INTERNATIONAL
TRAINING CENTRE
OF THE INTERNATIONAL
LABOUR ORGANISATION
TURIN

UNITED NATIONS
INTERNATIONAL RESEARCH
AND TRAINING INSTITUTE FOR
THE ADVANCEMENT OF WOMEN
INSTRAW

OMEN
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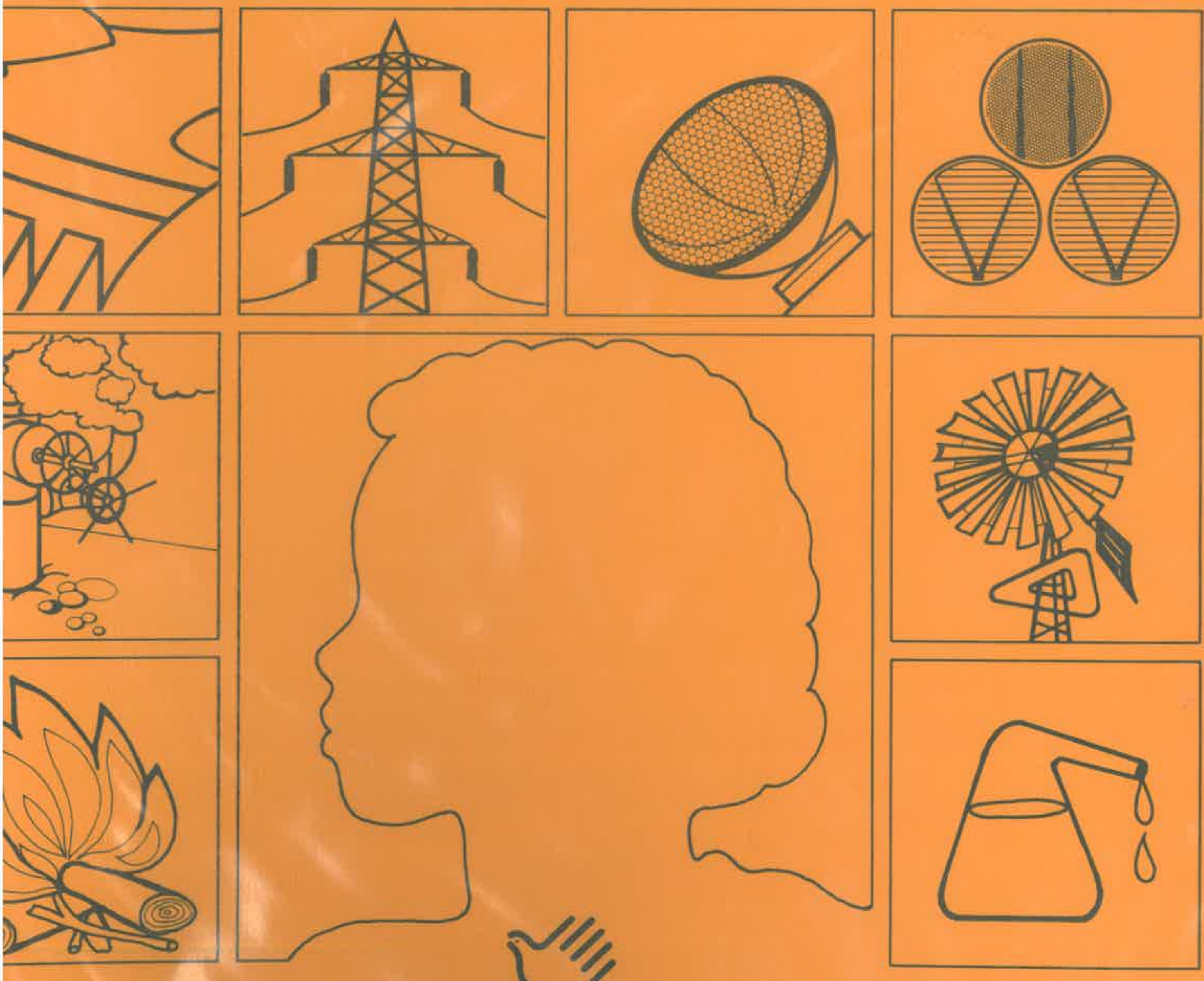
MODULAR
TRAINING
PACKAGE



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MODULE EWII

THE ROLE OF WOMEN IN NRSE

This module is conceived as a package containing all the information, examples, exercises, audiovisual and control aids necessary for:

- the **trainer** to deliver a lesson or conduct training activities;

and/or

- the **trainee** to analyse, reinforce and apply the theoretical concepts learned during training sessions;

and/or

- the **professional** as self-learning reference material to upgrade knowledge and skills related to effective integration of women in NRSE projects and programmes.

In order to reduce the learning time and improve the learning efficiency, keeping high the motivation of the user, the text of the module contains only that information and activities considered essential for the achievement of the training objectives as specified in the following pages. Additional reading material is included for those users who wish to study in greater depth specific subjects related to the subject considered in this module.

From a pedagogical point of view, the structure of the modular package consists of five components - as specified on the following page - which are easily adaptable to the needs of both the trainer and the trainee.

FOREWORD

Consistent with its policy to formulate training strategies and devise innovative methodologies for advisory services, **UN/INSTRAW** has devoted substantial resources to preparing, in collaboration with the **ILO Turin Centre**, a prototype training package on **"Women and New and Renewable Sources of Energy"**.

This training package is the joint production of seven years of INSTRAW research in this field, and scientific, technical and training activities of Energy Programmes in the ILO Turin Centre. It also contains material from other United Nations bodies and agencies, as well as decisions and recommendations from various meetings attended and organised by INSTRAW, both within and outside the United Nations system.

The training package was prepared by **Mr Giulio Piva**, Chief, Training Operations, ILO Turin Centre, and **Ms Borjana Bulajich**, Social Affairs Officer, UN/INSTRAW. The audiovisual aids were prepared by **Ms Adelina Guastavi**, Audiovisual Expert, ILO Turin Centre, with the support of the Media Production Section of the ILO Turin Centre. The training package was updated by **Ms Marina Vaccari**, INSTRAW Staff Member.

The team would like to express deep appreciation to **Ms Denise Zoccola** for the time and patience she has dedicated to the word processing of this training material.

The training package was finalised under the supervision of **Ms Dunja Pastizzi-Ferencic**, Director of INSTRAW.

The trainer will make use of the five components indicated above, while the trainee will only be provided with the material related to components 1, 2 and 3.

1. DEVELOPMENT PLANNERS, SENIOR OFFICIALS FROM MINISTRIES OF ENERGY, AND OTHER GOVERNMENTAL AND NON-GOVERNMENTAL ORGANISATIONS INVOLVED IN THE DEVELOPMENT AND MANAGEMENT OF ENERGY PROGRAMMES AND PROJECTS ON THE USE OF NRSE.

2. SENIOR OFFICIALS OF WOMEN'S ORGANISATIONS AND INSTITUTIONS AT NATIONAL, REGIONAL AND INTERNATIONAL LEVELS.

GENERAL OBJECTIVE

TO ENABLE THE USER TO RECOGNISE WOMEN'S ROLE IN NRSE AND TO IDENTIFY THE MAIN CONSTRAINTS TO THE INTEGRATION OF WOMEN IN ENERGY PLANNING AND POLICIES.

SPECIFIC OBJECTIVES

ON COMPLETION OF THIS UNIT, THE USER WILL BE ABLE TO:

1. RECOGNISE THE ROLE AND POTENTIAL OF NRSE IN THE ENERGY SUPPLY OF DEVELOPING COUNTRIES;

2. RECOGNISE WOMEN'S ROLE IN THE DEVELOPMENT, MANAGEMENT AND USE OF NRSE;

3. IDENTIFY THE MAIN OBSTACLES TO THE INTEGRATION OF WOMEN'S NEEDS IN ENERGY PLANNING AND ENERGY POLICIES.

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1. THE ENERGY PROBLEMS OF DEVELOPING COUNTRIES AND THEIR IMPACT ON WOMEN

1.1 INTRODUCTION

The consequences of the last decade's petroleum price instability have elevated the supply and use of energy to a priority level for governments around the globe. Nowhere have the ramifications had greater impact than in the developing countries.

Mushrooming populations, growing urbanisation, high unemployment rates, and the recent worldwide drop in commodity prices, have combined to both increase petroleum payments for oil importing countries, and trim the revenues of export. This loss of wealth, along with debt service payments and decreased export earnings, will leave many of these countries with a rapidly mounting inability to finance the investment needed to stimulate economic growth and, in certain cases, even to meet the minimum basic human needs of a large segment of their populations.

Current economic development trends are, moreover, moving almost all developing countries toward even greater dependence on petroleum. Therefore, if, as many studies have indicated, commodity prices remain depressed in the future, the current unfavourable economic position of developing countries will be further aggravated.

Finally, non-commercial energy resources, which play a critical non-industrial role in developing countries, have undergone serious depletion.

In short, the effects of the energy crisis have spread themselves throughout the economies of the developing countries.

Seen in this light, the **energy crisis of the developing world** has three basic components:

1. For the immediate future, developing countries must maintain oil imports.

2. Should non-commercial fuels continue to be directed to urban industry, the classical problems of providing the basic needs for survival to the rural and urban poor will be exacerbated.

3. Both domestic and imported energy resources must be managed in a more efficient manner, while greater use is made of local resources.

Although the important role of energy development has long been understood, it is only within recent years that we have come to fully appreciate the critical influence that sudden price changes and availability in energy fuels have on the development process itself. It has long been appreciated that **energy systems development** provides a critical link to the accumulation of material and productive resources, the ultimate goal of the development process.

Prior to the 1970's, developing country governments acknowledged this relationship between energy and economic growth by guaranteeing an adequate supply of fuels at prices which would not limit their productive use.

But more recently, this straightforward supply-side strategy has been augmented with an appreciation that a diversity of energy sources is required, and there **must** be **attention given** to the **efficient conversion units and end-use devices**.

In other words, today's **energy planner must consider both supply and demand-side approaches as complementary**.

With few exceptions, **oil-based fuels provide most of the commercial energy.**

The transportation sector is by far the largest consumer of oil products in the developing countries. (Estimates as high as **70%**.)

Industrial and **government** use is a distant second **(20%)**, followed by **commercial energy** use for food production and processing, and by upper class **urban household** consumption **(10%)**.

Non-commercial fuels, which include most NRSE, satisfy the basic subsistence requirements of most of the population, both urban and rural (95%).

Any **increase** in the **well-being of households** - improved diets, health or sanitary standards, better housing, more reliable cooking fuels - implies **greater energy use.**

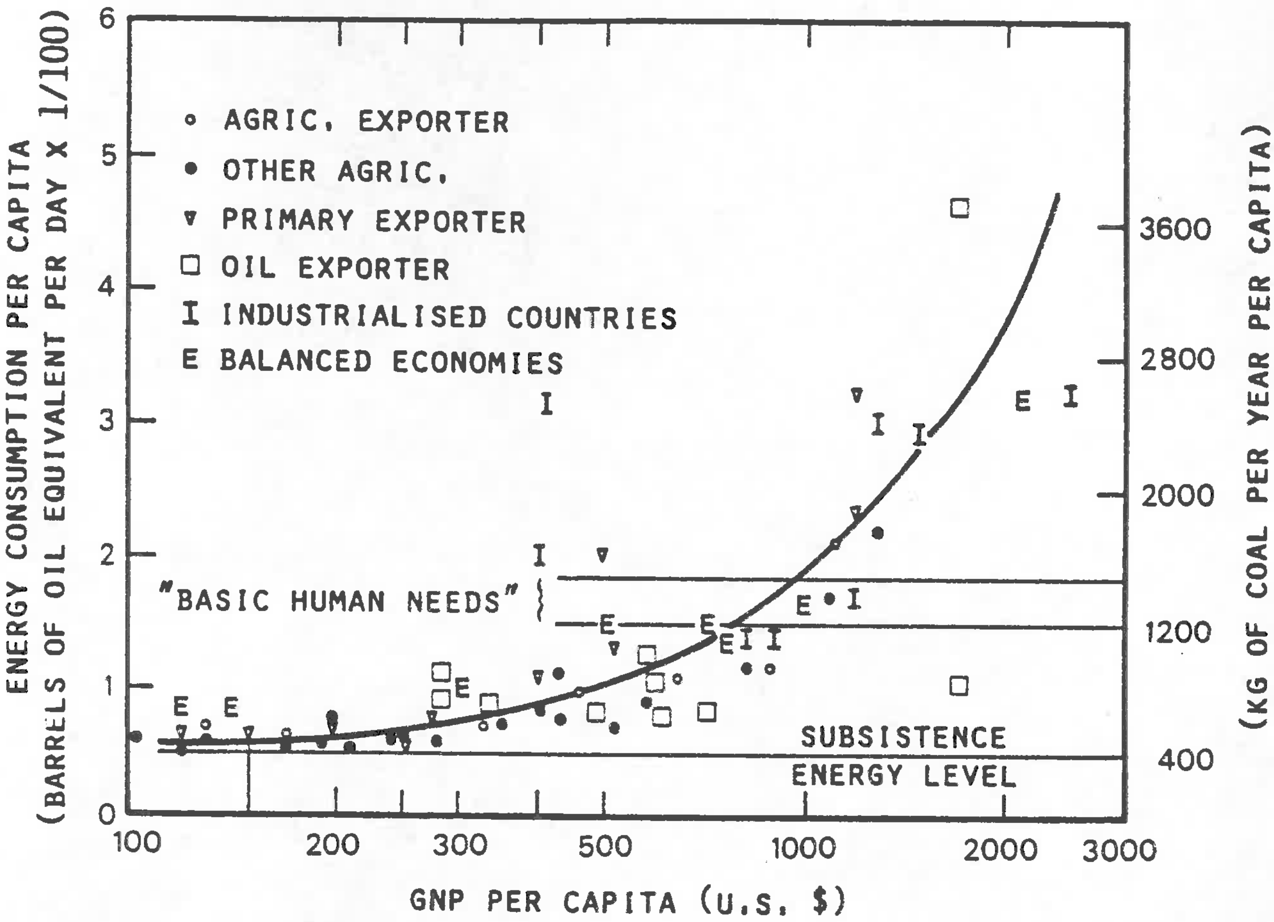
Upgrading the mobility of isolated **rural populations** inevitably leads to greater reliance on energy.

Increases in **employment** levels, despite the labour intensiveness of many industries, is associated with the **availability of energy**.

Thus, most developing countries have come to **associate** all **"progress"** with **greater production**, which in turn leads to greater needs for transport, higher degrees of urbanisation, and greater energy use.

It is therefore safe to conclude that, regardless of which development strategies are employed, **increased energy** and **more elaborate systems of energy production, distribution** and **utilisation** will be viewed by these countries as essential to their future well-being. This perception is in fact strongly supported by the direct and striking correlation between economic growth and energy consumption shown in fig. EWII-1.

RELATIONSHIP OF PER CAPITA
ENERGY CONSUMPTION TO PER CAPITA GNP



NOTE:
AN ESTIMATE OF 400 KGCE PER YEAR HAS BEEN ADDED TO EACH COUNTRY TO ACCOUNT FOR NON COMMERCIAL ENERGY USE.

FIG. EWII-1

1.2 THE ROLE OF NRSE IN THE ENERGY SUPPLY OF DEVELOPING COUNTRIES

Renewable energy resources occur in nature, in the **form of energy flow of indefinite duration**, as opposed to mineral deposits of finite amount. Thus, solar and wind energy, hydro-power and fuels of vegetable origin are considered as renewable, while mineral fuels are not.

NRSE technologies represent a significant opportunity to increase diversification and flexibility within the energy supply system. They include a large number of potentially viable options which contain feasible combinations of the various natural resources, conversion processes and energy products. Several of these technologies make important contributions to national, regional and local requirements for energy; others need still additional resources and development.

The recent growth of **interest in the exploration of renewable energy sources** in developing countries has been prompted by **two main factors: the instability of price of oil and gas**, and the **alarmingly rapid depletion of fuelwood supplies** in these countries.

Socio-economic development, which is associated with a growing demand for energy, has emphasised the need to develop domestic energy alternatives (and consequently NRSE).

As in many developed countries, conservation and increased efficiency in energy use are regarded as helpful but not sufficient to meet growing needs.

Renewable energy can substitute for oil in a variety of modern sector uses in transport, industry and the production of electric power. Quantifying the potential savings in oil, resulting from use of biomass, solar and other renewable energy sources is, however, difficult. The few studies which have attempted to do so suggest the possibility that renewable energy may be able to substitute optimistically **for some 5 to 15 per cent** of the oil consumed by the developing countries by the end of the century. Because of the differences in coverage, methodology and critical assumptions (for example, about world oil prices) these results can at best be regarded as indicative. However, they do point to the broad conclusion that renewable energy, while no panacea, can be expected to substitute for a small but significant share of oil consumption in the developing countries over the long run. An earlier and more substantial impact may be possible in regions and countries that are particularly well endowed with biomass.

Interest in renewable energy has also been stimulated by growing awareness of the existence of a **"second energy crisis" brought on by the depletion of forests in many of the developing countries.** In contrast to the change in oil prices, a highly visible modern sector phenomenon, the crisis in traditional energy supplies is a quiet one, but it poses a clear danger in the lives of much of the population of the developing world. Traditional renewable energy resources such as **firewood, charcoal, crop residues and animal dung,** account for virtually all of the fuel used in many rural areas, and may account for about **20 to 25 per cent of the total energy consumption** in the developing world. Africa is the most dependent upon traditional renewable resources, Asia somewhat less, and Latin America is the least dependent upon these resources. About **75% of the population** of the developing countries **uses traditional fuels, largely within households and primarily for cooking.** Most of these people have access to firewood, but roughly **1,000 million people use agricultural** and **animal wastes** to fuel their cooking fires.

The **rural energy crisis stems from the fact that the developing countries have been consuming their wood supplies far more rapidly than they are renewing them,** with grave environmental, economic and human consequences. Fuelwood harvesting to meet the energy needs of rapidly growing populations, land clearing for agricultural purposes and increased lumbering, together, are consuming the developing countries' forests at a rate of some 1.3 per cent or 10-15 million hectares a year. Deforestation, particularly on steep hillsides, has contributed to soil erosion that has reduced upland water storage capacity and increased the siltation of reservoirs (shortening their lives), irrigation canals (raising maintenance costs) and river beds (increasing the danger of flooding). The search for fuelwood has also been an important factor in the destruction of covering vegetation in arid and semi-arid areas, thus contributing to desertification. As fuelwood supplies have dwindled, people have turned increasingly to burning dung and agricultural residues, depriving the soil of valuable nutrients and organic conditioning material. It is estimated that the current use of dung for fuel "costs" some 20 million tons of foregone food grain production annually.

1.3 THE IMPACT OF THE ENERGY CRISIS ON WOMEN

The energy crisis, and especially the scarcity of fuelwood, affects women more than men. In developing countries, the task of collecting wood is in fact almost always assigned to women and children. As deforestation increases, women living in rural areas have to walk longer distances, carrying heavy headloads, to fetch the wood which is necessary to meet the household's needs. This represents a heavy work load and the time consumed in collecting and preparing fuel, which depends on different ecological conditions, may amount to several hours per day, preventing women from taking up more productive activities.

The decrease in agricultural productivity resulting from the decline in soil fertility due to deforestation forces women, who are largely responsible for subsistence food production, to increase their own labour inputs.(1)

In urban areas, where wood is usually commercially traded, the scarcity of fuelwood results in an increase of its price, and the cost for meeting the basic energy domestic requirements, such as cooking and heating, may represent a heavy burden for low-income households.

Deforestation also deprives women of the possibility of gathering wild forest products, such as fruits, herbs and seeds, which can be used in the household for many purposes, such as supplementing family nutrition, preparing medecine, dyeing cloths, or sold, thus representing a source of income.

The scarcity of fuel can have negative effects also on family hygiene, as women may reduce the amount of water boiled for drinking, or heated for washing. Family nutrition can also be affected by the shortage of fuelwood, as women may be forced to reduce the number of cooked meals, or turn to a different staple food, less nutritious but requiring a shorter cooking time. (See Additional Reading, Part I.)

The shortage of fuel does not only affect family nutrition, but it also impedes the development of different income-generating activities. It therefore causes major changes in general patterns of life and production, which indirectly result in changes in the role and occupation of women. Such changes have not yet been fully analysed, nor thoroughly documented.

One of the most common misconceptions is that fuelwood is used by women simply for cooking, while in fact it is used for many other purposes. The homestead fire provides light and space heating; it may be used to boil water, to process food, to prepare fodder for livestock, to extract medecine from leaves, to dye cloths. Fire has also many social and ritual uses, particularly as the focal centre for evening conversation in rural villages. When wood becomes scarce, much more than the family cooking is threatened: the basis of the family and village life is altered.(2)

In order to fight against the depletion of forests, governments and donor agencies are promoting reforestation schemes. A second alternative can be to promote the use of alternative fuels. Fuel substitution is already occurring spontaneously in many rural areas of developing countries, where wood is replaced by dung and agricultural residues. Other alternative fuels, such as kerosene, should be imported by most developing countries and therefore would represent a heavy financial burden for most of them. In addition, at the present stage they could be used for domestic purposes only by the more affluent part of the population, as they require the use of expensive stoves.

The third alternative is the adoption of fuel-saving measures, among which the development and dissemination of improved stoves is certainly the most important one. In many developing countries, over 70 per cent of the total fuelwood is used for domestic cooking, and if the energy efficiency of the cooking device can be increased, the total demand of biomass will decrease, and thus the pressure on forests. Women have a prominent role to play in this respect. (See Additional Reading, Module Four, Part IV.)

Women have been blamed for ecological destruction, since they are the primary wood collectors. But if they don't have access to any other energy source, how are they going to survive? Deforestation is not only a question of collecting wood, but a multidimensional problem of most developing countries.

2. NEW AND RENEWABLE SOURCES OF ENERGY POTENTIALS AND TECHNOLOGIES

2.1 NRSE POTENTIALS

The development of **NRSE will have its most important impact in helping developing countries meet this second energy crisis.** This **impact** should be **measured** not only **by the quantity of energy produced,** but also by the **contribution** made to **welfare and development.** Small hydro-electric units, wood burning power plants, wind pumps and other renewable sources of mechanical and electrical power, while perhaps not adding significantly to national energy supplies, can have a major impact on development and touch the lives of large numbers of the poorest people, especially women, by providing power for agriculture and rural industries.

The developing countries are in some respects at an advantage in developing renewable resources of energy, for example many of them are located in the latitudes that naturally receive the greatest amount of solar radiation. For example, India receives an average of 0.17 tons of oil equivalent (toe), or 1.2 barrels of oil equivalent (boe), per square metre per year, and the Sahelian countries 0.19 toe (1.4 boe), compared with average insolation levels of 0.15 toe (1.1 boe) in the United States and 0.09 toe (0.6 boe) in Western Europe. Where rainfall and soil conditions allow, the biomass produced by this abundance of solar energy gives many developing countries another major renewable energy resource. Unlike fossil fuel deposits, which yield energy in the relatively concentrated and portable forms suitable for large-scale industrial and urban use, solar radiation and biomass are most economically exploited on a small-scale, decentralised basis, and are thus well matched to the needs of dispersed rural populations. In addition, much of the equipment needed for many of the renewable energy technologies is suitable for domestic production in even the less industrially advanced of the developing countries.

The **relatively high cost of energy from conventional sources in many rural areas of developing countries is likely to make the development of some types of renewable energy economically attractive** there sooner than in the urban areas.

The power generated from conventional sources may be much more costly in remote inland locations where high transport charges make fuel substantially more expensive.

Of course we should not be too enthusiastic in the potential use of NRSE since some technologies are not yet mature, and others are too sophisticated, so that there is the need to analyse in detail how the NRSE as a primary form can be exploited and with what techno-socio-economic implications.

2.2 FORMS OF ENERGY

Energy in its <u>**primary**</u> form can be of different kinds, such as:

chemical which includes:

. fossil fuels: coal, oil, natural gas, peat....
. biomass: wood, agricultural residues, urban refuse...

potential which includes: waterfalls and flows

kinetic which includes: wind, waves

radiation sun

heat geothermal reservoirs, ocean thermal reservoirs

nuclear uranium

The primary form of **energy** cannot be used as such, therefore it **must** in general **be converted into a** <u>**secondary**</u> or **final form** before being used as useful energy.

Important **types of secondary energy** are, for example, electricity, mechanical power and chemical.

Fig. EWII-2 represents a flow diagram from primary energy to useful energy.

The main types of **useful energy** are **heat** and **mechanical energy:**

Heat is mainly used in household activities such as cooking, space heating or drying, and in various industrial applications.

Mechanical energy or **power** is typically used in the productive sector such as industry, agriculture and transportation.

To understand better **how NRSE can contribute to the principal energy consuming sectors,** it helps to note that:

I. **Agriculture** production accounts on average in developing countries for less than **5%** of the country's commercial energy consumption. High energy prices have least effect on subsistence agriculture, but most effect on yield-increasing technologies. The improvement of farm practices is needed to make better use of energy.

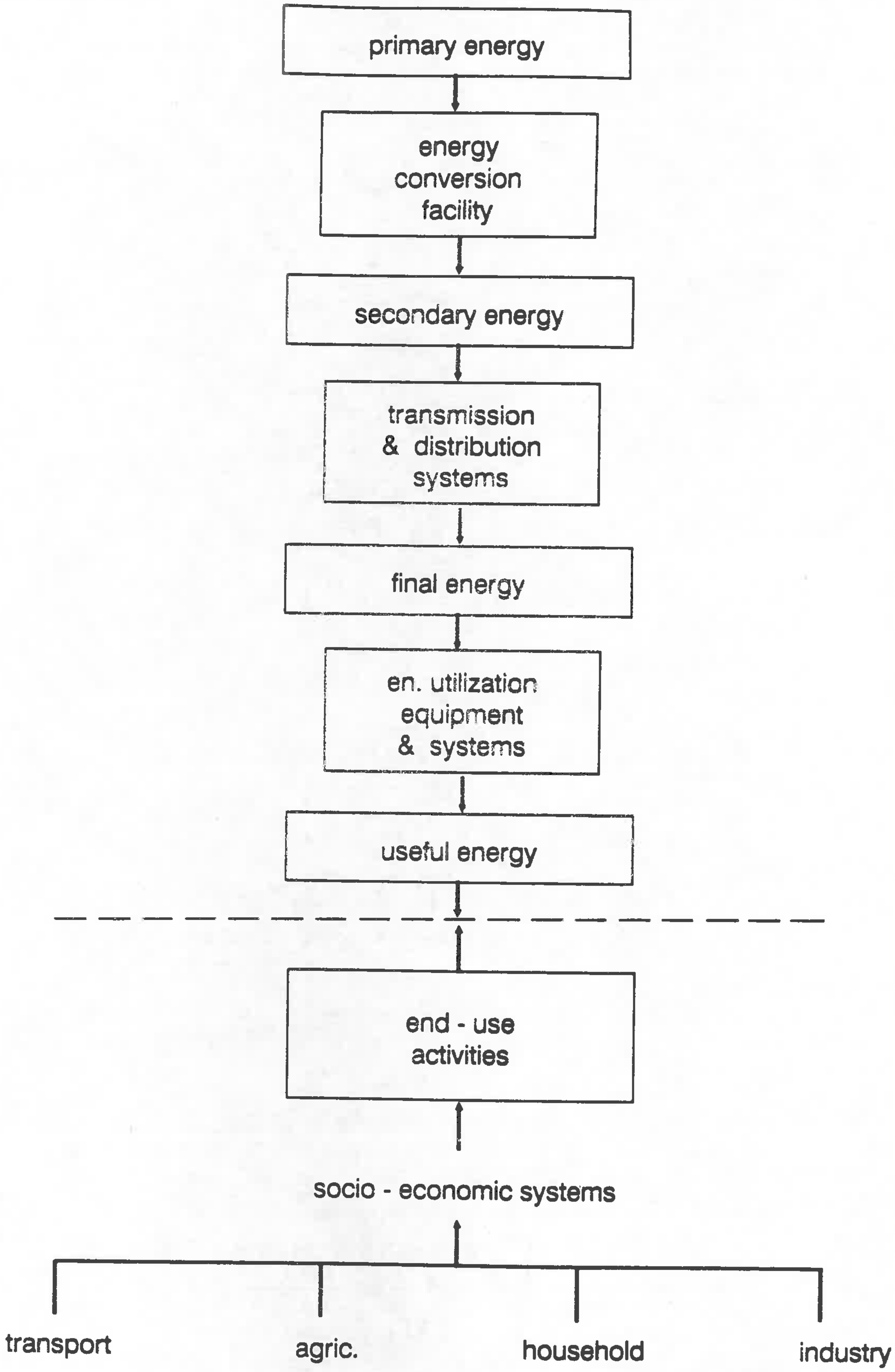

primary energy
energy conversion facility
secondary energy
transmission & distribution systems
final energy
en. utilization equipment & systems
useful energy
end - use activities
socio - economic systems
transport
agric.
household
industry

FIG. EWII-2

There is a possibility of using solar pumps for irrigation; there is also scope for organic agriculture using crop residues. The potential competition between food and energy crops, e.g. sugar cane used for alcohol production, algae for biogas, is likely to be an important area which must be taken into consideration and in which women can play a relevant role.

II. **Household (domestic).** Of the total energy consumption, household consumption accounts for an average of 45%, but only 10 to 20% of commercial energy consumption.

Energy is mainly used for cooking. As an example, biogas can be used for cooking and lighting, while solar pumps can help for water supply. Here there is a need to select technologies in line with users' (mainly women's) needs.

III. **Transport.** This sector accounts for 10 to 20% of total energy consumption mainly used for road transport. More than half the total petroleum consumption goes on transport in many developing countries. A reconstruction of a country transport system accompanied by the improvement of energy efficiency vehicles assisted by the introduction of alternative fuels (alcohol, biogas, etc.) can contribute to the improvement of the energy situation in this sector.

IV. **Industry.** This sector uses an average of more than 35% of commercial energy. According to experts, and with the present condition of industries in many developing countries, more than 15% of energy consumption can be saved in the next ten years.

V. **Electric power.** The use of electricity has grown along with the development process and is projected to continue at an annual rate of 8 to 9%. More efficient operations and loss reduction in generation and transmission of electricity may lessen the requirements for new capacity.

Local integrated systems, exploiting NRSE, especially designed for isolated rural areas can make a sensible contribution to the saving of commercial energy sources in this sector and to the improvement of the electricity supply to rural communities, where women are also involved as primary users.

A rough estimate indicates that NRSE can certainly **contribute by the year 2000 for much more than 20% of the total world energy consumption.** Some optimistic estimates indicate that the total contribution of NRSE may rise in the year 2000 as high as 52.7 billion MWh (megawatt hours) which will perhaps be 30% of the total world energy consumption. The table set out in Fig. EWII-3 gives an estimate of the present and future world use of NRSE, which are analysed herafter in this chapter and in more detail in Module EWIII.

PRESENT AND ESTIMATED FUTURE WORLD USE OF NEW AND RENEWABLE SOURCES OF ENERGY

Source	Present use in bilion (10^9) KWh	Utilization in the year 2000 in billion (10^9)
Solar	2 - 3	2,000 - 5,000
Geothermal	55	1,000 - 5,000
Wind	2	1,000 - 5,000
Tidal	0.4	30 - 60
Wave	0	10
Thermal gradient of the sea	0	1,000
Biomass	550 -700	2,000 - 5,000
Fuelwood	10,000 - 12,000	15,000 - 20,000
Charcoal	1,000	2,000 - 5,000
Peat	20	1,000
Draught animals	30 (in India)	1,000
Oil shale	15	500
Tar sands	130	1,000
Hydropower	1,500	3,000

Source: United Nations A/CONF. 100/PC/17

FIG. EWII-3

2.3 NRSE TECHNOLOGIES

2.3.1 Solar energy

The sun is responsible, with one exception, for every kind of energy on earth and has long merited the various forms of worship accorded to it by everyone, from the ancient Egyptians to modern holiday-makers.

According to the UN General Assembly on NRSE (August 1981), **solar energy** has a restricted meaning associated with the **direct capture of either the sun's heat or its light.**

The power transmitted to the earth by the sun can be assumed to be 1,500 to 2,000 kWh/m²yr; unfortunately, only a minimum percentage can actually be exploited. This is due to the fact that solar radiation is essentially diffused and highly variable, while any storage system to compensate these characteristics are still sophisticated and expensive.

Solar energy can be directly converted into thermal, electrical or chemical energy.

Thermal conversion can be obtained using:

. flat-plate collectors to heat water or air at moderate temperatures
. focusing collectors or concentrators to heat water at high temperatures by concentrating direct radiation on a small surface.

Electrical conversion can be obtained using:

. solar photovoltaic cells which are semiconductor devices which generate electricity from direct or diffuse solar radiation.

Chemical conversion can be obtained by:

. dissociation of water into hydrogen and oxygen by means of chemical cycles (still at research stage).

Some examples of the possible uses of solar energy are summarised below:

USER	NEED	TYPE OF EQUIPMENT AND TECHNOLOGY
Rural communities	Water pumping	Thermodynamic or photovoltaic pumps
	Cooking	Solar cookers
	Lighting	Photovoltaic lighting systems
	Crop drying	Solar driers, air collectors
	Small hospitals	Photovoltaic refrigerators Solar water heaters
Large villages	Water pumping	Photovoltaic or thermodynamic pumps
	Hot water	Solar water heaters
	Electricity	Electrothermal plants Photovoltaic plants
Industries	Cooling - refrigeration	Solar concentrators, solar engines
	Process steam	Solar concentrators
	Desalination	Direct evaporation (solar stills)
	Drying	Solar driers - air collectors

2.2.2 Hydropower

Water power is at least 2,000 years old. For generation, water wheels in Europe supplied mechanical power for grinding corn, washing wool and driving the bellows in blast furnaces until the 19th Century. Water power was first used in the 1880's.

Hydropower is a major energy resource next in importance to oil and coal; today it supplies about 23% of the world's electricity, which corresponds approximately 6% of the total primary energy consumption. Most of the world's hydropower potential is still unused: in fact 83% of the resource has in theory yet to be harnessed.

Developing countries are using only 8% of their potential water power while Europe is already using 59% of its hydropower potential and North America 35%.

Fig. EWII-4 gives the world hydroelectric potential and the exploitation rate.

Concerning the **technology**, there are **four basic elements** in a hydroelectric scheme:

. the dam
. the penstock or channel down which the water flows
. the turbine
. the generator.

Fig. EWII-5 shows a scheme of a hydroelectric power plant.

The technology is now **mature** and well-developed, but significant improvements in design and economy are still being made.

For the exploitation of **large-scale hydropower**, four **main problems** should be taken into consideration:

. geographical: in many cases potential hydrosites are far from populated areas;

. environmental: large hydro schemes, and particularly the reservoirs they create, can have pronounced harmful effects on the local environment;

. legal: in fact, more than 200 river basins straddle international boundaries;

. political: large hydropower developments, introduced when there is no great indigenous demand for electricity, have in developing countries sometimes become closed enclaves within a country.

From an **economical point of view**, the feasibility of hydroelectric power schemes is increased by multipurpose developments incorporating irrigation, flood control, water supply, etc.

An estimate presented at the World Energy Conference indicates that there seems little doubt that much more large-scale hydropower development will take place especially in developing countries (see Fig. EWII-6).

On the contrary, **small-scale hydro (mini and micro hydraulic power plants) prospects for developing countries look extremely good.**

WORLD HYDROELECTRIC POTENTIAL

While Europe is already exploiting 59% o its total hydroelectric potential, the Third World is using only 8% of its capacity. (Source: World Energy Conference, 1980)

	Technically usable potential		Present operating capacity		Percentage of hydropotential at present harnessed
	10^{12}kWh	% world total	10^{12}kWh	% world total	
North America	3.12	16	1.13	35	36
Europe	1.43	7	0.84	26	59
USSR	2.19	11	o.26	2	15
Oceania	0.39	2	0.06	2	15
NORTH	7.13	36	2.29	71	32
Africa	3.14	16	0.15	5	5
Latin AMERICA & Caribbean	3.78	20	0.30	9	8
Asia (excl USSR)	5.34	28	0.47	15	9
SOUTH	12.26	64	0.92	29	8
World Total	19.39	100	3.21	100	17

FIG. EWII-4

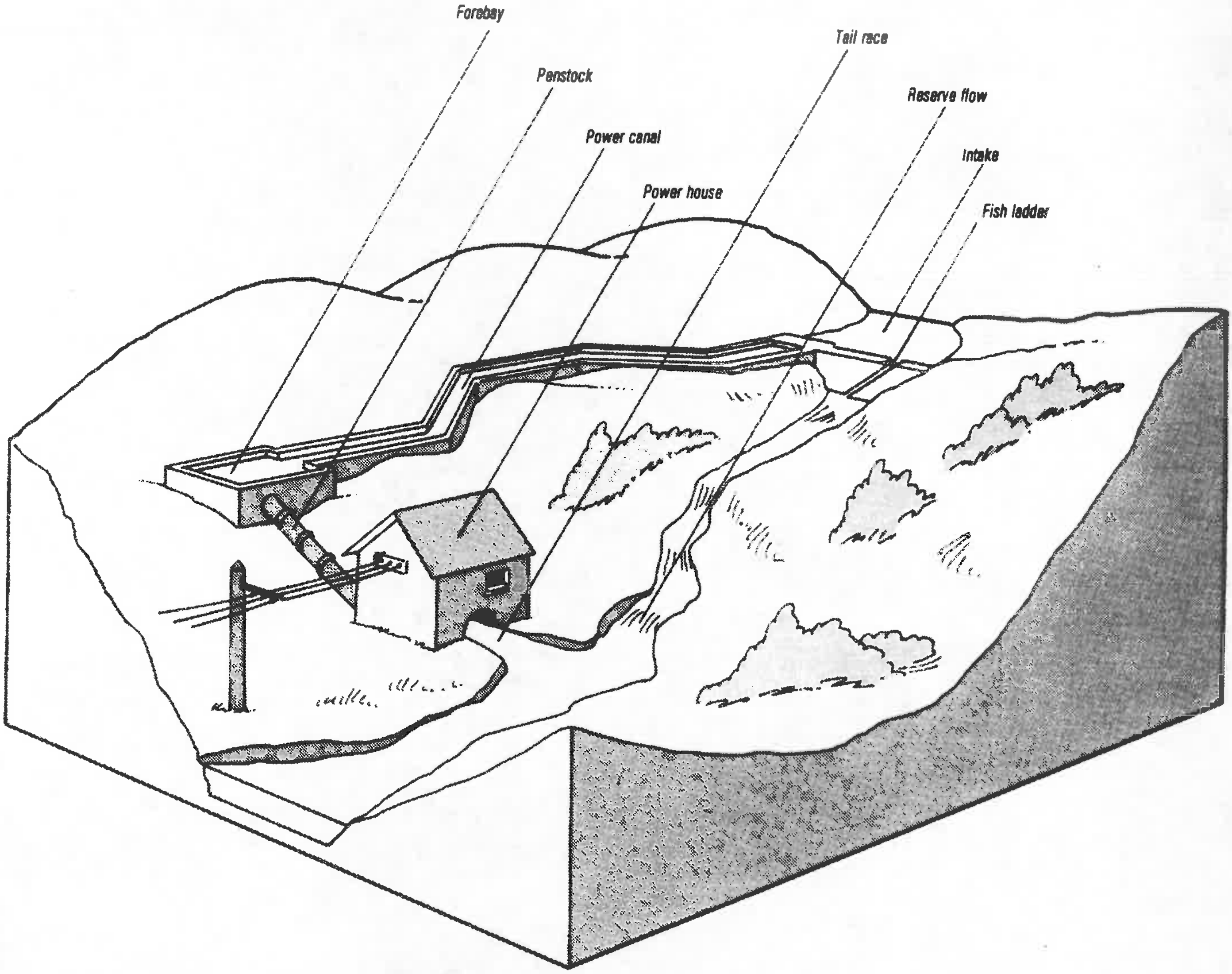

Forebay
Penstock
Power canal
Power house
Tail race
Reserve flow
Intake
Fish ladder

FIG. EWII-5

EXPECTED INCREASE IN ELECTRICITY GENERATED FROM HYDROPOWER, 1976 - 2020

The greatest increase are expected in the Third World and China.
(Figures in exajoules: 10 joules) Source: World Energy Conference, 1980.

