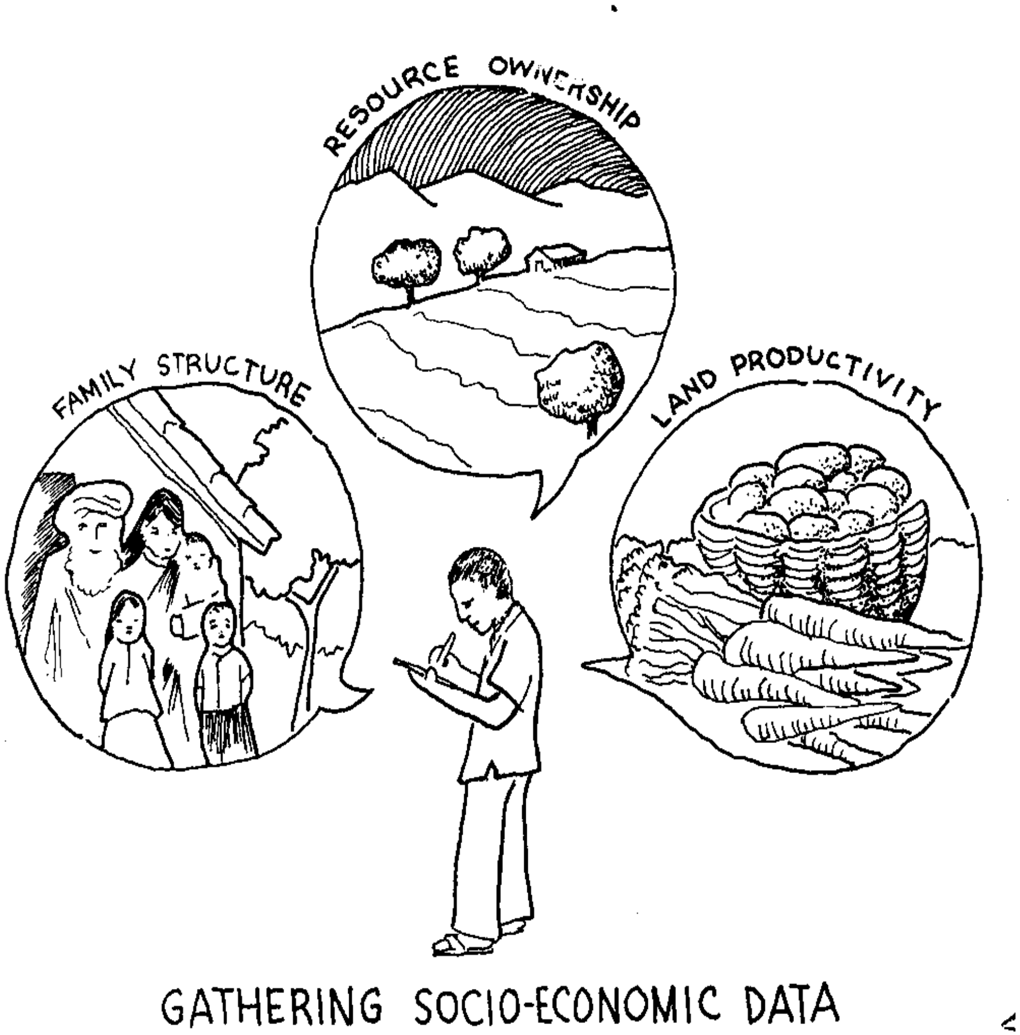

The field workers talked to families about what crops were produced on their land, crop yields, and whether the crops grown were used for themselves, sold, and/or given to other families.

They asked families the quantity of crop residues and how they were used.

* Did the family collect them?
* Did they allow others to collect them?
* Did they use them or give them away and to whom?

This information was then analyzed. The villagers were classified as to whether they were landless, poor, middle-income, or rich. The field workers found that the rich, comprising only 16 percent of the families, owned 83 percent of the trees, 58 percent of the crop land, and 47 percent of the cattle (see the table below). They also found that while families of different income groups used the same quantity of fuel per person for cooking food, different types of fuels were used by different income groups.

OWNERSHIP OF FUEL PRODUCING RESOURCES

	Families		Land	Tree	Cattle
	Number	%	%	%	%
Landless	22	45	2	5	5
Poor	11	23	13	5	24
Middle-Income	8	16	27	7	24
Rich	8	16	58	83	47
Total	49	100.0	100.0	100.0	100.0

How were data collected on energy use?

Every two weeks, the field workers went to see the families to get information about the previous day. They weighed the cattle dung and talked with the farmer about the use of the animal on the day before and how much dung was produced during that activity. They asked how the dung was used or would be used. They also discussed the type, source, and amount of cattle fodder used; how much milk the cattle produced; and how much time was given to care of the cattle.

At the same time, the field workers tried to estimate the amount of human and animal energy expended during a day. They talked with the family about the previous day's work. What kind of work was done and how long did it take? How many people were involved and how many animals? Was the work done for their own fields, or did they also spend time working in some other family's fields? Did they have non-family members working in their fields?

When they worked for another family, or another family worked for them, how were the people paid? Did they get cash, food, or fuel, and how much?

It was also important to determine crop yield. Families were asked about what had been planted over the last two weeks. They discussed the use of fertilizers:

* What fertilizers were used?
* Where were the fertilizers obtained?
* How much was used and for which crops?

Together, the farmers and field workers estimated how many crops were harvested, and talked about how the harvested crops were used. Were they eaten by the family itself, were some sold, were some given to non-family members for work or some other service? The farmers and field workers discussed crop residue use as well:

* How much did the family use?
* How much was gathered for use by non-family members?
* How much was left in the field or just burned?

Each few months, the field workers spent the whole day with a family to observe the use of fuel in cooking all the meals of the day. They weighed the fuel used for each meal, estimated the amount of food cooked, and counted the people fed.

Other sources of energy and their use were also discussed and noted. From these pieces of information a picture of the energy sources available and their use began to emerge, and a table of annual fuel use in Ulipur could be constructed.

ANNUAL FUEL USE IN ULIPUR

Percent

Crop Residues (from ten crops) 59.2

Animal Residues 2.7

Firewood (including twigs and branches)
From village trees 10.8
From the river 4.4
Purchased 5.2

Subtotal 20.4

Other Fuels
Doinshah (legume) 4.9
Bamboo 3.6
Water Hyacinth 1.6
Other crop residues and leaves 7.6

Subtotal 17.7

TOTAL 100.0

The information collected showed that the rich had access to almost twice the amount of energy (straw after livestock feed, jute, dung, and firewood, leaves and twigs) that they needed for cooking. The landless had access to only about 15 percent of their fuel needs for cooking. The rest of the energy they needed came from foraging for firewood, leaves, and twigs on public lands or on land owned by others. The landless were dependent on the rich for fuel and food in exchange for labor.

The landed poor, who required all the dung produced by their cattle (and more) for fertilizer, relied for cooking mostly on rice straw left over after the livestock were fed. Since the rice straw did not meet their needs for cooking fuel by about 13 percent, the poor were forced to bridge this deficit by spending valuable time foraging for twigs, leaves, and firewood and selling their labor during peak agricultural periods to the rich in exchange for fuel and food. They, along with the landless, were dependent on the rich. Of ten, their own crops suffered.

By looking carefully at the information on the sources of energy available in Ulipur and the uses they are put to for both energy and other purposes, the field workers constructed an energy flow diagram of Ulipur. This diagram masks the seasonal variation in energy availability, but shows the complex interrelations among resources as well as many uses each provides.

How to use the energy flow diagram

The energy flow diagram brings out the multiple and competing uses for particular resources. One is thus able to predict the effect on the ecological, social, and economic system of the village of using more of a particular resource for energy.

Suppose that the villagers expressed a need for night-time lighting and a more efficient cooking system. Suppose also that a biogas system based on animal waste is proposed. The energy flow diagram, along with the data on energy use by income, can

help in thinking through the implications of biogas for the resourse system prior to project design and implementation. Let's think this through together. <see images>

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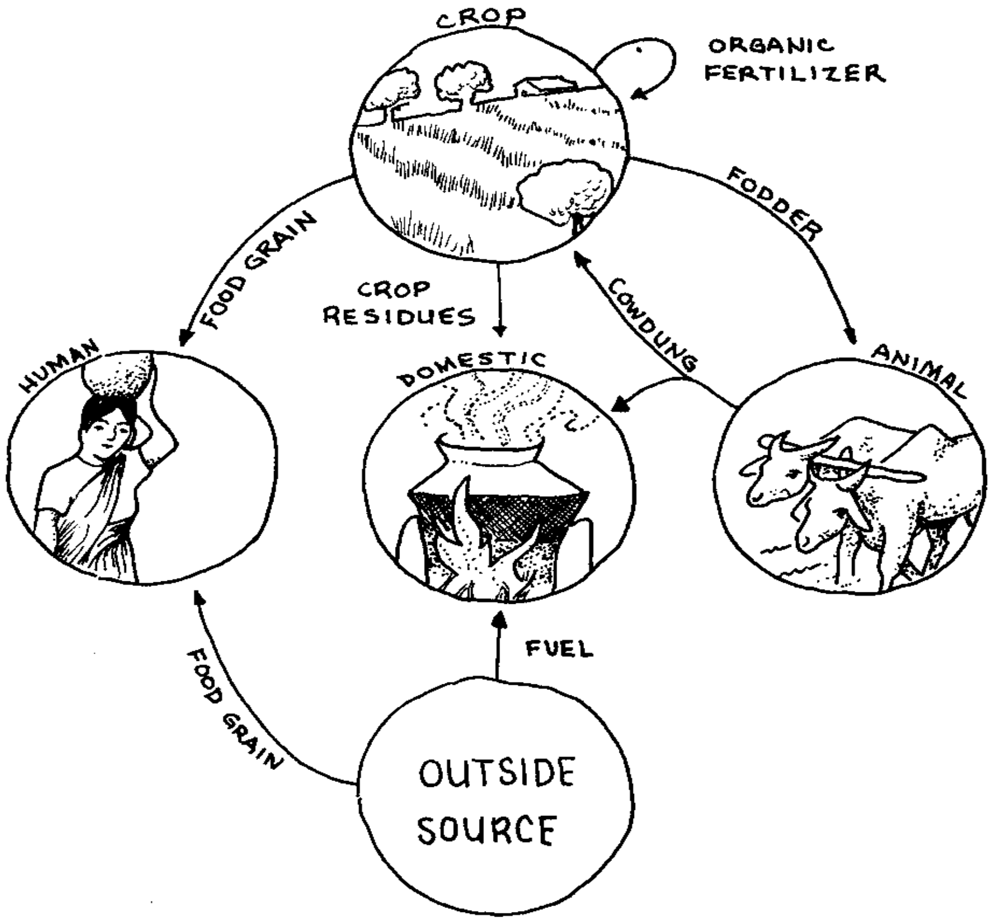

MAJOR ENERGY FLOW PATHWAYS IN ULIPUR, BANGLADESH

In Ulipur, 62 percent of dung is used for fertilizer, 13 percent

for fuel, and 25 percent is uncollected and probably uncollectable. The dung used as fertilizer has probably shown itself over time to be the amount needed to condition and enrich the soil; using any of this 62 percent of the dung would be likely to jeopardize agricultural yields. The rich have the use of almost all of the dung used as fuel.