	1976	2000	(increase 1976-2000)	2020	(increase 1976-2020)
OECD countries	3.78	5.37	(x 1.4)	7.80	(x 2.1)
Centrally - planned countries (incl. USSR and China)	0.72	2.88	(x 4)	8.70	(x12.1)
Developing countries (excl China)	1.17	4.49	(x 3.8)	11.80	(x 10.1)
WORLD TOTAL	5.67	12.7	(X 2.2)	28.30	(X 5.0)

FIG. EWII-6

Small-scale hydro - from less than 1 KW to about 10 MW of installed capacity - has several **advantages**:

. the technology is essentially the source for larger systems but simplified;

. initial capital investment need not be prohibitive;

. an area can be developed gradually with a number of small schemes;

. lead times are short.

In small-scale hydro systems women's intervention is essential in the definition of the installed capacity or, in other terms, users' needs.

Small hydroelectric power plants will become widespread in mountainous regions, and of particular significance for rural energy needs. This raises the questions of selecting proper sites from the community's point of view, their safety, and the maintenance of the plant. Care should be taken in tropical areas to ensure that the spillways below dams do not become a breeding ground for simulium damnosum, which is the carrier of river blindness. To this, women, because of the nature of their traditional tasks, are particularly vulnerable. Similar considerations apply to still waters above the dams where there is usually an increase in the incidence of chistosomiasis (Bilarzia).

2.3.3 Power from the seas

Three main **ways** have been suggested **for exploiting energy from the ocean**, which covers 72% of the world's surface:

. **tidal** energy
. **wave** energy
. **ocean thermal** energy conversion (OTEC).

a) **Tidal energy** exploits the twice-daily movement of masses of water, caused by the pull of the moon. About 100 sites exist worldwide which are suitable for large-scale projects, but there are many more where smaller schemes could operate.

The total potential generating capacity of the world's major tidal sites has been estimated at 13,000 megawatts, about 1% of the potential of hydropower.

Technology is available at high cost and with difficulties due to the need to construct large storage systems, necessary because of the intermittent operation of tidal-based electricity generation.

b) **Wave energy** could harness the up and down motion of waves on the sea's surface, which is originally caused by the wind blowing over the surface of the ocean.

The technology is not yet mature and it is complex. No large application is foreseen for developing countries.

c) **OTEC** makes use of the fact that water at the ocean's surface is warmer than water in its depths.

Theoretically, an OTEC plant works like any heat engine, but with much lower temperature differentials than those used in steam turbines or internal combustion engines.

There is a very optimistic estimate by experts, which says that there is a possibility of installing up to 10,000 MW by the year 2000, but this is still only a proposal.

The technology is not yet commercially available.

2.3.4 Geothermal energy

Radioactive elements in the earth's interior are continually decaying. The heat they release maintains the earth's core in a white-hot, molten state.

This heat seeps upwards towards the earth's surface. In most areas the heat flow is tiny. But in some zones geothermal heat is more concentrated - near volcanoes, magma flows, geysers and hot springs.

There are **two** main **ways of tapping geothermal energy**:

. using **steam** or **hot water** which occurs **naturally**;

. extracting the **heat** from **hot rocks**, by injecting and then recovering water.

The cheapest geothermal sources are in volcanic areas and these are mostly in developing countries.

Geothermal energy can be used for electricity generation, industrial processes, space heating, and bathing. Geothermal energy, which strictly speaking is neither new nor renewable, is technically and economically feasible in areas where hot water and steam exist near the surface and where there is a demand for heat and electricity.

Development will normally be large-scale and capital intensive.

Figs. EWII-7 and 7a show the world's geothermal generating capacity and installed low-temperature capacity.

A basic diagram of a geothermal power plant is shown in Fig. EWII-8.

GEOTHERMAL ELECTRICAL GENERATING CAPACITY 1980 AND 2000 (estimated)

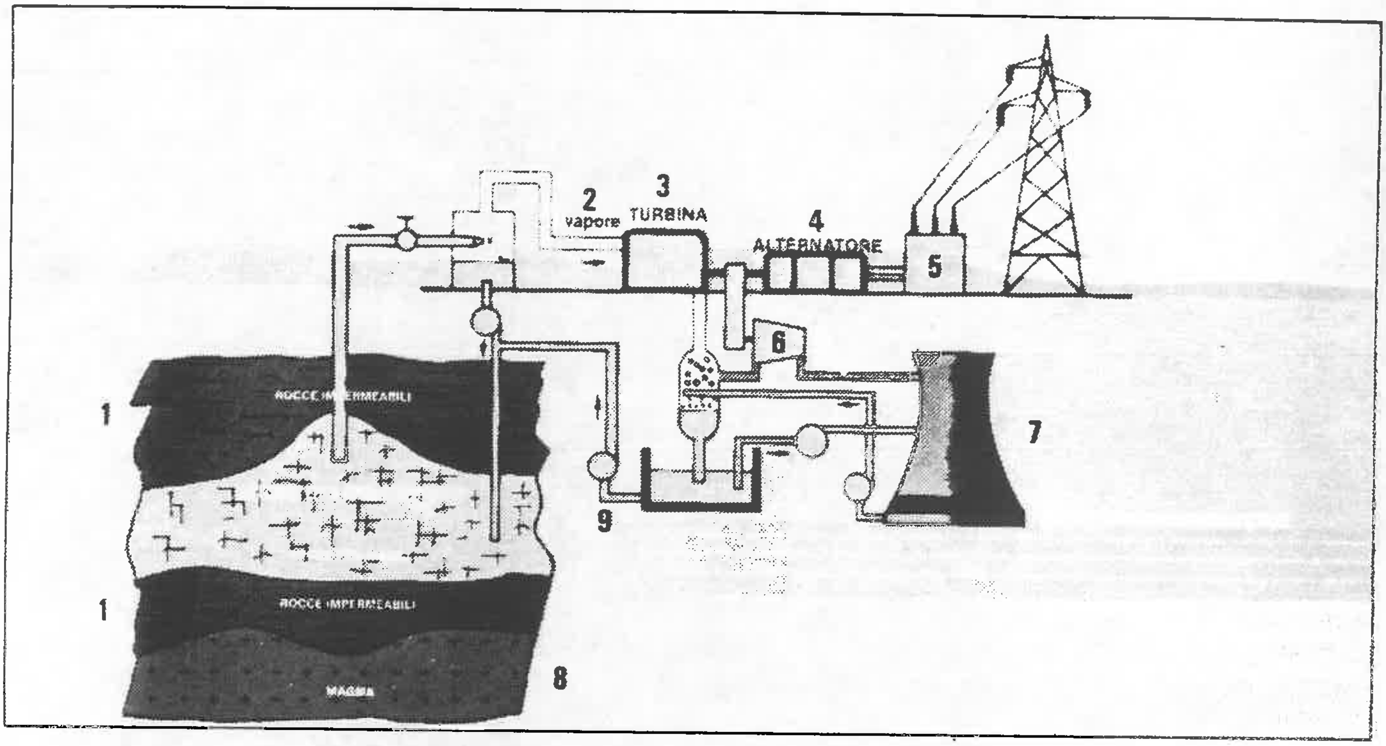
	1980		2000	
	MW	%of world total	MW	%of world total
USA	923	38	5824	33
Japan	168	7	3668 +	21
Italy	440	18	800	5
New Zealand	202	8	382 +	2
USSR	5	0	310	1
Turkey	0.5	0	3101	1
Iceland	32	1	68 +	0
France	0	0	15 +	0
TOTAL NORTH	**1771**	**72**	**11217**	**64**
Mexico	150	6	4000	23
Philippines	446	18	1225 +	7
El Salvador	95	4	535	3
Costa Rica	0	0	380 +	2
Nicaragua	0	0	100	1
Indonesia	0.25	0	92 +	0
Ethiopia	0	0	50	0
Kenya	0	0	30 +	0
Chile	0	0	15 +	0
TOTAL SOUTH	**691**	**28**	**6427**	**3**
WORLD TOTAL	**2462**	**100**	**17644**	**100**

FIG. EWII-7

INSTALLED LOW - TEMPERATURE GEOTHERMAL CAPACITY IN 1980

	FOR BATHING		FOR OTHER PURPOSES		TOTAL	
	MW	%	MW	%	MW	%
Japan	4394	82	81	3	4475	56
Hungary	547	10	619	23 1/2	1166	15
Iceland	209	4	932	35	1141	14
USSR	0	0	555	21	555	7
Italy	192	4	73	3	265	3
China	7	0	144	5 1/2	151	2
USA	4	0	111	4	115	1
France	0	0	56	2	56	1
Czechoslovakia	8	0	35	1 1/2	43	1
Romania	0	0	30	1 1/2	36	0
Austria	3	0	2	0	5	0
TOTAL	5364	100	2644	100	8008	100

FIG. EWII-7a



1 · IMPERMEABLE ROCKS
2 · STEAM
3 · TURBINE
4 · GENERATOR
5 · TRANSFORMER
6 · GAS COMPRESSOR
7 · COOLING TOWER
8 · MAGMA
9 · REINJECTION PUMP

FIG. EWII-8

2.3.5 Wind power

Windmills have been known since the year 2000 BC, when they were used in Babylon for irrigation.

The **power of the wind is proportional** to the **cube of wind speed**; this means that small variations in the annual average wind speed result in large variations in the available energy.

Wind power has a **great potential** for:

. **small-scale water pumping**, and
. **electricity generation** for isolated countries

but it can also be used for:

. **water desalination**: experience in India suggests using windmills for driving pumps in small reverse-osmosis desalination plants;

. **air-conditioning**: Pakistan and Iran still use small roof mounted wind catches, which draw in air through soaked matting and cool house interiors;

. **shipping**: recently, Japan has launched a sail-assisted oil tanker.

The technology is commercially available and is based on two types of wind machines: horizontal axis and vertical axis; Figs. EWII-9 and EWII-10 show the various types of machines.

Today there are two main uses for wind power: pumping water and electricity generation with direct back-up (i.e. with diesel generators).

It is accepted that in appropriate areas wind-generated electricity is already economic.

The wide diversity in designs appears to reflect both the need for different approaches to deal with different wind regimes, fabrication techniques, and applications and the fact that experience has not yet sorted out all the advantages and disadvantages of competing designs. Some approaches to windmill designs emphasise minimisation of cash costs, and keeping materials, fabrication and maintenance requirements within the capabilities of local artisans. The resulting "appropriate technology" designs appear to provide least-cost solutions in many cases, at least where low pumping heads permit low unit sizes and where modest windspeeds permit light-weight designs.

The cost of harnessing wind energy in a given area has been estimated at 20 US cents/kWh assuming a 5.5 hour/day operation with winds of 5 metres/second (11 mph) using locally manufactured or artisan-built windmills. If these cost estimates are correct, this type of windmill can compete with conventionally powered pumps in the same areas if

HORIZONTAL AXIS WINDMILLS

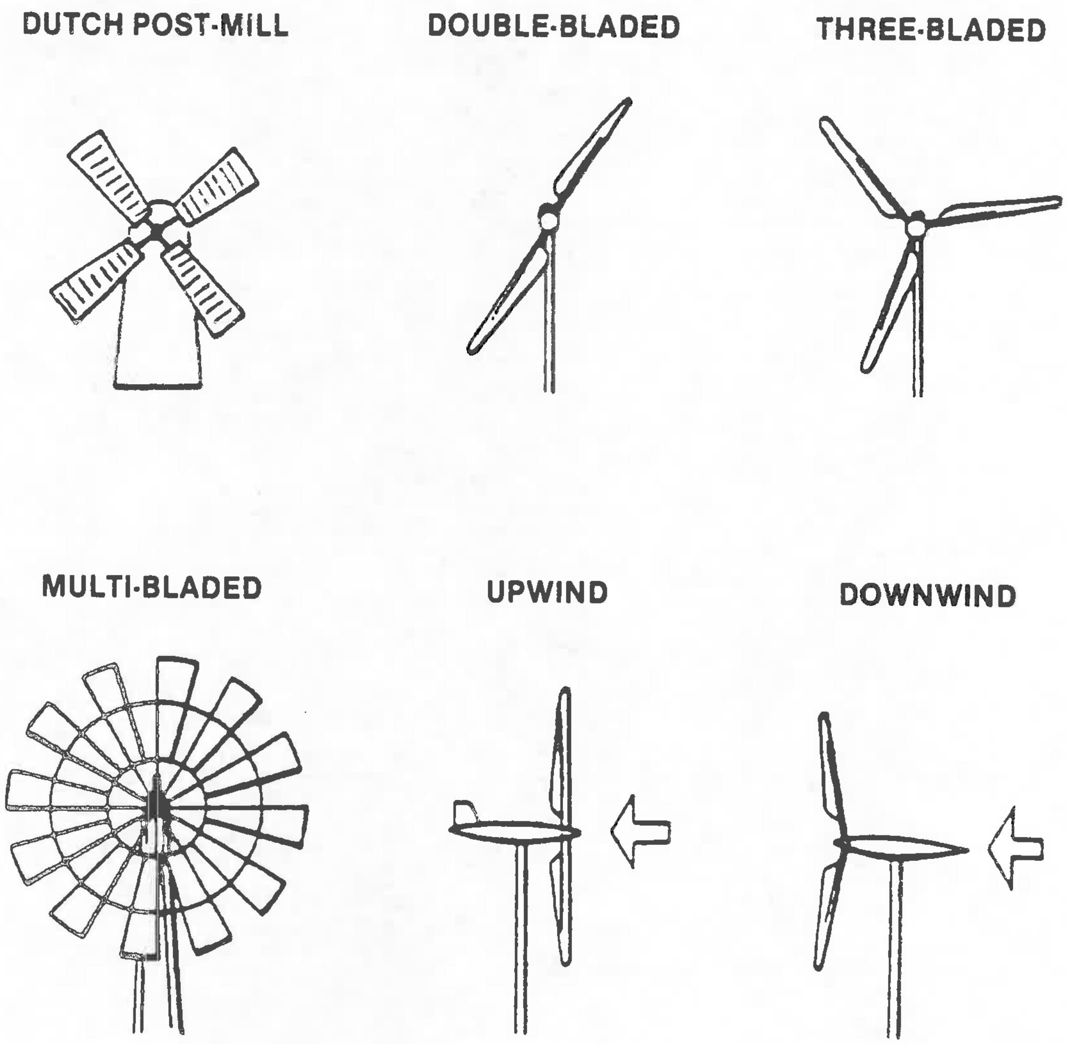


FIG. EWII-9

VERTICAL AXIS WINDMILLS

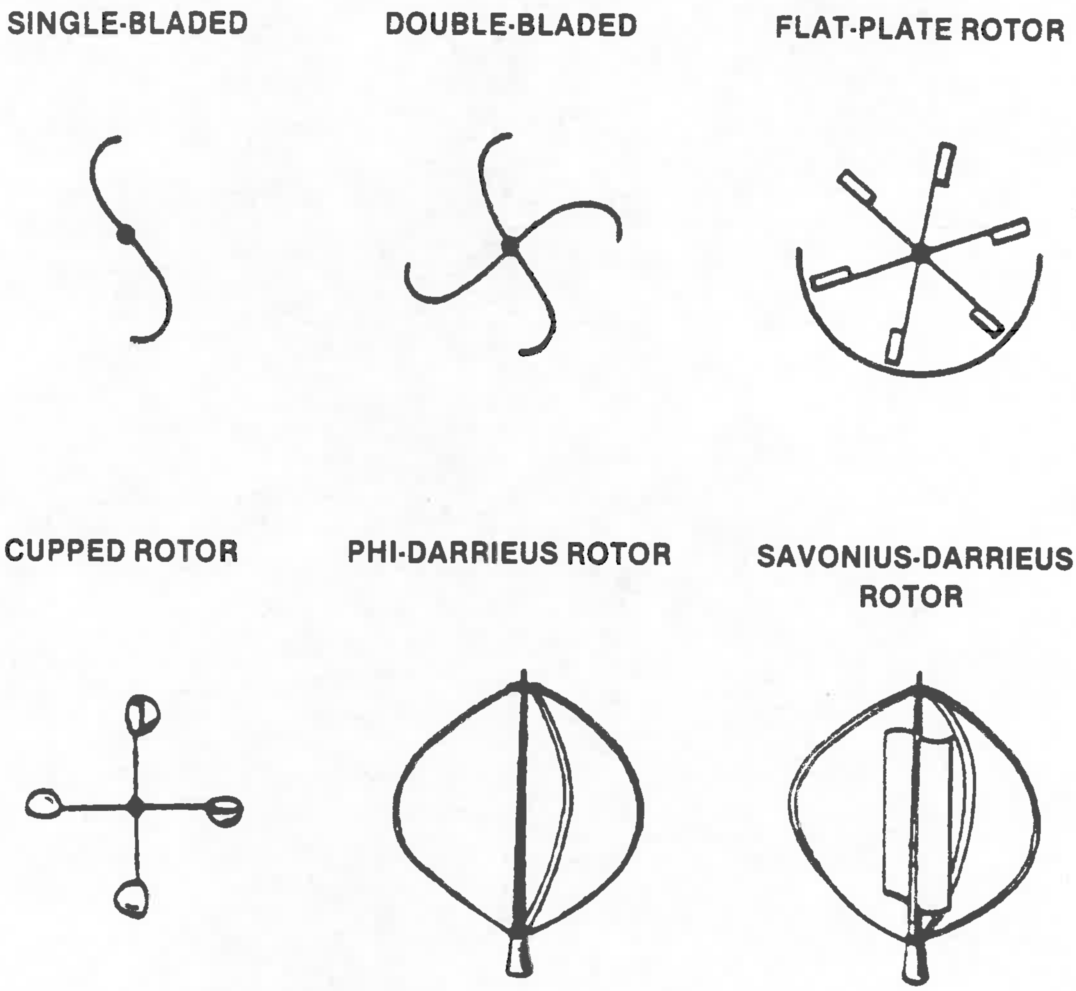


FIG. EWII-10

connections to a central electrical grid are not available and pumping heads are low. Winds are not generally as strong in the tropics as they are at higher latitudes, but there are areas where trade winds or geographic features such as mountains and cost lines produce average windspeeds of over 5 metres/second. Among the most interesting areas for wind-powered water pumps would appear to be parts of northern Argentina, Chile, Mexico, Peru, northeast Brazil, coastal areas of Africa northward from about Senegal in the west and Somalia in the east, India, Pakistan and the People's Democratic Republic of Yemen. Windmill-powered pumping is generally more competitive for relatively shallow water sources that require relatively small pumping capacity.

Wind-driven electric generators are available commercially in unit sizes up to at least 15 kilowatts rated capacity. Some of these can produce power at costs of 25 to 50 US cents/kWh at low load factors and 5 to 15 US cents/kWh at high load factors in locations with average windspeeds in excess of 5 metres/second.

2.3.6 Biomass

Biomass includes, strictly speaking, **all living material, whether plant or animal.**

Basic to all energy in biomass is the **photosynthetic process:**

- the green chloroplasts in the plant cells can convert carbon dioxide and water into biomass and oxygen by using solar electro-magnetic energy. The **energy** now **present** in **biomass,** therefore, **is originally solar energy;**

- where biomass is burned, the stored energy is released as heat which can be used, for example, for cooking or space heating. The chemical reaction taking place is in fact the reverse of the photosynthetic process;

- it will be clear then that **all biomass has an energetic value.** However, not all types of biomass have an equal fuel value. The fuel value may be impaired by ash content, and particularly by moisture content. Ash content varies by species and by plant tissue, e.g. tree leaves generally have a higher ash content than wood. Rice husks contain a high percentage of silica. Ash content virtually cannot be changed. Moisture content, however, can be reduced by drying.

The energy present in biomass can be made useful in various ways.

The most common one is **direct combustion**: burning biomass in the presence of oxygen (air).

Wood biomass also may be converted into **charcoal,** which in turn can be burnt.

It is also possible to **gasify biomass**, whereby the gases may be burnt or, after cooling and cleaning, can be used in internal combustion engines.

Certain **plants** produce **hydrocarbons** which have gasoline or kerosene-like properties. Also certain **plant oils** can be used as diesel fuel, while the sugars or starches produced by other plants can be fermented and distilled, producing alcohols.

Anaerobic fermentation of plant material or organic wastes results in **biogas**, mainly methane.

Organic wastes and residues are still forms of biomass. Their (sometimes low) energy content can be made useful by direct combustion (e.g. cow dung) or anaerobic fermentation (biogas).

Energy from biomass can be obtained through **two processes: thermochemical** and **biochemical.**

Thermochemical process: operated on lignocellulosic materials including wood, industrial and agricultural residues. Includes:

. direct combustion
. gasification
. pyrolysis
. direct liquefaction.

Biochemical process: operated on lignocellulosic material and agricultural products and residues, or urban or industrial wastes with high content of sugars and starches:

. anaerobic digestion (biogas generation)
. alcoholic fermentation (ethanol and methanol).

It will be clear that biomass in its many forms is an important source of energy:

Fuelwood

Firewood used for cooking accounts for 10-12 billion kilowatt hours (kWh) of energy. In Africa, 60 per cent of total energy is fuelwood and in rural India it accounts for 93 per cent of total energy consumption. Gathering fuelwood is contributing to deforestation and erosion. Shortage of fuelwood is the undisputed energy crisis affecting most of the world's poorer countries. Nevertheless, with better forestry practices it is one of the most promising of the new and renewable energy sources. Among the recommendations likely to be made are fencing specific plantations for fuelwood and the wider adoption of the old European practice of coppicing. In this, a mature tree is cut back low to the ground but with enough stump to permit lateral shoots to sprout. These coppice poles may then be harvested progressively. (Fig. EWII-11)

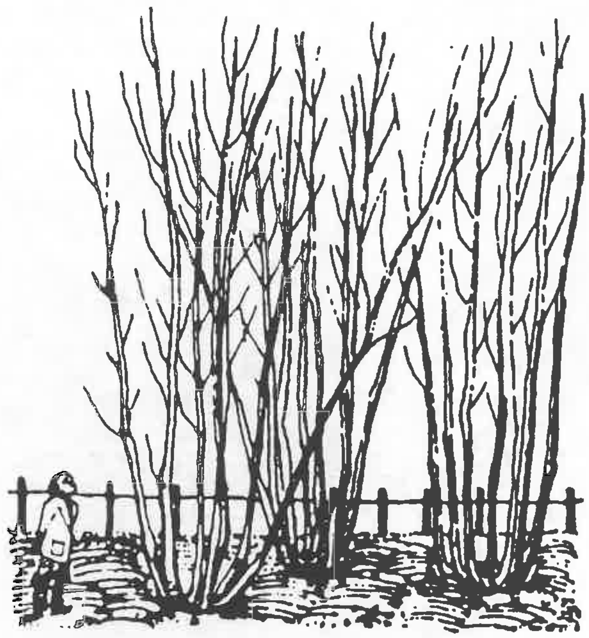
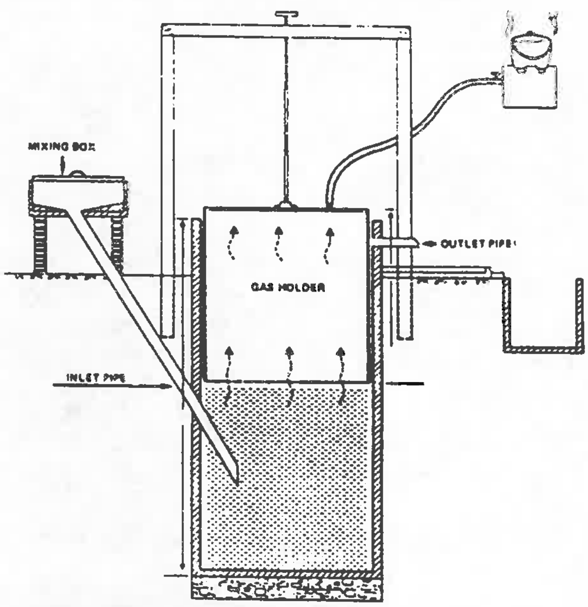


FIG. EWII-11

methane



BIOGAS PRODUCTION

FIG. EWII-12

Ethanol

Growing sugar cane for the production of ethyl alcohol by fermentation is the best known example and Brazil is the best known practitioner.

The use of a mixture of petrol with up to 20% by volume of alcohol requires no adjustment to car engines.

Other sources of biomass suitable for ethyl alcohol production are sweet sorghum, beet, cassava, corn, babassu palm nuts and potatoes. When the starting material is starch (as with the last four) another process has to be introduced to make starch into sugar first.

Methanol

One virtue of methanol is that most of the source material is waste that cannot be used as food. The sources are wood, crop residues, grass and waste fibres. The feedstock is cooked to give carbon monoxide which is then combined in the presence of a catalyst to make methanol. Among the problems, there is the fact that methanol cannot be mixed with petrol and that only large-scale plants are economical, which is not the case with ethyl alcohol (ethanol) production from biomass.

Methane

Almost anything of biological origin can be used to make methane.

Animal and human wastes and wet crop wastes, or even specially grown aquatic plants, algae and water hyacinth, are ideal sources. The key condition is that bacterial action should take place in an atmosphere where there is no oxygen - in anaerobic conditions; the key device is a digester which can be kept warm and sealed from the air usually by a water seal. Animal manure and other wastes are mixed with water to form a slurry and pumped into a digester where they are retained for two weeks or so.

The gas produced by the bacteria feeding on the organic material consists basically of two parts of methane to one part of carbon dioxide which ideally is stored in a separate gas holder. (Fig. EWII-12)

China and India are world leaders. Seven million Chinese digesters are in operation. They come in all sizes, from family to large village size. In China, gas is used for lighting and cooking but can equally well be used for stationary engines and electricity generating and transport. The resulting sludge is used as organic fertiliser and soil conditioner. Even in rich countries methane production may increase because it is the answer to the environmentalists' prayer.

Pyrolysis gas

Hydrocarbons, ketones and aldehydes, which burn like fuel oil, can be made by heating dry domestic and municipal waste under pressure at 500°C in the absence of air. The technology is still under development, but plants dealing with 200 tonnes of refuse per day are in operation in the United States and Europe. (Fig. EWII-13)

Charcoal

Many pyrolysis processes leave as a by-product char - close to another pure form of carbon which, when made by traditional means, is called charcoal. The material is produced by the slow burning of wood with a very restricted air supply. Compared to wood, it provides much greater useful heat, stores better and produces less pollution. Ten per cent of total fuelwood is transformed into charcoal for easy transport into towns and cities. More efficient methods of converting wood to charcoal would result in a higher yield. (Fig. EWII-14)

Oil-producing plants

These are headed by the oil palm (Elaeis guineensis) in respect of oil production (4-5 tons per hectare per year). Some other crops are soy beans, peanuts, castor beans and coconut palms. Palm oil can quite easily be converted into a fuel for diesel engines. Oil palms would produce annually some 20 tonnes/ha in fruit or 4 tonnes oil/ha, finally producing 4 tonnes of fuel, i.e. some 5,000 l/ha.yr. The process of fuel production is much simpler and energy-efficient than in the fermentation process.

Biomass

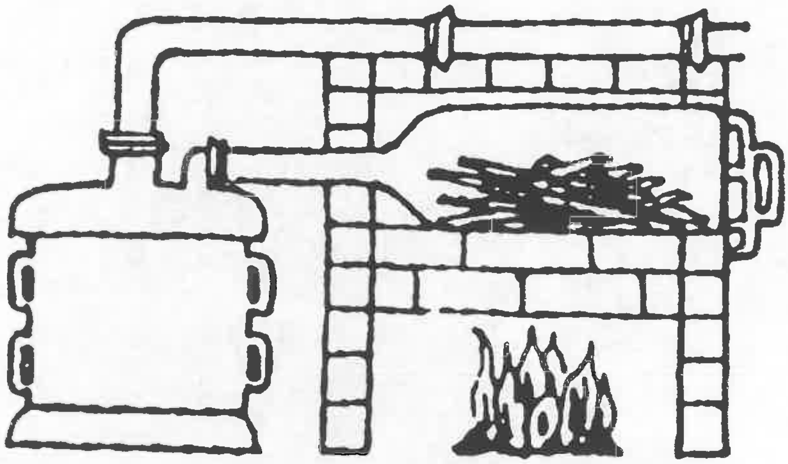
This constitutes an extremely important source of energy. In fact, according to approximate estimates it can contribute for 15% of the world's energy needs corresponding to 20 million barrels of oil a day (the present energy need of the United States!).

For one quarter of the world's population, mainly living in developing countries, biomass (mainly in the form of fuelwood) represents a major source of energy.

The technologies for the energetic exploitation of biomass are today mostly mature, but there are still many difficulties in diffusing them in developing countries because many of them have only recently been developed in industrialised countries, and still need to go through a realistic transfer and adaptation process.

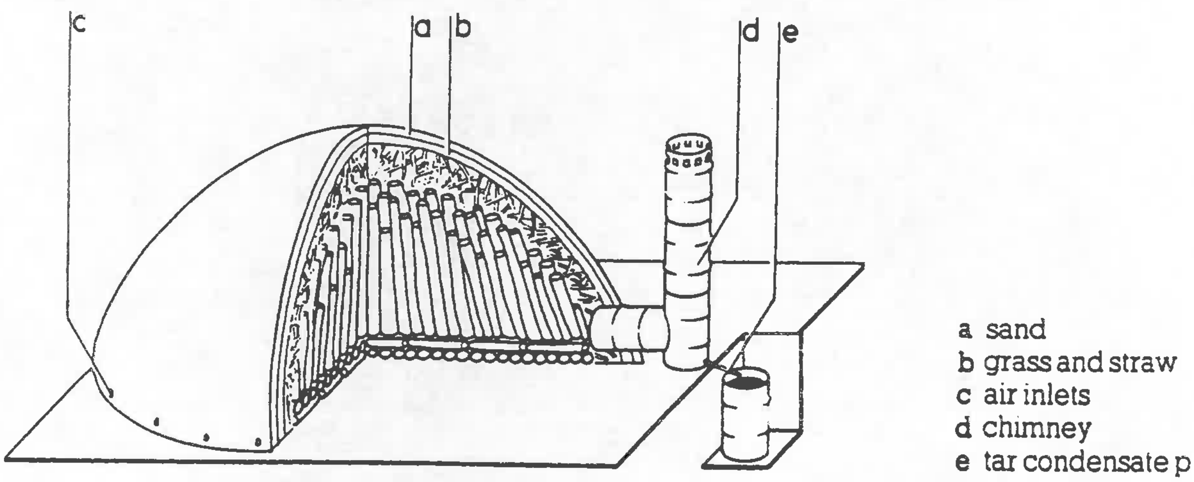
2.3.7 Draught Animal Power

Draught animal power can and does have a significant role in developing countries, especially in agriculture and for transportation. There



PYROLYSIS GAS

FIG. EWII-13



CHARCOAL MAKING

FIG. EWII-14

are approximately 400 million draught animals in the developing world, 80% of which are oxen and other bovine species. It has been estimated that it would cost approximately US$ 250 billion to replace them with fossil fuels and provide the people of developing countries with 150 million horse power. Animal power is often more economic than the use of mechanised agricultural and transportation equipment.

In addition, during their lives animals provide fertilisers, food and other useful products such as skin and bones. 85-90% of Africa and Asia depend on animals for providing mechanical energy to agriculture, and such contribution is going to continue in the foreseeable future.

The efficiency of draught animal power systems depends on several factors, and appropriate measures are needed to upgrade it. These include:

1) adequate feeding practices;

2) provision of veterinary health services;

3) improvement of the design of the harnessing devices and of animal draught vehicles;

4) full utilisation of by-products;

5) increasing the amount of time for which animals are used;

6) genetic improvements and breeding programmes.

Veterinary care, and genetic improvements and breeding are necessary in certain regions of the world where the use of animal power has been seriously impeded by livestock deseases, such as trypanosomiasis in Africa.

2.3.8 Peat

Peat is on the borderline between fossil fuel and living biomass and accounts for 1.1 per cent of world fossil fuel reserves. It is estimated that 210 million tonnes a year are being added to world peat bogs. The Soviet Union burns most of its 70 million annual tonnes in power plants which generate 3,500 megawatts. Peat gasification is less expensive than coal gasification and produces four times as much gas.

2.3.9 Oil shale

Oil shale is a rather vague term applied to sedimentary rocks containing kerogen, a complex mixture of polymers which when heated produces oil. Oil shale's attraction for innovators lies in the fact that the reserves of oil it represents are several times larger than conventional oil reserves. The earliest exploitation techniques depended on mining the rock and heating it separately. The problem is that the resultant rock is more voluminous than the original, so huge disposal problems are caused. Interest centres now on in situ extraction of oil. In principle, air is pumped down a bore hole, some shale is burnt and the heat is enough to mobilise the rest of the oil. This extraction process is grossly inefficient and may not be economic at current prices.

2.3.10 Tar sands

Tar sands are oil-bearing sands in which the oil is so viscous that it does not flow. Like oil shales, tar sands represent petroleum reserves several times greater than those in conventional oil reservoirs. Extraction methods shade into those used with conventional oil-steam, or hot gas injection. Even so, the fraction of oil extracted is very low - five to ten per cent. The largest commercial operations depend on mining the rock and washing it with hot water. So investment costs are very high.

2.2.11 Conclusions

While **many developing countries have favourable conditions to develop NRSE,** the **pace** at which the full potential of the resources can be developed will be **determined by the ability** of the countries **to:**

- **develop** adequate data on sources and uses of renewable energy;
- **enhance** their technical capabilities;
- **design** systems that can deliver renewable technologies in socially and culturally acceptable forms to large numbers of energy users, including women.

3. THE ROLE OF WOMEN IN THE DEVELOPMENT, MANAGEMENT AND UTILISATION OF NRSE

3.1 INTRODUCTION

In developing countries women have a small share in the modern production and distribution of energy. In rural areas, however, they have an important role in the planning, production and utilisation of energy for household and community consumption. Since conventional energy is not easily available, they mainly depend on non-conventional and new and renewable sources of energy.

Women are collectors of various energy sources, **disseminators, users, family educators, motivators** and **agents of change**. They are responsible in this regard not only for themselves, but also for the members of their families and the community at large.

In most developing countries women are the main users, suppliers and managers of energy sources. It has been estimated in fact that in the developing world the household energy consumption accounts for 45 per cent of the total, and in low-income countries this share rises to 75 per cent. Women are usually responsible for the entire domestic energy supply and for its utilisation. In addition, they are the users and providers of most energy required for certain tasks, such as traditional agriculture and food processing, which are typically a woman's task.

Women therefore have a central role in energy supply and utilisation, especially of NRSE. Notwithstanding this basic fact, their needs have often been overlooked in energy planning and in the development of energy technologies. Moreover, they have not been fully integrated in the implementation of energy programmes and projects.

The role of women in energy has up to now been largely ignored by the public at large and by the energy policy-makers, who rarely focus on the household energy problems involving basic human needs and women's work. This is especially important in rural areas, but also applies to the urban population, although they depend more on the planned and established energy consumption systems.

It is generally agreed that the main issue related to women and NRSE is not the incorporation of women in energy activities, as they are already active participants. Rather, it is **necessary** to make **women's participation** more **effective**, **easier** and **more productive.**

3.2 THE ROLE OF WOMEN AS SUPPLIERS OF ENERGY

3.2.1 Fuelwood producing, collecting and trading

Developing countries derive over 40 per cent of their total energy supply from biomass, mainly in the form of wood, which is traditionally collected by women.

Women collect wood to meet their household's needs, and often play a major role in the commercialisation of wood. Fuelwood trading in many countries is run by women, and represents for a large number of them the major or only source of income.

Women also have a central role in wood production. As the main users of forestry produce, they have an intimate practical knowledge of the characteristics of the different species, which makes their participation in the planning of forestry projects a most precious one. Women know which tree burns slowly and which fast, which smoke and which kindle easily.(3) Moreover, the experience women have in planting and seedling care, which derives from their traditional tasks in agriculture, makes their participation in the implementation of such projects indispensable.

3.2.2 Agricultural residue collecting and processing

Women also play a major role in collecting, storing and processing agricultural residues, which are an important source of energy and are increasingly used as wood becomes scarcer, both as a spontaneous reaction of consumers and within specific projects and programmes. More than one billion people in China and other Asian countries rely on agricultural residues to meet their basic energy needs.

The term agricultural residues refers generally to the whole spectrum of biomass material produced as by-products from agriculture. They include woody residues (e.g. coconut shells, cotton stalks); crop straw; crop processing residues (e.g. rice husks); green crop residues (e.g. ground nut tops); dung and manure.

Crop residues can be used in their original form and burnt to produce thermal energy, or can be utilised to produce producer gas, or ethanol and methanol used as commercial fuel for engines. They can also be pressed to form briquettes to be burnt to produce thermal energy.

Briquetting agricultural residues is also often a typical women's task when it is performed on a small scale at the household level. However, there is a tendency now towards industrial briquetting, where women could also play a special role as collectors of the resources to process.

Women also play a central role in the utilisation of dung and human nightsoil as a source of energy. Animal dung is used especially in Asia, and it is usually the task of women and children to collect it and press it into dung cakes, usually adding some straw. Dung can also be used to feed biogas plants, and once again women play a major role in the management of this energy resource. This is especially true when the biogas plant for which the dung is utilised is a family-sized one, such as the Chinese type. In China, over seven million biogas plants were built, using mainly pig manure and family nightsoil. Women have certainly played a central role in this programme, which represents the most important experience in the field of biogas.

3.2.3 Providing animate energy and developing NRSE technologies

Women, in the performance of their household, community and income-generating activities, contribute their human labour as a source of mechanical energy.

In many developing countries, animate energy, consisting of human energy and draught animal power, is the major input to agriculture and most other rural small-scale activities.

Energy research has usually underestimated or ignored the share of women in energy output. Time-use studies show that women, in the performance of their multiple functions both in the household and for income-generating activities, usually work in most countries longer hours than men. For example, in a field study undertaken by the Indian Institute for Science, selected villages in Southern India were surveyed, and it was found that women worked an average 9.69 hours per day, while men worked 5.68 hours per day.(4)

The development and dissemination of appropriate energy technologies, and especially NRSE technologies, may help to alleviate the drudgery associated with women's activities and reduce the time necessary to perform many tasks, leaving them time for more productive work or leisure.

Women, in the performance of their activities, may develop and build their own NRSE technological devices. For instance, they may build simple solar crop dryers, such as trays where coffee beans are put to dry after harvest. Many new NRSE technologies (e.g. cooking stoves, food processing equipment) are based on traditional models developed in the past, maybe centuries ago, by the ingenuity and talent of an unknown woman.

3.3 WOMEN AS USERS OF ENERGY

3.3.1 Women's energy needs at the household level

In the performance of their tasks in the household, in the community and for their income-generating activities, women need sources of energy to produce thermal energy, mechanical energy and chemical energy.

The energy needs of an average household in developing countries include fuel requirements, and energy for the performance of various tasks such as provision of its domestic water supply, cooking, lighting, space heating, boiling water, food processing, ironing, dyeing cloths. Energy is also needed for pest control, food production and processing, and fodder preparation, especially in rural areas. For urban wealthy dwellers, energy may also be needed for water heating, space conditioning, refrigeration, and for providing power for communication and other domestic equipment.

Cooking is by far the most consuming task. However, in order to recognise the implications and potential impact of fuel shortages on the energy supply required to meet domestic requirements, and on the resource endowment of an average household, the total energy balance of the household must be taken into account.

3.3.2 Women's energy needs at the community level

At the community level, energy is needed for pumping water, irrigation schemes, water desalination and water purifying, communications, lighting, transportation.

In addition, community centres and health-care facilities require energy for lighting, cooking, space conditioning, heating water, refrigeration for vaccines, etc. All those needs can be met using NRSE technologies, many of which are already proven and economically viable.

3.3.3 Energy for women's economic activities

Many women in developing countries are engaged in a number of income-generating activities, frequently related to the informal sector of the economy, which require the utilisation of energy resources. Such operations are often run by women in an informal way, on a part-time or seasonal basis, balanced with their household responsibilities. For this reason they are often ignored or undervalued by policy-makers and decision-makers, and left out of research and development projects.

Among women's typical informal sector enterprises are several food-processing activities, pottery and brick-making, beer brewing and catering. "Street food" so common in many developing countries is cooked and sold mainly by women.

Many women's small enterprises are energy intensive. Pottery making in Tanzania uses up to a cubic metre of wood for 100 large clay pots, which is nearly equivalent to the annual average per capita rural consumption in Africa. Fish smoking uses 0.8 m^3 per ton and brick-making 5 m^3 for a two-roomed house. (See Additional Reading, Part III.) Fuel is often a significant cost factor in these activities, and there is therefore a commercial motivation to improve the efficiency of the entire process, as reducing fuelwood consumption will result in increased income. In addition, there is an interest at the community and national level for energy saving.

4. THE INTEGRATION OF WOMEN IN NRSE PLANNING AND POLICIES

4.1 THE PARTICIPATION OF WOMEN IN ENERGY PLANNING AND POLICIES

Energy planning for developing countries is considered nowadays a crucial problem. Because of their fundamental role, women must be actively involved at all levels of energy planning, energy policy design, formulation and analysis.

Like all development problems, the **issue of energy is multidimensional** and lies not only within the socio-economic field, but also in others, including the technical, scientific, as well as the environmental sphere. Moreover, all these areas are interconnected; a problem that exists in one will very often influence the situation in the others. Furthermore, the seriousness of the energy problems is cause for great alarm. The demand for thesetypes of service is growing at an extremely rapid pace, as well as their requirements for financial resources. These points lead to other pertinent questions, for example:

1) how to manage such complex development problems, given the multiplicity of issues involved?

2) who determines what the priorities are?

3) how will co-ordination among various parties be achieved?

The ultimate success of national energy policies depends mainly upon concerted and integrated efforts at the national level of governmental and non-governmental bodies, including existing women's organisations.

One of the main elements required by energy policy-makers and investment decision-makers is the evaluation by economic, financial, social and cultural criteria of the potential of NRSE applications. This is needed in order to consider these sources as possible alternatives to conventional systems. It is therefore necessary to promote the participation of women, both in the field of general energy planning, with special emphasis on including NRSE applications, and also in the evaluation of specific NRSE technologies with a view to analysing their practical technological, economic and social utilisation potential for particular end-uses.

Usually, when discussing "women and energy" the only area of this vast field acknowledged by the energy policy-makers is the introduction of improved stoves in the household. Stoves are an important component, but not the essential factor, as the household's needs are multiple. Women are the primary collectors, users and managers of different energy sources. It should be recognised that an increased production and a more efficient utilisation of energy, and especially of NRSE, depend on the improvement of the role of women in NRSE. If they were properly informed of the energy problem, for instance, women would be naturally interested in using rationally the new and renewable sources of energy, thus contributing to energy demand management.

This however implies a number of actions at the national and international level, and a better social planning of development, as well as a better utilisation of energy resources, is demanded.

National energy policies and programmes are biased towards centralised energy networks and tend to ignore the problems faced by poor households, and especially by women living in rural areas. In order to enable women to improve their participation in this field, it would be necessary to decentralise, at least partially, energy production and consumption.

Wide dispersion of non-conventional energy sources, and different ways of using them, are common in most developing countries today. With the introduction of planning, new techniques, new technologies and equipment for developing non-conventional sources of energy, it would be possible to intensify development and ensure better co-ordination among various activities and participants, and to emphasise the importance of women's participation in an area in which changes are called for. It is therefore important to enable women to participate in decision-making on the production and utilisation of energy, and this can greatly contribute to bringing about changes in the way of life and general working conditions. Policy-makers and planners should evaluate the real impact of women's work in the management and use of energy, in order to improve the role of women in new and renewable energy sources.

4.2 THE INTEGRATION OF WOMEN'S NEEDS IN ENERGY PLANNING AND POLICIES

Notwithstanding the basic fact that women are the main users and producers of energy in most developing countries, their needs have been overlooked in energy planning and by energy policies. There has never been a well-defined goal to reach and involve them, nor a specific focus on women as a target group.

Preconceptions on the role of women have hidden their contribution to the energy sector and hampered planning for activities which could be effective and improve their conditions. The energy system has been mostly investigated from the point of view of men and the major contribution made by women has not been recognised.

Women in developing countries are often engaged in activities which belong to the informal sector of the economy, and their contribution to the well-being of society is therefore undervalued. National accounts and statistics often ignore their contribution to the economy. As a result, their needs and preferences are often overlooked or underestimated by decision-makers and energy planners.

Energy planning is hampered by a lack of specific data on the role and contribution of women in energy supply and use. Research and training of experts in this field are therefore necessary in order to contribute to more effective energy programmes and to the elaboration of policies consistent with their needs.

In addition, energy planners and decision-makers are not fully aware of women's specific needs and preferences in the field of energy, both those related to household tasks and even more those referring to women's income-generating activities.

Energy policies in developing countries should give priority to the household sector and should take into account that an adequate supply of energy for cooking, lighting and heating is a basic human need. National energy policies must incorporate women's concerns and interests. Energy policies should include specific measures for the development and dissemination of energy technology for women's use.

Specific actions in order to better inform and sensitise government officials, experts, politicians and all who participate in the formulation of energy policies, as well as the public at large, should be promoted.

The impact on women should be taken into account by policy-makers and decision-makers in deciding on energy source prices, subsidies, and any other policy measures.

4.3 RECOMMENDED APPROACH

Women's requirements and contributions should be integrated into national energy planning and programming for energy activities. Wherever possible, governments should:

a) ensure that women's needs and participation are duly considered by the existing institutional framewok responsible for activities in the field of energy;

b) provide directives to institutions for formal education, and to governmental and non-governmental agencies for the recruitment, training and advancement of women, to enhance their participation in management, policy making, planning and technical fields;

c) include features in regular communications media to publicise NRSE technologies especially aimed at women target groups;

d) support existing women's organisations or groups active in NRSE activities with adequate information, training or funds.

An issue for special consideration in energy planning and in designing energy policies is the linkage to income-generating activities for women.

Information plays a decisive role for the integration of women's needs and their participation in energy planning. Issues concerning women and energy, and especially NRSE, should be popularised through mass media, at the national and sub-national levels. Activities aimed at properly informing and sensitising decision-makers and policy-makers and the public at large should be undertaken using different communication means and through contacts with relevant governmental bodies and professional organisations, with the help of women's associations and organisations.

Energy assessment for planning includes the assessment of both the demand and the supply. In both cases, a considerable amount of data is needed, e.g. energy consumption, type of energy used, and activities linked to the use of these sources. Energy demand and supply, and energy balance sheets including projection of future energy requirements, should be determined in a dynamic way. Energy demand, particularly in the rural and poor urban areas of developing countries, consists mainly of energy needed in the household and on the farm. There is a tendency in energy planning to overlook these needs and concentrate on planning for the industrial sector. Women's household needs, such as cooking, washing, heating, the availability of continuous water supply, should be given priority.

An important element of energy policies is energy demand management. The purpose of energy demand management is to reduce the consumption of energy per unit of GDP, and to control the growth of demand so as to reduce its overall cost to the economy, as for instance by fostering the use of indigenous energy sources to replace imported energy. Demand management policies can shift consumption to higher values uses, reduce the energy cost of output, and promote a change-over to less costly sources of supply. At the national level, this means setting priorities among principal energy users - industrial versus household, public versus private transport, energy intensive versus non-intensive activities - and then ensuring that government policies are consistent with these priorities.

Women's needs and interest should be taken into account in demand management policies, and their participation assured, especially when the programme addresses a new and renewable source of energy such as fuelwood, where they play a major role.

The different share of each NRSE in total energy consumption, both commercial and non-commercial, must be taken into account in devising energy policies. Agricultural production, for instance, typically accounts for less than 5% of a developing country total commercial energy consumption, therefore demand management in this sector is unlikely to yield substantial reductions in total energy use.

Energy pricing is the most important tool in energy planning. The goals of energy pricing are therefore closely related to those of energy planning, but are more specific. The impact on women should be considered in taking measures concerning the price of energy sources.

The fundamental objective of energy planning and policies is economic growth, but social, financial and environmental objectives are also to be taken into account, and may sometimes be equally important. The economic growth objective requires that pricing policy promote economically efficient allocation of resources both within the energy sector, and between it and the rest of the economy.

The social objective recognises the basic right of all citizens to be supplied with certain minimum energy needs. Given the existence of significant numbers of poor consumers and the wide disparities of income, this may imply subsidised prices.

The government should be concerned with financial objectives relating to the viability and autonomy of the energy sector. Institutions in the energy sub-sectors, which are typically government-owned, need to earn a fair rate of erturn on assets, and to be able to self-finance an acceptable portion of the investments required to develop future energy resources. However, caution should be taken not to overlook the needs of the poorest segments of the population who cannot pay for energy services.

There are a number of additional objectives, such as the need for price stability, to prevent shocks to consumers from large price fluctuations, the need for simplicity in energy pricing structures to avoid confusing the public and to simplify metering and billing, and so on. As a long-run policy tool, the price indicates the consumer's willingness to pay and the use-value of energy. At the same time, the price signals to consumers the present and future opportunity costs of energy supply based on various sources.

Energy conservation measures are also an important instrument of energy policy. Energy conservation encompasses two concepts: increased efficiency in converting energy from one form to another (coal to electricity) or in converting energy goods and services (petrol to vehicle-miles) and reductions in the services provided by energy (lower indoor temperature in winter, driving fewer miles).

It is evident that women can play a key role in energy conservation programmes, especially those aimed at increasing the efficiency of household energy devices.

5. THE INTEGRATION OF WOMEN IN ENERGY RESEARCH AND IN THE DEVELOPMENT OF NRSE TECHNOLOGIES

5.1 THE IMPACT OF NRSE TECHNOLOGIES ON WOMEN

In subsistence economy animal and human energy have been used to perform such tasks as fetching water and growing food, while wood has been used for cooking, heating and lighting. With the development of modern society, animal and human energy has been replaced with mechanical and other energy devices, which are also presently used for many of the functions previously performed by wood.

The introduction of new energy technologies may help to save labour and time, and therefore can improve the quality of life. The benefits which derive from them should however be distributed equitably. Modern technologies, on the contrary, have almost always favoured men, leaving women behind.

As a consequence of the introduction of new energy technologies, women may be forced to abandon activities previously performed, damaging not only themselves, but also the entire household. In Indonesia women used to pound grain by hand, and this represented a source of income for them. When grain mills were introduced, women were displaced from their work and deprived of their principal source of income. (See Additional Reading, Part III).

The main reason why women are often excluded from the use of a new technology is a misconception that advanced technology and science are a field for men. In addition, the introduction of a new technology often implies working far from home and this may be against local customs. Moreover, women for several reasons referring to social and cultural norms and to their traditional role in the reproduction and maintenance of human resources, are also very often excluded from training in the use of the new technology. This, in turn, excludes them from the utilisation of the technology.

Little or no attention at all has been, or is still being, paid to designing or adapting energy devices to the gender of the end-users. Even technology designed to perform household tasks often does not properly take into account women's needs and preferences, and is often developed without their participation. This has been the main reason, for example, for the failure of many improved stove programmes.

5.2 WOMEN'S INTEGRATION IN THE DEVELOPMENT OF NRSE TECHNOLOGIES

5.2.1 Women's role in the development of NRSE technologies

Energy-consuming tasks should be clearly identified by type, quantity of energy consumed, time spent and performer gender to match appropriate technology to specific end-uses, thus obtaining the best results.

Many new energy technologies, especially the ones based on NRSE, are economically viable and sound for certain applications in developing countries, several of which relate to tasks traditionally performed by women.

Solar energy, for instance, is a proven and viable technology only for some specific end-uses, which include water heating, pumping and purifying, solar cooking, crop-drying, activities which are mainly performed by women. It is evident, therefore, that there is the need for full involvement of women, the end-users, in the design and adaptation of such devices.

The development and utilisation of new and renewable energy sources and related technologies in developing countries depends to a large extent on basic scientific research and technology development.

Women as users of NRSE technologies can provide valuable inputs for the development of technologies appropriate for household and community needs, and adapted to local conditions.

The following series of measures can be recommended in order to enhance the role of women in this particular area of activity:

1. Consider the ability of the users, particularly women, when developing promising technologies, in order to ensure their wide applicability.

2. Identify research needed concerning social and environmental implications of energy technologies, taking into consideration women's role and interests.

3. Promote pilot projects and programmes, including a research component, to develop and test new NRSE technologies for women's use.

4. Ensure the participation of women in the planning and implementation of pilot projects aimed at testing the interest of prospective consumers of a new NRSE technology.

5. Establish criteria for technical and economic evaluation of new technologies, taking into consideration women's actual needs and practices.

6. Promote women's participation in the identification and implementation of research and development activities relating to new and renewable sources of energy.

7. Allow for women's participation in the identification of the local market which will absorb the NRSE technologies, and in recommending measures for dissemination.

5.2.2 NRSE technologies for women's use

Many activities traditionally performed by women require the utilisation of energy resources and are often energy intensive. Despite this basic fact, decision-makers, experts and researchers to date have devoted little attention to this issue.

There are only a few examples of energy technologies specifically designed for women's use, the best known of which is represented by improved stoves. It is interesting in this respect to note that the main reason for the interest manifested by governments, researchers and decision-makers for this technology has been the concern for the depletion of forests, of which the use of wood as fuel to meet the household's needs represented a major cause.

The primary objective of stove projects was therefore to fight against deforestation. There is no doubt that objectives such as reducing the drudgery involved in collecting wood, improving women's comfort while cooking, or reducing the cook's health hazards were secondary objectives. This is apparent if only one observes that a number of stove projects started in different regions of the world in the mid 1970's, when the dramatic rise in oil prices forces many countries to rely increasingly on wood as a source of energy, and the existence of "a second energy crisis", the scarcity of wood, was brought to the attention of governments and the international community.

Even less examples exist of technologies specifically designed to help women in income-generating activities.

Perhaps the best-known example is the Chorkor fish-smoking project. In most developing countries, fish capture at sea is the responsibility of men, but when the catch is landed, it is taken in charge by women, who clean and sell it on the beach, or handle the processing (i.e. smoking, salting, drying, fermenting). In Ghana, women used to smoke fish in order to preserve it, using devices which were inefficient in terms of woodfuel consumption and produced harmful smoke. A FAO project, implemented in co-operation with the National Council on Women, developed in 1970 an improved smoker, known as Chorkor, which reduces fuelwood consumption, improves the quality of the smoked fish, and ameliorates working conditions, reducing the quantity of smoke inhaled by women workers.

UNIFEM and UNICEF were also involved in the dissemination of the technology which spread beyond Ghana's border to Togo, Benin and Guinea. Women participated in this process, as they were trained as trainers and extension workers to teach other women how to use and maintain the new device, and to commercialise the smoked fish.

Other examples of technologies based on NRSE for typical women's income-generating activities include the design of improved ovens for baking, kilns for charcoal making, micro-hydropower plants for irrigation, improved stoves for beer brewing. In Botswana, for instance, three types of ovens of different capacity, which can be used for small-scale bakeries, have been developed in the framework of a collaborative project between the Rural Industries Innovation Centre (RIIC) and the Botswana Technology Centre (BTC). The Government of Botswana has sponsored training in setting up a bakery, and thus several women have been able to start their own business.(5)

Dolo beer brewing in West Africa is a typical women's enterprise, and requires the utilisation of large quantities of wood or charcoal. In Burkina Faso, an improved stove model for dolo brewing has been developed which, according to an estimate, can save up to 50% of wood. The benefits for the women who make their living out of dolo beer making are evident, especially if one considers that the price of wood, because of increasing deforestation in the Sahelian Region, is extremely high, especially in the main cities. If one considers that in a city like Ouagadougou, dolo beer brewing is estimated to absorb 20% of the total fuelwood consumption, it is apparent that the new technology could also have an impact on the overall city energy supply.

The main reason for the lack of attention for energy technologies for women's income-generating activities can be identified in the fact that those activities are often performed by women in an informal way, in many cases as an extension of their household tasks, which are not included in national accounts and therefore do not attract the attention of planners and policy-makers. Therefore they are often underestimated and overlooked in national development plans and politics.

The examples we have just mentioned show that it is possible to develop technologies which can make a real impact on women's life. Several areas where research and development should be promoted can be identified. These include ceramics, soap making, food production and post-harvest technologies, food processing.

Research and development institutes should be encouraged to enhance their efforts in this area and pilot projects, aimed at developing new NRSE-based technologies and at field-testing them, should be identified and promoted.

6. CONCLUSIONS

6.1 PRESENT PROBLEMS

Despite their important and multiple roles, women are currently not adequately involved in NRSE activities. The entire process of energy development and use in developing countries should be reviewed, in order to better integrate women's needs and participation and to identify and promote specific actions in this respect.

Present problems include the following:

a) Not enough attention has been paid to the needs of women as users of NRSE. Women's role in developing, collecting, storing and distributing energy resources is not recognised as an issue of concern, nor given an economic and social value.

b) Women are often excluded from energy planning and energy policies at the national level, and from the planning and implementation of NRSE projects and programmes.

c) Research on NRSE and related technologies is not adequately oriented towards women's needs.

d) Energy technologies often do not take into consideration the socio-cultural context and level of knowledge in the communities in which they are introduced, and especially the role played by women.

e) Lack of consultation with women leads to improper design of NRSE technologies of which they are the end-users.

f) NRSE projects and programmes lack elements of communication and information on women.

g) Education in fields related to the development and utilisation of NRSE and training for women to use and maintain new NRSE technologies is insufficient.

6.2 POSSIBLE SOLUTIONS

The multisectoral nature of energy activities involving women requires appropriate co-ordination among the national institutions and authorities active in energy development programmes, as well as bodies in charge of education and training. Appropriate co-ordinating bodies at the national level should be made instrumental in the co-ordination between responsible ministries. National machineries for the advancement of women should assist in, and be consulted for, securing pragmatic action at the national level.

In general, the following measures can be identified as those leading to possible solutions to the problems women are facing in the energy sector:

- participation of women in identifying NRSE exploitation potentials;

- integration of women in energy planning and in the implementation of NRSE programmes;

- equal participation of women and men in education and training activities in the energy field;

- increase of information flows on NRSE potentials as they relate to women;

- identification of specific measures to encourage women to adopt new NRSE devices;

- promotion of research and development projects to address the specific needs of women in developing countries, and of pilot projects to introduce appropriate technologies to develop locally available sources of energy (biomass, solar, geothermal, hydro, etc.);

- promotion of projects aimed at community participation at all levels;

- assessment of the implications of the current energy policies on the role and conditions of women, with the aim of changing the general attitudes in energy development and planning toward women's needs and participation;

- evaluation of the role of women as producers, distributors and users of energy in communities under different environmental conditions;

- identification of methodologies for the management of energy programmes and projects, which take into account the role and needs of women, thus promoting their integration in each stage of the programme or project implementation.

(1) See "Wood for Energy", FAO, 1983.

(2) See "Restoring the Balance: Women and Forest Resources", FAO, 1987.

(3) Idem.

(4) See "World Survey on the Role of Women in Development", United Nations, 1986.

(5) See Kristoferson, L.A. and Bokalders: V., "Renewable Energy Technologies: Their Applications in Developing Countries", Pergamon, 1986, Chapter 10.

PART I: EXTRACT FROM "ENERGY AND RURAL WOMEN'S WORK: CRISIS, RESPONSE AND POLICY ALTERNATIVES", BY E. CECELSKI, IN INTERNATIONAL LABOUR REVIEW, VOL. 126, No. 1, JANUARY-FEBRUARY 1987.

PART II: EXTRACT FROM "MOBILIZING RENEWABLE ENERGY TECHNOLOGY IN DEVELOPING COUNTRIES: STRENGTHENING LOCAL CAPABILITIES AND RESEARCH", WORLD BANK, JULY 1981.

PART III: EXTRACT FROM "LINKING ENERGY TO SURVIVAL - A GUIDE TO ENERGY ENVIRONMENT AND RURAL WOMEN'S WORK", ILO, GENEVA 1987.

PART I

Energy and rural women's work: Crisis, response and policy alternatives

Elizabeth CECELSKI *

1. The crisis

More than a decade ago the world entered an era of higher energy costs. In 1983 the World Bank estimated that developing countries needed to invest about 4 per cent of their GDP in energy annually, or altogether US$130,000 million, in order to meet projected needs over the next ten years (IBRD, 1983, pp. xviii-xix). Even with the lower oil costs of late, such an investment still poses a very difficult problem for most developing economies, weighed down as they are by the world recession, deteriorating terms of trade for their raw materials exports, massive debts and recently, in much of Africa, drought and famine. And all developing countries, including many oil exporters, will need ever larger amounts of energy in the future owing to increasing population growth, urbanisation and industrialisation.

Up to now the impact of higher energy costs has been cushioned by large reserves of "free" wood and other biomass fuels (animal dung, crop wastes) from the fields and forests of rural areas, though at the cost of deteriorating living and working conditions in the rural subsistence sector. By the year 2000, however, more than 2,000 million people in developing countries will be suffering from an acute scarcity of fuelwood (FAO, 1981). The distinction between "free" traditional woodfuels and expensive "modern" fuels is already becoming meaningless in many Third World cities: woodfuels for cooking today are no cheaper, and sometimes even dearer, than kerosene or gas. There is already a huge "overhang" of household demand for these modern fuels, and higher woodfuel prices and rising incomes will obviously lead either to increased fossil fuel imports (or increased use of indigenous resources) or to rationing. Many governments are looking to biomass and wood cultivation and to crop residues as new sources of energy for modern industry, transport and household use, such as fuel alcohol and producer gas.

In most developing countries the household sector is still the largest single energy consumer – and the poorer the country, the truer this is. As

* International Labour Office.

table 1 shows, in lower-income countries such as Burkina Faso, Ethiopia and Nepal the household sector accounts for more than 90 per cent of total energy consumption. The share of biomass fuels in the household sector is similarly related to the level of economic development but remains at over 80 or 90 per cent in most countries.

Deforestation and even desertification are the most serious consequences of this unseen reliance on "free" biomass fuels. But agricultural productivity begins to fall well before these "natural" disasters strike. The growing use of tree, crop and animal residues for fuel deprives the soil of recycled nutrients and thus reduces crop yields and also agriculture's capacity to support livestock, thus diminishing the draught power available to farmers. Men are forced to leave the land in search of seasonal work or work in the towns in order to supplement rural incomes, further reducing the labour inputs available for agriculture. These "environmental refugees" swell urban populations and intensify the pressure on rural food and biomass resources, while food production declines.

Hardest hit by this crisis are rural women. Women are largely responsible for subsistence food production and must increase their own labour inputs as productivity decreases, while often forfeiting the help they need to receive from their menfolk, in such tasks as land clearing and ploughing, as a result of migration (an avenue often closed to women for social reasons). As the quality and quantity of forest and water resources decline, the time and effort that must be devoted to fuel and water collection, two of women's traditional tasks, also increase. The possibility of obtaining "minor" wild forest and field products to supplement family nutrition and incomes, e.g. through food processing for sale, is excluded. Women have little choice but to work more (and to use child labour to help them), cut down on family living standards and try to squeeze more output and income out of the land, thereby often contributing to the destruction of the ecological base – a vicious circle.

These are among the major findings of an ILO research project (supported by the Netherlands Government) on energy and rural women's work in several countries in Asia, Africa and Latin America. The ILO's interest in rural energy arises from its concern that sufficient energy supplies should be available both for meeting minimum basic needs and for promoting economic development and rural employment (ILO, 1982). Since 1982 comparative country studies have been made on the effects of the rural energy crisis on rural women and households in Peru, Ghana, Mozambique, India and Indonesia.[1] Multidisciplinary national teams carried out action research in several villages representing different ecological regions in each country. Information on the time use of family members, fuel search and use, and food consumption was collected through household sample surveys during the rainy and dry seasons and through detailed observation of individual women in each village. Group discussions and interviews were used to obtain more qualitative information and opinions as

Table 1. Household energy consumption and biomass[1] fuels in national energy balances, selected countries

Country	Year	Household energy consumption as % of total energy consumption	Biomass fuels as % of household consumption
Indonesia	1978	...	84.0
Nepal	1980/81	94.0	98.7
Thailand	1983	29.3	84.8
Burkina Faso	1983	92.7	97.7
Ethiopia	1982	92.8	99.5
Ghana	1985	72.0	94.0
Mozambique	1980	76.4	98.7
Senegal	1981	67.4	93.2
Tanzania (United Rep.)	1981	85.0	98.8
Zambia	1980/81	45.6[f]	91.8
Zimbabwe	1980	30.0	85.4
Ecuador	1984	32.8	30.5
Peru	1981	38.6	62.4

[1] For purposes of this table "biomass" means traditional, non-commercial fuels.

Source: UNDP/World Bank Energy Sector Assessment Program reports with the exception of the figures for Mozambique which are taken from P. O'Keefe and B. Munslow (eds.): *Energy and development in southern Africa*, SADCC country studies, Part II (Stockholm and Uppsala, Beijer Institute and Scandinavian Institute of African Studies, 1984).

well as to catalyse group reflection on the fuel problem and possible solutions.

II. The household response: Survival strategies

These country studies show that, confronted with changes in fuel and biomass availabilities, rural households are being forced to make various adjustments that adversely affect their living standards, work and consumption. The adjustments produce negative effects on working patterns; on family nutrition and health; and on the environment, agricultural productivity and incomes. Some aspects of the urban fuel crisis and rural-urban linkages are also relevant here.

Working patterns

Although the division of agricultural and other tasks between men and women varies considerably from one region to another, in general men tend to have greater access to the cash economy and public life and to perform work that generates cash income (wage labour, crafts, cash cropping) as their primary activity. Women's activities revolve more around the subsistence economy, family food production and household maintenance. These activities, while essential to family survival and welfare, are typically unpaid – although women's "secondary" activities (such as food processing) may make a substantial contribution to family incomes. The ILO country studies confirm this general pattern.

The double – or rather triple – burden on women of household, family agricultural and income-earning work is shown in table 2. In these examples women's work in agriculture ranges from a low of 1.3 hours daily (owing to the drought) in a savannah village in Ghana to a high of four hours in the Peruvian sierra, where the women work on family plots and as wage labourers in co-operatives or on state or private farms. Non-agricultural income-earning work, such as crafts, trade and food processing, ranges from a low of 0.1 hours in Mozambique, where few opportunities for such work exist, to a high of 6.3 hours in a Ghanaian village, where women's main occupation is fish smoking. Household maintenance – cooking, fuel and water collection, cleaning and child care – takes up the largest proportion of women's time in virtually all the villages studied. On average women work about the same number of hours as men in agriculture, while men work only slightly more hours than women in non-agricultural activities. Almost all the household tasks are performed by women alone. This triple burden means that women work considerably longer hours than do men, between 11 and 14 hours daily in the countries studied as compared with between eight and ten hours for men.

Two of the most time-consuming activities for women in these villages are fuel collection and cooking. The total time spent on them ranges from 1.5 hours daily in an irrigated village in West Java, where new agricultural wage opportunities for women seem to have replaced their household activities, to five hours in a savannah village in Ghana. These energy-related activities take up between 13 and 36 per cent of women's total work time. A major activity for women in most of the villages in fact is *cooking* – up to 34 per cent of women's daily workload; an exception is Mozambique where, because of the severe food shortage at the time of the study, only one meal per day was prepared.

Men, women and children have distinct roles in fuel supply and use. Interestingly, the division of labour in fuel collection activities varies little by region. Men usually cut down trees to be used for household fuel. The collection of "minor" fuels such as branches, bushes, dung and crop residues, on the other hand, is frequently done by women in conjunction with other activities such as medicinal herb gathering, or on their way back from work in the fields. Partly for this reason, women in these villages typically spend less time on fuel collection alone than on cooking, in most cases no more than an hour or two. More important, perhaps, is the change in women's work patterns when fuel gathering can no longer be combined with other work but must be the object of a separate trip.

Table 2. A rural woman's work is never done... (hours per day)

Country	Agricultural work [1]	Non-agricultural work [2]	Fuel collection and cooking	Other [3]	Total hours worked
Indonesia					
Irrigated village	2.9	0.2	1.5	6.9	11.5
Upland village	3.1	0.5	2.4	6.0	12.0
India					
Average of five villages	3.9	4.0	4.8	0.9	13.6
Ghana					
Savannah village	1.3	2.7	5.0	5.0	14.0
Fishing village	2.0	6.3	3.6	2.1	14.0
Forest village	3.8	0.3	4.1	5.8	14.0
Mozambique					
Average of four villages	3.1	0.1	1.8	9.0	14.0
Peru					
Coastal desert	1.4	2.0	2.2	5.6	11.2
Sierra	4.0	1.0	3.8	2.4	11.2
High sierra	4.0	2.0	2.9	2.8	11.7

[1] Family subsistence, wage employment and livestock raising. [2] Crafts, food processing and trade. [3] Cleaning, child care, social, community and religious activities; for Ghana, travel time is also included here.
Source: See note 1 at the end of the article.

Since women and children are responsible for collecting residue fuels, their workload is increased when these fuels have to replace others that are becoming scarce. Residue fuels include twigs and branches, bushes, thorns and weeds, crop stalks, pods and roots, animal dung, and even paper and plastic trash. Many residue fuels not only take more time to gather in sufficient quantities (the relative calorific value being lower) but also require more time and attention when they are used since they burn quickly and the fire must be constantly tended. When women and children regularly collect residue fuels, one may conclude that fuel scarcity has reached a level that is probably severely affecting the environment as well as family welfare. On the other hand, commercialisation of household fuels, whether woodfuels or "modern" fuels, is a sign of both fuel scarcity and the availability of cash incomes.

Nutrition and health

When families are really hard pressed, food production and cash earning take precedence over women's household tasks such as cooking and fuel and water collection, even though these are also essential for family welfare. The traditional "hungry season" before the harvest is a crucial period: food deprivation is acute at the very time when all the adults have to work the hardest. When more time has to be spent on particular tasks, whether in farming or in fuel collection, women's other work suffers. The case studies suggest that the total time spent on food preparation, including fuel gathering for cooking, may be limited simply because other subsistence activities demand more time. In villages where women had to spend more time on fuel collection, they spent less time on cooking. This, however, can result in a lower nutritional level.

To spend less time cooking is an extreme reaction to a fuel shortage. Generally, less fuel per head is used in those villages that experience fuel supply difficulties, although the amount also varies according to diet and other factors. Staple foods such as beans and whole grains have to cook a long time before they are edible (or even safe to eat, in the case of legumes). Cooking fewer meals, eating cold or reheated leftovers, eating more snacks or processed foods and even changing diets have been reported as fuel-saving devices in areas suffering from an acute shortage of fuel, such as the Sahel, Haiti, Mexico and Nepal.

In most of the countries studied (especially in drought-stricken Africa) the lack of food was so great that fuel shortages played only a minor role in determining diets. Many households had only two meals a day or sometimes only one. The quantities and types of foods cooked play an important part in determining fuel use per head. Coastal villages in Peru and Ghana where fish consumption is high use much less cooking fuel than inland villages relying on hard staples such as maize, cereals, potatoes and cassava. This suggests that studies on fuel-saving methods should take a hard look at foods requiring high energy inputs.

Family welfare can also suffer from the loss of products gathered from forests. In subsistence economies uncultivated areas provide food, medicines, building materials, tools and utensils. Foods gathered from these areas, mainly by women, are often an important nutritional supplement. Even arid and semi-arid savannahs and deserts can provide a variety of wild produce, which are especially important as a fallback during drought.

Wood and charcoal, let alone fossil fuels, are rarely purchased by these rural households for cooking, except for income-generating uses. Most poor households have had to switch increasingly to cooking with residue fuels since they cannot afford either wood or fossil fuels. This is not to say that they do not value and need "modern" energy sources such as kerosene and gas; in fact they often spend a considerable amount of time in searching for supplies of scarce kerosene. In the many countries which have found it necessary to limit imports and ration supplies even in the cities, very little kerosene finds its way to the countryside. Not only kerosene and other petroleum products but the equipment needed to use them (stoves, gas bottles) are expensive and difficult to find in rural areas because of high transport costs and small dispersed markets. However, where life styles are changing and incomes are rising rural households also wish to adopt more convenient cooking fuels, and indeed may need to do so in order to provide nutritious meals in keeping with new work and school patterns.

Kerosene was used only for lighting in most of the villages studied, but even so that use absorbed an appreciable proportion of rural household budgets. Table 3 shows that between 5 and 20 per cent of household expenditures went on fuel (mainly kerosene), while the food budget varied between 50 and 91 per cent. Because of the households' small cash incomes even this minor use of a commercial fuel has already affected food and other expenditures; and further commercialisation of household fuels is bound to make matters worse unless rural incomes increase.

Water and heating are also "luxury" uses of fuel that are frequently curtailed when fuel is scarce. However, washing is essential for health and heating is often essential for survival. In cold mountainous regions such as the Andes, Himalayas and Ethiopian highlands as much fuel is used for heating as for cooking, which may be one of the reasons why these regions suffer so much from fuel scarcities.

Besides taking more time to gather and use, residue fuels are also smoky and inefficient. Storing the large quantities needed in a dry place is practically impossible, especially in the rainy season. Even poisonous weeds are used for cooking by the poor in some of the villages studied (*retama* in Peru, *basoothi* in India). Rooms were quickly filled with smoke by the inadequate combustion of damp, low-quality fuels. The WHO has begun to document the serious health effects (especially eye and respiratory diseases) of lengthy exposure to emissions from biomass fuels in smoky kitchens (WHO, 1984).

The heavy workload of manual tasks imposed on women also affects their health. A study carried out in Karnataka State in India calculated that women's calorie expenditures were higher than those of men and that energy expenditures on domestic tasks were higher than on agricultural work (Batliwala, 1982). Many of these tasks (gathering firewood, fetching water, cooking, etc.) could be done mechanically or made more efficient through the use of alternative technologies and energy resources.