The distribution of resources implies that the rich would benefit most from a village biogas digester. They are the primary group using dung for fuel and so they already have the necessary raw material. Middle-income and poor families would need to divert some of the dung presently being used for fertilizer to the biogas digester. This could diminish crop yield for these two groups. Also, the use of dung for the biogas digester would increase the value for what was previously a free or low-cost good. This would hurt the poor who depend on its being freely accessible.

The ecological effects could be serious. If the poorer people decide to use dung for fuel rather than fertilizer, the fertility of their land could be reduced. A decline in rice production would reduce other fuel sources since rice straw provides about 75 percent of cooking fuel and jute stick provides about 15 percent of it. Less rice straw and jute stick would intensify competition between using them for energy and for other purposes, since jute stick is also used for construction, and rice straw to feed livestock. If livestock are fed less, they produce less dung for use as fuel or fertilizer, further decreasing crop productivity. The landless and very small land holders might be forced to get more firewood, which generates another set of environmental problems.

To address some of these problems at the beginning of a biogas project, one should ask:

* Would the poorer parts of the community get enough energy from the biogas digester so that they would not use for energy dung that is required as fertilizer, or use crop wastes that can have uses other than energy?

* Would the poor have access to the sludge by-product produced by the digester that can be used for fertilizer?

* Could the digester, by supporting an income-generating activity, provide enough income so that there would be other ways to obtain energy and fertilizer?

Summing up

The work described above in Ulipur was undertaken over the course of a year. Any village energy project must be preceded by study or collected knowledge of annual cycles and seasonal variations that can influence the demand for energy and availability of resources. The process of talking with community members in order to gather relevant data about socioeconomic relationships and resource distribution and use is a necessary one. Making use of existing data and consulting with others can often shorten the process but it should never be solely relied on for information.

Chapter VI

A PROCESS FOR PLANNING ENERGY PROJECTS

Ideally, a planning process follows a logical sequence of activities, each of which builds on another. It begins with information gathering and discussions with the participating community. As community workers and the community interact, needs, general goals, constraints, and options emerge. Projects develop as community workers and the community think through needs and goals, and how to attain them.

It is essential that community workers and local people devise a variety of approaches that will suit their goals and deal effectively with any anticipated constraints. From these alternatives the most suitable one can be selected as the project.

During implementation and operation, the project can be monitored to ensure it continues to meet its goals and to enable the community to resolve any problems that may arise. Finally, once the project is complete, it should be evaluated to determine if it was successful and to aid in the planning of future projects.

The diagram on page 64 shows the steps involved in the

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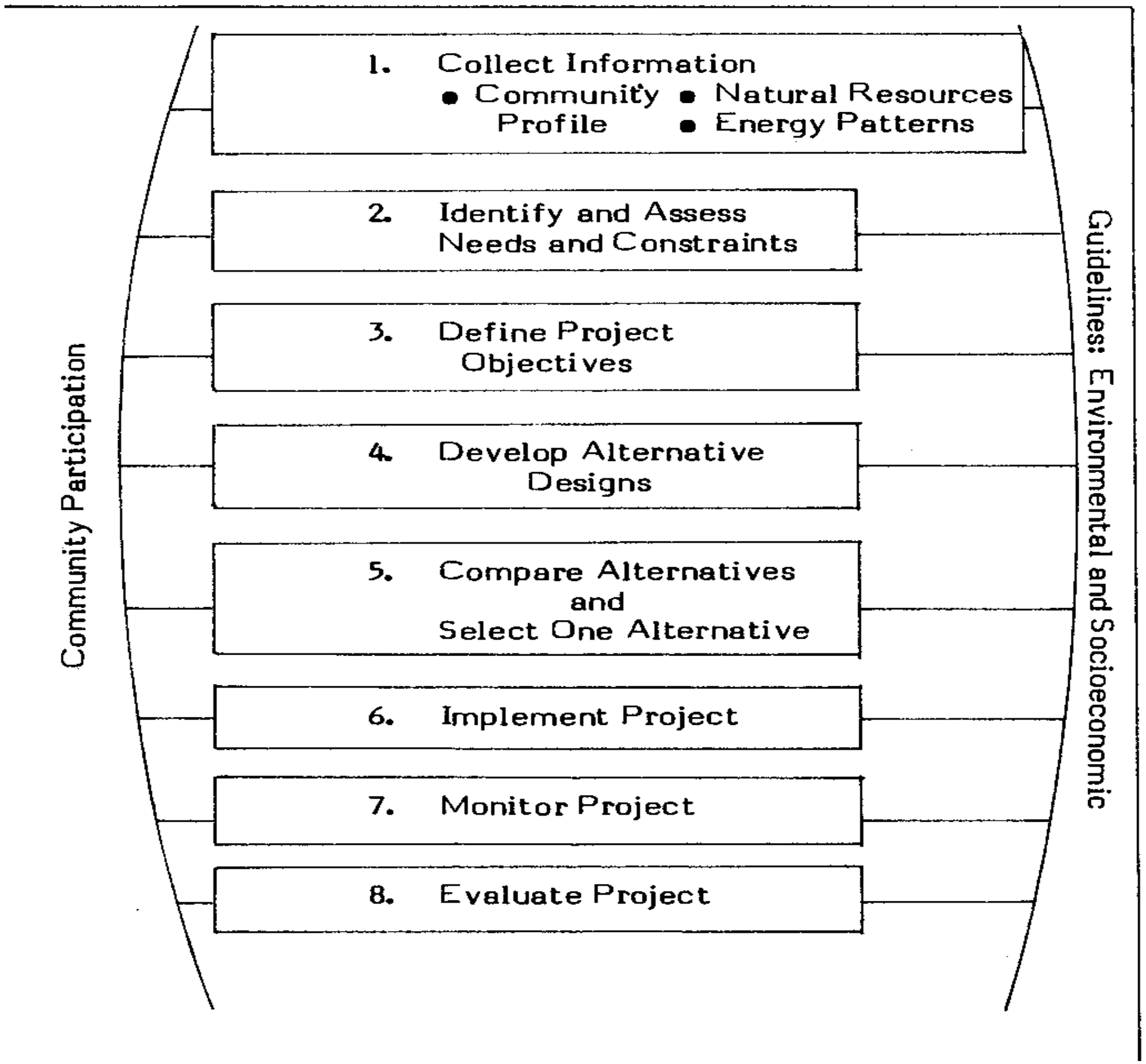
A PLANNING PROCESS



planning process. Each part of the process will be examined in detail in this chapter, especially as it applies to energy projects. Community participation and environmental and socioeconomic guidelines are integral parts of each step in the process and will be considered first.

Community participation

To establish a successful energy project, the community must participate fully in all aspects of the project. The project must address the needs of the community. As a source of invaluable information about the environment and local practices, the members of the community must be consulted. If the project is endorsed by the community it is more likely to meet the needs and to be adopted.

Communities, however,

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are groups of individuals, some of whom may have conflicting goals. Projects that address the goals of those with similar or at least non-conflicting goals, should also take into account the interests of non-participants in order to achieve equity.

During the initial discussions with the community, local issues of greatest concern will become apparent. Energy may emerge as a priority, it may be only indirectly related to the central problem, or it may not be an issue at all. Often projects fail because they are not directed to local priorities.

For example, a project to prevent desertification and provide fuelwood in Senegal was devised by foresters without talking with the villagers. The villagers were asked to plant trees around their gardens. When no one planted trees, forestry officials thought the villagers were lazy and ignorant. In later discussions, it was discovered that the villagers thought the gardens were not worth additional time because there was not a way to get the produce to market. To generate interest in improving the gardens, the need for roads and marketing infrastructure should also have been considered. One should establish that energy is a local priority before proceeding to plan an energy project.

Environmental and socioeconomic guidelines

Guidelines suggest those things that should be considered in designing, implementing, monitoring, and evaluating a project. Guidelines raise questions that will assist the planner to avoid pitfalls and to maximize possibilities. Guidelines are different from goals. For example, a goal might be to provide energy for lighting a school; a guideline would be to make use of local resources in providing energy for lighting.

Social, economic, and environmental factors may need to be weighed against each other to balance the advantages and disadvantages in these areas. A useful tool for examining relevant factors in relation to the project is Fred Weber's Ecological Mini Guidelines, which is included as Appendix B.

For example, economics may determine an energy project's feasibility, and the environmental benefits it will produce may make it attractive to development workers. But if the project does not grow out of community-voiced decisions, or if it cannot be operated, maintained, and monitored by the community, the social guidelines may dictate that the project should not be undertaken.

Below is a short list of some of the environmental and socioeconomic guidelines for energy planners. The list is not exhaustive but offers a general framework of the types of guidelines that may need to be considered in designing a project that best serves the needs of the community involved.

Environmental Guidelines - Environmental guidelines evaluate the community energy needs as they relate to the natural resource system.

* Identify the competing uses for the community's natural resources. Determine the appropriateness of using each resource, while considering the effects of its use.

* Use an integrated planning approach that places a high value on natural resource management. This will allow the planner the opportunity to develop energy projects

that manage resources rather than simply consume them.

* Consider how the project will maintain or enhance the ecological productivity of the natural resource base used to produce energy.

* Consider the need to use natural resources on a long-term, sustainable basis.

* Think of energy in terms of the purposes for which it will be used. Integrate energy planning with agricultural projects when appropriate because the natural resource system must provide both food and energy.

* Develop energy projects that reduce erosion, maintain soil fertility, and protect watersheds.

* Develop energy projects that take into account the seasonal availability of and demand for water, crop residues, and wood so that use does not exceed supply.

* Maintain or enhance water supply and quality by, for example, maintaining watersheds or taking care in the disposal of waste materials.

* Build into the project the length of time necessary to replenish the resource used for energy, being careful to consider the demands other than energy that are being placed on the resource.

* Identify the ecological values in traditional practices and apply them where possible.

Socioeconomic Guidelines - Socioeconomic guidelines help to incorporate the energy project into the local cultural and institutional structure to help ensure proper operation and maintenance.

* Involve all people who will be affected in all stages of energy project development.

* Make sure that the use of a natural resource for energy does not affect its use by the landless and very poor, who will be worse off and forced to over use other resources to meet their energy needs.

* Build upon the existing social organization and customs for environmental rehabilitation and conservation.

* Develop land use strategies that minimize conflicts between energy and agricultural goals. Integrating energy projects and food production projects will help.

* Develop energy technologies that provide multiple uses (such as a biogas system for energy, fertilizer, and waste management), so that maximum use is made of the investment and the resources.

* Develop energy sources that are most suited to the task both in terms of cost and energy quality so that resources are used efficiently.

* Balance health problems with other benefits in designing energy conversion devices; for example, smoke from cookstoves may create respiratory problems but it may also kill problem insects.

* Design projects that guarantee that the target population will have control of the energy source or energy end use.

As noted earlier these guidelines are not exhaustive. You may think of others to add to the list appropriate for project planning in your area.

Steps in the planning process

1 Collect information

The profile of the community consists of the socioeconomic organization, the way it produces and consumes energy, and the status of its natural resources. This information can be a very helpful planning aid. It should be designed to provide easy-to-use data on key social, cultural, ecological, and economic characteristics. The data should be carefully selected and the rationale for gathering them should be made explicit. Local people are extremely important in helping to identify relevant energy relationships as well as in helping to gather and analyze information.

Early discussion with community members will serve to direct the planner to certain problems, but a good planner will not form any conclusions regarding needs at this point.

There are two purposes to this step in the planning process. One is to determine the existing conditions. The second is to collect information that will permit the planner to quantify the relationships among energy use, natural resources, and the people who use the resources.