Little attention has been paid so far to the "working conditions" of female fuelwood collectors. Forest workers are provided with special equipment for harvesting trees, yet women collecting fuel for subsistence do the job with their bare hands and primitive tools. Loads weighing 25 to 35 kilograms on average (some were said to weigh as much as 80) are carried for miles on end and very often exceed the maximum weights allowed by the country's labour legislation (most legislation prohibits the carrying by women of loads weighing over 20 kilograms) (ILO, 1966).

The environment, agricultural productivity and income

A typical Peruvian valley in the Andes is graced by eucalyptus trees destined for poles and pit props for mines while the women from the villages

Table 3. Distribution of household expenditures among food, fuel[1] and other items in four countries (%)

Village	Food	Fuel	Other	Total
Indonesia				
Irrigated village	50	10	40	100
Upland village	63	5	32	100
India				
Average of five villages	87	9	4	100
Ghana				
Savannah village	85	5	10	100
Fishing village	81	8	11	100
Forest village	91	7	2	100
Peru				
Coastal desert	69	20	11	100
Sierra	71	5	24	100
High sierra	68	8	24	100
Average of 13 villages	78	9	13	100

[1] Fuel expenditures almost exclusively kerosene (for lighting), except in the coastal desert village in Peru.

Source: As for table 2.

scour the hillsides for bushes and roots for fuel. The Green Revolution in Malari (India) has left the landless and semi-landless without communal forests and with few fuel-producing resources of their own, so they use animal dung for cooking fuel instead of fertiliser for their meagre lands. Women in drought-stricken rural Ghana "mine" their fallow land for charcoal making. Are these women destroying the environment and creating a fuel scarcity? The principal causes of deforestation and fuel scarcity in the villages studied were population growth and the clearing of forests for agriculture. Ironically, deforestation often results in lower agricultural productivity and hence makes it necessary to expand cultivation still further. Present policies have failed on the whole either to increase agricultural productivity on existing cleared land or to generate enough off-farm or urban employment to absorb surplus agricultural labour. Land settlement schemes involving massive clearing of forest areas have often been the response of governments seeking an outlet for growing populations. Because they need to export raw materials in order to earn foreign exchange, many developing countries have also been forced to sell their tropical forests cheaply.

The breakdown of traditional systems of common property management of pasture lands has led to overstocking of animals and overgrazing in many marginal agricultural areas, for example much of the Sahel and Baluchistan (Pakistan). Fast-growing cities and towns and expanding rural industries have also depleted surrounding forests, where the trees have been felled for high-quality wood and logs rather than for the deadwood and minor fuels that rural households use for cooking. Refugee camps and new communal villages, in turn, cast smaller versions of the "urban shadow" on nearby forests.

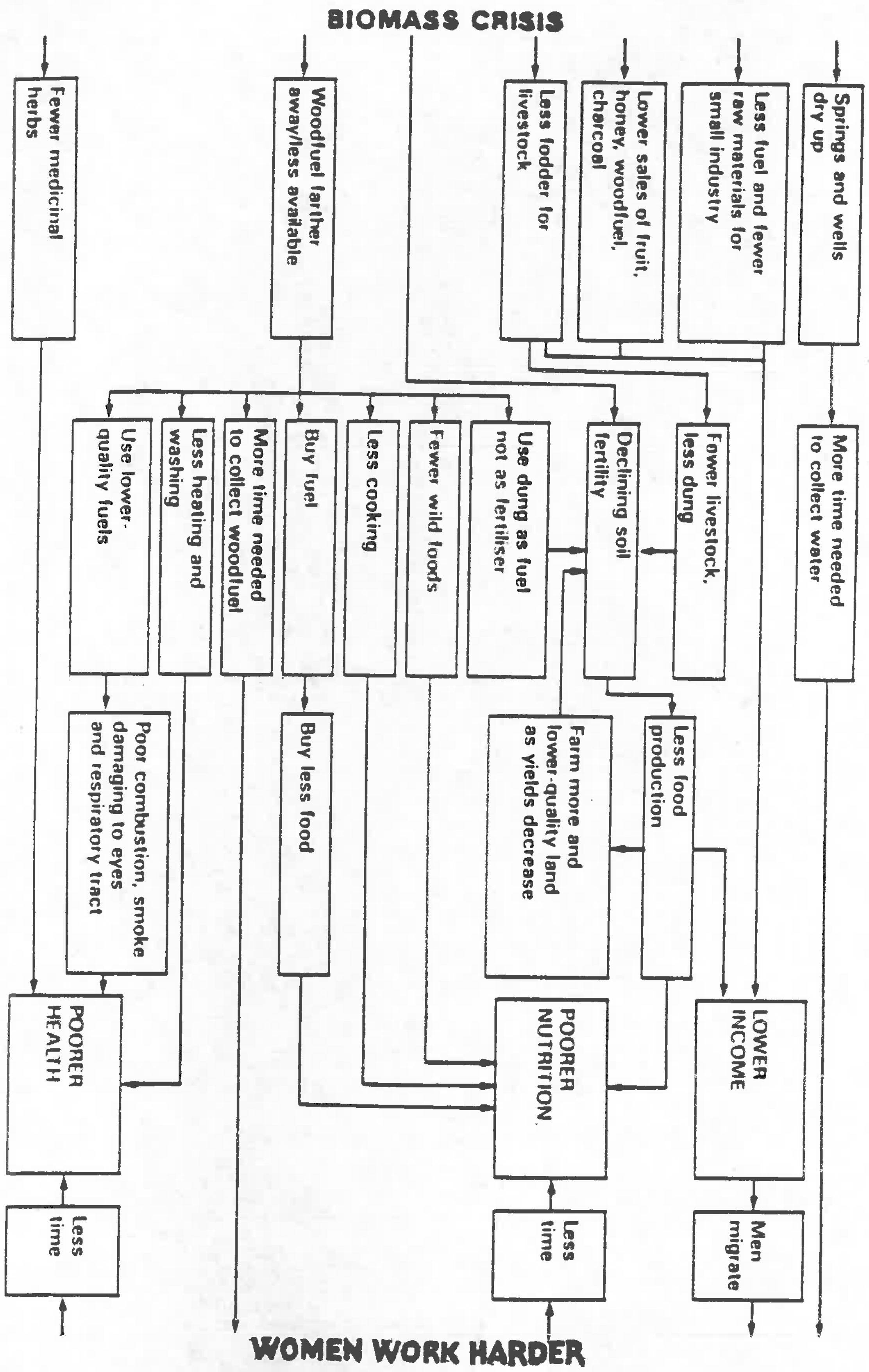
The damage caused to the environment by rural women in gathering a few twigs and residues for cooking is insignificant by comparison. It is hardly surprising that women in the villages studied saw little relation between their own actions and environmental deterioration. People usually feel that the encroachments being made on the environment are the work of external forces, which they and their communities have no power to control, any more than they can control fuel scarcity. Nor is any need felt for specific action to protect the supply of biomass, since fuel has always been considered a "free" good. In some of the Indian villages studied the women said that their fuel problems had been caused by the outside contractors who had come to cut down the trees and by the government restrictions placed on their use of the forest – things they could do nothing about. At the same time the pressures on the environment have had consequences for people's lives of far greater scope than the decline in fuel supplies. In Ghana, for example, the introduction of new cash crops such as cocoa has increased population pressures in settled areas and more land has been privatised. This in turn has restricted women's access to land and their ability to produce food as well as fuel in many cases. Moreover, the struggle of the poor simply to stay alive is so desperate in some countries that long-term fuel supply is often immaterial to them. In most of the countries studied food consumption at the time was below the minimum considered necessary for human survival. Poor women will therefore only feel they have a stake in efforts to tackle energy problems if they lead to an improvement in nutrition and income as well.

Women are hit the hardest by the negative effects of environmental deterioration on incomes and welfare. The most important effect is the long-term decline in agricultural productivity and hence in food production. This means that more land must be brought under cultivation and, since the soil is often unsuitable for farming, leads to still further deterioration. In the western Sudan, for example, the traditional practice of crop rotation has been abandoned on account of the growing population and low rainfall, causing soil erosion and lower land productivity. To compensate for the declining yields, women are forced to cultivate their millet or sorghum over larger areas and to work harder to achieve the same output. Such expansion further accelerates the process of soil erosion and prevents natural regeneration (Berar-Awad, 1985, and Ibrahim, 1982).

While more attention has recently been paid to the relationship between such "natural" disasters and human actions (Wijkman amd Timberlake, 1984), the logical connection between the food-fuel-water crisis and women's central concerns and activities is only beginning to be made (see, for example, Sen and Grown, 1985). The links between the two are illustrated in the figure showing the effects of the biomass crisis on rural women's work and basic needs. Given the sexual division of labour in the energy use and supply system as well as in agriculture, women's activities are affected more than men's work by environmental deterioration. As we have seen, not only is family farming – which is done mainly by women – becoming more difficult and less productive but women's household tasks – fuelwood collection, water fetching and cooking – are also becoming more burdensome. Furthermore, migration of male labour in search of jobs was an important phenomenon in all the villages studied. In many of them more than half the households were, in practice, headed by women for a good part of the year. If food production depends primarily on women's work, it is bound to fall sharply in areas suffering from ecological decline, and especially drought, unless more help is provided to improve their productivity.

In their search for cash income as the biomass system becomes less able to support a subsistence economy, many women in these villages are taking up low-productivity and low-wage crafts, agricultural wage employment when it can be found (at wages often half those of men) and at times even migration. In the countries studied women's contribution to household cash income ranged from one-third in some Indian villages to nearly 80 per cent during the dry season in Ghana. In relatively commercialised rural economies like Ghana and Peru women often have several sources of income, alternating between them seasonally and as opportunities arise. In Mozambique and Indonesia, on the other hand, women have fewer off-farm employment opportunities than men – being mainly restricted to agricultural wage employment – since at least seasonal migration is necessary to take advantage of most. These women make a larger contribution therefore in the form of subsistence production. In all these countries women's contribution to food production is high.

Many of women's key income-generating activities such as food processing and snacks (Indonesia), beer brewing (Peru) and fish smoking (Ghana) are fuel-intensive and the difficulty of procuring adequate low-cost fuel supplies has in many cases made production problematic. In some villages a division of labour among women in the processing of time- and energy-intensive foods has spontaneously developed. In a coastal village in Peru nearly every woman produces *chicha* beer both for sale and for home consumption at least once a week, but at other times she buys the beer from other women producers. In Ghana a variety of processed and semi-processed foods are prepared and marketed by different women, so that one woman may make and sell *fufu* (a cassava dish) while buying soup or smoked fish from other women to make up a complete meal. Partly for this reason (and because of the drought), expenditures on food in Ghana are extremely high (80-90 per cent of total spending). In cities such practices are often carried further by commercial bakeries or, as in Lima, the communal cooking of


BIOMASS CRISIS
Fewer medicinal herbs
Woodfuel farther away/less available
Less fodder for livestock
Lower sales of fruit, honey, woodfuel, charcoal
Less fuel and fewer raw materials for small industry
Springs and wells dry up
Use lower-quality fuels
Less heating and washing
More time needed to collect woodfuel
Buy fuel
Less cooking
Fewer wild foods
Use dung as fuel not as fertiliser
Declining soil fertility
Fewer livestock, less dung
More time needed to collect water
Poor combustion, smoke damaging to eyes and respiratory tract
Buy less food
Farm more and lower-quality land as yields decrease
Less food production
POORER HEALTH
POORER NUTRITION
LOWER INCOME
Less time
Less time
Men migrate
WOMEN WORK HARDER

meals in poor neighbourhoods. If they were promoted on a bigger scale significant savings in both women's time and their fuel use could be made. But it would be necessary to ensure that poor women themselves earn cash from the commercialisation of processed foods for otherwise they might be unable to afford to make or buy these foods at all. This seems to have happened to some extent in West Java where, although numerous snack and processed foods (e.g. *tofu*) are marketed on a larger scale, they are made available to poor families usually only as payment in kind or meals provided by employers.

Woodfuels and other "minor" forest products such as honey, flowers, seeds, leaves and wild fruits are critical to survival when agriculture fails or supplementary income is needed. Wood itself is the basis of much small industry and other forest products can also be sold directly or processed to increase their value, thus providing employment and income. Some 30 million people in India alone are estimated to derive part of their livelihood from forests (Kulkarni, 1983). In the rural areas studied wood collection and charcoal making, transport and marketing are an important source of income for many rural women and men, especially in Africa where rationing and shortages of fossil fuels have kept the cities reliant on woodfuels. The profitability of this market makes plantations for woodfuel processing near cities and towns a promising rural income-earning activity, provided it can be so organised as not to damage the environment and to ensure regeneration. Lessons learned from past experience with other cash crops should be heeded, however, so as to avoid mistakes that harm the poor's welfare, such as displacement of food crops, concentration of land and transfer of resources from women to men. Food production has been adversely affected mainly by "energy crops" such as sugar-cane for alcohol production, though similar harm has been caused by eucalyptus plantations for woodfuel in India.

Here it may be worth adding that the urban poor are probably suffering even more than the rural poor from the effects of fuel scarcity since their incomes have not kept pace with rising prices and they cannot fall back on subsistence production or their own labour in residue fuel gathering. A recent survey found that in Addis Ababa more than two-thirds of the cash income of the lowest income group was spent on cooking fuel (ILO, 1986b). Many of the fuel-saving practices that had been adopted by the poor in this survey had adverse effects on nutrition and health, and these were far more evident than in rural areas – cooking less, reheating, and eating cold food. Some poor households were even using residue fuels dangerous to their health.[2] Because they cannot afford the kind of stoves needed to burn more efficient fuels the poor continue to rely on woodfuels even though their cost (per unit of delivered energy) in most Third World cities today is higher than that of kerosene, gas or electricity. Yet it is the latter fuels that official subsidies often favour. Measures are urgently needed to enable urban poor households to meet their minimum basic energy needs.

III. Policy and project approaches

The findings of the ILO country studies reviewed here raise questions about the effectiveness of many current energy policies and projects and point to some possible alternative approaches. In this section we first discuss how energy can serve as a starting-point for addressing poor people's priority concerns and then describe a participatory approach to project design and implementation in line with these priorities. Strategies combining energy and rural development objectives are then suggested in three areas: managing energy demand and improving family welfare through better household fuel planning; increasing energy supplies while improving rural biomass resources and agricultural productivity; and using energy to increase women's productivity and their incomes.

Energy as a starting-point for rural development[3]

In highlighting the interdependent nature of basic human needs, including energy, the ILO country studies show that the pressure on women's time has greatly increased because of the growing scarcity of accessible woodfuel, together with the loss of food production and income sources resulting indirectly from deforestation.

Yet in most of the villages studied women did not regard woodfuel and cooking efficiency as top priorities. Their immediate preoccupation is the need for quick solutions to desperate food and income deficits. First of all, then, it is essential to help poor women understand the causes of these problems and to gain more control over resources that can provide their families with securer and higher levels of food and income. The need for locally conceived solutions and approaches is borne out by the great diversity of the ecological and other circumstances of the villages, even within the same country.

This does not mean of course that energy supplies are not important to these women. Energy is a very effective starting-point for addressing rural women's priority concerns with food, income and time saving. A schema of three different stages of environmental and socio-economic degradation can be used to put the women's priorities in these villages into perspective (table 4). Stage I is characterised by a biomass-rich subsistence economy; stage II by a natural resource system under pressure; and stage III by an advanced degree of ecological deterioration. Each stage corresponds to a particular priority for energy-related interventions. While conceptually these stages are separate, in practice more than one strategy may be needed simultaneously since many of the villages have characteristics of more than one stage.

In *stage I* signs of degradation are absent. Tree cover provides nitrogen fixation and mineral retention to the soil, while natural springs and rain provide water; agriculture is based on long fallow periods or even shifting cultivation. Access to many types of high-quality woodfuel is free, on

Table 4. Energy shortages and policy priorities at different stages of environmental and socio-economic degradation[1]

Stage	Fuel access/types	Labour time	Income	Agricultural productivity and nutrition	Migration	Policy priority
I	Free access to high-quality wood	Minimal	Forest-based industries and trade, food processing still viable	Little erosion. Nutrition based on a variety of locally cultivated and gathered products	Minimal	*Energy for labour and time saving* to increase efficiency and productivity in specific tasks, e.g. improved animal traction for water lifting, hydro grain milling, better drying for fish and herbs, more efficient beer brewing
II	Access limited and increasingly privatised. Type of fuel used corresponds to income level; the poor mostly use residue fuels being unable to afford more convenient ones	More time spent on fuel gathering, cooking, water collection and agriculture	Forest-based industries and incomes declining	Falls as a result of erosion, diversion of organic matter to fuel. The rich take control of best lands and other resources. Diets depend increasingly on purchased foods	Male migration becomes an economic necessity for poor households	*Energy for cooking and rural employment* to save time and raise incomes, e.g. through energy and resource-based income activities
III	All high-quality fuels commercialised and severe penalties imposed for encroachment on private resources	Satisfaction of basic needs alone requires all household time, with negative effects especially on women's health	No natural resource-based or fuel-intensive industries or employment	Yields of staple crops fall dramatically. Food from relief or purchase. Nutrition and health poor	Out-migration of "ecological refugees" to cities	*Energy for reclaiming waste lands and generating incomes*, e.g. through public forestry and infrastructure works

[1] Concept based on a schema in Newcombe, 1984.

common land or individual plots. Gathered foods and forest products are important in artisanal production and are sold and traded for income. Forest products are also available for housing construction and other uses and forests are a source of food, as well as fodder, especially useful during droughts and the "hungry season". Medicinal plants are widely used and there is sufficient fuel for heating and water boiling. Nutrition and health are sustained by a variety of locally produced items. Male migration is minimal since agriculture and small industries based on local resources provide adequate subsistence.

Energy for labour and time saving is nevertheless needed even in this relatively biomass-plentiful system. More food, easily accessible water and some cash income are frequently needs that could be met through a locally appropriate energy source. Improved animal traction for water lifting, small hydro grain milling, better drying methods for fish or other foods, and more efficient beer brewing are some possibilities. The proper choice depends on a clear analysis of women's existing activities and time use and of locally available non-human energy sources that could increase the efficiency of these activities.

Ecological disequilibria and resource limitations are inherent in *stage II* as loss of tree cover and use of animal dung and crop residues for fuel decrease soil fertility. Finding fodder for animals becomes a problem. As the amount of arable land becomes insufficient for year-round subsistence, permanent or seasonal male labour migration begins, adding to women's work burden. Living trees are felled for fuel by the well-off, but branches and twigs, bushes and residues become the major cooking fuels for the poor. Access to private, state and communal lands is controlled. Fuel entitlements may be tied to employment contracts or depend on kin or other social relationships. Households with enough cash switch to more convenient charcoal or fossil fuels. The amount of time that women devote to the preparation and use of low-quality fuels increases. Sale of fuelwood and charcoal making become important income-earning activities. But other small industries are curtailed on account of the shortage and high cost of raw materials and fuel. Diets become increasingly dependent on purchased foods. Nutrition and health may suffer from lack of wild foods and fuel.

Energy for cooking and for rural employment is needed in this stage to generate cash for the many new items that have to be purchased and to replace jobs lost owing to the deterioration of the biomass base. Basic activities such as cooking and fuel collection take up a large amount of women's time, so that labour-saving cooking technologies may be necessary to release women for income-earning activities. As more activities are commercialised and families are less able to support themselves through their own production, there are also more potential opportunities for women to specialise in income-earning production and processing, e.g. in energy-related and resource-based activities such as making building materials (bricks and tiles), appliances (ceramics), clothing (knitting and weaving) and food processing (drying, baking, brewing), and in petty trade in these products.

In *stage III* ecological decline is patent and biomass and cooking fuels are very scarce. Agriculture is in retreat. Top soil is depleted, ground cover disappears and there are few crop residues for fodder so that livestock raising becomes less viable. Dung, roots and sweepings are the only fuels available and most households must purchase all or most of the fuel they need. Droughts may become increasingly frequent and populations increasingly dependent on food relief. Nutrition and health are poor. The final resort for entire families is out-migration as "ecological refugees" to cities or relief camps.

Energy for reclaiming wastelands and generating incomes on fragile lands is a priority in this extreme situation. Gradual rehabilitation through progressive planting of grasses, bushes and trees and labour-intensive infrastructure works, e.g. terracing and irrigation, could provide the "energy boost" from outside that these degraded areas need, while also employing people displaced from agriculture.

While this rough outline makes it possible to conceptualise the type of energy intervention that may best respond to the priorities of the poor (and especially of poor women) and the local physical and socio-economic circumstances, in order to translate those priorities into effective action a participatory approach to project design and implementation is essential.

Energy for the poor: A participatory approach to project design and implementation[4]

Attempts to remedy the situation should start from an assessment of existing activities, needs and problems made both by external and national experts and by the people themselves. The assessment should be based on participatory methods – which can include both quantitative surveys and qualitative interviews and group discussions. Implicit here is the idea that needs can be effectively identified and solutions acted on only if the individuals and groups concerned have themselves analysed their problems and found the answers. Action research can help the target populations to understand how their immediate poverty problems relate to broader environmental and social issues and to identify technological and other alternatives for making improvements. This approach usually requires a sensitive outsider able to establish close links with key members of the community and provide continuing support to fledgling women's and peasants' groups.

An organisational framework is necessary for helping the people to analyse their needs and to overcome the many obstacles to effective action. The groups set up for the purpose can include both men and women. However, experience has shown that working with women separately, or taking specific measures to make sure that women are able to voice their concerns, is often necessary to ensure that they benefit. If they do not, the project is likely to fail in its other goals as well.

Projects that start from the preconceived notion that improved stoves or village woodlots are *the* solution to the problems facing women will probably not respond to their most pressing needs. However, renewable energy and forestry projects, where they avail themselves of proven energy sources (such as wind-powered irrigation of vegetable or other "home" gardens or hydro-powered grain grinding) and more efficient end-use devices (such as fish smokers and food processing stoves), can help women to meet their priorities of increased income and family welfare while at the same time economising on woodfuels or complying with other energy policy objectives.

Another essential step in this approach is to facilitate access to land, technical expertise and credit. Secure legal land rights are fundamental for any forest- or agriculture-based activity. The lack of access to appropriate technical expertise is a major obstacle for women in improving their productivity. Special mechanisms such as group credit, as well as group access to marketing and raw materials, are also needed to enable the poor to undertake new activities.

Let us now see how this approach can be applied in trying to achieve two common energy policy goals – managing energy demand and increasing energy supply – by combining them with rural development objectives.

Managing energy demand and increasing family welfare through improved household fuel planning and cooking efficiency[5]

Managing energy demand obviously implies dealing with the needs and preferences of energy consumers, and in households these are primarily women. Many attempts to popularise new, more efficient stoves have foundered on the discovery that women cooks are not chiefly concerned about saving fuel. Even where fuel is commercialised, as in urban areas, fuel savings are often considered less important than time saving and other user conveniences. Partly for this reason, the results of efforts to save fuel have often been disappointing (Manibog, 1984; Foley and Moss, 1983).

Moreover, given the decline in fuel use and living standards that many poor families are experiencing as a result of higher costs and growing scarcity, it would hardly be surprising if more efficient stoves and fuels were being used not to save fuel but rather to restore family welfare (e.g. use of heating, more cooking) to pre-scarcity levels. This is why it may be unrealistic to launch programmes to improve cooking efficiency with the sole aim of saving fuel. It is also why nutrition and health planners and extension services, as well as energy policy-makers, should be involved in planning and carrying out such programmes. If they are to be successful, such programmes must be implemented by interdisciplinary teams and based on a systematic assessment of needs.[6] The characteristics valued by women in cooking should be determined before the programme is launched, and the stove design should provide for local variations in cooking habits, fuels, seasonal and alternative uses of the stove, and so on. The nutritional and health aspects of women's cooking are also extremely important.

Stoves should be properly designed and tested by both technicians and cooks to ensure that they *do* deliver promised benefits in fuel saving and other respects. The collaboration of stove technicians with consumers' (women's) groups can be an effective way of choosing stoves to satisfy individual needs, as was confirmed in a recent project in Ethiopia (ILO, 1986b). Adequate production capacity and marketing networks must also be ensured.

The urban areas should receive special attention, partly because of the often desperate need of the urban poor for cooking fuel and partly because these areas tend to siphon off rural woodfuel resources. A variety of alternative fuels, stoves and other means of achieving fuel economies should be considered. Improved stoves are in fact more likely to catch on in urban or highly commercialised rural areas, where the cash costs of inefficient fuel use are high. Co-ordinated approaches to cooking practices, pot materials and types, diet, and fuel preparation and storage may be as effective in saving fuel as are improved stoves, and merit more attention.

Stoves projects in rural areas, however, come up against great obstacles. The low cash cost of biomass fuels in most areas tends to make the purchase of artisan-made stoves financially unattractive despite the potential saving of women's time in fuel collection. On the other hand the fuel efficiency and ease of construction of low-cost owner-built "mud" stoves have been increasingly questioned: smokelessness, prestige and other factors may be more important than fuel savings for some rural users.[7] Improved stoves certainly have a part to play in reforestation programmes and in the general efforts of extension agents to improve nutrition and health.

Biogas technology has not lived up to its expected potential for providing rural cooking fuel either; successful household or community projects are rare. However, biogas experiments may have failed because it was mainly men, without much interest in household energy, who organised them and set the objectives. Pilot projects for biogas plants run by women, for example a cattle-owning group, might therefore be tried.

While some changes in food use patterns in response to fuel scarcities have been identified (reducing the number of meals, cooking less, eating processed foods), the links between fuel savings and nutrition need to be investigated more thoroughly in the light of other factors; nutritionists should, at the very least, establish what potential effects such dietary changes may have on nutrition. The apparent inverse ratio between time spent on cooking and that spent on fuel collection also has nutritional implications which should be looked into more closely.

Nutritionists could also help to identify fuel savings that could be made in food preparation. Basic information on the quantities of fuel needed to cook different foods, or at least on cooking times and methods, is needed to show how foods can be cooked with less fuel. Other cooking methods and the use of retained heat, or hayboxes, might also be systematically investigated and the findings disseminated by nutritionists and home economists. The availability of processed foods also changes food habits, and their consumption often has a detrimental effect on nutrition. On the other hand, the availability of ready-to-eat "street foods" reduces the fuel demand of many households.

Increasing energy supply and promoting agricultural productivity: Forests and land for food, fuel and fodder

Like demand management, energy supply development must take into account users' priorities, especially those arising from the shortfalls in food and income that households have experienced as a result of the general rural biomass crisis and the decline of agricultural productivity. Fuelwood is the lowest-value wood product of forests and therefore is unlikely to be the most important product for rural households (unless profitable external markets such as cities are nearby and natural forest resources are depleted to the extent that cash cropping of trees for sale becomes worth while). Yet it is also clear that it is far beyond the capacity of forestry services to plant enough trees to meet future wood and fuel needs. This can be done only by decentralising tree planting and therefore fuel production.

It has been explained above why, with the biomass crisis, rural women urgently need alternative sources of food and income. These needs could be met by combining tree and other biomass planting.[3] Increasing food production was the top priority identified in Ghana and Mozambique, yet fuel is scarcer than food in some areas of Kenya, fodder for livestock is an important need in much of Asia, and in the relatively monetised rural economy of Peru earning cash income from natural resources is essential. The nature of the agrosilvicultural farming system that ought to be introduced will depend partly on households' and women's access to land: agroforestry can be practised on small farms, and food/fodder/fuel production can be combined in home gardens, on wastelands or on communal holdings. The legal and sociological obstacles to women gaining control over land deserve special attention.

Where the priority needs are to stabilise soil production, to generate income and to grow other products, the solution may be to *combine trees and field crops* on women's own holdings or on family land. This approach need not be limited to tree planting but can include bushes and other plants: or there may simply be a need for better management of fallow and shifting cultivation, e.g. by leaving some of the more valuable species when clearing. Scattered farm trees, improved fallows, alley cropping, mulching, buffer strips, terracing, windbreaks, live fencing and "interstitial" planting between crop fields are agroforestry techniques that can be practised on farms to improve agriculture and also produce wood, fodder, fruits and so on, either for immediate sale, for further processing or for home consumption.

Even in areas where land is scarce or where women do not control extensive farmland, the land immediately surrounding the homestead is often used by women to grow vegetables and other foods for family consumption. The productivity of these *home gardens* can often be greatly increased by combining tree and bush cultivation with agriculture. Like more extensive agroforestry, home gardens can provide food, fodder and fuel (not to mention cash income); and the time previously spent on walking to gather such resources can be put into cultivating the gardens. The diversity of crops and products in these agroforestry systems can also help to avert the problem of seasonality and timing of production, so that some food crops are available when supplies are otherwise low.

Near cities or industrial markets, other potential income-generating activities lie in the production on *wood lots or orchards* of fuelwood, charcoal, poles, fruit or other items for sale or further processing. Women already have experience with food and raw material processing, charcoal making and wood preparation, and with trade and commerce in these products. These wood lots and orchards could also serve to provide wood and other products for home consumption.

The above proposals for making good the existing food and income shortfalls are all based on the assumption that women can add trees to land they already control. However, many women head, or belong to, families that have no land, especially in certain parts of Asia and Latin America. Yet these women have an even more urgent need for biomass products and income. Enormous expanses of uncultivated *wastelands* (overgrazed pasture lands, communal property, roadside ditches, etc.) exist on every continent. Some governments have already launched experimental schemes to give the poor access to such land. While the most notable example is India, such schemes are not limited to Asia. In Lesotho, for instance, it has been proposed that deep gullies caused by erosion should be reclaimed by leasing them to co-operatives of the landless in return for a labour commitment to maintain the reclamation infrastructures.[3] The potential for land regeneration in the Sahelian region, for example as part of labour-intensive public works, is obvious.

Because of their need to secure quick returns of food and income, women and the poor in general will have to start gradually with quick-growing grasses, food crops and medicinal herbs, for example, before they can invest in bushes and trees that take longer to grow. This sequence could also help to restore degraded lands. External assistance will often be required to enable poor groups or individuals to secure rights to these lands. Even where property rights as such are not acquired, right of access to what is grown on the land would give women a guarantee that the fruits of their labour are not lost to others. While individual control over land may be a necessary incentive in some situations, in others groups may be able to carry out activities jointly. Organisations of women and the rural poor will also require external assistance in obtaining the expertise, credit and marketing facilities they need.

Using energy to improve women's productivity and incomes

In all of their income-generating activities women are handicapped by their restricted access to land, raw materials, technology, skills, credit, extension services and so on. Transport and marketing (apart from what they can carry on their heads) are often major problems because of the constraints on their mobility and social contacts and because they seldom own means of transport, whether donkeys or trucks. To produce sound results any income-generating project must solve the problem of access to these essential inputs.

Energy is only one of the inputs needed for successful productive activities but it is crucial in determining the labour requirements and productivity of any small industry. So far, however, direct energy use in women's productive activities has received little attention.

More efficient energy supplies could improve the productivity of women's small-scale industrial work, especially work that is fuel-intensive such as food processing and ceramics. The scarcity of both fuel for process heat and labour for cutting, grinding, stirring, etc., often puts limitations on women's non-agricultural activities. Fish smoking ovens, rice parboiling units, oil purifiers, palm fruit sterilisers, crop driers and roasting units are examples of fuel-saving equipment that could increase the profitability of women's post-harvest and food processing activities.[10] They should be viewed, however, as part of a package of inputs needed for income generation, together with raw materials, credit and marketing.

Perhaps the most important constraint that women face, however, is their lack of time: this is the "real energy crisis" for them (Tinker, n.d.). The availability of alternative energy sources could release women from repetitive, unproductive household tasks and thus give them more time for productive work. The improved household fuel supplies and technologies discussed above are one such strategy. Time- and labour-saving technologies are crucial for improving women's productivity, income and health, but, ironically, in order to purchase such technologies women must first earn income or have access to credit.

The differentiation made between "household" and "productive" work and the low value placed on women's work generally are obstacles to improving the productivity of their household work. Although time-use studies have highlighted the long working hours of women, the opportunity cost of women's time is usually considered to be zero. Alternative methods of evaluating women's time are needed. One possible approach is cost-benefit analysis to quantify the cost of fetching and preparing woodfuel (as well as other household tasks), based on local minimum wage or current agricultural wage rates, in order to arrive at a realistic idea of women's economic contribution. Such assessments could then be compared with similar analyses of the cost of providing subsidies for alternative fuels and/or credit systems for the purchase of alternative stoves.

Conclusion

Rural women are shouldering the major burden of environmental degradation and economic distress in many developing countries: working longer hours to produce enough food and income to support their families while having at the same time to collect fuel and water, with less family labour available because of male migration. In times of crisis, such as drought and famine, women's contribution to family income and survival is even more crucial. Yet the access of many women to resources, including energy, is actually declining, while their workload is increasing. Fuel for cooking and heating, wild foods, fodder, and biomass raw materials (including energy) for small industry are becoming increasingly scarce in many regions and the shortages, which can have serious repercussions on family nutrition and health as well as on incomes, are likely to get worse.

Neither energy policies nor rural development policies have so far come to grips with the links between rural women's work, energy and the environment. Poor women have often failed to see the links themselves because of their overriding, immediate preoccupations with food and income. Energy can nevertheless serve as an extremely useful starting-point for meeting women's priorities through participatory projects. Grass-roots organisations have a vital role to play in identifying group needs, in obtaining access for the poor to such essential inputs as land, credit and technical expertise and in overcoming other obstacles.

It is possible both to manage energy demand and to increase family welfare through improved household fuel planning and cooking efficiency. Woodfuel supplies can be increased and agricultural productivity promoted through agroforestry and other more efficient ways of using land to produce food, fuel and fodder. Decentralised energy supplies can improve the productivity of women's income-generating and household activities. And by combining rural development and energy goals in a participatory approach, it is possible to meet both objectives more effectively.

Notes

[1] Examples cited in this article are mainly drawn from the following ILO country studies: E. Alcántara et al.: *Crisis de energía rural y trabajo femenino en tres áreas ecológicas del Perú* (Geneva, ILO, 1986; mimeographed World Employment Programme research working paper; restricted); E. Ardayfio: *The rural energy crisis in Ghana: Its implications for women's work*

and household survival (Geneva, ILO, 1986; mimeographed World Employment Programme research working paper; restricted); S. Dasgupta and A. K. Maiti: *The rural energy crisis, poverty and women's roles in five Indian villages* (Geneva, ILO, 1986); P. García et al.: *Trabajo femenino rural, combustible de uso doméstico y nutrición familiar* (Geneva, ILO, 1986); Indonesian Rural Women's Work and Energy Project Team: *Rural women and social structures in change: A case study of women's work and energy in West Java, Indonesia* (Geneva, ILO, 1986; mimeographed World Employment Programme research working paper; restricted); F. Sow: *Les femmes et les projets d'énergie au Sénégal: impact sur le travail féminin et le bien-être familial* (Geneva, ILO, 1986).

[2] Plastic wastes reported to be eating away metal roofs and chat twigs said to transmit tuberculosis.

[3] I am indebted to Ben Wisner for many of the ideas, and indeed for key phrases, in this section (Wisner, 1986).

[4] For a comprehensive discussion of participatory approaches see in particular P. Oakley and D. Marsden: *Approaches to participation in rural development* (Geneva, ILO, 1984) and ILO: *Report of a Regional Workshop on Women's Organisation and Participation in Development*, Madhurai (India), 18-22 November 1985 (Geneva, forthcoming).

[5] This section and the following one are based on the findings and conclusions of a Preparatory Meeting on Energy and Rural Women's Work held in Geneva in October 1985 (ILO, 1986a).

[6] Some useful guides to stove project assessment and monitoring have recently been published. See, for example, Joseph et al., 1985, and Intermediate Technology Consultants, 1985.

[7] In one of the villages studied in West Java improved stoves were introduced under a rural development programme to raise the inhabitants' consciousness of women's work and the technology they use in the household, to stimulate interest and experimentation in technologies with forward and backward linkages to rural industry and marketing, and to provide a fledgling co-operative with the challenge of managing a technology and small industry development problem, in addition to saving fuel (Poerbo et al., 1985).

[8] The following section is based partly on French, 1986.

[9] Personal communication to the author from Ben Wisner.

[10] A useful manual on these and other ways of easing rural women's work is ILO, 1984.

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PART II

MOBILIZING RENEWABLE ENERGY TECHNOLOGY IN DEVELOPING COUNTRIES: STRENGTHENING LOCAL CAPABILITIES AND RESEARCH

1. INTRODUCTION

Background

The increased price of fossil fuels and the threat of deforestation present the developing countries with a major challenge. An important element in their response will be the mobilization of technology for the use of renewable energy resources. 2/ Renewable energy will do more than save scarce foreign exchange by replacing increasingly expensive fuel imports. Not only will it continue to be the major source of cooking fuel for the poorer majority, but it will also provide energy for development in forms that are less costly, more efficient, and more appropriate than expensive fuel imports.

In seeking to increase their use of renewable energy, the developing countries face three obstacles. First, they face a rapidly evolving technology since renewable energy technology was neglected in favor of fossil fuel technologies during the years that cheap petroleum was available. Second, they must choose, for a broad range of applications, from technologies that vary in sophistication from photovoltaic cells to clay stoves and village fuelwood

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2/ Renewable energy is used in this discussion to mean an energy form, the supply of which is partly or wholly regenerated in the course of the annual solar cycle. The specific forms of renewable energy discussed are solar and wind energy, small hydropower, and fuels of vegetable origin. Large-scale hydroelectric power is not considered because it involves conventional technology with a well-established role in electric power systems. Wave, ocean thermal, and tidal power are also not discussed. The line between renewable energy technology and conservation technologies has been somewhat arbitrarily drawn: specifically, wood stoves are considered, but passive solar architecture is excluded.

lots. Third, many of the rapidly changing technologies that they must become acquainted with and match to their needs were developed to meet needs other than their own. These obstacles can be overcome if appropriate and adequately funded research and development efforts are supported by the international community.

Where will the technological advance required for the practical applications of renewable energy in developing countries originate? Much of the impetus will stem from the efforts of public or private companies in industrialized countries. These companies are responding to the new energy economics by using modern materials and established engineering principles to improve neglected technologies, as well as to develop new technologies.

To speed this advance, several industrialized countries (and a few developing ones) have encouraged research, development, demonstration, and commercialization of renewable energy technologies and applications. These activities have taken place in both government institutes and in the productive sector. 3/ They range from the applications of well-known principles of science and engineering to explorations at the frontiers of knowledge. The policies and programs involved are concerned mainly with sophisticated technologies needed by the industrialized countries. Once these technologies are proven, they will become available to the developing countries through normal commercial channels. Advances in such fields as the hydrogen economy, photosynthesis, and fusion could have major long-term effects on energy use throughout the world.

3/ The productive sector refers to that part of the economy, whether privately or publicly owned, which produces goods and services.

Experience shows, however, that technology imported from industrialized countries seldom matches the needs of developing countries. It requires major changes in scale and extensive adaptation to suit local conditions. This is true even for the modern sector of developing economies. Many technologies of great potential use in the developing countries have only been minimally tested in these countries. In any event, such technology is frequently beyond the resources of poor people in developing countries. Their special needs are unlikely to attract investment in innovative technology from the private sector.

For these reasons, many of the technologies needed in developing countries will be developed or adapted locally or will be transferred from other developing countries. The widespread application of these technologies can be brought about in developing countries by two significant steps: by advancing or adapting these technologies; and by building within the developing countries the capability to undertake these advances and apply them effectively. This task requires competence in engineering and in both the natural and social sciences. It requires the ability to assess needs and resources. And it requires the skill to choose, adapt, and create the necessary technologies, as well as the ability to establish appropriate institutions for the manufacture, commercialization, and distribution of these technologies.

The Report

The World Bank has recognized the need of its member countries to meet the challenge of developing their renewable energy resources. It constituted a Task Force on Renewable Energy in December 1979 to consider the Bank's role in the development of renewable energy and to recommend an action program for Bank lending and activities in the years immediately ahead. The findings of the task force are reflected in the Bank's report Energy in the Developing Countries (August 1980) and are presented in detail in the paper Renewable Energy Resources in the Developing Countries (November 1980). These documents reflect the Bank's commitment to support the development of renewable energy both by expanding its investment lending, particularly for fuelwood and alcohol production, and by providing greater technical and financial assistance for the strengthening of developing country institutions.

In Energy in the Developing Countries it is pointed out that "attention needs to be given to strengthening national research programs and to the possibilities of organizing international programs of research on specific renewable energy technologies." The Bank has been particularly concerned with research and development requirements for increasing the utilization of renewable resources in developing countries and with the scientific and technical capabilities of developing countries for using renewable energy. During a special study of these subjects undertaken in connection with the Task Force exercise, consultants prepared reports on renewable energy programs and capabilities in a number of developing countries, on bilateral assistance for renewable energy development, and on biomass production research needs; additional analyses of renewable resources and technologies were prepared by Bank staff and consultants. To review and reinforce its work in this area, the Bank also convened in November 1980 the Ad Hoc Advisory Committee on Research and Technological Capacity for the Use of Renewable Energy, consisting of twelve experts from developing and developed countries.

The discussion of renewable energy resources in this report is divided into three sections. It begins with an assessment of needs for building a local capability for mobilizing renewable energy technology in developing countries. This theme is treated first because the basic issue for developing nations is not so much promoting the development of particular items of technological hardware, but rather developing the capability to identify problems and match solutions to them. After a brief overview, the section reviews the present state of national capability and the scope of existing aid programs. It concludes with several recommendations. The following section addresses the need for research into and assessment of an extensive list of technologies relevant to the needs of developing countries, beginning with agricultural technologies for biomass production and their applications, and then technologies for generating heat, mechanical, and electrical energy. On the basis of this review, new international programs are proposed. The final section summarizes the report's recommendations and possible institutional arrangements for implementing them.

2. BUILDING CAPACITY IN DEVELOPING COUNTRIES FOR MOBILIZING RENEWABLE ENERGY TECHNOLOGY

Because many techniques at various levels of sophistication can be used for expanding renewable energy resources, some degree of local technological capacity in renewable energy is within the reach of every developing country. Some countries are planning and implementing major integrated multisectoral programs for the exploitation of renewable energy resources. They aspire to leadership in areas that require a substantial industrial and technological base, such as the production of ethanol fuel from biomass. Other countries may find it more appropriate to concentrate on adapting and diffusing simpler, less expensive technologies, such as cooking stoves and biogas.

The aforementioned report on "Renewable Energy Resources in the Developing Countries" stresses the two important roles of national research programs: "In the first place, [they are] a vital part of the technology transfer/absorption mechanism in that they enable developing country scientists and technologists to acquire direct working experience with the new technologies. And, second, they enable the developing countries to acquire the technical ability to adapt imported technologies to the local environment and to improve on traditional local technologies."

The full range of requirements for mobilizing renewable energy technology in developing countries is very broad because mobilization involves many interrelated activities: resources have to be surveyed, needs have to be assessed, existing technology has to be reviewed and matched to national resources and needs, and research must be undertaken to develop and/or adapt technologies. The technologies so developed must be demonstrated, and steps taken to assure their local manufacture, commercialization, and diffusion. Policies also have to be established concerning the economic and sociocultural elements affecting use of renewable energy resources, and this includes establishing incentives for their use. Furthermore, the consideration of renewable energy must be integrated into a broad energy policy covering sectors such as agriculture, industry, urban development, and transport.

This type of comprehensive approach to technological development should stimulate institutions ranging from those of the scientific and technological infrastructure--universities, government laboratories, extension services, and the like--to the engineering groups of operating ministries or of private or public sector manufacturing firms, and consulting and engineering organizations. Also involved will be nongovernmental organizations active in community development, resource survey groups, analysis divisions of energy or planning ministries, and private individuals. A proper balance will have to be achieved between efforts to stimulate technological innovation and adaptation and efforts to diffuse technology and encourage its use.

The effective mobilization of renewable energy technology depends on cooperation and synergy among these organizations and individuals. The precise form of this cooperation will depend on a specific country's objectives; on its social and cultural traditions; on its finances, basic materials, and human resources; on the level of its overall development; and on the technologies it needs to use. Local cadres in China, for example, have taken major responsibility for the design and implementation of projects for biogas, small hydropower installations, and village fuelwood. National and provincial organizations are responsible for advanced training, research, and the planning and coordination of the technological development involved. In Guatemala, India, and Sri Lanka, informal voluntary organizations with an intimate understanding of local problems have made important contributions to biogas projects and to the improvement of cooking stoves. Brazil, on the other hand, has a national program on fuel ethanol, which is centrally managed by the federal Ministry of Industry, although most investment is undertaken by private firms. Participants in the program include the national petroleum monopoly, several national laboratories, private research centers, and a large number of manufacturing organizations.

The worldwide response to the new energy era is at an early stage. Insofar as renewable energy is concerned, the adequacy of this response in developing countries will depend, in the first instance, on the creation of sufficient political awareness and commitment. Policymakers must therefore be provided with adequate information on renewable energy needs and resources in the context of overall energy planning and policy advice. To date, the development of renewable energy has often been neglected in the formulation of overall energy policy. The integration of technological capacity with policy making in the renewable energy field, and of renewable energy with overall energy problems, is an objective that has proved as elusive as it is desirable. It must nevertheless be pursued by developing as well as developed countries.

Present State of National Capability

Almost every developing country is attempting to improve its use of renewable energy resources. These activities range from major investments to a few uncoordinated demonstrations. A preliminary review of nineteen countries indicates that their capabilities for mobilizing renewable energy technology stand at three general levels:

At the highest level are countries with a full range of institutions, technical skills, expertise for social analysis, and policy commitment for renewable energy; next, we find countries with a relatively recent policy commitment but only a limited capability, or conversely some capability but no policy commitment; the third level is characterized by countries with a minimal policy commitment and a low level of capability, activities are limited to a few projects, both technical skills and the mechanism for the diffusion of renewable energy technology are limited, and there is little coordination among the few institutions or individuals showing initiative in this area.

Among the countries at the first level, the policy commitment to mobilize renewable energy technology is generally high. There is a strong, or a rapidly emerging, scientific and technological community, supported by adequate facilities. These countries have a substantial manufacturing base and there exists a degree of synergy among the organizations concerned with renewable energy technology.

One of these countries has effectively diffused biogas, small hydropower, and village fuelwood systems throughout its rural areas. It has done so as part of an overall development strategy that emphasizes building local self-reliance, technological infrastructure, and the capability for decisionmaking and innovation. Another has concentrated on the development of alcohol fuels, an area in which it is a world leader, and it also has capabilities and programs in other areas. Two others pursue research and diffusion programs in almost all areas of renewable energy. Another employs policies that encourage renewable energy applications. It has established a large number of research, manufacturing, and training institutions dealing with renewable energy technology. Senior personnel are limited in number, but the government has introduced an aggressive program to encourage skilled emigres to return. Still another country, though not as advanced as others in this category in terms of manpower and infrastructure, has a framework for research, manpower training, and diffusion of technology.

Countries at the second level of capability have concentrated on relatively simple technologies. The commitment of their governments to the use of renewable energy resources is leading to the creation of an infrastructure, of human resources, and of appropriate policy and institutional mechanisms. Most of these countries lack technical personnel and rely on expatriates for their senior staff. In one country the need to develop strong organizational and project management skills in public sector organizations was identified as a critical condition for further progress. Some countries have a large number of entities working on renewable energy, and are in the process of formulating policies to establish linkages among them. Others are capable of research and manufacturing, but not of performing surveys or making energy assessments. Others have a concrete plan, but lack the financial and technical resources to implement it. Accordingly, mechanisms for commercialization and diffusion have not yet fully evolved in these countries. They have achieved a reasonable degree of informal cooperation at the working level, but lack a mechanism to insure that renewable energy projects are continuous or that they are consistent with broad national objectives.

Countries at the third level lack an institutional framework for formulating policies and programs for the development and diffusion of renewable energy technologies. Activities are limited to a few uncoordinated projects. A few countries in this group have virtually no indigenous capacity for either research or diffusion. The few active projects that are being undertaken in the countries are managed and executed by expatriates. There is no evidence of a coordinated attempt to develop and exploit renewable energy resources. Of this group, two oil-exporting countries have given low priority to renewable energy resources and have not tapped their skilled manpower potential. As a result, even the limited activities pursued at universities and other research centers are isolated and fragmented. In another oil-exporting country, skilled scientific researchers are working on a few projects and have well-equipped facilities, but there is no apparent interest in diffusion or commercialization of renewable energy technology or equipment. In two other countries, the research effort is neither coordinated nor linked to the productive sector for diffusion and commercialization. Both these countries have recently begun to develop an energy plan.

In certain parts of the world, efforts at regional cooperation in the field of renewable energy have begun. Such cooperation would allow countries to pool their limited financial or technological resources. In West Africa, for example, six nations (Senegal, Mali, Niger, Upper Volta, Ivory Coast, and Mauritania) have agreed to establish a regional renewable energy institute in Bamako (Mali), linked to affiliated centers in member countries. A number of Pan-Arab organizations, including the Organization of Arab Petroleum Exporting Countries (OAPEC), have expressed interest in cooperation among Arab countries in renewable energy research.

Assistance Programs

An increasing amount of financial and technical assistance for the development of renewable energy resources has been made available to developing countries in recent years under bilateral and multilateral programs. A survey of eight bilateral programs indicates a mounting interest in renewable energy assistance from this source, although the programs studied varied widely with respect to organization, funding, and program development. 4/ The World Bank has been increasing its lending for fuelwood projects and, as already indicated, intends in the future to expand substantially its lending for the development of this and other renewable energy sources. The regional development banks have also been concerned about increasing their support for renewable energy. Almost all of the major specialized agencies in the United Nations system now have programs for renewable energy, and the regional commissions are also paying increasing attention to this area.

Most of the developing countries are receiving assistance under one or more of these programs, which have undoubtedly contributed to the development of renewable energy awareness and technology in a number of important ways. In general, however, existing assistance programs do not appear to have fully recognized the critical importance of building local capability for renewable energy development. Not much attention has been given so far to the analysis of needs, the development of local capability to undertake research on the technological, social, and economic impact of renewable energy resources, or to planning for the widespread utilization of these technologies. The creation of local institutions and mechanisms for the marketing and commercialization of renewable energy technologies has also been neglected. Specific projects have frequently been regarded as ends in themselves rather than as a means for securing, through extensive testing, evaluation, and adaptation, the widespread use of the technologies within the country.

4/ T. Bartlem and R. T. Hoffman, "Policies and Programs for Renewable Energy Assistance in Eight Development Agencies: Summary and Critical Evaluation" (World Bank mimeo report, January 1980; available from the Science and Technology Unit). The eight programs are those of United States, United Kingdom, France, the European Economic Community, Germany, Canada, Sweden, and the Netherlands.

Programs of bilateral aid for the development of renewable energy resources are relatively new and still evolving. Most of them have been oriented toward the demonstration of hardware developed in the laboratories and enterprises of the donor country. Some donor countries have attempted to use aid to create export markets in the developing countries for their own solar industries. Most of the research is still done in the home country. The technologies are not designed to suit conditions in the developing country; rather, many project conditions seem to be chosen to display and test the technologies under particularly favorable circumstances. Now that they have gained experience in renewable energy assistance, however, the bilateral agencies seem to recognize increasingly the importance of building local capability.

Many aid agencies are inadequately informed about the activities of other such agencies. They could benefit from a systematic exchange of information, including interagency meetings. Topics involved could be the overall level of efforts of each agency in each country and in each technology, as well as information on project plans and experience. This process should have a threefold impact: the agencies could learn from each other's experiences, avoid duplication of efforts, and agree on priority areas for aid activities. Ideally, incountry coordination is the task of the recipient country and is an element of local capability. The purpose of coordination among donors would be to make this task easier.

Recommendations

The extent to which countries need external assistance in developing their capability for the use of renewable energy resources depends on three factors: commitment, current capability, and national resources and needs. The following recommendations, which have taken into account these factors, first consider the three levels of capability already described, and then address broader needs.

Developing countries of the first group have substantial programs for development of at least a few kinds of renewable energy resources and several have successfully manufactured internationally competitive equipment. Equally important, they have achieved a degree of synergy among different programs and at least the beginnings of coordination with policymakers. Several countries have done this with little or no outside help. In their fields of competence, these countries can relate to the scientific and technological community of the world as full members or even as leaders. They can collaborate with their peers in other countries, define their own needs for expert assistance, and offer assistance to other developing countries less advanced in these fields. In these countries, needs for international cooperation are likely to involve advanced training, the expansion of existing infrastructure, and funds for research, development, engineering, demonstration, and market development. The funds would be channeled both to government institutes and to the private sector; and would include measures to facilitate international collaboration with national researchers. Measures to encourage the transfer to and mastery of imported technology in the private sector may also be needed, as well as measures to facilitate joint ventures and other suitable business arrangements between domestic and foreign firms.

Countries of the second group have recognized the potential importance of renewable energy. They have made a start, in most cases a small one, toward launching a balanced program and policy reasonably consistent with their equally limited overall energy efforts. These countries, in most cases, need external assistance in formulating and executing policies and programs. They also need help in developing a manpower and institutional base. If such assistance were offered, these countries would be expected to respond favorably, as they are in the early stage of building their capability. It is particularly important that investment and demonstration projects in these countries be planned and implemented in such a way as to maximize the building of local capability. Close linkages between research, development, and demonstration programs and the productive sector should also be encouraged.

Awareness of the potential importance of renewable energy technology is very low in the third group of countries. Research, development, and demonstration activities are confined to laboratories, frequently in universities, which are isolated from potential users. In such countries, official interest and support might be best attracted by a dual approach, that is, one that would combine policy studies projecting energy needs and the available resources and technologies with a program aimed at selecting, adapting, and diffusing a particular renewable energy technology to meet some major national need. Such programs can be effective only if they carry through all stages of the innovative process, including the identification of a need, the selection and adaptation of a technology, and commercialization and diffusion, at least on a pilot or, preferably, on a semicommercial scale. If this process were successful, it would be followed by international support for broader technological infrastructure programs in renewable energy that would include appropriate diffusion mechanisms.

Whatever the level of involvement in renewable energy, most developing countries need to conduct a substantial training program. Such a program for renewable energy professionals should include not only training in a professional function but also measures to facilitate career development, for example, international travel and collaboration and sabbaticals abroad. There is also a need for broad multidisciplinary training of energy planners, training in specific technologies, and training of professionals for whom energy is not a primary concern, such as irrigation or transportation specialists. There is a particular need for short courses to inform energy planners who were trained only in conventional technology of developments in, and potentialities for, the use of renewable energy.

An effort should be made at the national level to collect the technical and socioeconomic data needed to formulate national policies on renewable energy. A helpful approach is to establish the pattern of energy demand and supply. Simple models can then be applied to provide different scenarios for judging the overall impact of renewable energy technologies. Patterns of energy use in villages should also be studied.

Bilateral and multilateral development assistance agencies should expand and intensify their efforts to assist in the building of local capabilities. Such efforts should encourage cooperation among scientists and organizations of developing countries whenever appropriate to the task at hand. Indeed, renewable energy provides a particularly fertile ground for technical cooperation because much information of primary interest to one country may derive from the experience of others.

Development assistance agencies should ensure that their projects take into account local capability to assess needs; to evaluate the appropriateness of technologies to address those needs; and to choose, adapt, create, and diffuse suitable technology, including local manufacture when appropriate.

Investment projects for the large-scale application of proven renewable energy technology should be undertaken in such a way as to promote the building of local technological capability and the linking of that capability to the social and economic needs of the country. This development of local capability is a normal aspect of the operational work of the Bank and of many other agencies that assist in development, but it deserves special emphasis in the case of renewable energy technologies. In some cases adaptation of policies and procedures within the aid agencies may be required. This would accommodate the need to plan and to monitor closely the spending of relatively small sums of money for critical capability-building undertakings.

Assistance for the development of technical capability to mobilize renewable energy technology seems particularly suited to grant financing, and there is a critical need to maximize the availability of grant financing to assist the development of this capability. It is unrealistic, however, to expect that sufficient international grant financing will be available to meet all such needs and developing countries should not be reluctant to borrow, if necessary, for the purpose of strengthening their scientific and technological capabilities, in view of the potentially high returns to investments for this purpose.

Aid donors have already begun to reorient their activities in the directions suggested above. They can be further stimulated to provide financial and technical assistance to aid local research, development, demonstration, and diffusion capabilities if priority requirements are expertly identified and reflected in projects suitable for financing. Special efforts should therefore be made to diagnose needs country by country, and to assist in the elaboration of national plans of action for developing technological capability for utilizing renewable energy resources. Practical constraints, such as emphasis on promoting the export of hardware developed in the donor countries and, in some cases, the lack of experienced staff, make it difficult for bilateral agencies to undertake a comprehensive review of the needs of a country and to prepare an action plan.

An international program is therefore needed to help diagnose the priority needs of particular countries for assistance. Such a program would help in the preparation of a plan of action for the development of local capabilities, including proposals for technical assistance. But it would not normally extend to the actual implementation of that plan. This would be the task of existing bilateral or multilateral developmental assistance efforts. The scope of this international program of diagnostic assistance would be thus analogous to the assistance to the development of national capabilities in agricultural research to be rendered by the newly established International Service to National Agricultural Research (ISNAR) of the Consultative Group on International Agricultural Research (CGIAR). 5/ Diagnostic assistance

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5/ ISNAR was established to fill the gap between the work of the international programs funded by the CGIAR and that of national programs of agricultural research. ISNAR will maintain an international staff that will provide technical assistance in the diagnosis of national needs for agricultural research and in the preparation of plans of action and proposals for technical assistance. The implementation of the plans would be funded by bilateral or multilateral sources. The German technical assistance organization (GTZ) has been designated by the CGIAR as executing agency with the task of launching ISNAR, and a staff is now being recruited.

should be available for a wide range of technologies. The program will frequently require close cooperation with existing agencies, such as the Food and Agriculture Organization of the UN (FAO) and the United Nations Industrial Development Organization (UNIDO).

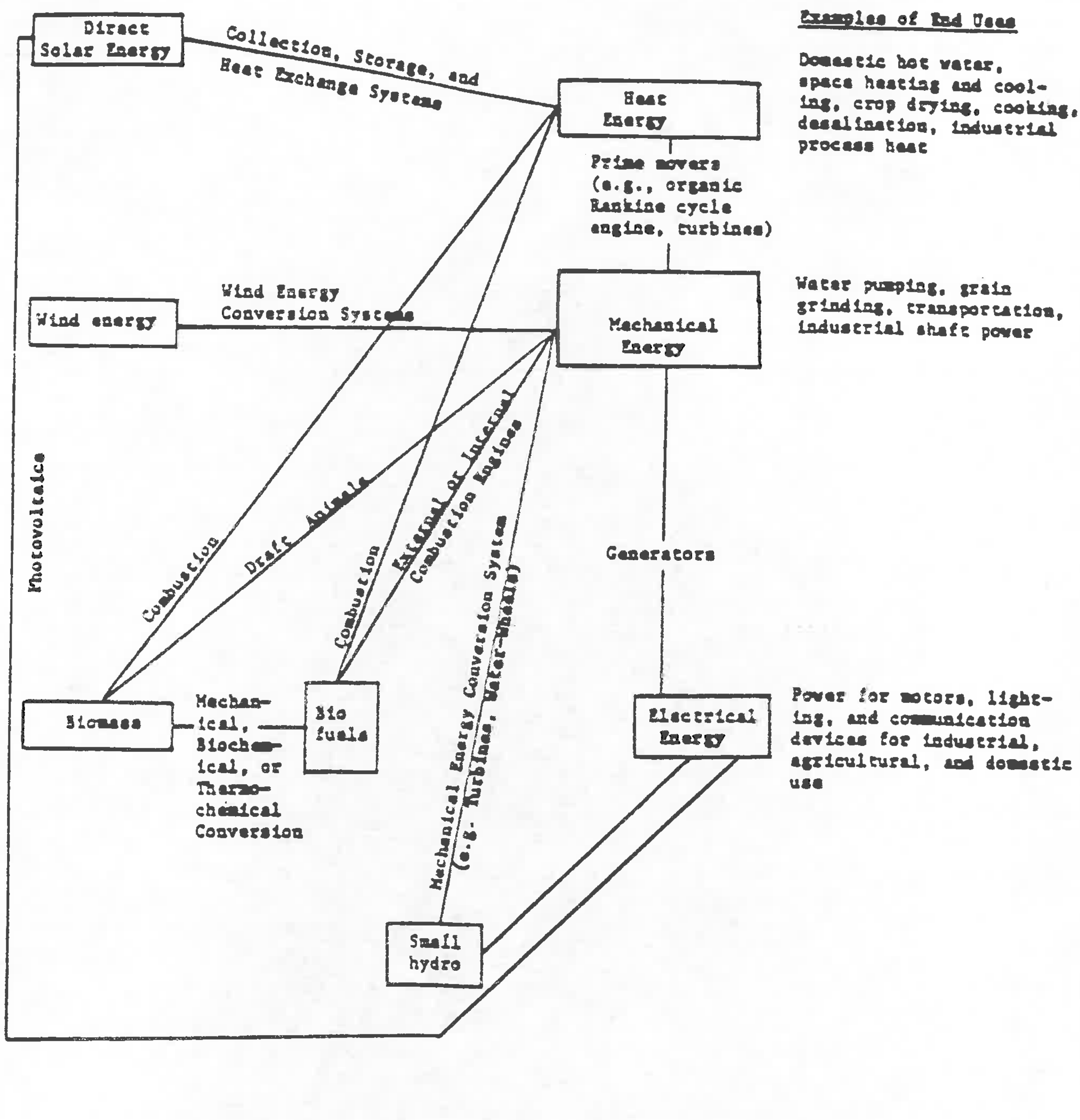
The program, in producing its diagnoses, will thus serve an integrative function that can help donors orient themselves to building capacity in developing nations. It may be useful to convene meetings which would use the results of the diagnoses as a tool to facilitate the coordination of the efforts of bilateral and multilateral donors.

3. RENEWABLE ENERGY TECHNOLOGIES ORIENTED TO THE NEEDS OF DEVELOPING COUNTRIES

Renewable resources can provide energy for a wide variety of applications in the domestic, agricultural, industrial, and transport sectors of developing countries. All these sectors require usable energy in the form of heat energy, mechanical shaft power, or electricity. Figure 1 on page 21 summarizes the main pathways for conversion of renewable energy resources (biomass, solar, wind, and hydro) into these forms of energy. Renewable energy systems may be used individually as "stand-alones" or in hybrid modes with each other, or with fossil-fueled systems. A wind electric conversion system, for example, can be used to produce electricity either alone or in combination with solar-or diesel-powered generators.

Of the energy resources included in Figure 1, biomass merits special consideration because of its present importance and future potential in developing countries. About 70 percent of the population of the developing world--some 2 billion people--today depend on biomass in the form of wood, crop residues, and animal waste to meet their most basic energy need, which is for cooking fuel. Moreover, biomass is a highly versatile energy source. It can serve not only in its traditional role in meeting the major energy requirements of the poor, but it can also meet a wide variety of the needs of the modern sector when converted to suitable solid, liquid, and gaseous fuels. Gasoline substitutes, for example, can be produced from biomass by the fermentation and distillation of plant sugars to produce ethanol, by the gasification and liquefaction of wood to produce methanol, by the pyrolysis of wood and crop residues to produce gas, and by a number of other biochemical

Figure 1: MAJOR RENEWABLE ENERGY RESOURCES AND APPLICATIONS FOR DEVELOPING COUNTRIES



and thermochemical conversion processes. Biomass fuels can be produced through large-scale industrial processes, or on a small scale for local use. On the other hand, biomass resources are unevenly distributed in the developing world. Although some countries are well endowed with biomass, others are poor in biomass because of natural conditions (for example, insufficient rainfall) and/or overuse (for example, deforestation).

The technologies that can convert renewable energy resources into usable forms of energy take the form of industrial processes and equipment. Equipment for some of the more sophisticated of these technologies--photovoltaics, large-scale wind energy conversion systems, wood gasification--can be developed and manufactured only in the industrialized countries, or in some of the more advanced developing countries. Efforts in developed countries are naturally oriented toward their own needs, and special attention is sometimes needed to ensure that technologies suited to developing countries receive attention. Most renewable energy technologies, however, are relatively well known. In most developing countries they can be adapted to local conditions and manufactured by the industrial sector, or, in the case of simple, village-level technologies, they can be adapted and produced by private organizations working closely with artisans and small workshops.

Review of Technologies and Applications

The following review focuses on the technologies and applications that appear most likely, on technical and economic grounds, to be relevant to meeting the energy needs of developing countries in the near-medium term future. The technologies are reviewed here in order to determine the need for innovation and/or adaptation in meeting developing country requirements, the extent to which these needs are being addressed at present through research and development in the developed and the developing countries, and the ways in which the gaps in the present research, development, demonstration, and diffusion effort might best be met through national and international action.

From this review, there emerges a tentative list of requirements for national and international action in research, development, assessment, and evaluation of technologies as they apply to the conditions and needs in developing countries. Technology for biomass production is assessed first, followed by technology for the conversion and use of biomass, and technology for the conversion of direct solar, wind, and small-scale hydro into heat, mechanical, and electrical energy. Specific recommendations are then presented.

Agricultural Technology for Biomass Production

Many developing countries are well endowed with biomass but its production for energy purposes can conflict with agricultural requirements. Thus it is essential to develop biomass production technologies that do not compete with food or cash crops and that will be successful under stress conditions such as arid or saline soils, swamps, and steep slopes. Such technologies should also be labor intensive and adaptable to small farms production.

Biomass energy may be derived from trees, shrubs, oilseeds, grasses, roots, field crops, agricultural residues, or aquatic plants. (See Table 1, page 27A.) Of the technologies for producing biomass, the only ones of near-term technoeconomic interest are the growing of trees for wood fuel and the growing of certain "energy crops," particularly sugarcane (and, to a lesser extent, cassava and sweet sorghum), for fermentation into ethanol. The technology for producing vegetable oil from oil palm and sunflower is also in hand. The technology for using such oil routinely as diesel fuel, however, is still to be fully mastered. Finally, large quantities of straw and other agricultural residues are currently wasted or used inefficiently as fuel. With improvements in harvesting, densification (briquetting, pelletizing, and so on), and conversion technology, more of these materials could be used more efficiently for energy purposes.

There is a pressing need to expand and upgrade energy-oriented biomass production research on both tree-growing and energy crops. There should, in each area, be an expanded effort involving not only applied research of the type now under way but also mission-oriented basic biological research that so far has had little application in this field. Experience confirms that much can be expected in the short term from applied research on familiar biomass sources as represented, for example, by field trials and species selection of fast-growing trees for different ecological conditions. Lesser known species should also be surveyed and investigated. For the longer run, there is much promise in the application to biomass production of the advanced research techniques--e.g. somatic cell culture 6/, genetic engineering and microbiology--that are producing exciting results in other areas of biology. Such research can be pursued at modest cost; it offers an opportunity for research in developing countries, with suitable international support, to play a leading role in the advancement of science, and at the same time to be of direct benefit to the host country.

These lines of research all present to the scientific community the challenge of stimulating communication, collaboration, and cross-comparison

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6/ Somatic cell culture is a technique that allows an entire plant to be grown from a single cell taken from a part of a plant other than the seed.

among all workers concerned with biomass production, whatever their disciplinary origins or institutional affiliations, as well as between these workers and the general agricultural research community.

Trees. Research into tree growing in tropical areas has traditionally been directed toward selection of provenances 7/ suited to industrial wood products and, to a lesser extent, to erosion control and other aspects of soil and watershed management. 8/ In the past few years, some research agencies have shifted their attention to the need for fast-growing trees for fuelwood, fodder, fruit, and pole production, either for forests, village fuelwood lots, or as part of farming systems for smallholders. In general, however, there has been little change in the direction of forestry research, so that it does not reflect the growing concern of developing countries with energy and agriculture-related forestry development. The lag in attention to important new directions in forestry may be attributed in good measure to the inadequate funding of forestry research, a long-standing problem in much of the developing world. Preliminary estimates indicate that the developing countries at present receive only about $10 million a year in aid for forestry research.

The problem of funding forestry research is understandable in the context of its long-term nature and the many pressing claims on developing

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7/ A provenance is a source of planting material--e.g., a particular geographical area.

8/ This section draws on the preliminary results of work being done to identify priorities in developing country forestry research. The results of this work, which is sponsored by the Bank and FAO, in consultation with CGIAR research programs, the International Center for Research on Agroforestry, and various bilateral aid donors, will be presented at an international forestry research meeting in Japan in September 1981.

country resources. Yet, wherever energy-oriented forestry research has been undertaken, it has paid off handsomely. Tree-breeding programs--for example, work in Hawaii on the giant ipil-ipil (Leucaena), in Sweden on the willow (Salix spp), and in Australia on Eucalyptus--have resulted in spectacular increases in yield. Available evidence indicates that breeding programs can be expected to result in growth gains of at least 10 percent for most species, and 15-25 percent gains for some, while applied research in the form of pilot trials of the introduction of exotic species can yield up to twenty times more biomass a hectare than the natural forests they replace. Thus, there seems to be a strong economic case for stepping up forestry research, particularly research into indigenous species suitable for the production of fuelwood and fodder. A recent U.S. National Academy of Sciences study identified some sixty species of trees and shrubs as particularly promising sources of fuelwood in developing countries. 9/ There are no specialized research programs under way at present for most of them.

Those in the forestry profession contend that applied research on growing trees is best suited to national institutions that are highly familiar with local soil, management, environmental, and social conditions. Energy-oriented forestry research is being conducted in several major institutions in developing countries; as well, a substantial number of research centers in the developed countries have programs appropriate for developing countries. There is a clear need to expand and strengthen the work being done in the developing countries, however, and to build closer links between developed and developing country institutions. Forestry research at the international level is poorly coordinated despite the efforts of the Forestry

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9/ National Academy of Sciences, Firewood Crops, (Washington, D.C., 1980).

Division of the Food and Agricultural Organization, which serves as a unifying force throughout the world forestry profession, of the Commonwealth Forestry Council, which is coordinating tests of promising species and provenances, and of the International Union of Forestry Research Organizations (IUFRO), which links research institutions throughout the world but whose programs have been of more benefit to developed than to developing countries.

The forestry research community also needs to strengthen its links with those doing research on other approaches to the biomass energy problem. New approaches to the growing of trees--such as short harvest times and close spacing--are blurring the lines between the discipline of forestry and the study of other forms of biomass, such as shrubs and grasses. An important objective of biomass research is to evaluate according to common criteria all forms of biomass suited to a particular ecological condition. This type of evaluation will enable farmers and competent local authorities to select the system best suited to their needs.

Institutions whose primary mission is in other fields should also recognize the priority of research on tree growing. Research on the use of the leaves of leguminous trees, 10/ of which Leucaena is an example, as a source of fodder and fertilizer in small farm systems would seem to be a high priority for national agricultural research laboratories, and for the international agricultural research centers funded by CGIAR. Basic research on the mechanisms and the ecology of biological nitrogen fixation is being carried on in various agricultural research institutions and universities. Such programs should be extended to include biomass production species, both leguminous and

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10/ Leguminous trees, like other legumes, have nodules on their roots that harbor symbiotic bacteria that fix nitrogen from the air. They are therefore net contributors of nitrogen to the soil.

Table 1: PROMISING ENERGY CROPS OTHER THAN FUELWOOD TREES

	Use	Species	Advantages	Research Needs
Crops producing readily fermentable carbohydrates				
Sugar crops with residual fuel	Ferment into ethanol using residual fuel for processing energy	Sugarcane (Saccharum officinarum)	Well-known, thoroughly researched production technology; tolerant of poor soils; relatively efficient converter of solar energy; sugar production and fermentation self-sufficient for fuel.	Collect genetic material from China-Assam-Burma Triangle; breed and test varieties and establish cultivation regime for maximum biomass; establish centralized service for recording, processing and disseminating varietal data; select or develop machinery and system to harvest total biomass.
		Sweet Sorghum (Sorghum vulgare)	Efficient converter of solar energy; shorter growing season than cane.	Carry out field trials in areas in which sugarcane cultivation is difficult because of cold winters or prolonged dry season. Collect germplasm.
Starch crops with residual fuel		Sago Palm (Metroxylon spp.)	Tolerates saline swamps; high yields.	Define agronomic requirements; breed for earlier maturity and higher starch content; try to harvest earlier; use more incident light in early years.
Starch crops with little residual fuel	Ferment into ethanol; external energy source required	Cassava (Manihot esculenta)	Widespread crop under subsistence conditions on poor soils; drought tolerant; self-storing underground.	Increase yields under subsistence regime; develop systems for management under large-scale cultivation and for inter-cropping with legumes to maintain soil fertility.
		Buffalo Gourd (Cucurbita foetidissima)	Combination oilseed and starchy root; yield apparently very high; native of arid lands; vine is ruminant feed.	Test against possible competitors in a wide range of ecological environments; check evapotranspiration requirements.
		Carob (Ceratonia siliqua)	Grows in Mediterranean climate on rocky soil with no other use; agronomic requirements well documented.	Test under similar conditions in other regions.
		Tamarind (Tamarindus indica)	Drought resistant; grows on poor rocky soil.	Collect germplasm in Sub-Sahelian Africa; test best Indian varieties under similar conditions elsewhere.
		Tania (Xanthosoma spp.), Taro (Colocasia esculenta)	Tolerates swampy conditions.	
Cellulosic and ligno-cellulosic (woody) plants	Direct combustion (e.g., cooking fuel, woodburning power plants); digestion into biogas; conversion to methanol/ethanol	Straw	Available in vast quantities	Assess resources; estimate opportunity costs from other uses (e.g. animal feed); develop harvesting, handling and briquetting regime and technology at various scales and degree of mechanization; product analysis; analyze costs in each of several countries; select grasses, species, and varieties.
		Grasses	Efficient converters of energy	
		Saltbush (Atriplex)	Tolerates very high salinity; possible protein producer.	
Hydrocarbon-producing plants with minor residuals	Diesel fuel	Milkweed, Copperwood (Euphorbia)	High genetic potential.	Little research to date.
		Neem (Azadirachta indica)	Traditional crop in India	Agronomy and selection almost nonexistent.
		Castor (Ricinus communis)	Oil can be used as diesel fuel	Little research to date; work beginning in Brazil.
		Jojoba (Simmondsia chinensis)	Tolerates aridity, salinity; high-value oil.	Investigate irrigation requirements; develop methods for commercialization of oil for cosmetics, pharmaceuticals.
with residual fuel		Oil Palm (Elaeis guineensis)	Well-known, thoroughly researched technology. Uses land unsuited to foodcrops; extraction self-sufficient for fuel; smallholder production often successful.	Compare with other crops for biomass production potential; test as diesel fuel (no special agronomic research required).
Also producing protein		Safflower (Carthamus tinctorius), Sesame (Sesamum indicum), Sunflower (Helianthus annuus)	Agronomy well-known; extensive breeding has been carried out on sunflower; sunflower oil is reported to be used on a commercial scale as diesel fuel.	Develop technology for refining oil for regular use as diesel (no special agronomic research required).
		Buffalo Gourd (Cucurbita foetidissima)	See above.	

Source: R.A. Yates, "Biomass Production Technology: Current Status and Research Needs" (July 1980).

nonleguminous types. Many other areas of basic biological research hold promise for increasing the productivity of forests. These include research on the microbiological communities called mycorhiza, which are attached to plant roots, and on virus, bacterial, and fungus diseases of trees. Modern methods of somatic cell culture, including recombinant DNA techniques, could greatly speed the pace of forest research.

Energy Crops. Table 1 summarizes the classification of the principal energy crops. The most familiar of these is sugarcane, on which research goes back more than a century. Its agronomy is well known. Additional effort is required to collect genetic material. A new breeding program should be started with a view to maximizing the total biomass. The technoeconomic potential for harvesting the total biomass of sugarcane should be evaluated. Research on cassava, by contrast, is recent, although the agronomy for this crop is well known. The research stems largely from the interest of CGIAR in cassava's role as a subsistence crop, especially in drought-prone areas. Existing research, although aimed primarily at subsistence agriculture and the production of starch for industrial purposes, is equally relevant to biomass production. Cassava culture frequently depletes the marginal soils on which it is found, and gullying can be severe on slopes. If intensive large-scale plantings are to be considered, special attention should be paid to research on soil conservation systems. Sweet sorghum is a third crop suited to the production of sugar for fermentation into fuel ethanol. It is now grown commercially on a limited scale in a few southern states of the United States. Despite its promise, there has been little research on sweet sorghum in the United States. Research on this crop in Brazil began only in the last few carried out in areas in which a short growing season gives this crop an advantage over sugarcane.