Often, local people prove to be an invaluable source for such information. In other cases, however, it may be necessary to consult technical documents to obtain data on characteristics such as to the amount of insolation (soler radiation) in an area or imported energy use. When properly collected, this information can help save extra project costs.

The data should be organized to provide easy-to-use information on key social, cultural, ecological, and energy characteristics. Several types of information that should be collected are outlined below.

*** Community profile--socioeconomic characteristics**

-- Who are the people using the resource?

Examples:
Population size, growth rate, diversity, and age groups

Number of households

-- Who or what affects/controls access to the resource?

Examples:
Land ownership and land tenure system

Indicators of average income per household (roofing materials, painted or white -- washed building, number of animals)

Employment information, specifically in-house and rural industry sources

Available credit mechanisms for energy projects (credit mechanisms may only be available for agriculture, check to see if these can be applied to energy)

-- What is the local management system (actual and potential)?

Examples:
Community structure including leaders, economic status, etc.

Cultural traditions, attitudes, and perceptions related to energy sources and natural resources, and their uses

-- What are the outside forces affecting local resource management?

Examples:
National, regional, and local policies that affect energy use and supply (laws, taxes, subsidies)

Regional and national energy markets, population centers

-- What factors affect the energy supply?

Example:
Agricultural practices

-- What are the public health considerations?

*** Natural resources--ecological characteristics**

-- What are existing uses of natural resources?

Example:
Land use patterns, particularly agricultural land and forested areas

-- What is the physical environment?

Examples:
Soil: composition, organic content, ground cover,

erosion, use of local fertilizers, and steepness of slope

Water: local sources, quality, amount and seasonal variability of rainfall and stream flow, condition of watersheds, ground water supplies, and use

Climate: annual temperatures, seasonal floods and droughts, amount and seasonal variability of solar insolation (energy that reaches the earth), maximum and minimum wind velocities, and seasonal variations

-- What is the biological environment?

Examples:
Flora and fauna: vegetation (stable, changing, balanced, requirements, and limiting factors for regeneration), feed and water requirements of animals

Biological communities in the area: composition, diversity, stability

Biomass: amount of natural standing forests and forest residues; amount of trees and shrubs outside of forests, in open rangelands, around agricultural fields, in home gardens, along roads;

types of crops grown; crop residues and seasonal availability

-- How are the natural resources being used or managed?

* Energy Use Patterns

-- What are the energy characteristics of this community?

Examples:
Energy sources: present and future energy sources in terms of quantity, price, location, and variability of supply of biomass, biogas, hydro, organic wastes, agricultural residue

Energy conversion/process pathways: i.e., what happens to the energy between the source and the final end use, how is it transported, transmitted, or converted, etc.

Energy end-use patterns: how is energy being used, how much is used for cooking, heating, lighting, rural industrial use, household use, etc. Organize this information by both cost and the social classifications (household/industry use, income, geographic location) identified above

Imported energy: amount, prices, and variability in supply of electricity, liquid fuels (e.g., gasoline, kerosene, diesel), gaseous fuels (e.g., propane), and coal. Measure the time required for energy collection; Identify the producers and middlemen for energy and their role in the community

It may not be essential to collect all of these data. The specific data that are important to the development of an energy project will often be determined as the development worker and the community jointly assess community needs.

2 Identify energy needs and constraints

After examining the information identified and collected for the profile of energy patterns, some further refinements may be needed before determining the needs of this community and the constraints on those needs.

The following should be explored about each energy source:

* how much energy is used directly and how much is converted for use in households, agriculture, small-scale industry, and transportation (including where the resource comes from and whether there are seasonal variations in type and quantity)

* trends in energy consumption patterns, costs/benefits pricing, energy intensity for particular end-use functions, and energy-economy relationships

* energy efficiency in key end-use devices

* competing non-energy uses of the natural resources used for energy: how much is used for food, fodder, fertilizer, fiber, or construction; by whom

* changes in the demand for, availability of, or access to resources.

The assessment should also provide information on what groups of people are using the various energy types, how they are using it, where the sources are, what the seasonal patterns of supply and use are, and how much it is costing.

It is essential to determine the factors that are or will affect future availability of sources. For example, predictions of future energy needs may be based on observations of declining supply or increasing costs.

Analysis of the relationships between the energy source, competing uses of that resource, and the overall stability of natural resources is often ignored. An adequate analysis of fuelwood supplies might indicate that the effects of using land for agriculture would deplete fuelwood sources. And the situation would grow worse as population increased. Analysis would allow energy planners to focus on the causes of the problem rather than designing solutions that address the results of trends.

It is essential to remember that current energy use occurs in

the midst of several interrelated and dynamic socioeconomic and environmental processes. Too often solutions for energy problems are based on technological perceptions. This can be avoided by planning projects that match the management of resources with the demand for energy that promotes development. The planner and the community must look at energy needs in this broader context.

The information will help the community to identify specific energy problems that can be remedied through small-scale projects. During the identification process, the community may find that potential energy sources are not being used for energy or that certain resources are being over used, which in turn is resulting in environmental problems.

The socioeconomic analysis will help the development worker identify the groups that exist in the community, which of them control access to resources, what outside factors affect access to those resources, and the costs of those resources. This will allow the planner and the community to compare the energy needs of different socioeconomic groups and to predict which group of people will likely benefit from a proposed project.

An important part of assessing needs is identifying constraints -- the technical, economic, social, and environmental factors that restrict efforts to meet local energy needs. This will allow the planner to identify the factors that will impede or promote future development efforts in general. For example, if energy is not available or is inadequate for water lifting for

irrigation, this might be considered a technical constraint.

In Indonesia, subsidies on kerosene acted as an economic constraint to fuelwood management. As a result of the low price of kerosene, demand for biomass declined, which in turn contributed to a lack of management of fuelwood supplies. When the subsidy was removed, an increase in the demand for biomass led to increased prices for those resources. Because other fuelwood supplies were not available, the consumption of crop residues increased dramatically. People did not begin to plant fuelwood species to meet the growing demand until the price of fuelwood increased. Efforts to increase the fuelwood supply while kerosene was being subsidized would not have succeeded because the government pricing policy was acting as an economic constraint.

An example of a social constraint can be found in Sri Lanka. For religious and cultural reasons, dung is not considered acceptable for use as fuel. And in other countries, researchers have found that a lack of access to or control of a resource may be a constraint to efforts to provide energy supplies by encouraging tree planting. Where villagers do not own the land they farm or the trees that are on their farms, they have little or no incentive to manage what they may not be able to use.

Environmental factors can also act as a constraint to energy supplies. For example, cultivation of marginal lands often uses the same farming practices that were used on productive soils. And often, these farming practices are inappropriate for the site. The clearing of land results in a reduction of potential biomass energy supplies, increased rates of soil erosion as a result of the lack of ground cover, and a depletion of nutrients in the soil. This reduces the amount of water that can be stored in the soil and increased flooding frequently occurs. The subsequent degradation of the watershed then seriously threatens the water supplies in the area, constraining the successful introduction of a hydro project.

Additional examples of constraints include a poor match of an energy supply with an end use. This may occur when rural electrification is proposed for an area where the major energy need is for cooking. Inadequate supplies of water or wind for hydro or wind energy projects are examples of technical constraints. The cost of technologies, pricing policies, and subsidies can all act as economic constraints to energy supply. Planners must be aware of the wide range of factors that may constrain the supply, use, development, and management of energy resources before they can successfully propose solutions to alleviate local problems.

3 Define project objectives

The next step is to formulate objectives for a project that will be undertaken to meet the needs given the highest priority. Project objectives should serve the needs of the community for improving the quality of life. Technological solutions should be secondary in determining objectives. Combining energy development with natural resource management can contribute to effective local and regional development. Supplying the energy needs of a community can have several components and a single project may be only one of those components. Objectives may be defined that help solve several problems in a region. For example, a project that provides electrical energy to a community may also provide employment, and thus, a guaranteed market for energy from biomass. This energy could be supplied from fuelwood, agricultural wastes such as sugar cane by products, industrial wastes from milling operations such as wood chips and fiber, etc. Such a project could promote management of biomass sources that were previously neglected by providing a needed economic incentive.

Project objectives must be clearly defined: for instance, if the goal is to increase energy supply, one specific objective may be to provide seedlings of fast-growing tree species to 123 families. This objective may be further defined by indicating a plan for training 10 farmers to grow these seedlings. Thus, a clearly-defined objective not only sets the task precisely but also provides a standard by which the project can later be eveluated.

The guidelines at the beginning of this chapter can help determine the requirements for meeting the project's objectives. For example, if a guideline for developing energy technologies that provide multiple uses is adopted, the project might include growing trees that can be used for livestock feed and construction materials in addition to supplying energy. Such a project might also have associated environmental benefits by providing erosion control on steep hillsides.

In another example, community members may voice strong concern over the need for both erosion control and more fuelwood while the development worker's assessment of the resource and climatic conditions may indicate a need for watershed management. The community and development worker must then decide which need has a higher priority, given the range of technical, social, and economic conditions present.

4 Develop alternative designs

Once objectives are defined, alternative designs for implementing the project can be considered. One of the first steps in developing designs is to examine each identified need in terms of the effort required and the kinds of resources necessary to meet it. In many cases, the development worker may want to seek some additional assistance if the problems indicate a need for special knowledge. If one of the alternative designs includes a small-scale water installation, for example, consultation with hydropower specialists, water resource managers, and health specialists may be necessary. In general, a variety of opinions is always helpful in reviewing decisions in order to identify and deal with possible problems.

The design of the alternatives should be based on the community's identified needs. It should be consistent with the environmental, social, technical, and economic guidelines, as well as technically feasible or appropriate. Consideration of the constraints will help to identify conditions that restrict the present energy situation or may limit the effectiveness of the project.

5 Compare alternatives and select one alternative

Evaluations of possible projects can be made at various stages in the planning process. In the early phases of designing a project, an inventory of local and non-energy technologies that meet identified needs can be matched against the technical resources available at the project site. Many inappropriate technical solutions can be eliminated at this planning stage based on the constraints already identified. These might include an inadequate supply of a resource (wind, water), excessive costs, lack of technical skills, etc. For those solutions that are feasible, an analysis of the benefits and costs of a project should be made. The analysis is based on a comparison of the alternative designs and uses criteria derived from the previously-mentioned guidelines. These can be summarized as:

* Economic and financial analysis: a thorough evaluation of the costs and benefits of a project from the viewpoint of the community and its individuals should be conducted. This should address the long term concerns of a project's ability to be sustained: will the project succeed in the absence of economic support from outside the community?

* Analysis of technical feasibility: a thorough evaluation of the technical application of a given technology must be conducted at this stage. The most critical question to be

asked at this stage is whether or not the alternative energy solutions are appropriate to meet project objectives. Additional questions include whether the technology is proven or if it is still experimental, can it be adapted to the local conditions, are the raw materials available, can parts be located if needed, etc.

* Assessment of social and cultural impacts: technologies that require substantial changes in the social, legal, and cultural institutions in a project area will often be found unacceptable and end in failure. However, the planner should not assume that a new technology will not be readily adapted because of social and cultural reasons.

SAMPLE BENEFITS/COSTS
DATE___________ ANALYSIS CRITERIA PROJECT DESCRIPTION________

ECONOMIC RETURNS

Self-Sufficiency. Rank high a project which can be shown to lead to jobs, skills, training, improved markets or other economic gains which are returned directly to the community and can be shown to increase local self-sufficiency. Move toward the lower end of the scale if a project must rely on continued subsidy and/or it becomes less clear that the economic gains will be returned to the community.