Research should also be undertaken on a number of promising alternative raw materials for ethanol production, including buffalo gourd, carob, and tamarind. These crops have received relatively little attention from researchers. They need to be planted for evaluation of comparative yield vis-à-vis possible alternatives, including oilcrops and forest crops. They may have advantages over sugarcane or cassava under special ecological conditions. The potential of the sagopalm for brackish swamps, for example, is particularly attractive, although increased intensity of cultivation could result in problems of salinization.

The situation among hydrocarbon-producing crops is similar. The agronomy of some crops (notably oilpalm and sunflower) is well advanced; other crops have only been identified. Assuming that tests prove that these oils can be used as a diesel replacement, then pilot processing units can be installed for the better known plants. For the lesser known plants (especially for those suited to arid environments), comparative yield trials are required. Unfortunately, the literature is severely lacking in information about the water consumption, quality, and productivity of the arid-land plants. All work on these plants must include an evaluation of these factors.

The exploitation of straw and dry, wild grass requires the testing and selection of suitable harvesting and briquetting equipment rather than research. Censuses of the quantities of materials available are also required. They would be used, first, as combustible fuels; at some later stage, when the technology is developed, these materials may be converted to other forms of fuel. Research is also required to determine whether other plants are suitable for use in the same way as straw and wild grasses. Examples include cultivated grasses (including sugarcane) and saltbushes. In many cases, potential for extraction and use of the protein-rich sap should be investigated.

Preliminary screening is required to determine whether field trials would be justified on other plants. Certain plants that have already been identified, such as Babaçu (Orbignya spp), Caryocar, Copaiba (Copaifera spp), and Jessenia, should be checked to determine whether their potential for high yields justifies field trials. Some of the most promising species are described briefly in Table 1. 11/ A survey by major herbaria would also be useful to identify additional species.

Technologies for Conversion and Use of Renewable Energy Resources

Technologies for the conversion of renewable resources into energy can be divided into first, those for the conversion and use of biomass, and second, those for the production of thermal, mechanical, and electrical energy from direct solar, wind, and small-scale hydro. Many of these technologies will be developed and supplied by the modern sector of industrialized and developing countries after appropriate research. Other simpler and smaller scale technologies are suited, after adaptation to local conditions, to manufacture and maintenance by small workshops and artisans in villages and small towns in developing countries.

11/ See also R. Revelle, "Flying Beans, Botanical Whales, Jack's Beanstalk, and Other Marvels," in The National Research Council in 1978 (Washington, D.C.: National Academy of Sciences, 1978).

Research into, and the development, commercialization, and diffusion of modern industrial sector processes and equipment are advancing steadily in industrial companies in developed countries. They are also taking place in a few relatively advanced developing countries. In both instances, government participation in and support of such research is a major element in national programs.

A large problem for planners and prospective users of these renewable energy technologies in developing countries is that of making informed choices among competing processes and equipment and deciding to what extent to encourage local manufacture. This task is made more difficult by the absence of agreed standards, quality criteria, and evaluation methodologies. In many cases, it is compounded by the absence of reliable data on performance under conditions typical of developing countries.

In the case of simpler technologies for exploitation of renewable energy resources, such as cooking stoves and sail windmills, the major problem is typically adaptation to local social, economic, and environmental conditions, a task that up to now has taken place principally through small, private organizations in developed and developing countries. These organizations are often closely in touch with the needs of the poor in the particular place where they work. But they are underfunded. They are also relatively isolated from each other, from the local scientific and technological communities, from the government, and from the mainstream of the economy. Such "appropriate technology" organizations can and should continue to play an important role, consistent with their capabilities. They are in need of relatively small sums to facilitate research, collaboration, communication, and development of agreed evaluation methodologies. With some exceptions they are, however, unlikely to be capable of managing on their own the problems of large-scale diffusion of these technologies.

The lack of reliable performance data and evaluated experience referred to earlier is particularly acute in the case of these less sophisticated technologies. Some of them, such as windpumpers, can be manufactured partly or wholly in the productive sector of most developing countries, although external technical assistance may be needed to help initiate the process. On the other hand, the commercialization of some of these technologies (for example, simple wood stoves) may not offer sufficient incentives to private industry.

Biomass Conversion and Use. The technologies for the conversion of biomass into usable fuels are classified in Table 2 on page 32A. A variety of processes are currently being developed--or the older ones revived--for the conversion of biomass into solid, liquid, and gaseous fuels by means of several techniques. Examples of such fuels are charcoal and densified solid fuels, ethanol, methanol, fuel oil, biogas, and producer gas. The major biomass conversion technologies include gasification, pyrolysis, anaerobic digestion, fermentation, and acid hydrolysis. Many conversions may be carried out either by large, modern installations or by simple, small-scale equipment suited to use at the village level.

In the cases of charcoal production and densification techniques like briquetting--the solid fuel conversion technologies most interesting to developing countries--the principal requirements are for adaptation to local conditions, testing, and demonstration. These are tasks for local researchers and renewable energy organizations, but they can be made easier

Table 2: TECHNOLOGIES FOR CONVERSION OF BIOMASS INTO USABLE FUELS

Conversion Process	Processed Fuel	Starting Material	Needs for Research, Development, and Demonstration: Major gaps	Needs for Research, Development, and Demonstration: Who should fill these gaps	Needs for Information and Standardization: Large-scale technology	Needs for Information and Standardization: Small-scale technology
Extraction	Fuel oil	Oil seeds	Evaluation of existing small-scale equipment	Developing country laboratory or consulting firm	None	A
Fermentation	Ethanol	Sugar, starch	Improvement in yields and process efficiency	Industrial sector in developed and developing countries	B	A,B
Enzymatic digestion and fermentation	Ethanol	Wood	Improvements in biochemical and engineering process efficiency	Industrial sector in developed and developing countries	None	None
Gasification/liquefaction	Methanol	Wood or other cellulose	Develop technoeconomically efficient process	Industrial sector in developed and advanced developing countries	None	None
Carbonization	Charcoal	Wood	Improvements in yields and process efficiency; adaptive research on small-scale plants	Private organizations and firms in LDCs with external collaboration	B	A,B
Anaerobic digestion	Gas, biogas (methane)	Animal and agricultural residues	Microbiological, materials and substrate research, local adaptation and societal issues	Public and private laboratories; private organizations and firms in developing countries	B	A
Pyrolysis	Oil, char, gas	Urban wastes, agricultural residues, wood	Adaptation to local conditions	Developing country industrial sector	B	None
Briquetting	Briquettes	Agricultural residues, straw	Development and adaptation of small-scale machines	Public and private laboratories, private organisations, and firms in developing countries	B	A,B
Gasification	Producer gas	Wood, agricultural residues	Process improvement, adaptation to various feedstocks, development of small-scale machines	Public and private laboratories, private organizations and firms in developing countries	B	A,B

Notes: A. Develop agreed evaluation methodology for users; encourage exchange of design and performance data among workers in different countries; review state of the art.

B. Develop and promulgate standards by which manufacturers can report performance data, and criteria by which users can judge suitability to various applications.

research and development are required to improve the efficiency of the processes and to adapt them to different feedstocks. Considerable effort is being made to improve equipment for large-scale applications in the more advanced countries, but developing countries generally need better information with which to assess technical alternatives and choose equipment. The task of adapting small-scale equipment to local conditions is one that developing country institutions can perform well, especially if they have access to adequate information on technological developments and experience elsewhere.

Technologies for the use of biomass-based fuels are summarized in Table 3 on page 34A. Traditional technology for medium-temperature heat for cooking with biomass fuel—a pot supported over a wood, charcoal, or cowdung flame by three stones—makes inefficient use of increasingly scarce and expensive fuel. Experience in parts of the developing world demonstrate that groups closely in touch with local people (particularly women) and their cooking needs can design more efficient cooking stoves that are socially acceptable, at least in pilot trials. Such stoves can be produced from relatively low-cost materials and hold great promise for reducing wood consumption, especially in areas where wood is scarce and its cost is high in proportion to the income of the poor. The methods for diffusing these improved stoves are still untested on a large scale, however, and the social, cultural, and institutional obstacles to such diffusion remain to be understood and overcome.

Other cooking fuels derived from biomass may also be technoeconomically viable. Such fuels include straw briquettes and vegetable oil from oilseed crops. The comparative promise of such fuels, in terms of both economic and social factors, has not been adequately assessed.

Table 3: TECHNOLOGIES FOR THE USE OF FUELS DERIVED FROM BIOMASS

Forms of Energy	Technology	Major Technological Gaps	Who Should Fill These Gaps	Needs for Information and Standardization
Medium temperature heat (100-300°C) (cooking)	Cooking stoves	Local adaptation and fabrication	Developing country laboratories, extension and artisan training services, private organizations	A, B, C
High temperature heat (above 300°C)	Direct combustion	None		B
Mechanical shaft power	Internal combustion engines	More efficient alcohol powered engines: adaptation of diesel engines to biomass-based fuels	Industrial sector in developed and more advanced developing countries	A, B
	Pedal power	Development and assessment of alternative designs	National laboratories, rural extension bodies	C
	Draft animal power			C

Notes:

A. Develop agreed methodology for evaluation by users; encourage exchange of design and performance data among workers in different countries; review state of the art.

B. Develop and promulgate standards by which manufacturers or fabricators can report performance data, including suitability criteria for most important implications.

C. Rekindle interest in hitherto neglected technology, e.g., by educational materials, conferences, small research grants or demonstrations.

Technologies that use biomass to produce heat for industrial processes and to generate electricity are based on the direct combustion of one or another form of biomass in a boiler of suitable design. Such boilers are available, but there are no agreed standards by which to judge the performance of such equipment with biomass fuels according to an agreed format and test methodology.

Many systems which are actually or potentially available can provide stationary mechanical shaft power from fuels derived from biomass through either external or internal combustion engines. External combustion engines, operating by the Rankine cycle, may be powered by high- or medium-temperature heat from any fuel, and are suited to small- and large-scale applications, respectively.

Fuels derived from biomass can be most directly and conveniently substituted for fossil fuels in internal combustion engines. Diesel engines can be fueled by gas derived from biomass, by vegetable oils, or by other more exotic vegetable products such as the sap of the copaiba tree or the refined latex of certain species of milk-weed. Similarly, gasoline engines can be powered by liquid or gaseous fuels derived from biomass. In this relatively new application of renewable energy technology, as well, agreed standards--that is, test methodologies by which manufacturers of engines adapted to running on ethanol and other biomass-derived fuels can report performance data--do not exist.

In many developing countries, the draft animal is a major source of stationary or mobile mechanical shaft power from renewable sources of energy. Despite this dominance, the role of the draft animal is for the most part unstudied. No country has an integrated policy program or institutional framework for dealing with the technology (genetics, feed, veterinary medicine, harnesses, tools, vehicles, and so on) of draft animal power.

Human pedal power is the most elementary technology for the production of mobile or stationary mechanical shaft power. The bicycle pedal and sprocket form an efficient device for the exploitation of human muscle power, as is shown by the recent successful flight of a pedal-powered airplane over the English Channel. Bicycles are used throughout the world, especially in Asia, for the transport of peoples and goods. Low cost, ergonomically sound designs exist for low-lift pumping, threshing, and grinding by pedal power. Although pedaling is drudgery, as are other less efficient technologies--handpumps, for example, are used for irrigation in South Asia--the widespread use of such methods shows that a technology based on low-cost pedal power would find a market and could contribute to productivity. At present, however, a design available in one part of the world may be completely unknown in another, and reliable performance data are scarce.

Use of Direct Solar, Wind, and Small-scale Hydro. Table 4 on page 36A summarizes technologies that could be used to produce heat and mechanical shaft power or to generate electricity from direct solar, wind and small-scale hydro resources.

The technology for heating water by means of simple flat plate solar collectors is well known. Focusing-type collectors capable of producing higher temperatures are being designed and tested in the industrial countries. Although the amount of energy used for the production of hot water is relatively modest in most developing countries, it is needed in hospitals,

Table 4: MAJOR TECHNOLOGIES FOR USE OF RENEWABLE ENERGY RESOURCES FOR THE PRODUCTION OF HEAT, MECHANICAL, AND ELECTRICAL ENERGY

Form of Energy	Technology	Major Technological Gaps	Who Should Fill These Gaps	Needs for Information and Standardization
Heat	Solar collectors			
	Flat plate	Local adaptation and manufacture	Developing country laboratories and industrial sector	A,B
	Focusing	Design and materials improvement	Developed country laboratories and industrial sector	B
	Solar crop drying	Local adaptation and manufacture	Developing country laboratories and industrial sector	A,B
	Solar cookers	Low cost heat storage and transmission	Laboratories and private organizations in developed and developing countries	A
	Solar ponds	Research on unlimited ponds, control of wind effects, local adaptation and fabrication	Developing country industrial and public sector laboratories	A,C
Mechanical shaft power	Commercial wind-pumpers	Local manufacture	Developing country industrial sector	A,B
	Sail windmills	Reliable performance data; comparative evaluation and improvement of traditional designs	Laboratories and private organizations in developed and developing countries	A,C
Electricity generation	Small hydro	Local adaptation and manufacture	Developing country industrial sector and government agencies	A,B
	Wind generators	Develop and test equipment	Developed country industrial sector	A,B[a]
	Photovoltaic	Cost reduction in cells and "balance of system" costs; encouragement of applications where market incentives are limited	Developed country industrial sector	B,C[b]

Notes: A. Develop agreed methodology for evaluation by users; encourage exchange of design and performance data among workers in different countries; review state of the art.

B. Develop and promulgate standards by which manufacturers can report performance data, including suitability criteria for most important applications.

C. Generate performance data by internationally managed or coordinated field demonstrations.

a. When technology nears techno-economic feasibility.

b. For specific applications for which private investment is likely to be inadequate.

restaurants, and hotels; in the homes of the better off; and in such industries as food processing. The manufacture of flat plate solar collectors is already well established in some developing countries and could be profitably undertaken in many others, if the design were adapted to local climatic conditions and locally available materials and technology were used in manufacturing. In the case of focusing collectors, the research needed to improve designs and materials is being pursued in the more advanced countries.

Crop drying frequently accounts for a substantial portion of the commercial energy used in developing country agriculture. The availability of low-cost dryers could help considerably in improving crop quality and in reducing post-harvest losses. Solar energy may be used to heat air for crop drying. A sizable number of dryers, varying principally with respect to types of air convection and air temperature, have been designed and tested on a variety of crops. Although further research is needed to optimize design, the application of solar energy to crop drying in developing countries now mainly calls for adaptation to local climatic conditions and agricultural practices. The prospects for local manufacturing should provide industrial researchers in developing countries with adequate incentives to pursue this work.

The solar pond is a promising technology for heating water close to the boiling point, a temperature sufficient to allow this method to be used for process heat, generation of electricity, or desalination. First developed in Israel (with partial funding from the World Bank), solar ponds show considerable promise for applications in developing countries because of their simplicity and low cost.

Solar cookers have been notorious failures in numerous trials, largely because of the natural resistance of people to cook in the open in the heat of the day, but also because of other social and technical reasons. The need for a technological fix to the problem of the increasing cost of cooking fuel is so pressing that there is little alternative but to continue efforts to design a low-cost system and to understand better the obstacles to its diffusion. To be successful, the design must be compatible with local cooking practices and with the comfort of the cook, as compatible as possible with social and cultural norms, and should possibly be linked to a back-up wood stove. Recent successful commercialization of such cookers in the state of Gujarat in India raises hopes that a practical approach to this problem may be possible.

Of the technologies for the production of stationary mechanical shaft power from renewable energy resources, that for commercial windmills mechanically linked to a water pump (windpumpers), is well known and proven. It requires only local adaptation, commercialization, and application in sites where it is technoeconomically feasible. Again, there is no standardized format for testing and reporting performance.

A promising "noncommercial" technology for pumping water by wind energy is that based on the traditional small-scale sail windmill. This has been used for centuries in regions of Crete, Thailand, and the Yucatan (Mexico) with reliable, steady, low-speed winds. Such windmills have been successfully installed by private voluntary organizations in Tanzania. They are technically inefficient but are cheap to construct, and can be fabricated and repaired in traditional local workshops. On the other hand, reliable cost and performance data are sparse.

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Electricity may be generated from small-scale hydro installations, or from a system combining thermal energy from a solar pond or a solar thermal power plant with a prime mover. Electricity may also be generated by photovoltaic cells and by small- and large-scale wind electric conversion systems ("wind generators").

Small-scale wind electric conversion systems are already cost-effective for remote windy areas. Similarly, small-scale hydro power involves well-known and proven technology. Widespread application in developing countries, however, will require cost-effective approaches to site identification and evaluation, and equipment designed for local conditions and for low-cost manufacture by local industries. Agreed standards for testing and reporting performance would greatly facilitate the application of both technologies. In addition to the many well-known applications of small-scale electrical systems, an application of wide potential interest is the small-scale manufacture of fertilizer in remote areas by the electric arc process. This has been demonstrated recently at laboratory scale.

Large-scale (more than 200 kilowatts) wind energy conversion systems based on modern materials and aerodynamic principles are undergoing rapid research and development in technologically advanced countries. They are likely to be capable of producing electricity at competitive costs where there are suitable wind regimes, but such regimes appear to be present in relatively few areas (for example, coastal zones) in developing countries. The technology will be available to developing countries through commercial channels. Most developing countries will have to look to imported equipment, but the manufacture of certain components of wind energy conversion systems will be possible in some cases.

Photovoltaic systems, which convert sunlight directly into electricity, are especially attractive for use in developing countries because they appear to be relatively easy to maintain and are simple to operate. They are the only solar electric option commercially available today. At present, these systems are competitive only for applications requiring a small quantity of electricity remote from a grid, such as educational television, refrigerators, and communications stations. Manufacturers in technologically advanced countries--and the governments that support them--predict a rapid decrease in the cost both of the cells and balance of the system. The application of photovoltaic technology is being promoted by manufacturers based in developing countries, although few endeavor to collect performance data for comparative purposes, or for general evaluation or follow-up. 12/ A limited amount of local adaptation is needed for photovoltaic applications in developing countries, but technology and equipment will generally be available commercially. Local manufacturers in many countries, however, will be able to supply important elements of photovoltaic systems (for example, supporting structures, batteries).

Recommendations

The following specific recommendations for international support for the development of renewable energy technologies fall into two clearly defined categories: one deals with technologies for the production of biomass, and one with technologies for the production of heat, mechanical, and electrical energy from direct solar, wind, small hydro, and biomass resources.

12/ In three countries the UNDP has financed and the World Bank is executing a comparative evaluation of photovoltaic irrigation pumps suitable for small farmers, along with limited tests of a solar thermal pump, and UNDP is considering extension of this project to additional countries in a second phase.

Biomass Production Technology

Biomass production technology offers clear opportunities for a major advance in the state of the art through research. It is reasonable to expect well-designed and executed research to improve the productivity of well-known species such as sugarcane, cassava, sweet sorghum, and various fuelwood and leguminous trees, and to identify species that are potentially more productive. In addition, revolutionary developments in biological research give promise of major technological advances that might be achievable through collaboration between developing country scientists working at the frontiers of knowledge and their colleagues, either in the laboratories of developed countries or in agricultural and forestry laboratories of developing countries. Such programs would benefit almost all developing countries. Only one or two developing countries, however, could organize such efforts on their own.

An international effort would make possible an efficient program that would benefit all developing countries. Such an international program must first investigate improvements in technology for the production of biomass from well-researched species such as sugarcane, cassava, and many species of trees. In sugarcane production, for example, there is a threefold need: to breed varieties specifically for their potential as biomass producers; to collect germplasm from the border area where China, India, and Burma meet, the last area in the world with major resources of uncollected germplasm and an area in which wild varieties are in danger of disappearing; and to study regimes to maximize biomass yield through proliferation of woody material ("energy cane"). In the case of cassava, genetic materials need to be collected and soil conservation systems investigated to minimize soil depletion.

Comparative evaluations of yield need to be made for sweet sorghum, a crop little known outside the United States, to investigate its potential advantages over sugarcane, cassava, or other fermentable crops under special ecological conditions.

Breeding programs and species trials of well-known varieties of fast-growing trees should be substantially expanded, as should research to develop improved planting and harvesting techniques. Programs should be established to test promising new species of trees, shrubs, rootcrops, and grasses in a variety of sites, and to compare their potential as biomass producers with each other and with traditional producers such as oilseeds and sugarcane.

In addition, national programs of agricultural research dealing with small farmer agriculture, the multilateral and bilateral agencies that assist them, and the international agricultural research centers funded by CGIAR, should devote increased attention to the role of trees in small farmer agriculture, both as sources of fuelwood and, in the important case of leguminous trees, of fertilizer. Further staff work and consultations with the research community, as well as with such organizations such as FAO and the International Center for Research in Agro-Forestry, are needed before detailed proposals can be made in this area.

Finally, with respect to both tree growing and energy crops, there is a need for an international program of mission-oriented basic research to explore the potential of new developments in genetic engineering, somatic cell culture, biochemistry, microbiology, and physiology to open new avenues of biomass production research.

Use of Direct Solar, Wind, Small Hydro, and Biomass

The bulk of the technologies for the use of renewable energy in developing countries to produce heat, mechanical and electrical energy from direct solar energy, wind, small hydro, or biomass-based fuels are based on well-known principles. However, even familiar technologies need to be adapted to specific circumstances in developing countries. In the case of some technologies, widespread application in developing countries depends on further scientific progress. Bilateral aid programs and national energy programs in developed countries should, among other things, encourage local investors and entrepreneurs to develop technologies for use of renewable energy resources that are particularly suited to the needs of developing countries.

In the case of technologies that mainly require adaptation to the circumstances of developing countries, the major task for the international community is to support national capabilities and programs of research, development, commercialization, and diffusion. This support should include efforts to adapt smaller scale technologies to local needs by private organizations devoted to community development or to "appropriate technology."

In the case of most of the technologies that require further scientific progress, much research and development are already under way in the more advanced countries. The primary problem is to ensure that the resulting technological advances are accessible to developing countries that can benefit from them. One approach would be to establish independent international industrial research and development programs in these areas. A number of possible practical as well as political difficulties appear to argue against this approach. To be effective, such international research would have to include not only the design and testing of conceptual prototypes, but also close collaboration with potential manufacturers in developing manufacturing prototypes and involvement in the commercialization of the product. These programs require close working relations with the productive sector, and this is difficult for a publicly owned institute even at the national, let alone the international level. Moreover, such international research might be open to the objections that it would duplicate ongoing efforts in the advanced countries, on the one hand, or would divert financial and human resources from the strengthening of national programs, on the other hand.

It therefore appears that international effort in this area would be more productive if it took the form of programs for assisting developing countries to assess the usefulness, impact, and development potential of technological advances being made around the world. Such assistance would complement the assistance to local capability for research, development, assessment, and manufacture discussed under the recommendations presented in Chapter 2.

In general, the critical need in the developing countries is for policymakers to be able to assess the technical and economic aspects of processes and equipment. To do so, they require information on the present state of, and likely future developments in, technology. Such information must be sufficiently evaluated by experts before policymakers can use it to formulate strategies and make decisions. Planners, for example, need to know the best present assessment of whether diesel fuel could in the future be most economically derived from wood, from oilseeds, or from animal and agricultural residues. They also need to know how fuel from such sources is likely to compare in price and quality with conventional or novel fossil fuels. In addition, officials and entrepreneurs in developing countries need: reliable performance data on alternative pieces of equipment; evaluated experience with the technological, institutional, and social aspects of different applications of renewable energy technology; and disinterested assessments of alternative applications of renewable energy technology to high priority needs of the developing world, preferably in comparison with traditional technology or modern technology using fossil fuels.

Criteria by which to judge the suitability of alternative technologies for various applications and conditions have not, however, been developed. Moreover, in many cases, the data required do not exist. There have rarely been disinterested comparisons of alternative systems for the many applications typical in the developing world. Even the methodologies for such comparative evaluations are still under development. The present sources of data and evaluations for many technologies are the manufacturers of equipment, most of whom are in developed countries. In general, they have no agreed standards for reporting performance data, naturally convey an optimistic view, and do not adequately consider social and institutional problems.

Tables 2, 3, and 4 summarize the need for information and standardization for each of the technologies reviewed. These needs go far beyond the exchange of documentation. Rather, their major emphasis lies in measures to promote the generation of data, evaluations, standards, and other information not now generally available in the forms best suited to the needs of various classes of users.

For many technologies--such as large-scale pyrolysis and briquetting--that are likely to be embodied in equipment manufactured in the developed countries and in the modern sector of more industrially advanced developing countries the most economical approach is to develop and promulgate, in cooperation with manufacturers, users, and (as appropriate) private community development organizations, internationally agreed standards by which manufacturers would report performance data. (Such technologies are designated B in the column "needs for information and standardization" in Tables 2, 3, and 4). Standards are available for only a few renewable energy technologies such as solar collectors, and these exist in only a few countries.

For technologies that are likely to be embodied in equipment suited to small-scale manufacture in developing countries, or to artisanal or self-help construction at the village or community level, the major need is for agreed methodologies by which the user can evaluate the performance of the equipment and the broader aspects of his experience with the technology. Such methodologies can be used as a framework within which to facilitate the exchange of designs and performance data and the issuance of periodic reviews of the state of the art. (Such technologies are designated B in Tables 2, 3, and 4.) Some bilateral aid agencies are beginning to develop such methodologies for particularly technologies they are helping to promote.

For certain promising technologies (designated C in Table 4), there exist neither reliable performance data nor realistic prospects for obtaining any such data from existing or prospective national or international programs. Such technologies include solar ponds, sail windmills, and biogas. The promise of these technologies is sufficient to warrant funding and management of international comparative demonstrations in several developing countries for the purpose of generating performance data.

In the case of a few technologies, world interest has lagged to such a degree that there is a need for an international effort simply to revive professional interest. This can be done through seminars, publications, travel, demonstrations, and small research grants. Such technologies include many aspects of biomass technology, such as direct combustion of grasses, as well as draft animal power and pedal power.

Finally there is a need for a limited amount of genuinely international research on a number of special topics, for example, the optimization of solar crop dryers; microbiological aspects of biogasification; the development of a continuous biogas digestor suited to dry, straw-rich fermentation mixtures; and the development of simple, practical microcomputer programs to estimate incoming solar radiation in the field.

These proposals should be checked against expert opinion in different parts of the world. Detailed assessments that take into account likely future developments and the likely cost of the work proposed should also be made of the potential contribution of the various technologies.

4. IMPLEMENTING THE RECOMMENDED PROGRAMS

The paper concludes that there is a clear need both for additional research on renewable energy technologies and applications of special interest to the developing countries and for strengthening the scientific and technical capabilities of developing countries for mobilizing renewable energy technologies to serve their own needs. A variety of ways in which national governments and the development assistance community can help to meet these needs are suggested. In addition, it is recommended that new international programs be undertaken to:

- Diagnose, on a country-by-country basis, the technical assistance needed to strengthen national scientific and technological capabilities for renewable energy utilization;
- Support research, using both current and advanced methods, on biomass production technology of particular interest to developing countries;
- Assist in the generation, standardization, evaluation, and exchange of information on the performance in developing countries of the biomass conversion, solar, and other renewable technologies of greatest interest to them.

The international programs recommended in this report could be undertaken by various institutional frameworks. Most of the programs could be handled by institutions that already exist in the developing and industrialized countries. Central administrative staffs would be required countries having specific experience with particular species or research approaches should greatly increase the effectiveness of such programs and avoid the delays that would otherwise be associated with the establishment of new institutions. The trials would be funded and coordinated by a small central secretariat of professional plant scientists, backed by sufficient administrative capability to manage a large number of simultaneous research contracts in different parts of the world. The secretariat would need to collaborate closely with the FAO.

A somewhat different style of operation would be needed for mission-oriented basic research that uses sophisticated biological techniques. Most of the work would be done in university laboratories in developing countries, often in collaboration with local centers of applied agricultural or forestry research and/or with laboratories in developed countries. A possible funding mechanism would be research grants made in response to project proposals submitted by research workers and vetted by a review of groups of peer researchers under the general oversight of a scientific advisory committee. Such peer review is a common mechanism of insuring high standards of professional quality in basic research, and can be adapted to the management of basic research that is directed toward a practical goal.

Information, Assessment, and Standardization. The recommended international programs of testing, demonstration, evaluation, standardization, assessment, and research would be carried out under the guidance of a small central secretariat that would formulate policies and programs, raise funds, and provide overall technical and administrative oversight.

TRAINER'S GUIDE

HARDWARE

1. Overhead projector
2. Screen
3. Slide projector, 24 mm with synchroniser
4. Blackboard
5. Flipcharts (optional)
6. Tape recorder

DOCUMENTS TO BE USED BY THE TRAINER

See "Module Structure", page 2

DOCUMENTS TO BE DISTRIBUTED TO TRAINEES

EWII-1.1: Target groups

EWII-1.2: Objectives

EWII-2.1: Table of contents

EWII-2.2: Text

EWII-2.3: Additional reading

EWII-2.4: Glossary

EWII-2.5: Bibliography

EWII-3.1: Checklists on key issues for group work

EWII-3.2: Evaluation questionnaire

KEY POINTS	TRAINING METHOD AND ACTIVITIES	DOCUMENTS TO BE DISTRIBUTED	AVA
	INTRODUCTION		
1. Objective	Presentation	EWII-1.1	
2. Energy problems of developing countries and their impact on women	Presentation/ discussion	EWII-1.2	EWII-1
3. NRSE in energy supply of developing countries	Presentation/ discussion	EWII-2.1	EWII-2 EWII-3
4. Impact of energy crisis on women	Presentation/	EWII-2.2	EWII-4
	PRESENTATION		
5. NRSE potentials	Presentation		EWII-5 EWII-6 EWII-7
6. NRSE technologies	Presentation		EWII-8 EWII-9 EWII-10 EWII-11 EWII-12 EWII-13 EWII-14 EWII-15 EWII-16 EWII-17 EWII-18 EWII-19 EWII-20 EWII-21 EWII-22 EWII-23
7. The role of women as suppliers of energy	Presentation/ discussion		EWII-24

KEY POINTS	TRAINING METHOD AND ACTIVITIES	DOCUMENTS TO BE DISTRIBUTED	AVA
8. Women as users of energy at the household level	Presentation/ discussion		EWII-25
9. Women's energy needs at community level	Presentation/ discussion		EWII-26
10. Women's energy needs for income-generating activities	Presentation/ discussion		EWII-27
11. The integration of women in NRSE planning and policies	Presentation/ discussion		EWII-28 EWII-29 EWII-30
12. Recommendations	Presentation/ discussion		EWII-31
13. Women's integration in the development of NRSE technologies	Presentation/ discussion		EWII-32
14. Conclusions	Presentation/ discussion		EWII-34
SUMMARY			
15. Key issue checklists	Group discussion	Checklist EWII-3.1	
16. Presentation on checklists	Plenary discussion		

KEY POINTS	TRAINING METHOD AND ACTIVITIES	DOCUMENTS TO BE DISTRIBUTED	AVA
	MONITORING AND CONTROL		
17. Key issue check-list	The participants will work in small groups and discuss 4.3, 5.2 of the text	EWII-2.3 EWII-3.1	
18. Module evaluation questionnaire	Individual activity	Questionnaire EWII-3.2	

NAME OF TRAINER ....

COUNTRY .... DATE ....

AVERAGE EDUCATIONAL QUALIFICATIONS OF PARTICIPANTS ....

....

.... NUMBER OF PARTICIPANTS ....

Mark the box which corresponds best to your opinion on each question.

1. To what extent has the module achieved the objectives stated?

☐ over 80%

☐ 70 - 80%

☐ 60 - 70%

☐ 50 - 60%

☐ less than 50%

2. Did the objectives meet the needs of the group?

totally ☐ ☐ ☐ ☐ not at all

3. On the basis of the objectives stated, the subject matter is:

relevant ☐ ☐ ☐ ☐ irrelevant

4. The progression of the subject matter is:
(Give reasons for your answers)

too fast ☐ ☐ ☐ ☐ too slow

5. List the topics you would like to have treated in the package more extensively:

   a) ....

   b) ....

   c) ....

6. List the topics you would like to have treated to a lesser extent:

   a) ....

   b) ....

   c) ....

7. List the topics not included in this module that you think should be included:

   a) ....

   b) ....

   c) ....

8. The technical quality of the audiovisual material was:

   high ☐ ☐ ☐ ☐ low

9. The relevance of the audiovisual material was:

   high ☐ ☐ ☐ ☐ low

10. The quantity of the audiovisual material was:

   high ☐ ☐ ☐ ☐ low

11. The sound/slide package (where applicable) was:

   too long ☐ ☐ ☐ ☐ too short

12. Your global evaluation, bearing the objectives and teaching resources of the module you have tested in mind, is:
(Give reasons for your answer)

excellent ☐ ☐ ☐ ☐ mediocre

After completion, please forward this document to:

UN/INSTRAW
P.O. Box 21747
SANTO DOMINGO
The Dominican Republic

EWII-19: ENERGY FROM BIOMASS

EWII-20: USE OF BIOMASS

EWII-21: COMPARISON BETWEEN TRADITIONAL ENERGY AND NRSE FOR THERMAL ENERGY PRODUCTION

EWII-22: COMPARISON BETWEEN TRADITIONAL ENERGY AND NRSE FOR ELECTRICITY PRODUCTION

EWII-23: NRSE POTENTIAL

EWII-24: THE ROLE OF WOMEN AS SUPPLIERS OF ENERGY

EWII-25: WOMEN AS USERS OF ENERGY AT THE HOUSEHOLD LEVEL

EWII-26: WOMEN'S ENERGY NEEDS AT THE COMMUNITY LEVEL

EWII-27: WOMEN'S ENERGY NEEDS FOR INCOME-GENERATING ACTIVITIES

EWII-28: THE PARTICIPATION OF WOMEN IN ENERGY PLANNING AND ENERGY POLICIES: CONSTRAINTS

EWII-29: POSSIBLE SOLUTIONS

EWII-30: HOW TO INTEGRATE WOMEN'S NEEDS IN ENERGY PLANNING AND POLICIES: CONSTRAINTS

EWII-31: RECOMMENDED APPROACH

EWII-32: THE IMPACT OF NRSE TECHNOLOGIES ON WOMEN

EWII-33: WOMEN'S INTEGRATION IN THE DEVELOPMENT OF NRSE

EWII-34: HOW TO INTEGRATE WOMEN IN NRSE ACTIVITIES

THE ENERGY SITUATION OF DEVELOPING COUNTRIES

AN ADEQUATE ENERGY SUPPLY IS A PREREQUISITE FOR DEVELOPMENT

MOST DEVELOPING COUNTRIES MUST IMPORT OIL

COMMERCIAL ENERGY IS USED MOSTLY FOR INDUSTRY AND TRANSPORT

HOUSEHOLD AND AGRICULTURAL NEEDS ARE MET MAINLY BY NRSE, ESPECIALLY WOOD AND AGRICULTURAL RESIDUES

NRSE HOLD A GREAT POTENTIAL FOR REPLACING OIL

BOTH COMMERCIAL AND NON-COMMERCIAL ENERGY

AND BOTH IMPORTED AND DOMESTIC ENERGY

MUST BE MANAGED IN A MORE EFFICIENT MANNER

NEW AND RENEWABLE SOURCES OF ENERGY

SOLAR ENERGY

HYDROPOWER

POWER FROM THE SEAS

GEOTHERMAL ENERGY

WIND POWER

BIOMASS

PEAT

OIL SHALE

TAR SANDS

ANIMAL DRAUGHT POWER

NRSE CAN SUBSTITUTE FOR OIL IN:

- ☐ HOUSEHOLD
- ☐ TRANSPORT
- ☐ INDUSTRY
- ☐ ELECTRIC POWER PRODUCTION

NRSE CAN SUBSTITUTE FOR

5 TO 15%

OF THE OIL CONSUMED BY DEVELOPING COUNTRIES BY THE END OF THE CENTURY

THE IMPACT OF THE "SECOND ENERGY CRISIS" ON WOMEN

WOMEN ARE MORE AFFECTED THAN MEN BECAUSE:

1) THEY HAVE TO WALK LONGER HOURS CARRYING HEAVY HEADLOADS TO FETCH WOOD
2) AS SOIL FERTILITY DECLINES, THEY HAVE TO WORK HARDER TO GROW FOOD
3) THEY ARE DEPRIVED OF THE POSSIBILITY OF GATHERING MINOR FOREST PRODUCTS
4) THEY HAVE TO COPE WITH NUTRITION, HEALTH AND SANITATION PROBLEMS IN THE HOUSEHOLD
5) THEIR INCOME-GENERATING ACTIVITIES ARE NEGATIVELY AFFECTED

CONTRIBUTION OF NRSE

- ☐ **TRADITIONAL RENEWABLE ENERGY SOURCES ACCOUNT FOR 20-25% OF TOTAL ENERGY CONSUMPTION IN DEVELOPING COUNTRIES**

- ☐ **75% OF THE POPULATION OF DEVELOPING COUNTRIES USE TRADITIONAL FUELS LARGELY WITHIN HOUSEHOLDS AND PRIMARILY FOR COOKING**

- ☐ **MOST OF THE POPULATION HAS ACCESS TO FIREWOOD, BUT ROUGHLY 1,000 MILLION PEOPLE USE AGRICULTURAL AND ANIMAL WASTE TO FUEL THEIR COOKING FIRES**

PRIMARY FORMS OF ENERGY

CHEMICAL:
- ☐ FOSSIL FUELS (COAL, OIL, NATURAL GAS)
- ☐ BIOMASS (WOOD, AGRICULTURAL RESIDUES, URBAN REFUSE)

POTENTIAL: WATERFALLS AND RIVER FLOWS

KINETIC: WIND, WAVES

RADIATION: SUN

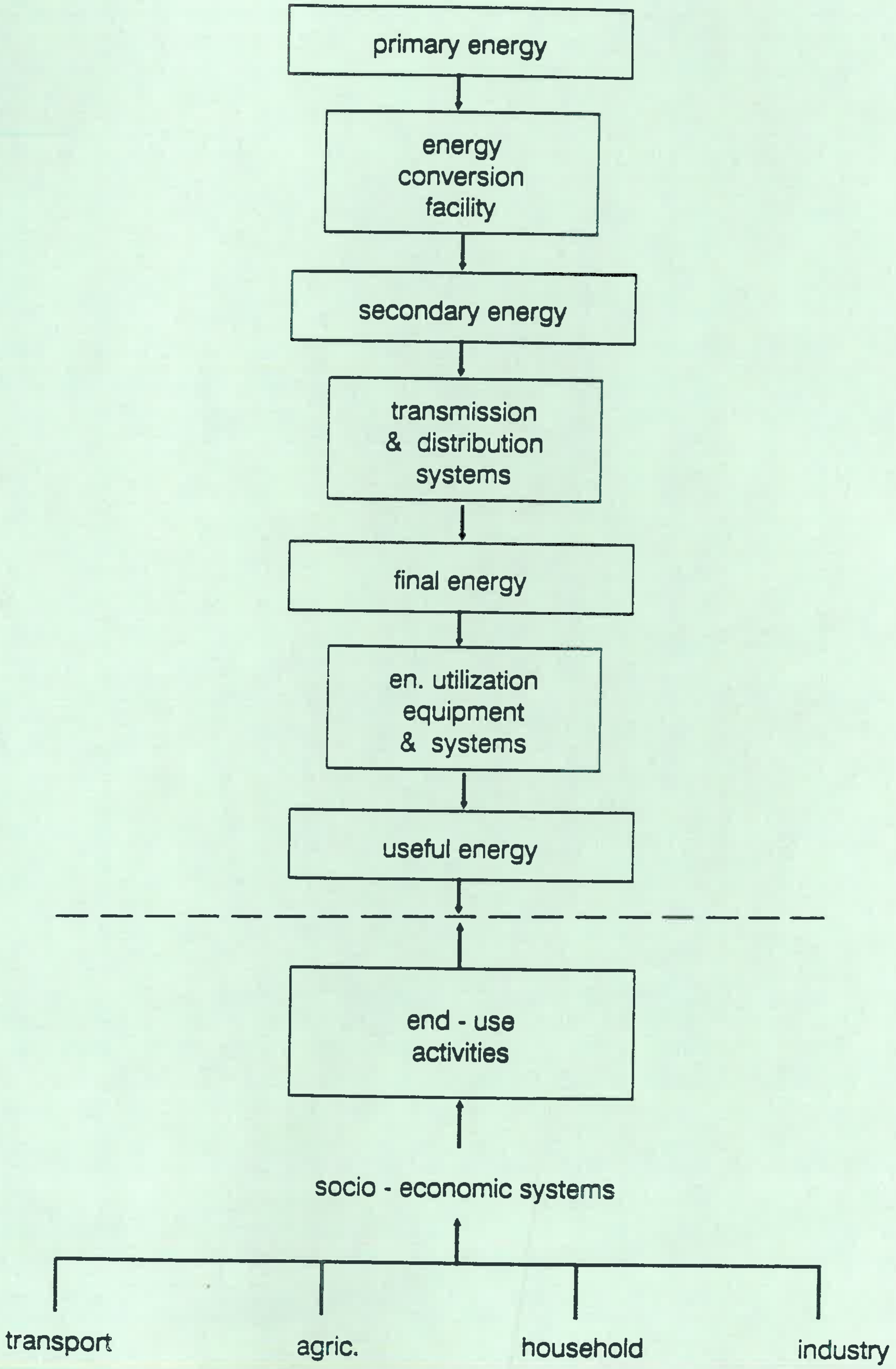
HEAT: GEOTHERMAL RESERVOIRS, OCEAN THERMAL RESERVOIRS

NUCLEAR: URANIUM

USEFUL ENERGY

HEAT

MECHANICAL ENERGY OR POWER



primary energy
energy conversion facility
secondary energy
transmission & distribution systems
final energy
en. utilization equipment & systems
useful energy
end - use activities
socio - economic systems
transport
agric.
household
industry

PRESENT AND ESTIMATED FUTURE WORLD USE OF NEW AND RENEWABLE SOURCES OF ENERGY

Source	Present use in bilion (10^9) KWh	Utilization in the year 2000 in billion (10^9)
Solar	2 - 3	2,000 - 5,000
Geothermal	55	1,000 - 5,000
Wind	2	1,000 - 5,000
Tidal	0.4	30 - 60
Wave	0	10
Thermal gradient of the sea	0	1,000
Biomass	550 -700	2,000 - 5,000
Fuelwood	10,000 - 12,000	15,000 - 20,000
Charcoal	1,000	2,000 - 5,000
Peat	20	1,000
Draught animals	30 (in India)	1,000
Oil shale	15	500
Tar sands	130	1,000
Hydropower	1,500	3,000

Source: United Nations A/CONF. 100/PC/17

SOLAR ENERGY

THE POWER TRANSMITTED TO THE EARTH BY THE SUN CAN BE ASSUMED TO BE

1,500 TO 2,000 kWh/m^2.year

BUT ONLY A MINIMUM PERCENTAGE CAN BE EXPLOITED

IT CAN BE DIRECTLY CONVERTED INTO:

- ☐ **THERMAL ENERGY**
- ☐ **ELECTRICAL ENERGY**
- ☐ **CHEMICAL ENERGY**

SOLAR ENERGY CONVERSION

THERMAL CONVERSION CAN BE OBTAINED USING:

- ☐ FLAT-PLATE COLLECTORS TO HEAT WATER OR AIR AT MODERATE TEMPERATURE
- ☐ FOCUSING COLLECTORS OR CONCENTRATORS TO HEAT WATER AT HIGH TEMPERATURES BY CONCENTRATING DIRECT RADIATION ON A SMALL SURFACE

ELECTRICAL CONVERSION CAN BE OBTAINED USING:

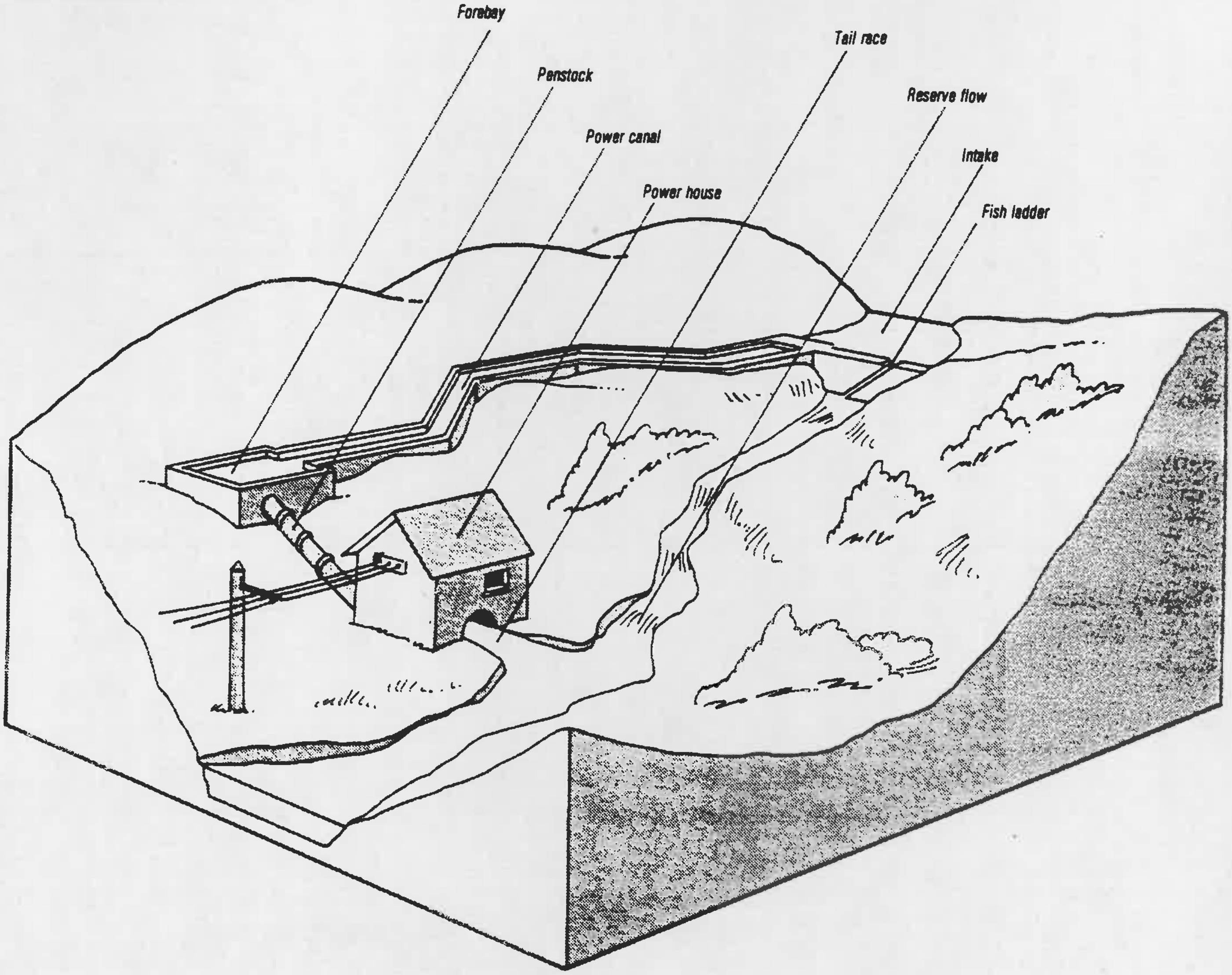
- ☐ SOLAR PHOTOVOLTAIC CELLS WHICH ARE SEMICONDUCTOR DEVICES WHICH GENERATE ELECTRICITY FROM DIRECT OR DIFFUSE SOLAR RADIATION

CHEMICAL CONVERSION CAN BE OBTAINED BY:

- ☐ DISSOCIATION OF WATER INTO HYDROGEN AND OXYGEN BY MEANS OF CHEMICAL CYCLES (STILL AT RESEARCH STAGE)

SOME APPLICATIONS OF SOLAR ENERGY TECHNOLOGY

USER	NEED	TYPE OF EQUIPMENT AND TECHNOLOGY
Rural communities	Water pumping	Thermodynamic or photovoltaic pumps
	Cooking	Solar cookers
	Lighting	Photovoltaic lighting systems
	Crop drying	Solar driers, air collectors
	Small hospitals	Photovoltaic refrigerators Solar water heaters
Large villages	Water pumping	Photovoltaic or thermodynamic pumps
	Hot water	Solar water heaters
	Electricity	Electrothermal plants Photovoltaic plants
Industries	Cooling - refrigeration	Solar concentrators, solar engines
	Process steam	Solar concentrators
	Desalination	Direct evaporation (solar stills)
	Drying	Solar driers - air collectors


Forebay
Penstock
Power canal
Power house
Tail race
Reserve flow
Intake
Fish ladder

WORLD HYDROELECTRIC POTENTIAL

While Europe is already exploiting 59% o its total hydroelectric potential, the Third World is using only 8% of its capacity. (Source: World Energy Conference, 1980)

	Technically usable potential		Present operating capacity		Percentage of hydropotential at present harnessed
	10^{12}kWh	% world total	10^{12}kWh	% world total	
North America	3.12	16	1.13	35	36
Europe	1.43	7	0.84	26	59
USSR	2.19	11	o.26	2	15
Oceania	0.39	2	0.06	2	15
NORTH	7.13	36	2.29	71	32
Africa	3.14	16	0.15	5	5
Latin AMERICA & Caribbean	3.78	20	0.30	9	8
Asia (excl USSR)	5.34	28	0.47	15	9
SOUTH	12.26	64	0.92	29	8
World Total	19.39	100	3.21	100	17

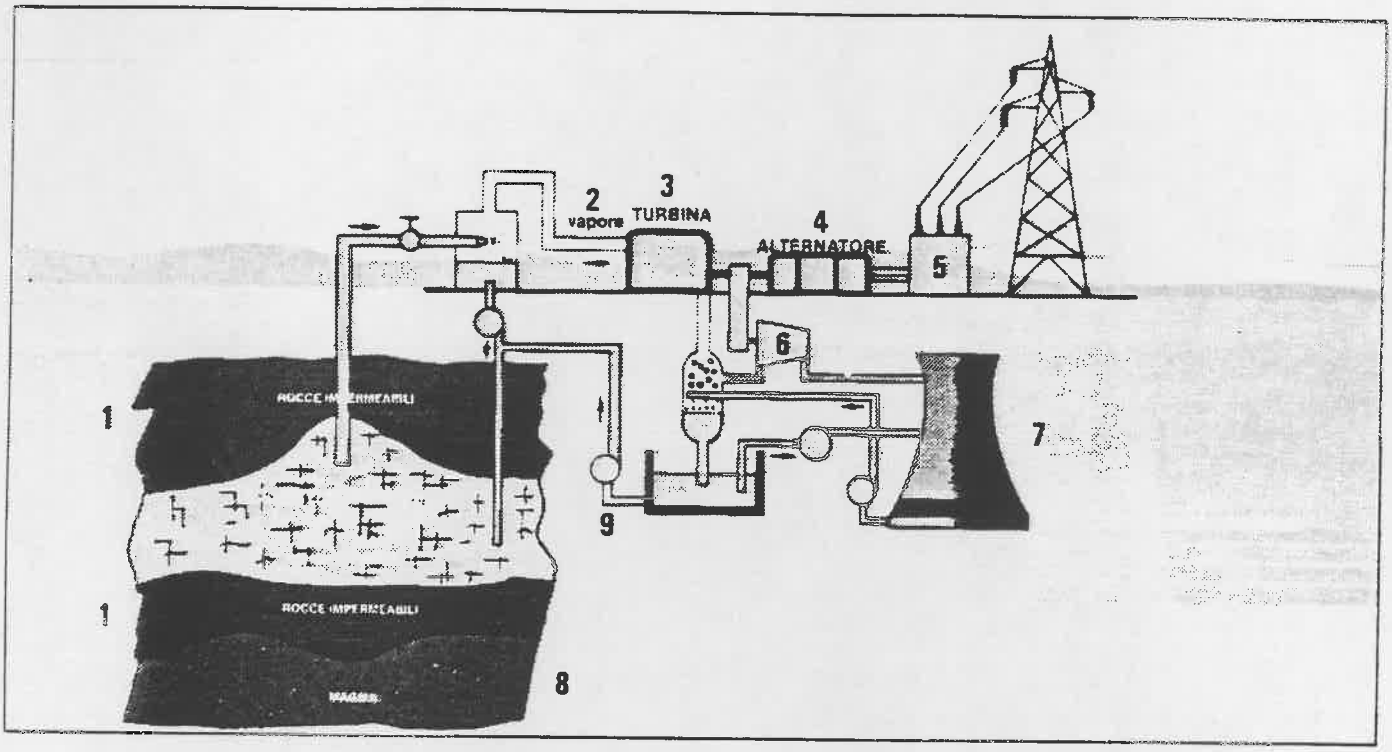
EXPECTED INCREASE IN ELECTRICITY GENERATED FROM HYDROPOWER, 1976 - 2020

The greatest increase are expected in the Third World and China.
(Figures in exajoules: 10 joules) Source: World Energy Conference, 1980.

	1976	2000	(increase 1976-2000)	2020	(increase 1976-2020)
OECD countries	3.78	5.37	(x 1.4)	7.80	(x 2.1)
Centrally - planned countries (incl. USSR and China)	0.72	2.88	(x 4)	8.70	(x12.1)
Developing countries (excl China)	1.17	4.49	(x 3.8)	11.80	(x 10.1)
WORLD TOTAL	5.67	12.7	(X 2.2)	28.30	(X 5.0)

POWER FROM THE SEAS

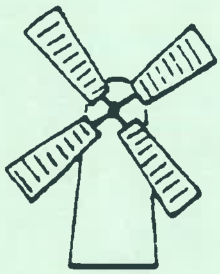
- ☐ TIDAL ENERGY EXPLOITS THE TWICE-DAILY MOVEMENT OF WATER CAUSED BY THE PULL OF THE MOON
- ☐ WAVE ENERGY HARNESSES THE UP AND DOWN MOTION OF WAVES ON THE SEA'S SURFACE
- ☐ OCEAN THERMAL ENERGY CONVERSION (OTEC) EXPLOITS THE DIFFERENCE IN TEMPERATURE BETWEEN WATER AT THE SURFACE AND IN THE OCEAN'S DEPTHS



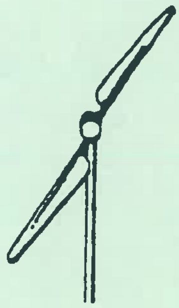
1 - IMPERMEABLE ROCKS
2 - STEAM
3 - TURBINE
4 - GENERATOR
5 - TRANSFORMER
6 - GAS COMPRESSOR
7 - COOLING TOWER
8 - MAGMA
9 - REINJECTION PUMP

HORIZONTAL AXIS WINDMILLS

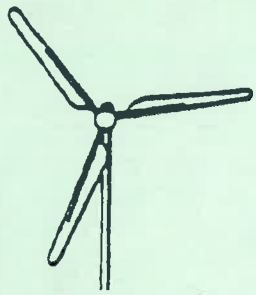
DUTCH POST-MILL



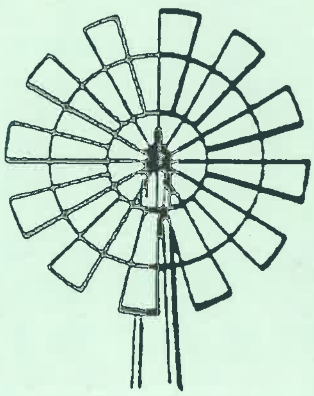
DOUBLE-BLADED



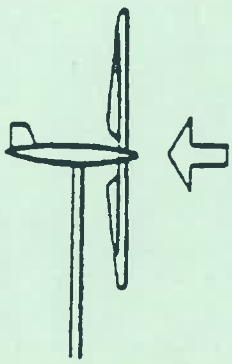
THREE-BLADED



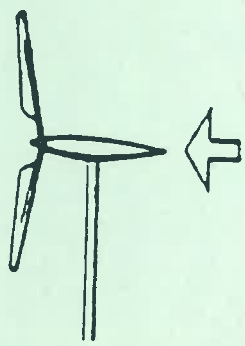
MULTI-BLADED



UPWIND



DOWNWIND



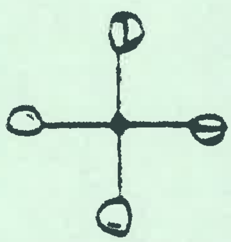
VERTICAL AXIS WINDMILLS

SINGLE-BLADED

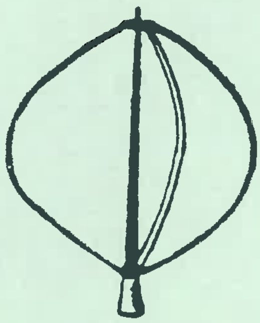
DOUBLE-BLADED

FLAT-PLATE ROTOR

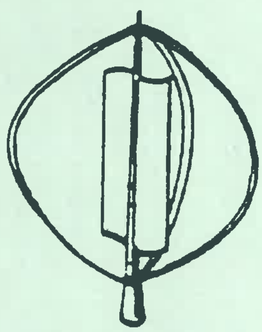
CUPPED ROTOR



PHI-DARRIEUS ROTOR



SAVONIUS-DARRIEUS ROTOR



ENERGY FROM BIOMASS

THERMOCHEMICAL CONVERSION OF LIGNO-CELLULOSIC MATERIALS INCLUDING WOOD, INDUSTRIAL AND AGRICULTURAL RESIDUES

- ☐ DIRECT COMBUSTION
- ☐ GASIFICATION
- ☐ PYROLISIS
- ☐ DIRECT LIQUEFACTION

USEFUL PRODUCTS: HEAT, GAS, ALCOHOLS AND HYDROCARBONS, CHARCOAL

BIOCHEMICAL CONVERSION OF LIGNO-CELLULOSIC MATERIALS, AGRICULTURAL PRODUCTS AND RESIDUES, URBAN AND INDUSTRIAL WASTES WITH HIGH CONTENT OF SUGARS AND STARCHES

- ☐ ANAEROBIC DIGESTION
- ☐ ALCOHOL FERMENTATION

USEFUL PRODUCTS: BIOGAS, ETHANOL, METHANOL, ORGANIC FERTILISERS

USE OF BIOMASS

BIOMASS

- ☐ CONSTITUTES AN EXTREMELY IMPORTANT SOURCE OF ENERGY CONTRIBUTING UP TO 15% OF THE WORLD'S ENERGY NEEDS, EQUIVALENT TO 20 MILLION BARRELS OF OIL A DAY (APPROX. THE PRESENT ENERGY NEEDS OF THE UNITED STATES)

- ☐ FOR 1/4 OF THE WORLD'S POPULATION, BIOMASS REPRESENTS THE MAJOR ENERGY SOURCE

COMPARISON BETWEEN TRADITIONAL AND NRSE FOR THERMAL ENERGY PRODUCTION (AFTER FURLAN, MANCINI, SAIGH)

TECHNOLOGY	CAPITAL COST $/kW	OP. TIME h/yr	ENERGY COST cents/kWh
Solar heating (san. water)	300 - 600	2000	1.5 - 3.0
Solar heating (space)	400 - 800	500	8 - 16
Solar cooking	200 - 300	500	4 - 6
Biogas (family)	500	contin.	0.6
Alcohol from sugar cane	80	4000	2
Biomass (forest)	-	-	0.03 - 0.07
TRADITIONAL SYSTEMS			
Coal (25$/ton)	-	-	0.3
Oil (12$/barrel)	-	-	0.7

COMPARISON BETWEEN CENTRAL PRODUCTION OF ELECTRICITY AND NRSE ELECTRICITY PRODUCTION (AFTER FURLAN, ET AL.)

TECHNOLOGY	POWER kW	CAPITAL COST $/kW	OP. TIME h/yr	ENERGY COST cents/kWh
Wind	1	3000 - 6000	2500	12 - 24
	5 - 15	1000 -2000	2500	4 - 8
	3000	450	2500	2
Small hydro. units	0.05 - 10	1000 - 7000	4000	3 - 18
Photovoltaic	1	15000 - 30000	2000	75 - 150
CENTRALISED SYSTEMS				
Large hidro. units.	250,000	800 - 1500	4000	2 - 4
Coal thermoel. plant	300,000	500	4000	2
Oil thermoel. plant	300,000	400	4000	3

NRSE POTENTIAL

THE PACE AT WHICH THE FULL POTENTIAL OF NRSE CAN BE DEVELOPED WILL BE DETERMINED BY THE COUNTRY'S ABILITY TO:

- ☐ **DEVELOP ADEQUATE DATA ON SOURCES AND USES OF RENEWABLE ENERGY;**
- ☐ **ENHANCE THEIR TECHNICAL ABILITIES;**
- ☐ **DESIGN SYSTEMS THAT CAN DELIVER RENEWABLE TECHNOLOGIES IN SOCIALLY AND CULTURALLY ACCEPTABLE FORMS TO LARGE NUMBERS OF ENERGY USERS; AND**
- ☐ **STRENGTHEN INSTITUTIONS FOR ENERGY PLANNING AND PROGRAMMING**

THE ROLE OF WOMEN AS SUPPLIERS OF NRSE

PROVIDING ANIMATE ENERGY

DEVELOPING NRSE TECHNOLOGIES

FUELWOOD PRODUCING, COLLECTING, TRADING

AGRICULTURAL RESIDUE COLLECTING AND PROCESSING

WOMEN AS USERS OF ENERGY

ENERGY NEEDS AT THE HOUSEHOLD LEVEL:

- ☐ WATER SUPPLY
- ☐ COOKING
- ☐ LIGHTING
- ☐ SPACE HEATING
- ☐ BOILING WATER
- ☐ FOOD PROCESSING
- ☐ IRONING
- ☐ DYEING CLOTHS
- ☐ PEST CONTROL
- ☐ FOOD PRODUCTION
- ☐ FODDER PREPARATION
- ☐ REFRIGERATION
- ☐ POWER FOR RADIO, TV AND OTHER DOMESTIC APPLIANCES
- ☐ SPACE CONDITIONING
- ☐ OTHER

WOMEN'S ENERGY NEEDS AT THE COMMUNITY LEVEL

- ☐ WATER SUPPLY
- ☐ TRANSPORTATION
- ☐ COMMUNICATIONS
- ☐ IRRIGATION SCHEMES
- ☐ WATER DESALINATION
- ☐ WATER PURIFYING
- ☐ REFRIGERATION, LIGHTING, SPACE HEATING, ETC. FOR EDUCATION, TRAINING, HEALTH CARE AND OTHER COMMUNITY CENTRES

WOMEN'S ENERGY NEEDS FOR INCOME-GENERATING ACTIVITIES

FUEL-INTENSIVE ACTIVITIES TYPICALLY PERFORMED BY WOMEN:

- ☐ CATERING
- ☐ FOOD PROCESSING
- ☐ POTTERY MAKING
- ☐ BRICK-MAKING
- ☐ BEER BREWING
- ☐ SOAP MAKING

THE PARTICIPATION OF WOMEN IN ENERGY PLANNING AND POLICIES: CONSTRAINTS

LACK OF EDUCATION AND TRAINING IN TECHNICAL FIELDS AND HIGH-LEVEL MANAGEMENT

LACK OF PARTICIPATION IN DECISION-MAKING BODIES

LACK OF AWARENESS OF THEIR POTENTIAL CONTRIBUTION

POSSIBLE SOLUTIONS

PROVIDE DIRECTIVES AND TAKE MEASURES FOR ENHANCING WOMEN'S PARTICIPATION IN EDUCATION AND TRAINING IN TECHNICAL FIELDS AND MANAGEMENT SKILLS

SUPPORT EXISTING WOMEN'S ORGANISATIONS OR GROUPS ACTIVE IN NRSE ACTIVITIES WITH ADEQUATE INFORMATION, TRAINING AND FUNDS

SENSITISE POLICY-MAKERS AND DECISION-MAKERS ON THE NEED TO INVOLVE WOMEN

HOW TO INTEGRATE WOMEN'S NEEDS IN ENERGY PLANNING AND ENERGY POLICIES: CONSTRAINTS

LACK OF DATA AND INFORMATION ON WOMEN'S ACTIVITIES

MISCONCEPTIONS ON THE ROLE OF WOMEN

LACK OF AWARENESS OF DECISION-MAKERS AND ENERGY PLANNERS OF THE NEED FOR SPECIAL CONSIDERATION OF WOMEN'S NEEDS

RECOMMENDED APPROACH

DATA AND INFORMATION COLLECTION ON WOMEN'S ROLE IN NRSE

SENSITISATION OF POLICY-MAKERS AND DECISION-MAKERS

SENSITISATION OF THE PUBLIC AT LARGE USING MASS MEDIA

ENCOURAGING WOMEN'S PARTICIPATION IN DECISION-MAKING

PROMOTING SURVEYS ON THE IMPACT OF CURRENT ENERGY POLICIES ON WOMEN

THE IMPACT OF NRSE TECHNOLOGIES ON WOMEN

POSITIVE EFFECTS:

- ☐ NRSE TECHNOLOGIES MAY HELP TO SAVE LABOUR AND TIME
- ☐ THEY MAY IMPROVE COMFORT AND CONVENIENCE
- ☐ THEY MAY IMPROVE SOCIAL STATUS

NEGATIVE EFFECTS:

- ☐ THEY MAY INCREASE DRUDGERY IF NOT PROPERLY DESIGNED
- ☐ THEY MAY DISPLACE WOMEN FROM THEIR WORK

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NEGATIVE EFFECTS:

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- ☐ THEY MAY DISPLACE WOMEN FROM THEIR WORK

WOMEN'S INTEGRATION IN THE DEVELOPMENT OF NRSE

NRSE TECHNOLOGIES SHOULD BE ADAPTED TO THE PERFORMER GENDER

PILOT PROJECTS SHOULD BE PROMOTED TO DEVELOP AND TEST NEW NRSE TECHNOLOGIES FOR WOMEN'S USE

RESEARCH ON NRSE TECHNOLOGIES SUITABLE FOR WOMEN'S USE SHOULD BE IDENTIFIED AND PROMOTED

WOMEN SHOULD PARTICIPATE IN IDENTIFYING AREAS FOR RESEARCH AND DEVELOPMENT OF NRSE TECHNOLOGIES AND IN CARRYING OUT SUCH ACTIVITIES

HOW TO INTEGRATE WOMEN IN NRSE ACTIVITIES

WOMEN SHOULD PARTICIPATE IN NRSE POTENTIALS ASSESSMENT

THE PRESENT ROLE OF WOMEN IN NRSE SHOULD BE INVESTIGATED

WOMEN'S NEEDS AND PARTICIPATION SHOULD BE BETTER INTEGRATED IN ENERGY PLANNING AND POLICIES

THE PARTICIPATION OF WOMEN IN EDUCATION AND TRAINING IN THE ENERGY FIELD SHOULD BE ENHANCED

RESEARCH ON AND DEVELOPMENT OF NRSE SYSTEMS FOR WOMEN'S USE SHOULD BE ENHANCED

PILOT PROJECTS IN THE FIELD OF NRSE HAVING WOMEN AS TARGET GROUP SHOULD BE PROMOTED

INFORMATION ON NRSE TECHNOLOGIES FOR WOMEN'S USE SHOULD BE DISSEMINATED

THE INTEGRATION OF WOMEN IN NRSE PROJECTS AND PROGRAMMES SHOULD BE PROMOTED

MODULE EWIII

RELEVANT NRSE SYSTEMS: CHARACTERISTICS AND TECHNOLOGY

FOREWORD

Consistent with its policy to formulate training strategies and devise innovative methodologies for advisory services, **UN/INSTRAW** has devoted substantial resources to preparing, in collaboration with the **ILO Turin Centre,** a prototype training package on **"Women and New and Renewable Sources of Energy"**.

This training package is the joint production of seven years of INSTRAW research in this field, and scientific, technical and training activities of Energy Programmes in the ILO Turin Centre. It also contains material from other United Nations bodies and agencies, as well as decisions and recommendations from various meetings attended and organised by INSTRAW, both within and outside the United Nations system.

The training package was prepared by **Mr Giulio Piva,** Chief, Training Operations, ILO Turin Centre, and **Ms Borjana Bulajich,** Social Affairs Officer, UN/INSTRAW. The audiovisual aids were prepared by **Ms Adelina Guastavi,** Audiovisual Expert, ILO Turin Centre, with the support of the Media Production Section of the ILO Turin Centre. The training package was updated by **Ms Marina Vaccari,** INSTRAW Staff Member.

The team would like to express deep appreciation to **Ms Denise Zoccola** for the time and patience she has dedicated to the word processing of this training material.

The training package was finalised under the supervision of **Ms Dunja Pastizzi-Ferencic,** Director of INSTRAW.

This module is conceived as a package containing all the information, examples, exercises, audiovisual and control aids necessary for:

- the **trainer** to deliver a lesson or conduct training activities;

and/or

- the **trainee** to analyse, reinforce and apply the theoretical concepts learned during training sessions;

and/or

- the **professional** as self-learning reference material to upgrade knowledge and skills related to effective integration of women in NRSE projects and programmes.

In order to reduce the learning time and improve the learning efficiency, keeping high the motivation of the user, the text of the module contains only that information and activities considered essential for the achievement of the training objectives as specified in the following pages. Additional reading material is included for those users who wish to study in greater depth specific subjects related to the subject considered in this module.

From a pedagogical point of view, the structure of the modular package consists of five components - as specified on the following page - which are easily adaptable to the needs of both the trainer and the trainee.

1. INPUT DOCUMENTS

   1.1 Target groups

   1.2 Objectives

2. BODY OF THE MODULE

   2.1 Table of contents

   2.2 Text

   2.4 Glossary

   2.5 Bibliography

3. OUTPUT DOCUMENTS

   3.1 Checklists on key issues for group work

   3.2 Evaluation questionnaire

4. TRAINER'S GUIDE

   4.1 List of training material

   4.2 Lesson plan

   4.3 Trainer's guide evaluation form

5. VISUAL AIDS

   5.1 List of audiovisual aids

   5.2 Transparencies

The trainer will make use of the five components indicated above, while the trainee will only be provided with the material related to components 1, 2 and 3.

1. DEVELOPMENT PLANNERS, SENIOR OFFICIALS FROM MINISTRIES OF ENERGY, AND OTHER GOVERNMENTAL AND NON-GOVERNMENTAL ORGANISATIONS INVOLVED IN THE DEVELOPMENT AND MANAGEMENT OF ENERGY PROGRAMMES AND PROJECTS ON THE USE OF NRSE.

2. SENIOR OFFICIALS OF WOMEN"S ORGANISATIONS AND INSTITUTIONS AT NATIONAL, REGIONAL AND INTERNATIONAL LEVELS.

GENERAL OBJECTIVE

TO ENABLE USERS TO IDENTIFY THE BASIC TECHNOLOGIES AND OPERATIONAL CHARACTERISTICS OF THE MOST RELEVANT ENERGY SYSTEMS BASED ON THE EXPLOITATION OF NRSE.

SPECIFIC OBJECTIVES

ON COMPLETION OF THIS UNIT, THE USER WILL BE ABLE TO:

1. IDENTIFY THE PRINCIPLES OF OPERATION AND THE MAIN TECHNOLOGICAL CHARACTERISTICS OF:

   - PASSIVE THERMAL SOLAR SYSTEMS;
   - ACTIVE THERMODYNAMIC SOLAR SYSTEMS;
   - PHOTOVOLTAIC SOLAR SYSTEMS;
   - SMALL-SCALE HYDROELECTRIC SYSTEMS;
   - GEOTHERMAL SYSTEMS;
   - WIND ENERGY SYSTEMS;
   - BIOMASS BASED ENERGY SYSTEMS.

2. INTERPRET THE TECHNICAL IMPLICATIONS IN THE PROPOSALS OF PROGRAMMES OR PREFEASIBILITY STUDIES CARRIED OUT TO DEVELOP IN SPECIFIED AREAS ENERGY SYSTEMS BASED ON THE EXPLOITATION OF NRSE.

Page

Page

1. GENERAL INTRODUCTION

The text of this modular unit gives only a brief, general description of those systems and technology most commonly used to exploit the energy potential of NRSE. For the purpose of this module, they are not presented in sufficient detail and depth to enable the user to make a definitive choice or selection of a system or technology. The user will need additional study and reading material.

The present state of the art will be discussed and an indication of any further development will be given where possible. Some **NRSE technologies** are mature, others are still subject to major developments. What matters are obviously the **technical and economical characteristics**, but also a range of less tangible aspects; amongst the latter are **environmental, infrastructural, social** and **human** (users) **characteristics** of a technology.

The **economic** characteristics are complicated in itself, because of the site specificity of renewable energy technologies and the dependency on costs of infrastructural provisions, like subsidies and management structures. This results in complications relating to indirect costs and benefits.

Environmental costs of energy technologies are often indirect and so are environmental costs and benefits of alternatives. The same applies to public health aspects. The effects are partly long-term and not yet all identified.

Social and human characteristics of energy technologies relate to acceptance of the technology on the one hand, and positive and negative effects on the other hand. The introduction of a new technology may benefit certain groups in society and deprive others, or generally affect an existing socio-economic structure of labour, production and consumption. However, as compared to other technological innovations, there is as yet little reason to dramatise the impact of introducing new energy technologies.

The **infrastructure** viability of energy technologies goes beyond conditions of subsidies and management or control structures. Relevant is the feasibility of building up a support structure such as: inputs, maintenance and repairs together with the required skills, the existence of extension networks, markets, facilities and information flows. They all affect the scope for dissemination of a technology, and the accessibility for the users of credit facilities for investments. Relevant is also the organisational and administrative capacity of the agents dealing with the energy problems.

Last but not least, is the infrastructure which provides a link between research, development and manufacture of NRSE equipment. It is an important determinant for the impact of NRSE technologies on a larger scale.

2. SOLAR ENERGY SYSTEMS

The sun emits a large amount of radiant energy, part of which is absorbed by the atmosphere, while another part is reflected back into space; the remaining part reaches the earth's surface as **direct** or **diffuse radiation.** The former reaches the terrestrial surface locally in a straight line from the sun, while the latter is reflected in the atmosphere by clouds, dust, etc. (See Fig. EWIII-1).

The rate at which the solar irradiation reaches the earth's surface is called global irradiance, and is measured as a power in Watts per square metre (W/m^2); it's magnitude depends especially on the latitude, altitude, seasons, hour of the day, meteorological conditions. (In a tropical zone, on a sunny day at noon it can reach a peak value of 1,000 W/m^2.)