Funding Availability. Rank high a project where funds are available quickly and easily (perhaps from local sources). Move toward the middle for projects where some funding is available but additional funds must be sought. Use the lower end of the scale in cases where funding is not readily available and a long time lag seems likely.

Net Profit. Rank high a project where careful calculation of economic factors indicates that the product or project will bring in more than it cost. Move lower on the scale as the project's economic profitability appear less clear.

TECHNICAL RESOURCES

Local Techical Support. If the project requires involvement of change agents, technical support groups, extension services, and these are available, rank high. Move toward the opposite end of the scale as availability and access to such support becomes less clear and/or difficult.

Technology Availability. Rank as high a situation where the technology exists and seems adaptable to the situation. Move toward the lower (costs) end as the technology requires more extensive commitments to research and development. Rank high situations where technology makes maximum use of local human and material resources. Move lower toward the opposite end as resources must be obtained from outside sources and this could cause delays and/or failure to use local resources adequately.

Technical Impact. Rank high a project in which the technology or project once launched can be maintained by local residents--this implies training in upkeep and repair and arrangements for replication. Move lower on the scale in situations where provision for these activities has not been made. Rank high a project which introduces a technology which seems to require little change in everyday life. Move toward the lower end as the technology seems to require alterations in lifestyles, culture, traditional patterns, etc.

SOCIAL AND CULTURAL ENVIRONMENT

Community-expressed Need. Rank high a project based on community-expressed need. Move toward the opposite end as community involvement in need identification becomes less clear.

Social Returns. Rank high projects which can be shown to bring cultural and social gains to the community. Move toward lower end as social and cultural gains become less clear and/or the effects of the effort seem likely to be socially or culturally descriptive. Rank high a project which enables residents to participate with least risk. Move toward the lower end of the scale as it becomes clear that participants run more risk, i.e., as their investment demands a level of commitment which would have serious consequences were the project to fail. Assume for project feasibility that the smaller the degree of change required in local custom, the easier it will be to get the project underway. Rank as high projects which require little change; move lower as more change is required.

NATURAL ENVIRONMENT

Relevance to Guidelines. Rank as high a project which meets all or most of the guidelines for an ecologically sustainable activity. Move lower as the project fails to meet these guidelines.

Use of Alternative Control Methods. Rank high a project which makes maximum use of biologically sound control measures; move lower as the project must rely on chemical control methods.

Alternative Design #1 (Costs) 1 2 3 4 5 6 7 8 9 10 (Benefits)
- +

economic returns ____

technical resources ____

social/cultural ____

physical environment ____

Alternative Design #2

economic returns ____

technical resources ____

social/cultural ____

physical environment ____

* Assessment of environmental impacts: the proposed alternatives should be evaluated to determine if they will have any direct negative impacts on the environment. Will the projects have negative secondary effects? Often indirect effects can be far greater than primary ones.

Extensive checklists exist that the planner should use to determine actual impacts. Few projects properly estimate the economic costs of environmental damage and this should be done at this stage. Projects should also contain a plan to mitigate such damages. Properly planned projects may result in improved management of natural resources, which will have significant long-term benefits to the community.

Each of these criteria should be considered in relation to each of the project designs. In addition, there are some general points that should be considered:

* What are both the long-term and the short-term effects of the project?

* Will meeting one criterion mean that another cannot be met, thus making the project infeasible (e.g., will making the project economically viable have negative effects on the environment).

* Is another viable alternative for meeting the community's needs lacking?

* What would be the effects if no action were taken?

Consideration of all of the above will assist in making a choice among alternative designs.

A sample benefit/cost analysis is offered on the preceding pages. It is intended to help project planners compare alternatives according to the four basic criteria: economic returns, technical resources, social and cultural, considerations, and environmental concerns.

The alternative designs are evaluated and measured for each of the four criteria by using a simple scale numbered from 1 to 10. The lower end (left) of the scale represents costs or negative effects; the upper end (right) represents benefits or positive effects. The five-point mark in the middle of the scale represents a situation where benefits and costs are evenly balanced. The four ratings are then averaged to give a total average for the design. Alternative designs can then be compared to select the design that appears most beneficial.

There is no magic about this measuring system. It is relatively easy to use. It allows alternatives to be reviewed: Will modifying parts of an alternative change its rating? Development workers will probably want to adapt the system to fit a particular situation

6 Implement project

Community participation should be an integral part of implementing a project. Whenever possible, the use of local materials and local technicians and craftspeople should be encouraged. In this way, future maintenance is not likely to be beyond the community's resources. Community pride, developed

through commitment to the project, successful participation by individual community members, and receipt of valued benefits, is the best guarantee for continued maintenance and long-term benefits.

7 Monitor project

A plan to monitor the project should be incorporated into the original design. This will allow the development worker and the community to make any needed corrections in the project design and assist project implementation. Furthermore, projects may have environmental effects that must be monitored. It is difficult to predict all effects because environmental interactions are often more complex than anticipated. For example, the changes brought about by an energy project may not be immediately apparent; the successful achievement of a project's energy objectives may mask environmental degradation or other negative effects. Therefore, it is important to continue to monitor the project after it has been implemented.

A simple program of measuring change can be set up to identify trends that may be harmful First, it is necessary to collect and maintain relevant data for evaluating and monitoring the effects of a project. For example, for a hydroelectric project, it would be necessary to keep information on such factors as water quality, flooding, siltation, land displacement, aquatic life, etc. Such data can then be used to help identify the maintenance procedures necessary for the project's continued operation. Unforseen benefits may be encouraged, such as improved health conditions from flood control measures. Negative trends may be corrected before the problems become too severe, such as the planting of trees around the project site that cannot be used for fodder and whose planting would decrease the food available to livestock.

8 Evaluate project

Evaluating the project provides information about what the project achieved and, in particular, whether it met the objectives and needs initially established by the community and the development planner. These evaluations also allow development workers to share experiences with each other and provide much-needed information on the activities of private voluntary agencies.

Examining, analyzing, and reporting on the environmental, technical, economic, social and other causes of success and failure foster improved future planning and programming decisions. This is particularly important in a new field of work such as energy development.

The special character of the activities of private development organizations requires complementary evaluation techniques that are appropriate for projects involving the poor. These projects are usually low-cost, highly participatory, innovative and place particular emphasis on process as well as quantitative results. In tailoring an evaluation to fit your particular circumstances, the Evaluation Sourcebook (Santo Pietro, ed., 1982) could be very helpful.

VITA is a repository for information that may be helpful for your needs. Through VITA you may make information on your projects available to others.

Chapter VII

ENERGY SOURCES AND ENVIRONMENTAL CONSIDERATIONS

The environmental concerns associated with a variety of small-scale energy sources are discussed here. The points made are intended only as guidelines, since specific environmental benefits and costs depend largely on local conditions.

Although human energy is not discussed directly in this section, the substantial contribution of human energy has been stressed throughout this manual Specific energy technologies may affect human health, use of time, and income as well as cultural and behavioral patterns. Perhaps the greatest challenge is to find technologies that reduce the time needed to complete a task, maintain or increase income, and are adaptable to socio-cultural norms. Women's needs and chores are a special case. The nutritional and health status of people will directly affect the amount of work they can accomplish. Since natural resource degradation reduces agricultural productivity and therefore the amount of food available to fuel human energy, the uses of specific sources of energy should be carefully evaluated in terms of their impact throughout the agricultural resource system.

Solar energy

The sun is the ultimate source of clean and abundant energy. For thousands of years it has been used directly by people to dry food and clothes, to warm homes and courtyards, or to evaporate water from salt ponds. <see image>

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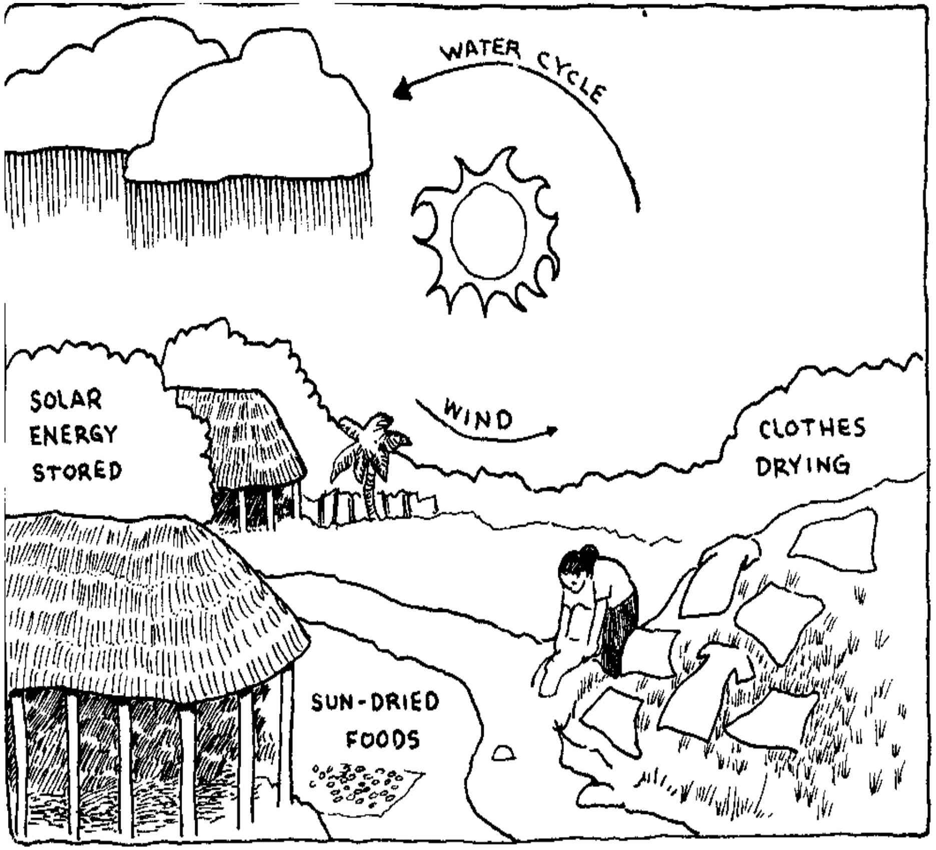

THE SUN PROVIDES ENERGY FOR MANY PURPOSES

Indirectly, solar energy makes the wind and water move. Intercepted by green plants on land and sea, it becomes the source of energy for all life on earth. This energy is released whenever people burn wood, coal, or petroleum products.

Solar energy has the potential for providing even more than this. Converted to electricity by photovoltaic cell, it can be used to supply power to motors, refrigerators, lights, communications equipment, and the like. When concentrated or "trapped," solar rays can generate high temperatures for rapid drying, cooking, and baking.

Most developing countries lie in a belt between 30[degrees]N and 30[degrees]S of the equator, where the average solar power is 700-800 watts per square meter, or six kilowatt-hours per day with eight hours of sunshine. If it were possible to capture even half of the energy falling in one day on one square meter of surface, it would be sufficient to cook food for an entire family plus do the work of three adults.

However, the great abundance and versatility of solar energy carry certain limitations. The most obvious is that solar energy is directly available only during daylight hours when skies are not overcast. For use at other times, the energy must be stored, either in chemical form in batteries, or as retained heat in water, rocks, or other such materials.

Another limitation of solar energy is that by the time it reaches the earth, it is very diffuse and must be trapped or concentrated. Usually this can be done by using durable transparent or highly reflective surfaces and a certain amount of space. Even with the most efficient photoelectric cells it would take over 10 square meters of collector surface to power a small water pump or grain mill. If the energy is to be used for cooking or baking, a minimum area of 1.5 square meters may be required.

The use of solar energy generally has no adverse impact on the environment at the local community level. To the extent that solar devices may reduce the consumption of fossil fuels, dung, or fuelwood their use has measurable environmental benefits.

However, since solar energy can be used in so many different ways, it may be helpful to consider briefly some of its possible functions.

Drying: Low-frequency heat radiation from the sun passes easily through a transparent window of a box. Once inside, however, the heat rays change and are unable to pass back out of the same window. This is how solar heat energy is "captured."

A solar food dryer is essentially a box with at least one

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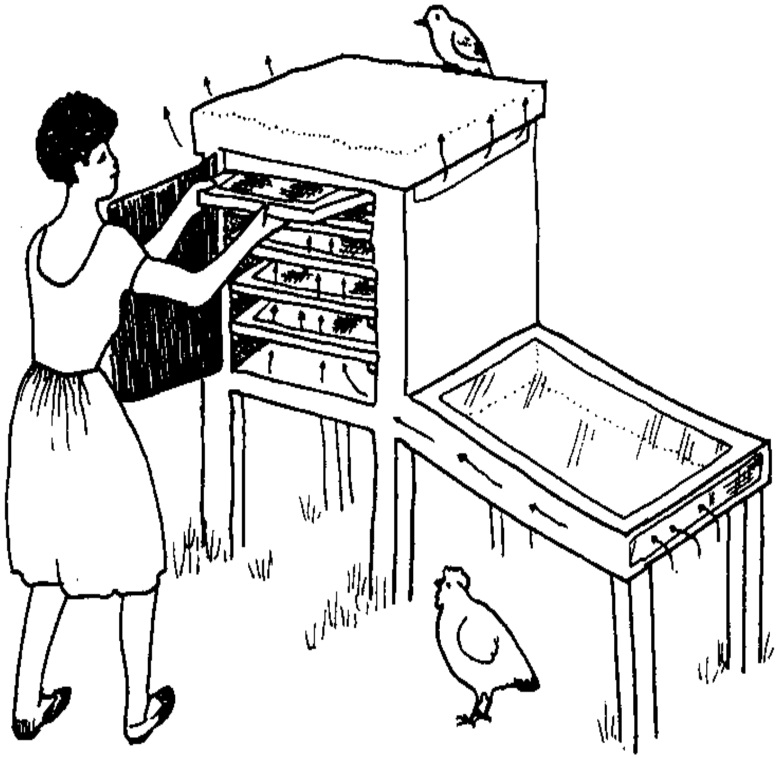

A SOLAR FOOD DRYER

transparent side where solar energy raises the inside temperature and sets up a ventilating convection current of air. Fruit, grain, vegetables, and fish can be dried inside. Food is traditionally dried by exposing it directly to the sunlight in the open air. A solar food dryer will do the same job more rapidly, using less space, and with much less spoilage. Moreover, there is less interference from flies, birds, and other animals.

A solar dryer requires a large amount of transparent glazing material. Plastic sheeting stretched over wooden frames is probably the least expensive and most adaptable material. However, most plastics eventually lose much of their transparency and become yellow and brittle under long exposure to the sun's rays. Glass does not yellow with age, of course, but it is often very expensive in poor countries. Glass is also heavy and fragile. <see image>

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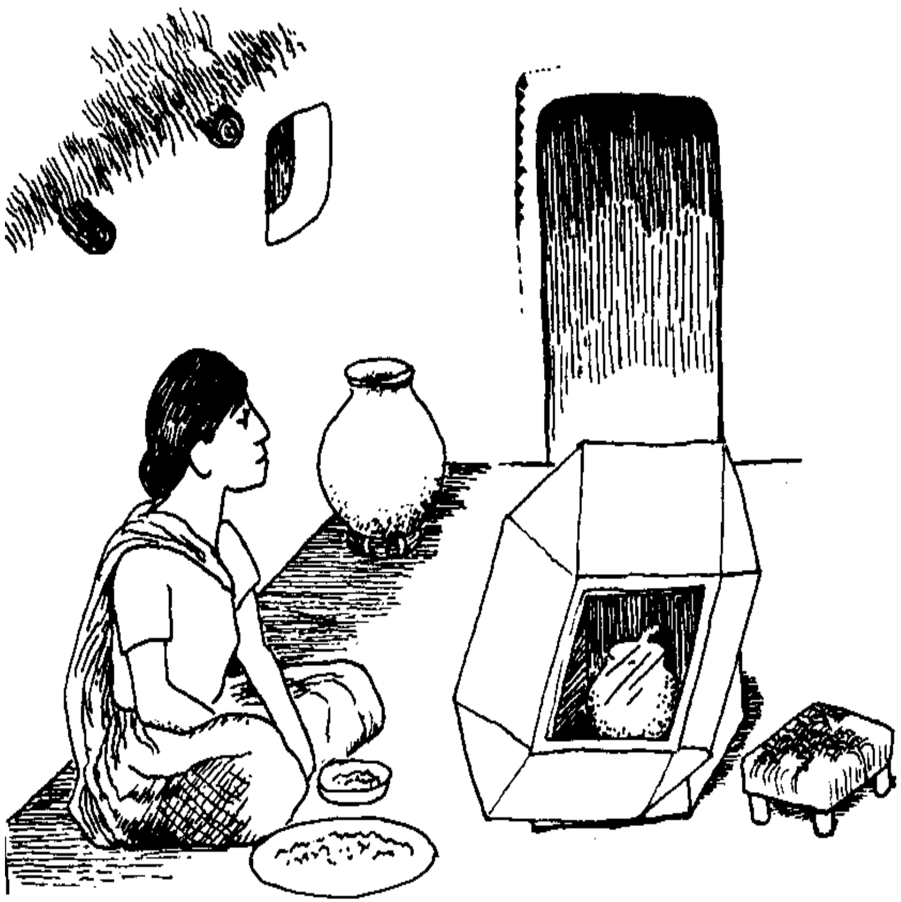

Cooking: At present, cooking with solar energy appears suitable only for food that can be baked or simmered for long periods without much attention. Breads, beans, rice, many sauces, and cereals may be adapted readily to solar cooking. Most disc reflector stoves (not solar ovens) require frequent adjustment of focus throughout the day. Foods that require frying, stirring, or other manipulation are difficult to prepare with solar heat.

The use of solar energy for cooking has not been widely accepted by women in poor countries. There are many reasons for this:

* Unwillingness to cook in the hot sun with the bright glare of a reflector.

* Fear of the intense heat at the focal point, which can cause burns and eye damage.

* Restriction of cooking time to bright daylight hours.

* Stove designs that limit pot size and make it awkward to stir or manipulate the pot contents.

* Stoves that are unstable and easily damaged by winds, domestic animals, and curious children.

* Lack of replacement parts, repair skills, and facilities.

* Initial cost of solar appliances.

Electricity generation: The technology for converting solar energy to electricity continues to make rapid progress. Photovoltaic cells are now available with conversion efficiencies of 18 percent at a price that continues to decline.

Maintenance of a photovoltaic system is limited to regular cleaning of the panel surfaces. However, the cleaning must be carried out by trained individuals designated to maintain the system.

A National Aeronautics and Space Administration (NASA) pilot project in Upper Volta demonstrates the benefits of photovoltaics to a rural village. The system was installed in 1975 and later expanded. Early technical and design problems have been resolved, and the village now has a reliable source of electricity. The use of this energy is governed by a local cooperative organization The power runs a grain mill, water pump, small refrigerator, and (with rechargeable batteries) a few electric lights.

Income from the mill is sufficient to acquire spare parts and maintain the system. One indirect benefit has been evening reading instruction made possible by the electric lights.

The NASA project was quite expensive, but, as a pilot project, shows the potential for photovoltaics in a rural setting when they become more economically feasible. However, rural electrification through photovoltaics is still several decades away. The advantages of simplicity and reliability must be matched with further improvements in conversion efficiency, a longer functional life of the solar cells, and above all reduced costs.

According to one source, there have been some negative environmental effects of this project. Due to the ease of lifting water for animals, herders tended to remain in the village for longer periods. This change in herding practices resulted in some overgrazing. With less fodder available around the village, the raising of small animals by some women was negatively affected. More cattle damage to crops was also reported. Because the water system installed was a lifting rather than a delivery system, women spent as much time carrying water as before the system was installed, but, with the new system, had to wait in line behind the herders.

Solar ponds: A solar pond is a very large solar heat collector that operates on the same principle as the solar food dryer. However, instead of trapping heat rays under a transparent window, the heat is trapped under several layers of salt water. The pond has fresh water on the surf ace and very salty water at the bottom, with a salinity gradient in between.

This system can generate heat to temperatures as high as 100[degrees], which is high enough to be used directly (water heating, for example). In some parts of the Middle East the energy is often used with a special engine (Rankine cycle) for pumping water or generating electricity.

Solar ponds can create serious environmental damage; their design and construction require assistance from those skilled and experienced in this technology. Large amounts of salt are required, and a leak in the bottom of the pond could seriously contaminate ground water supplies. Also, the steeply sloping sides could lead to accidental drownings of people and animals. Because of the high temperatures, objects sinking to the bottom cannot be easily retrieved without special equipment. The hot brine of a solar pond corrodes many metals. Finally, water evaporated from the pond surface must be replaced by water from other sources.

Wind

There is nothing new about harnessing the energy of the winds. Since ancient times wind has been used for sailing boats, lifting water, and threshing grain. More recently, it has been used to generate electricity. Properly designed, maintained and located to match specific tasks, wind machines can provide years of reasonably reliable service.

In developing countries a water-pumping wind machine is

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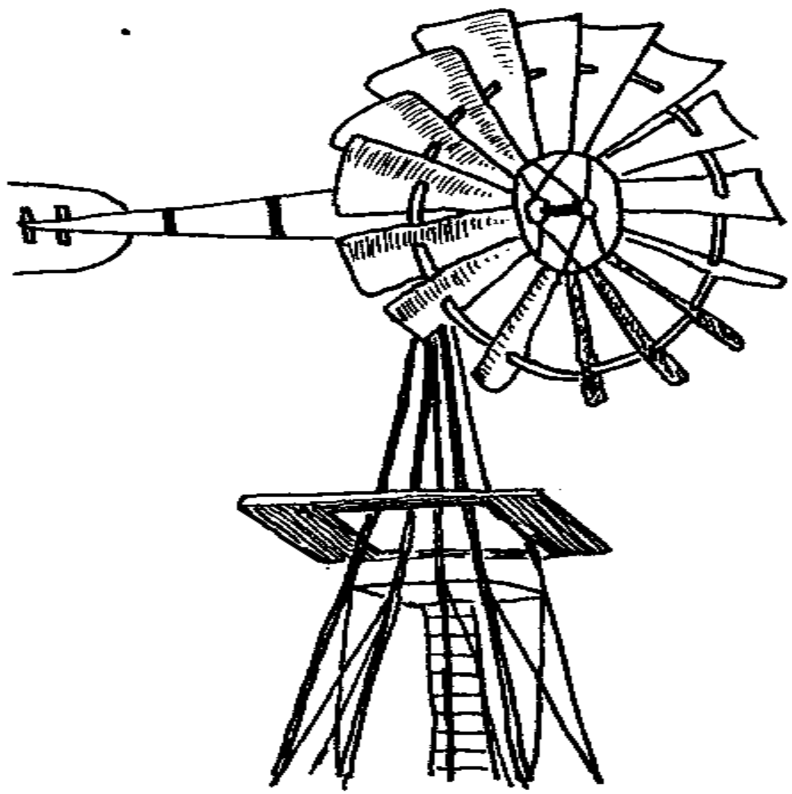

A WATER-PUMPING WIND MACHINE

particularly suitable, both for irrigation pumping and for supplying potable water. When water is pumped from the ground, the well can be closed and protected from contamination. On the Philippine island of Higatangan, 1,600 people depend on water pumped by two wind machines, each with rotors three meters in diameter. In Africa, several Malian fishing villages use wind irrigation systems to increase yields in vegetable gardens, providing a diversity of income and food supply sources.

One limitation to any

wind machine is that it runs only when the wind is blowing. A steady breeze day after day is uncommon in most parts of the world. Before considering wind power at a particular site, it is important to know the short- and long-term patterns of local winds. A wind-powered irrigation system has little value if the air is calm when water is needed most. The same is true of grain mills and any other wind-powered device.

Compared to other renewable energy systems, wind machines have more moving parts, which are exposed to much stress, not to mention rain and dust. Months of spinning and vibrating can loosen important components or cause parts to become worn. A regular program of surveillance and maintenance is essential to keep the machine operating well. Spare parts must be on hand, along with someone who knows how to make necessary repairs. The Third World is littered with the relics of wind machines that have failed simply for lack of replacement parts and maintenance.

Certain precautions are important to avoid possible environmental effects from wind machines. For example:

* There is a danger with wind-driven water pumps of pumping more water than is needed for irrigation, livestock, or domestic uses. This wastes water and may also create an unhealthy situation around the pump. An automatic shut-off mechanism solves the problem. Moreover, as with any newly installed water system, overgrazing near the water supply can be a serious problem.

* In most cases, wind machines should be mounted on a tower at least 40 feet off the ground and 15-20 feet above any nearby obstruction, such as a building or tree. This makes the mechanism highly visible, difficult to service, and dangerous if it topples. Mounting the machine on a roof is likely to cause vibration noise and apply unwanted stress to the roof.

* The rotor must be equipped with an automatic feathering device to protect the machine from winds exceeding its design capacity. There should also be protection from lightning damage.

* Vertical-axis machines generally require a larger site than comparably sized horizontal-axis devices because of the wider spread of supporting guy wires.

* When using lead-acid batteries for storing excess

electricity, it is important to keep them well ventilated to avoid the accumulation of explosive hydrogen and oxygen gases.

Water (Hydropower)

Under certain conditions it is possible to gain useful energy from flowing water. Hydropower for mechanical or electrical energy is produced when the pressure of flowing water is directed at a waterwheel, turbine, or hydraulic ram. Waterwheels, which produce powerful mechanical energy at slow speeds, are best suited for applications such as grinding grain or lifting water. Water used to produce electrical power is generally applied at high pressure to a specially-made turbine, which can be as small as 10 centimeters in diameter. Hydraulic rams are essentially automated water pumping devices that use the kinetic energy of water flowing in a pipe to lift the water higher than the source.

Small rivers and streams can provide the energy source for small-scale applications. Called micro- or mini-hydro, depending on the amount of power generated, such applications function either with or without a dam, depending on local topography. The most environmentally sound way to tap this resource is to take advantage of naturally occurring gradients that do not require construction of a dam. This will also be the cheapest option. It requires a relatively steep stream gradient and good year-round flow.

No-dam hydropower production requires diverting some water

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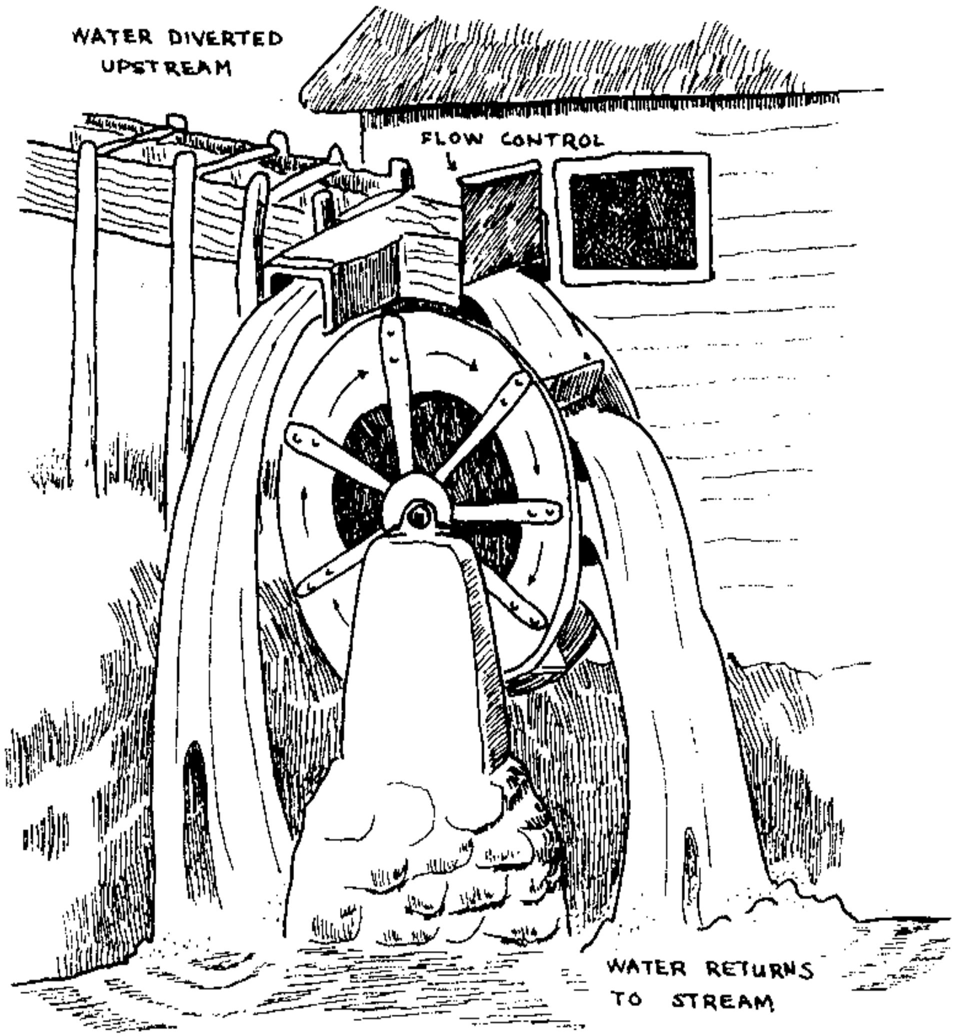

DIVERTING WATER FOR HYDROPOWER

from the stream and passing it through a channel to the power converting device. This channel may be open, as in the case of

most water wheels, or it may be a closed pipe, which is typical for hydraulic turbines. The channel does not slope downward as much as the stream, so that after a short distance the water level in the channel is higher than that in the corresponding section of stream. This difference in height is called the "head". The maximum power to be derived from the water depends on the size of the head and on the maximum rate of flow through the channel No-dam hydro projects have a minimum of environmental drawbacks, since they divert water flow along short sections of the stream and do not flood the land.

In areas where the stream flows gently and a long channel is not practical, it is tempting to create a head over a short distance by constructing a dam across the stream. This creates a reservoir of water that may have many beneficial uses, such as for irrigation.

However, dams both large and small are widely viewed as environmentally problematic. They should be undertaken only with skilled professional help. Even with such assistance all the problems will not be immediately apparent. Some of the problems that may be encountered include:

* Inundation, or flooding, of the land behind the dam may cause loss of plant and animal life, increase in soil erosion around the reservoir, reduced land available for food production; changes in water temperature that can affect quality of the water.

* Alteration of the normal flow of the stream will reduce availability of nutrients and sediment downstream for crops and for fish life. It can also threaten fish migrations and hinder navigation.

* Increased incidence of water-borne diseases is a common effect of the creation of a large body of still water that creates a vector for disease.

* Insufficient attention to geology and topography of the area may result in a real threat to public safety as the dam may not be able to withstand the force of the moving water.

A special note is appropriate concerning the environmental impact of hydraulic rams. With few moving parts, hydraulic rams are generally reliable and effective. However, they are also very noisy, sounding a loud "Clack!" every 1-2 seconds. This can be extremely annoying to people living close by.

Biomass

The importance of biomass (fuels derived from organic materials such as trees, crop residue, and dung) as a staple fuel in developing countries can hardly be overstated. More than 200 million people depend on wood to meet their basic energy needs, mostly for cooking and heating. <see image> The only other reasonable, i.e.,

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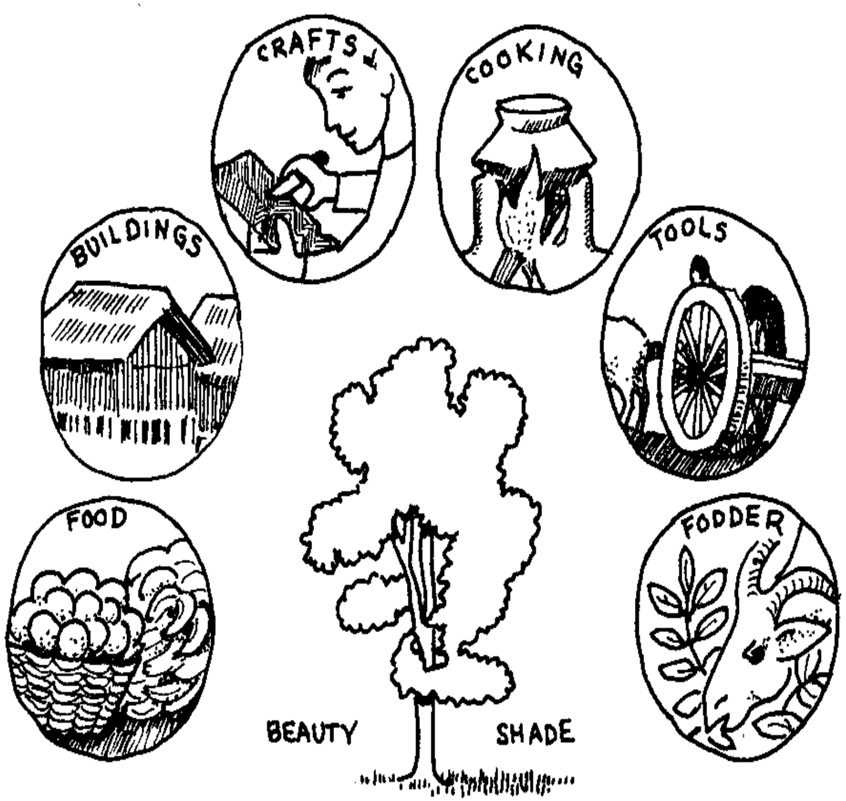

TREES HAVE MANY USES

less costly, alternative for them is to burn animal dung, straw, or other agricultural wastes.

Fuelwood: With the population of the Third World increasing by over three percent per year, the consumption of fuelwood has never been greater. At the same time, overgrazing, heavy timbering, climatic changes, and the expanding demands of agriculture are rapidly destroying the world's remaining forests. Fuelwood, which in the past had always been considered "renewable," is now being consumed as a finite resource.

The increasing scarcity of fuelwood causes much hardship among the poor. In the capital cities of the Sahel, for example, people often pay more for wood than for the food they cook. In rural areas the cost of wood is measured in the time and effort it takes to collect it. For the most part, wood is seen as a public resource that anyone may take, and yet no one is responsible for its replacement. This is a familiar dilemma wherever the earth's resources are involved.

Most people burn wood by necessity rather then by choice. While smoke from the fire may repel unwanted insects, it also irritates the eyes and damages the lungs. It blackens pots, utensils, and whole kitchen interiors. The burning characteristics of wood include distinct "flaming" and "coaling" phases that complicate attempts to use the heat efficiently. These disadvantages are made even worse whenever dry wood becomes damp.

The practice of burning charcoal for domestic energy is often seen as an unnecessary squandering of fuelwood. Converting wood to charcoal sacrifices as much as 80 percent of the original energy. On the other hand, where long distances are involved, it may actually be more energy efficient to make and transport charcoal than to haul the original quantity of wood. Moreover, when cooking, it is possible to use heat more efficiently from glowing charcoal than from a flaming wood fire. So, whether it is better to use charcoal or raw wood depends on at least three factors: where the fuel comes from, how it is transported, and how it is used.

For many people in rural areas, trees and shrubs have other uses besides providing energy. They are a source of fodder for domestic animals, especially in dry seasons when grasses are less available. Often leaves are a staple in local foods, or they are important ingredients of medicinal teas and drugs. Fibers for basketry and cord, large fronds for roofing, and straight poles for construction are also derived from trees.

Trees and shrubs play a dominant role in land-based ecosystems in land-based ecosystems. Their leaves and branches shade the soil and cushion the impact of heavy rain. Roots hold the soil and help retain water. Roots and leaves provide the soil with important organic material and scarce minerals. Decaying organic material creates a favorable soil structure that helps absorb water and resist erosion. Trees and shrubs can create windbreaks, reducing wind velocity at ground level and helping retain soil moisture.

With widespread deforestation these important functions are

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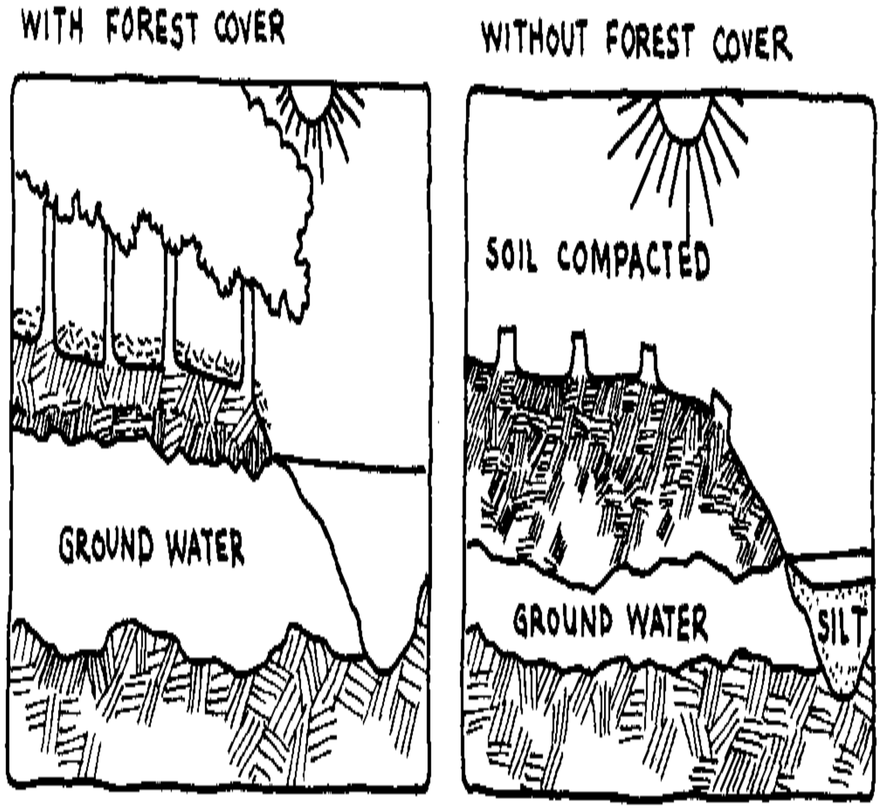

lost. The changes this brings vary according to local climate, topography, and other factors. In general, the results include an increasingly harsh environment, with increased soil erosion, degraded soils, silted waterways, and possibly lowered water tables. Especially alarming is the loss of soil fertility and reduced food production.

One long-term solution to deforestation is an intensive program of forest management. Many local species, when properly cultivated, can develop sustained yields much greater than unmanaged forests. Village woodlots and large-scale tree plantations using fast-growing species are other possible methods of increasing wood supplies and maintaining the ecosystem.

Additional benefits of new trees may include forage for domestic animals, nectar for bees, nitrogen fixation for increasing soil fertility, and the full range of soil and water conservation functions. Information on sustainable forestry projects can be found in Environmentally Sound Small-Scale Forestry Projects by Peter Ffolliott (published by Codel/VITA, 1983).

On a short-term basis, much can be done to reduce the rate of domestic fuelwood consumption. Cooking over an open fire or on a poorly designed stove can waste energy. Reductions in fuelwood consumption can be achieved in a number of ways:

* Shield the open fire from drafts and breezes so that the flames will lick the pot directly.

* Protect fuelwood from moisture so that it burns dry and yields the highest possible heat energy.

* Cover all cooking pots with well-fitting lids.

* Arrange to have pots seated at the proper distance from the fuel bed (that distance being roughly equivalent to half the maximum pot diameter).

* Where possible regulate the draft if using a stove.

* Soak dry beans or grains overnight to reduce cooking time. Even better, soak them in a tenderizing solution, such as that derived from papaya fruit.

* Use a haybox (an insulated, heat-retaining box) to cook foods requiring long simmering. Or use a haybox to keep noon leftovers hot so no reheating is needed in the evening.

* Extinguish the fire the moment the food is cooked.

* Take advantage of retained heat by cooking over a simple, enclosed stove for warming water, drying wood, or keeping food hot after the fire is out. For more discussion on fuelwoods see Ffolliott, 1983.

Biogas: Using plant and organic wastes to generate clean, combustible gas can be an attractive prospect in some situations. Biogas production can also yield a quality fertilizer and soil conditioner, which the Chinese report has boosted crop production as much as 130 percent. In some areas biogas production has reduced the incidence of hookworm and other parasites by providing safe disposal of human feces. <see image> Finally, the substitution

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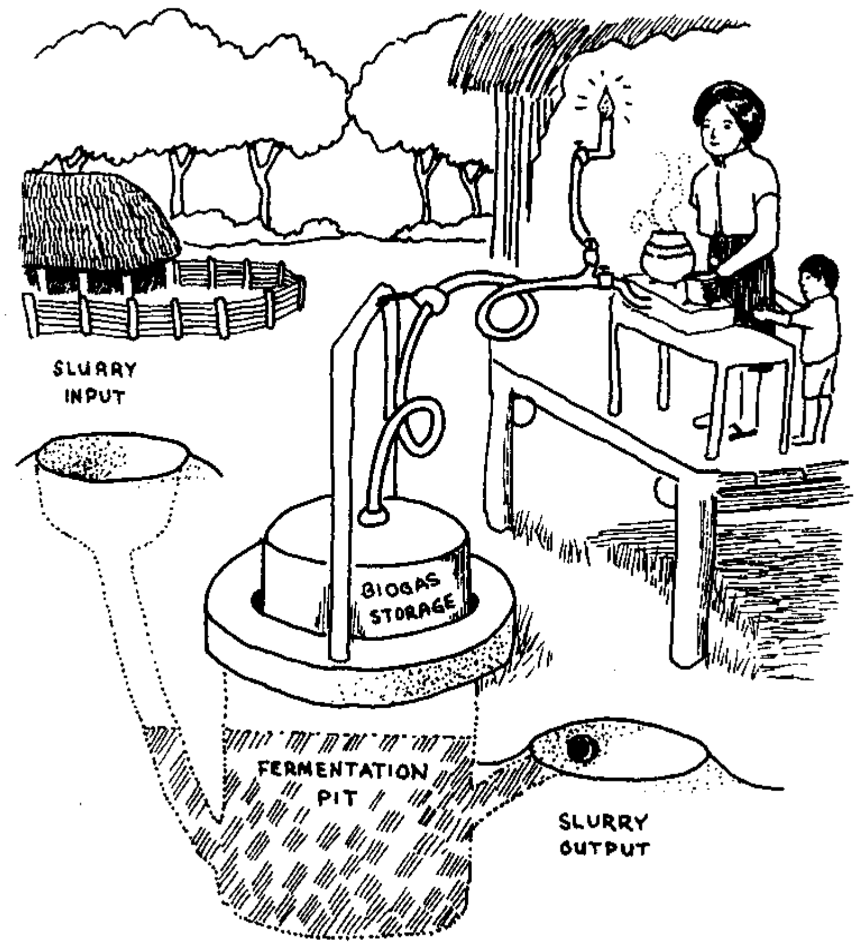

MANURE CAN BE CONVERTED TO BIOGAS FOR LIGHTING AND COOKING

of biogas for wood or dung fuels may have other valuable health and environmental benefits.

Biogas is a mixture of 60-70 percent methane plus carbon dioxide, water, and often hydrogen sulfide gas. One popular use is for night-time lighting, where a bright lantern may consume only 0.7 cubic meters (2.5 cubic feet) of gas per hour. For cooking, a single 5-10 centimeter (2-4 inch) burner consumes 0.2-0.4 cubic meters (8-16 cubic feet) per hour. Refrigeration consumes slightly over one unit volume of biogas per unit volume of refrigerated space per hour. When substituted for diesel fuel, biogas burns very cleanly, with 7 cubic meters providing the energy equivalent of 4 liters of fuel (250 cubic feet per gallon fuel). In China, a fuel of 70 percent biogas and 30 percent diesel oil is said to provide power to some 150 small-scale electrical generators.

Like wind and hydropower, biogas production is practical only when certain conditions are met. In addition to a proper digester, there must be:

* A steady, year-round supply of organic material that provides the proper balance of carbon and nitrogeru Fresh manure from one cow can yield 0.17 cubic meters (6 cubic feet) of gas per day. The same amount of gas can be generated from the fecal wastes of nine adult people or 30 large chickens.

* An adequate supply of water sufficient for a 6:1 ratio with dry organic solids fed into the digester. A biogas unit using cow manure, for example, initially requires at least 3.5 liters of water for every 0.1 cubic meter of gas produced (1 gallon per cubic foot). Once the digester is operating effectively, much of the liquid overflow

(supernatant) can be recycled in place of fresh water.

* The daily services of a responsible person knowledgeable in digester operation. There are two types of digesters: those able to accept a small continuous flow of input and those requiring a single large quantity of material (batch loaded). A continuous--feed system requires monitoring digester performance, preparing and adding raw materials, and disposing of the supernatant and sludge. A batch-loaded digester requires less daily attention, but demands much labor whenever the batch is changed.

In China, household and village biogas systems have been built and used with some success. However, recent reports indicate a number of problems. Experience may differ in regions where water is scarce or where livestock roam freely and distribute their manure around the countryside. Often a biogas generator is more effectively installed in an institutional setting than in a village or household. In Africa, biogas operations have been used at schools, hospitals, military installations, and prisons.

Although biogas digestion is widely regarded primarily as an energy-producing technology, it can also play a major role in sewage disposal, agricultural production, fish farming, and livestock maintenance. It may be that biogas digestion has its greatest potential in integrated applications where energy production is but one part of a larger system.

Sludge from biogas systems is rich in readily available plant

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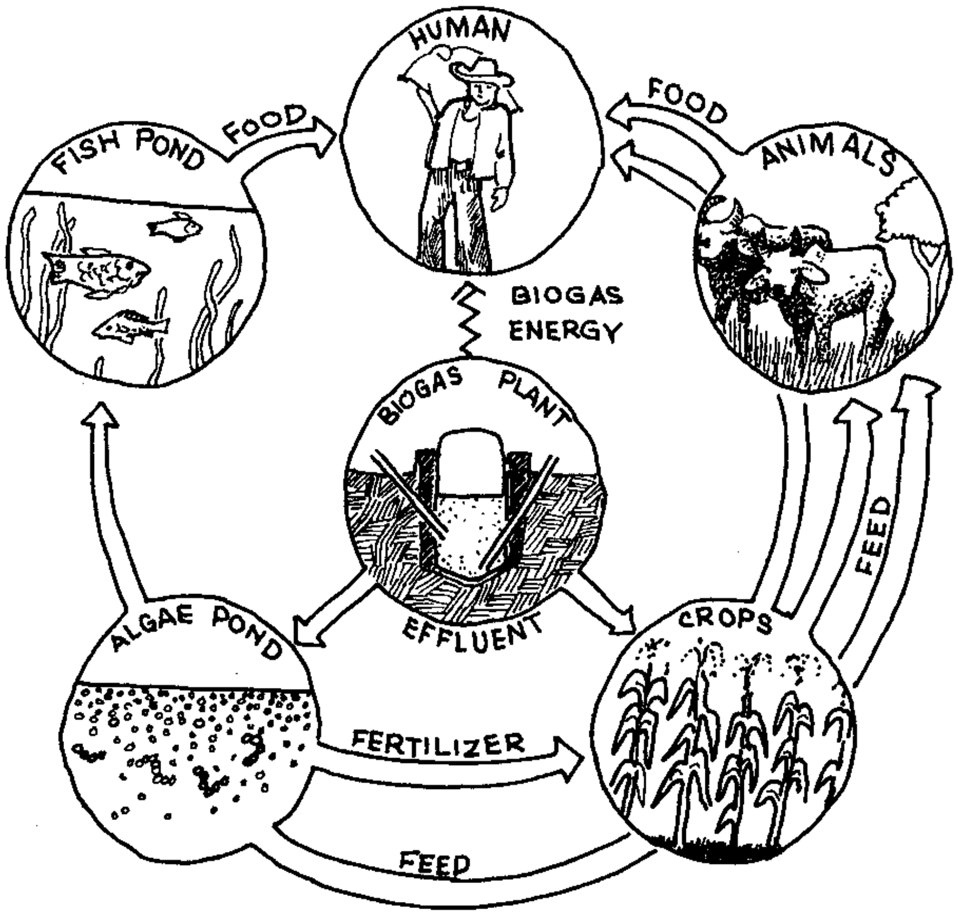


AN INTEGRATED BIOGAS SYSTEM

nutrients. Where fish culture is feasible, a limited quantity of sludge may be used to support algae and insects, which are then fed to the fish. A more common use for digested sludge is to improve soil fertility. For maximum benefit, it is advisable to mix sludge with the soil while it is still very fresh. Sludge loses much of its effectiveness when it stands. If necessary, sludge may be stored in a pit or large container and then covered to minimize exposure. This will probably be necessary because fertilizing is seasonal but sludge is produced continuously.

The operation of a biogas digester presents several potential environmental problems. With proper planning and operation these can be minimized:

* Special precautions are required if human or hog wastes are to be used. People and pigs share similar fecal-borne parasites and pathogens, and although few of these survive the digestion process, more study is required on the safety of handling digested sludge. Some authorities warn against applying sludge to soil where root and vegetable crops are cultivated. In any case, raw fecal wastes should always be considered extremely hazardous. If the digester is built close to lavatories or livestock sheds, the excrement may be deposited directly without unnecessary handling.

* Disposal of liquid overflow (supernatant) from the digester may occasionally present a problem. Normally this liquid is clear and odorless, and also has some value as dissolved fertilizer. If water is scarce, the supernatant may be recycled into the digester with new organic feedstock. Otherwise, it can be used to water plants or moisten composting materials. With an improperly working digester the supernatant may be dark and

extremely offensive. If not recycled, this liquid should probably be buried or mixed with soil in an isolated spot.

* As with natural gas, precautions must be taken to prevent leaks of biogas into the air. Surveillance is very important, since biogas normally is odorless and difficult to detect. In a closed room, leaking gas can lead to asphyxiation or explosion.

* In areas where manure or dung is considered a free community resource, the installation of biogas digesters may cause unwanted changes in local economics. If manure suddenly becomes valuable it may become a marketable commodity, and will no longer be available to the very poor. The question of who stands to lose or gain from an energy project is one that deserves attention in the initial planning phases.

Ethanol: The production of ethanol (or ethyl alcohol) is based on small-scale technologies that have existed for centuries for making beers and spirits. As a fuel, ethanol can be burned directly in modified spark-ignition internal combustion engines. It may also be dehydrated and mixed with gasoline for a high-octane fuel. Ethanol is a valuable raw material in chemical and pharmaceutical industries, so its production can foster a profitable small industry.

Ethanol can be made from a wide variety of plants containing abundant sugars or starches. Sugar cane, sweet sorghum, corn, and cassava are most often used. The plant material is crushed or softened by soaking, fermented, and finally distilled to isolate the alcohol. The fermentation and distillation phases require considerable energy inputs, and it is debatable from an energy standpoint whether the whole process results in a net gain or a net loss.

Equally important is the issue of using nutritious food to manufacture a liquid fuel. If energy crops are substituted for food crops, the result could be higher food prices and less available food. If, however, ethanol is produced from surplus or spoiling crops there is no competition with human food. Also, solid residues from ethanol production may be fed to livestock as a high-protein dietary supplement.

The disposal of liquid residues, which may amount to 12-13 times the volume of the final product must be considered. "Thin stillage," as it is called, has a strong odor and high acid content, and contains may organic solids and solubles. Land application of thin stillage could be harmful to many kinds of soils, especially those with high clay content. Stillage should not be disposed of in areas where it may flow into or contaminate lakes and streams.

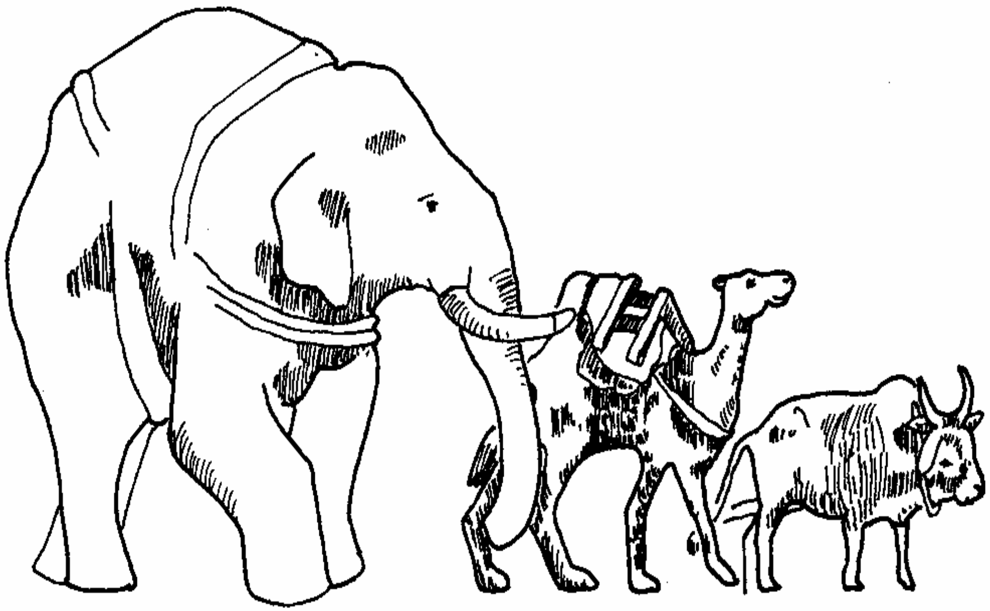
Finally, significant amounts of water are used in the production of ethanol. For every unit volume of ethanol produced, about 16 volumes of water are needed for generating steam, cooling, and preparing mashes. This demand for water must be evaluated against available supplies and alternative uses.

Animal traction

Approximately 335 million draft animals provide about 150 million horsepower for at least 200 million people in two thirds of the world. This source of energy is rarely given much attention, but its contribution to economic activity, especially in rural areas, is very significant.

In various parts of the world bullocks, oxen, buffaloes, horses, camels, llamas, donkeys, and elephants are integral to energy systems supporting agriculture and transportation. In agriculture they are essential for plowing, harvesting, threshing, and lifting water. Animals transport farm produce, other commodities, and people. For short distances with lengthy loading and unloading times they are cost-competitive with trucks, and can often travel on terrain where trucks cannot. <see image>

esex105.gif (353x486)



Draft animals would live longer and perform much better with simple improvements in the design of carts and harnesses. Too often the harness pulls against the animal's neck instead of its shoulders. Not only is this debilitating to the animal, but it also prevents it from applying its full weight to the task. Other improvements include better herding, feed, and husbandry practices.

Draft animals need not compete with people for their food. Usually they can stay healthy on a diet of natural vegetation and water. Environmental problems can result from overgrazing. A solution, if the animal is penned or tethered, is to provide a daily

ration of water and fodder; this requires human energy to bring the water and fodder. The use of animals that combine assistance with farming and dairy products production is another solution.

Chapter VIII

MATCHING ENERGY SOURCES WITH ENERGY USES

Energy is a means to a specific end. It helps pump water, cook meals, and plow soil. Not all forms of energy perform these tasks equally well. This chapter analyzes specific tasks requiring energy ("end uses") and discusses major factors in selecting the most appropriate way to provide energy for use in households and agriculture.

Because of the enormous amount of time spent by people in rural areas on survival as well as income-producing tasks, the effect of using specific energy technologies and sources on time and income, especially as it relates to the work of women, should be carefully considered.

Household energy

In households, energy is used to prepare food, heat water, provide space-heating and light, and carry out a variety of other tasks. In many countries it represents well over 90 percent of all energy used.

Cooking: Probably no household task is performed as regularly as cooking food. However, the energy requirements of cooking are as varied as the food itself. Cooking may include baking, frying, boiling, simmering, roasting, or steaming, sometimes demanding high heat, sometimes low, or else one followed by the other.

Perhaps the most universal cooking task is the cooking of rice, beans, or grains. Here water is brought to a boil, and then the mixture is simmered for up to several hours. Simmering essentially means holding the mixture at a temperature close to boiling. Once that temperature is attained, little additional energy is needed beyond whatever is necessary to replace heat lost to the environment.

What sources of energy are most appropriate for cooking beans, grains, or rice? In a well-insulated box, solar energy can easily maintain the temperature of boiling water, although bringing the mixture to its initial boil may take some time. A charcoal fire starts out relatively cool and gradually builds up heat, which is just the opposite of what is needed. Even though millions of women cook beans or rice over charcoal, they usually waste the excess heat produced during simmering. A properly managed wood fire begins with hot flames licking the pot, later settling down to a bed of coals that produce a low, even heat--and this is exactly the energy pattern required. Greater control of the fire is possible with biogas, so the cook need use no more energy than is necessary for the task.

Actually, since little or no additional energy is needed for the

simmer phase, a pot of boiling rice or beans may be removed