There are two types of **solar systems**:

a) **passive** solar systems (thermal systems);
b) **active** solar systems (thermodynamic systems).

a) In **passive** solar systems (**thermal conversion**), the transfer of the thermal energy produced by the sun occurs through three natural physical phenomena:

- **conduction:** heat is transferred into a body without macroscopic mass transport
- **convection:** heat is transferred between a solid surface and a fluid which is in contact with the surface
- **radiation:** direct heat transfer as electromagnetic waves

b) In the **active** solar system, the energy flows are "forced" (not naturally) by means of specific equipment. This can be used for:

- production of electricity through **thermodynamic conversion.** Thermodynamic conversion is a process through which thermal energy is transformed into mechanical or electrical energy making use of the various types of thermodynamic cycles (which use a fluid for the conversion of the heat into mechanical energy):
- direct production of electricity through **photovoltaic conversion.**

2.1 PASSIVE THERMAL SYSTEMS

The simplest method for collection of solar energy is to design windows of buildings to collect systematically the solar energy

THE IMPACT OF SOLAR RADIATION WITH THE ATMOSFERE

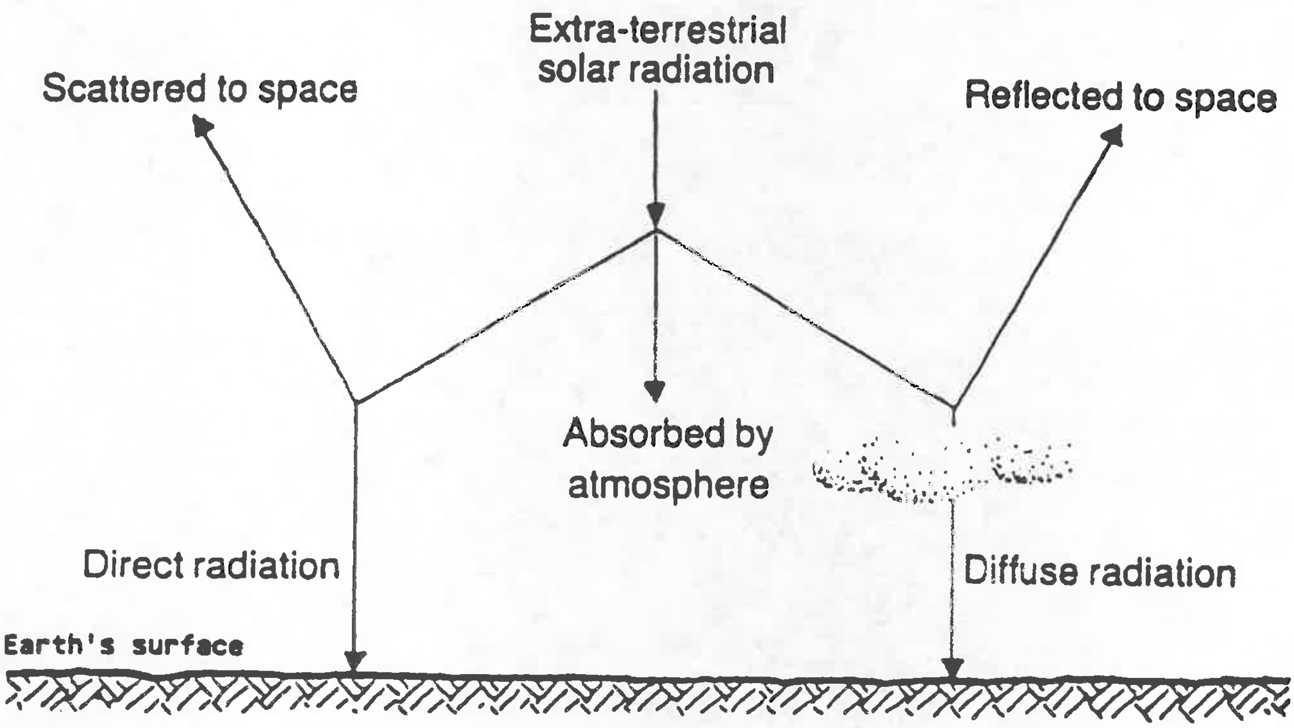


FIG. EWIII-1

available in the cold season. Methods of solar collection that make no use of ancillary equipment like fans and pumps are known as passive systems. **Passive collection** is the **simplest** and hence usually the **most cost-effective way of gathering solar energy (direct and diffuse)**, and many of the techniques have been used for centuries. Technically speaking, passive heating techniques are well understood. They have the advantage of using traditional materials and traditional building techniques, and are usable in a wide range of climates.

Passive systems are characterised by **low working temperatures** and **low thermal efficiencies**, compensated by **simple technologies**. A typical simple example is the TROMBE WALL: an ordinary masonry is painted black and a plate of glass or a plastic sheet erected in front of it isolate a layer of air which, when heated (by the heat stored in the black wall which "collects" the solar radiation), rises and enters the house through special ducts (Fig. EWIII-2).

2.1.1 Solar water heating

Solar water heating is today the most **mature solar technology**, in terms of technology itself, **economic viability** and **commercial availability**. Systems in use today are almost exclusively of the simple flat collector type.

A conventional **flat-plate collector** consists of a metal absorber plate, typically steel, aluminium or copper, through which is circulated a heat transfer fluid, shown in Fig. EWIII-3. The fluid is usually a water/glycol solution or air, although mineral oils or refrigerants can also be used. The absorber must be insulated at the back and sides to prevent heat loss, and covered at the front with a transparent material. Solar radiation passes through the cover and heats the absorber plate, which has a black surface to increase absorption. The transparent cover is usually opaque to the long-wave radiation emitted by the absorber plate, and therefore there is a build-up of heat in the space between the cover and the absorber. This is the well-known "**greenhouse effect**".

By connecting the collector site to a storage tank (Fig. EWIII-4a) on the "cold" and the "hot" sides, a close circuit is achieved in which the hot water rises by natural convection (thermosyphon phenomenon) and is thus a simple and practically foolproof device if properly designed.

Other systems which are still simpler, and have become quite popular already in a number of developing countries, are of the **tank-in-collector type** (Fig. EWIII-4b). No separate storage tank is provided here and the collector volume is larger and contains all the water usable. Such systems are considerably cheaper but have the disadvantage that use of hot water is limited to the evening hours. During the day, the entire contents of the collector heats up only slowly and during the night, hot water not used cools down again.

THE TROMBE WALL

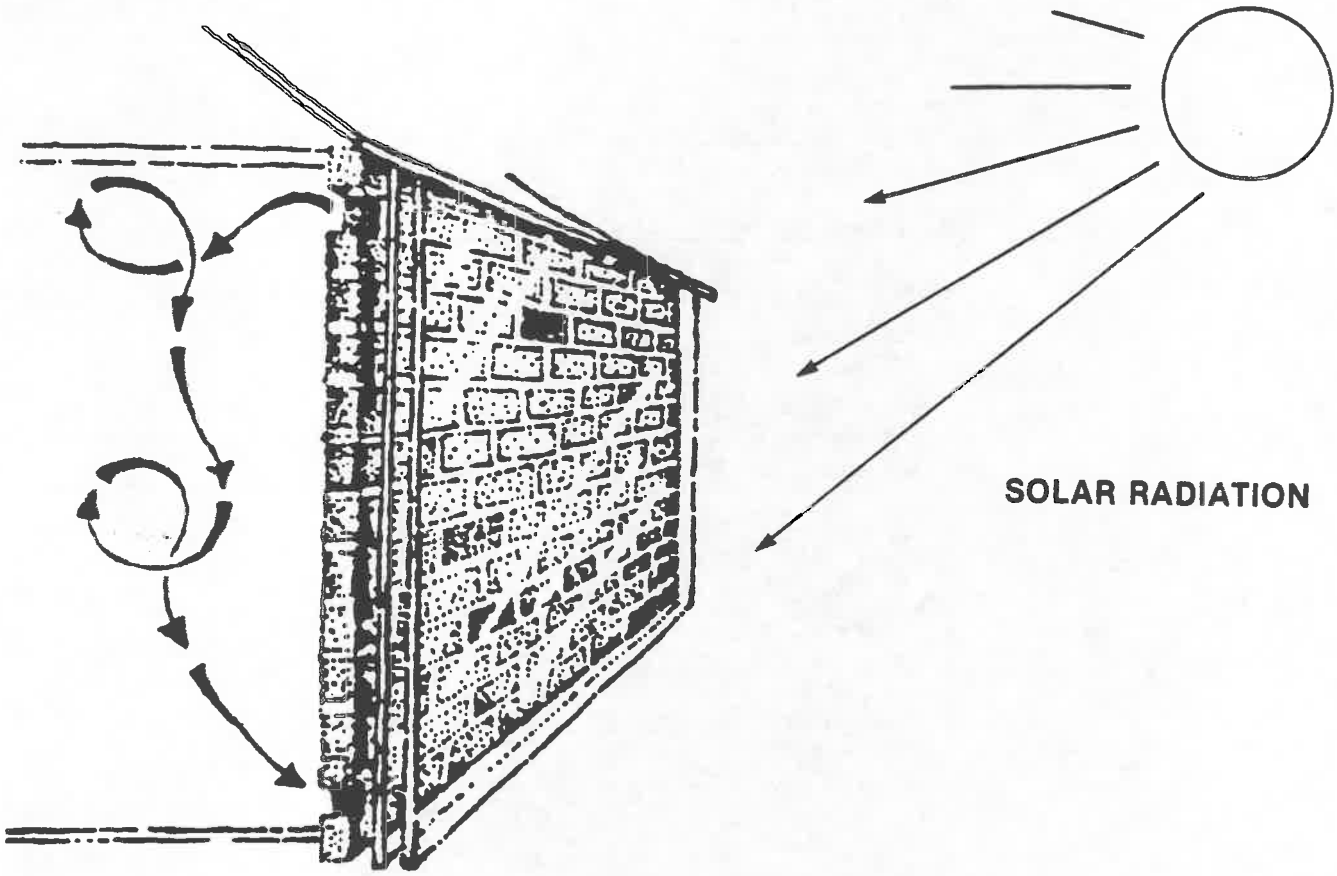


FIG. EWIII-2

TYPICAL CONSTRUCTION OF A FLAT PLATE SOLAR COLLECTOR

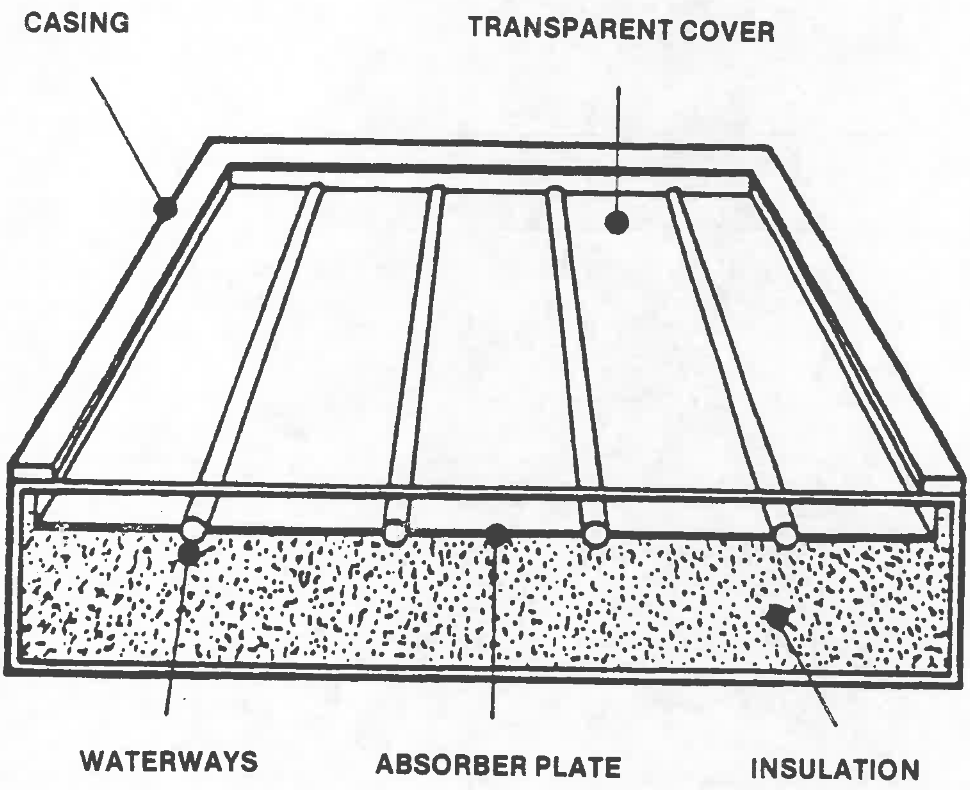
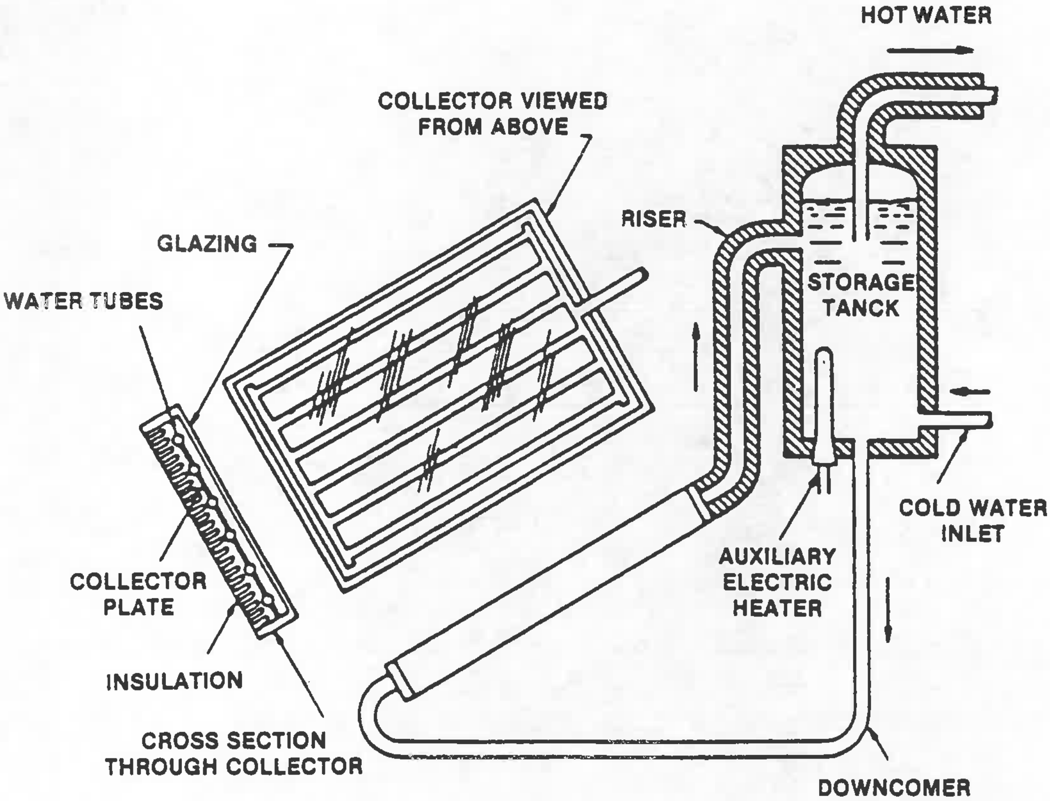


FIG. EWIII-3

NATURAL-CONVECTION SOLAR WATER HEATER WITH STORAGE TANK



TANK-IN-COLLECTOR TYPE SOLAR WATER HEATER

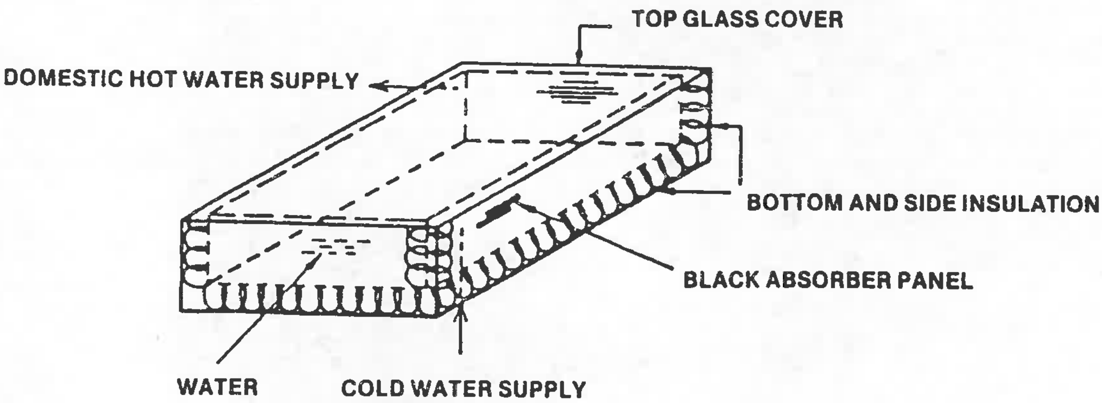


FIG. EWIII-4

A common problem with solar water heaters is of course the non-predictability of the sun in some regions. The hot water supply in these cases is not guaranteed, and often an alternative hot water system is required. Quite common are already electric booster elements of perhaps 1 kW output. These are built into the storage tank and are thermostatically controlled. If the temperature of the water in the storage tank drops below a set limit, the booster is switched on, irrespective of solar radiation available.

All solar heaters discussed here are low temperature systems. **Water** will normally not **heat up** to more than **70 to 80°C**, if the efficiency is to remain reasonable. It is an advantage to design a system for a water temperature as low as acceptable. In domestic use, 200 litres heated up to 50 to 60°C is often satisfactory and always more economical than a smaller quantity heated up to say, 90°C, because losses at lower temperatures are smaller.

In the more favourable climates, solar water heating has the potential to substitute for conventional hot water systems to a large extent. This is true however mostly for urban areas and in the wealthier sections of the population. The poor, and people in rural areas, usually have no water supply installed in their homes and are traditionally not familiar with the luxury of hot water. The scope of solar water heating is less clear in this area and it is as a rule not the commercial systems that are applicable, but more likely other low-cost and quite likely owner-built systems.

2.1.2 Solar cooking

Three types of solar cookers have been developed: **solar heat boxes** (Fig. EWIII-5), which must be oriented manually towards the sun's radiation and are composed of an insulated box with double-glazing; **parabolic disk-type reflectors** which concentrate the direct beams on a focal zone where the pot is placed (Fig. EWIII-6); and a system in which the **solar collection** is **separate from the cooking stove** and heat is transported by a working fluid (Fig. EWIII-7). The latter makes it possible to cook inside the house and to install a heat storage system for cooking when the sun is not shining (Fig. EWIII-8). It is well known that a number of promotional demonstrations of solar cookers failed. Such factors as high unit costs, lack of storage facilities for supplying heat to cook the food during evening hours, unreliable units which could not withstand rural conditions and inadequate social acceptability were responsible for the failure. In the last two years, however, it seems that the insulated box cooker in certain parts of India (especially Gujarat State) has been introduced with a reasonable amount of success. Collector surface, and therefore costs, of solar cookers depend on average overall solar radiation, types of fuel and cooking habits, but also on the thermal efficiency of the cooker. Those **thermal efficiencies** are again related to design, materials and state of maintenance of the equipment. As an indication, one can summarise the following efficiencies:

OVEN TYPE COOKER

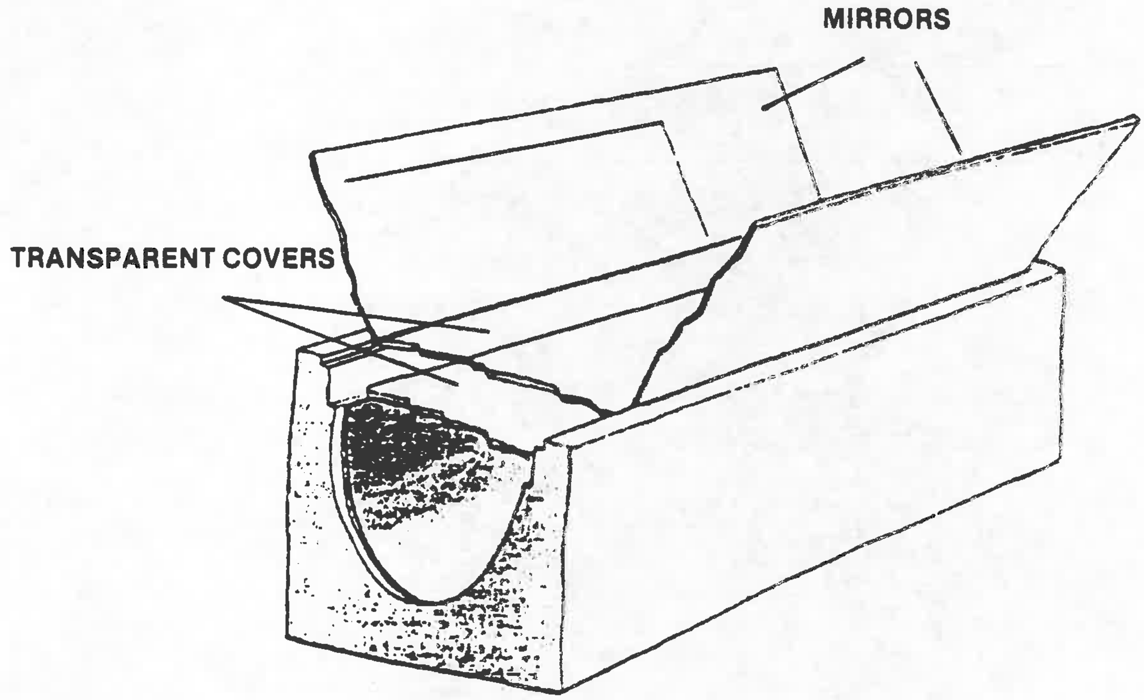


FIG. EWIII-5

SIMPLE SOLAR COOKER

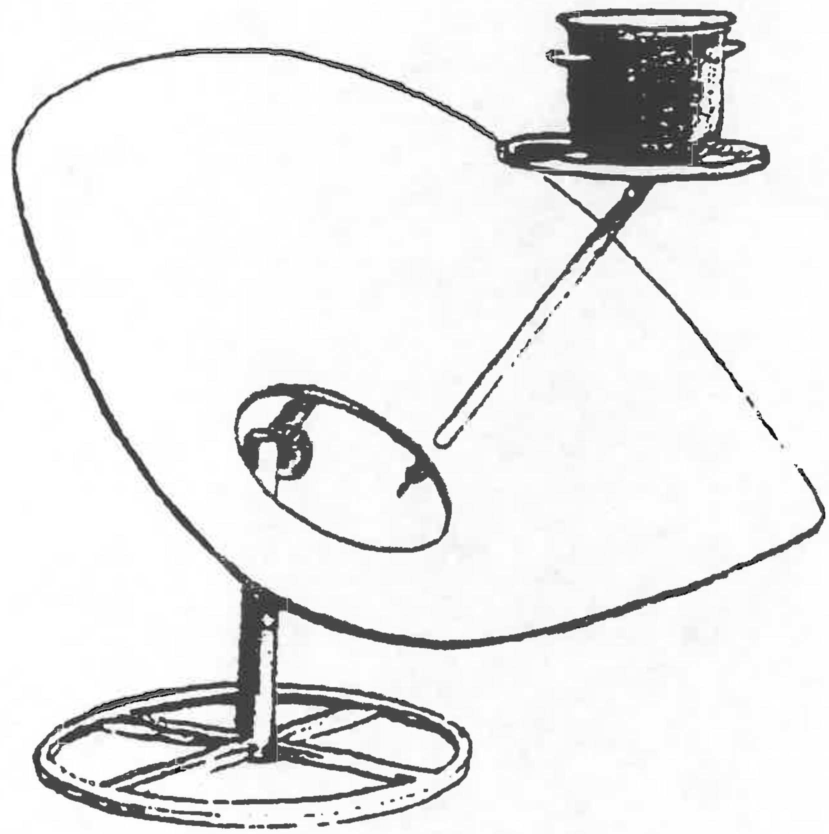
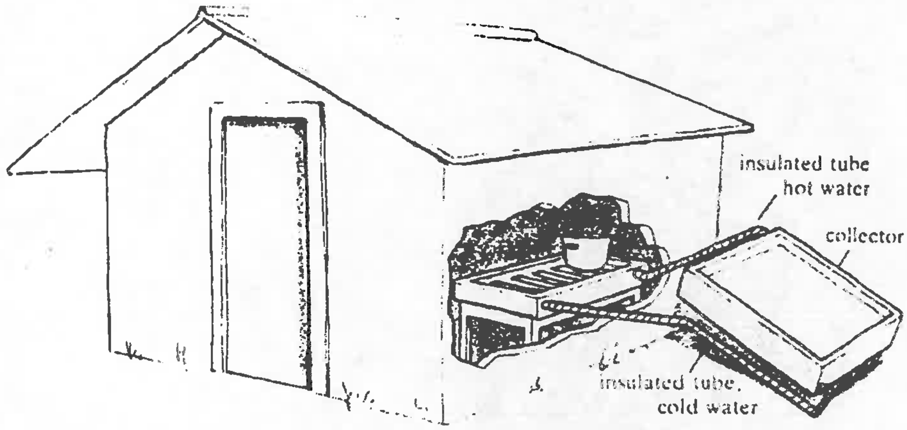
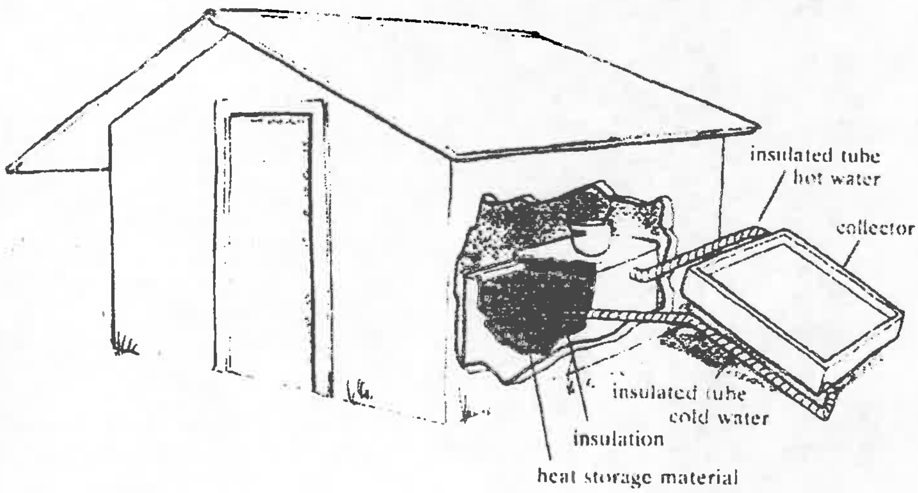


FIG. EWIII-6



Solar cooking with heat transport.

FIG. EWIII-7



Solar cooking with heat transport and heat storage.

FIG. EWIII-8

- **flat-plate solar cooker** with heat transport: **10-20** per cent (of total solar radiation)

- **parabolic disk reflector cooker: 60-70** per cent (of direct beam radiation)

- **insulated box cooker: 35-45** per cent (of direct beam radiation).

2.1.3 Water distillation

Water distillation by means of solar energy has been studied extensively and is already in use. One system consists of a **shallow pool with a blackened bottom,** the whole being covered with an inclined glass window or plastic foil (Fig. EWIII-9). Water evaporates and condenses against the foil which is cooled by outside air. Insulation is poor and the heat transfer to the ambient via the window determines the maximum distillation rate. With separate solar collectors the systems will be less simple, but can probably have a better efficiency, as both the solar collection and a distillation vessel may be better insulated.

The simplest system is a **vessel** in which the water is **heated with** the help of a **solar collector** (Fig. EWIII-10). The escaping vapour is cooled by incoming water and ambient air. In this way, the evaporation heat has to be delivered, but not the heating of the water. With a latent heat of 2200 kJ/kg and an average collected heat of 90 W/m², it should be possible to produce 3,5 kg of water per 24 hours per m² collector surface. The collector then has to work just above 100°C, which must be possible for a good collector. Because of the high water vapour temperature, heat exchange with the ambient air is much easier, and moreover the heat exchanger area can be chosen at will.

The system may be again made better but more complicated by using active systems.

2.1.4 Crop drying

Of all the direct uses of solar energy, sun drying of crops is perhaps the most ancient and widespread. Traditionally, drying is done by spreading the products on the groups in the open air, exposing them to the sun. However, at the same time they are exposed to bad weather and insects. In order to reduce the risk resulting from such hazards, **solar driers** have been designed, built and used extensively. The earlier units were **based on the "greenhouse effect"**. They reduced drying times, enhanced the quality of the products, and were found particularly useful for products which were harvested in the wet seasons. Solar driers have also been used for timber and wood drying. Generally, the principle of the solar drier is to heat air in a suitable solar collector and circulate it by natural or forced means

SIMPLE SOLAR STILL

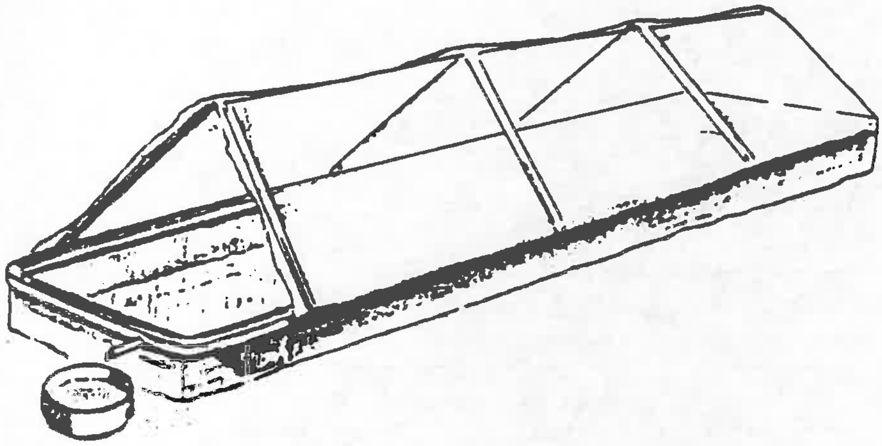


FIG. EWIII-9

SOLAR DISTILLATION PLANT

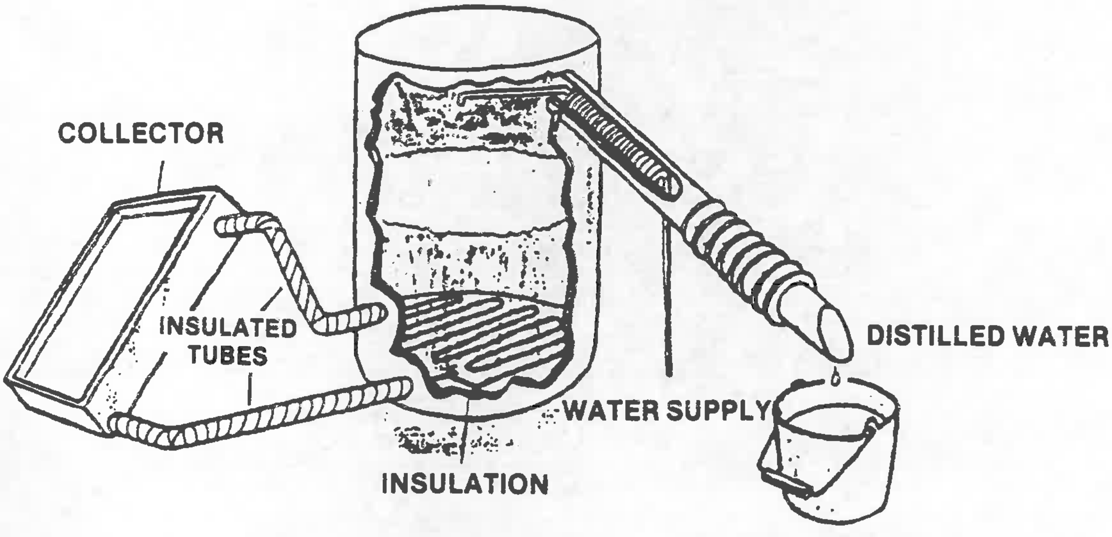


FIG. EWIII-10

through the product to be dried. The solar collector - or air heater, as it is normally called - may be external to or form an integral part of the drier. Solar driers are particularly suited to small homesteads and villages in developing countries, where they can play a large part in crop preservation. As an added incentive, the technology involved in the construction and operation of a typical drier is simple enough to be universally applied. One attraction of solar driers is that several designs can be built by using mostly locally available materials.

Solar driers are **classified** according to their **heating modes**, or the manner in which the **heat derived from solar radiation** is used. In this regard, several general categories have been set up, which are defined below. In general, a drier has been classified according to its principal operating mode. Some of the direct and mixed-mode driers also use circulating fans and are not, strictly speaking, totally passive systems. Driers using only solar or wind energy for their operations are classified as passive systems.

Sun or natural driers. These driers make use of the natural action of ambient solar radiation, and of the ambient temperature, humidity and motion of the air to achieve drying.

Solar driers - direct. In these units, the material to be dried is placed in an enclosure with a transparent cover or side panels. Heat is generated by absorption of solar radiation on the product itself as well as on the internal surfaces of the drying chamber. This heat evaporates the moisture from the drying product. In addition, it serves to expand the air in the enclosure, causing the removal of this moisture by the circulation of air.

Solar driers - mixed-mode (direct and indirect). In these driers, the combined action of the solar radiation incident directly on the material to be dried and pre-heated in a solar air heater furnishes the heat required to complete the drying.

Solar driers - indirect. In these driers, the solar radiation is not directly incident on the material to be dried. Air is heated in a solar collector and then ducted to the drying chamber to dehydrate the product.

Solar timber driers. These driers have been put in a special category, since they constitute an important application of this technology. In most cases, forced ventilation is used, since proper circulation of air helps control the drying rate so as to avoid case-hardening.

Fig. EWIII-11 shows a fruit and vegetable drier.

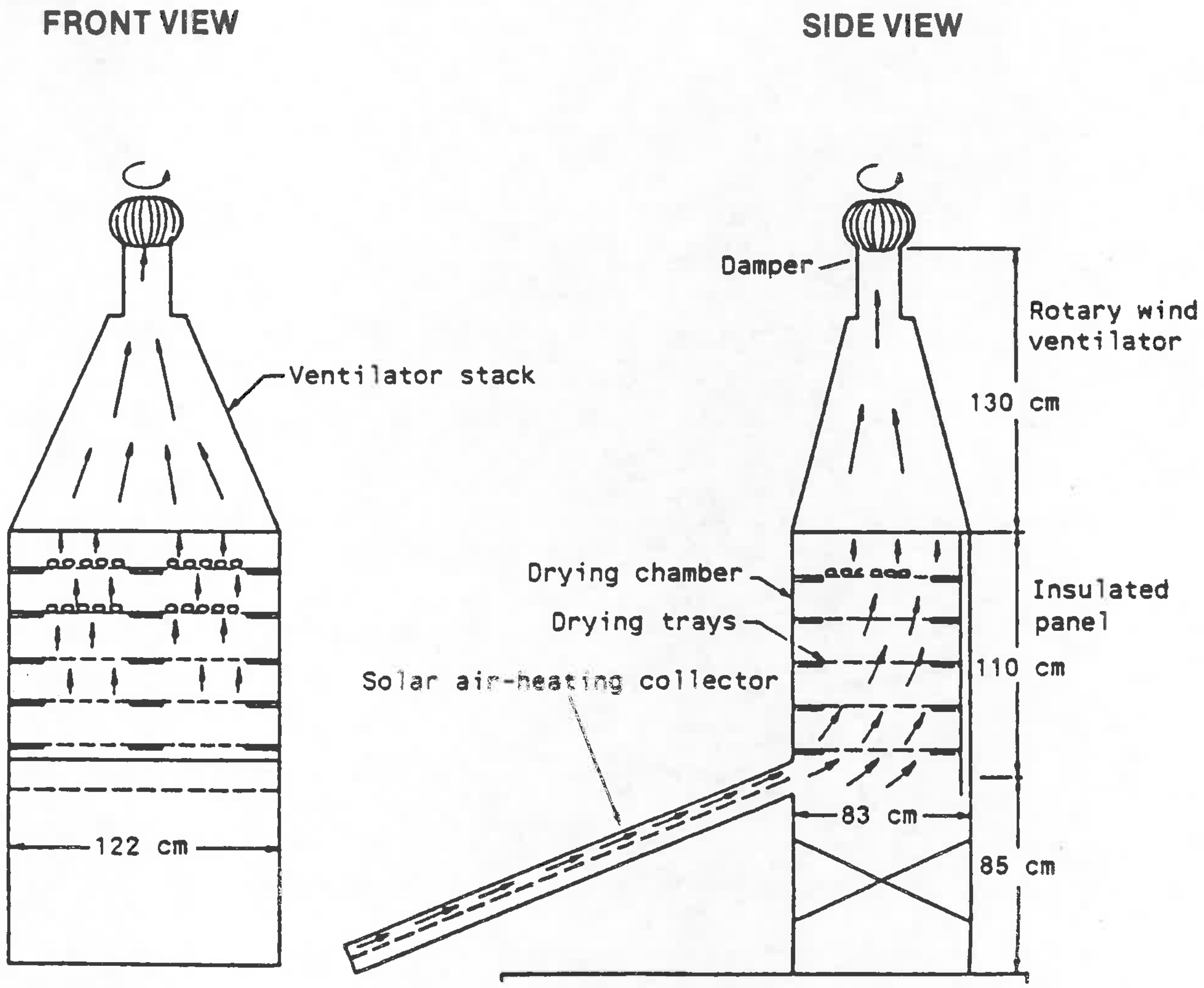

FRONT VIEW
SIDE VIEW
Ventilator stack
122 cm
Damper
Rotary wind ventilator
130 cm
Drying chamber
Drying trays
Solar air-heating collector
Insulated panel
110 cm
83 cm
85 cm

FIG. EWIII-11

2.2 ACTIVE THERMODYNAMIC SYSTEMS

The low thermal efficiency and working temperature, typical of passive systems, can be raised by "active thermal" collection.

It is very difficult to obtain fluid temperatures in excess of 150°C with the use of even the most sophisticated flat-plate collectors, because their surface thermal losses become appreciable. A possible and practical means of achieving higher temperatures is by the use of concentrating-type solar collectors. This necessarily implies that practically all of the diffuse component of solar radiation is lost to the system; attempts must be made to **utilise as much** of the **direct solar beams** as **possible**. Hence, **the concentrator** is normally **equipped** with a **tracking device** which, in effect, ensures that it "follows the sun" continuously. The **absorber** in this case is **located** close to the **geometric focus** of the concentrator, to ensure that it intercepts most of the incident direct radiation. There are, in general, **two types of concentrators**: the **linear-focusing concentrators** and the **point-focusing** ones. The former are generally equipped with a single-axis tracking system, and the latter with a two-axis system. In the former case, the absorber is a tube on which the solar image shifts as a function of the sun's position, while in the latter, the absorber covers the area around the focal point. Point-focusing systems are far more sophisticated and complex than linear-focusing systems and can only be justified when high temperatures (300°C to 1,000°C) are to be reached.

Fig. EWIII-12 shows three types of linear-focusing collectors.

Thermodynamic conversion is a **process** which **converts the thermal energy of solar radiation into mechanical energy** through a classical thermodynamic cycle (such as RANKINE, BRAYTON, etc.); it can also be used for the joint production of electricity and heat.

It should be noted that the technology adopted in thermodynamic conversion is sophisticated and costly and often difficult to realise in developing countries.

2.2.1 Solar engines

The operating principles are simple: a **high-temperature solar collector system** causes the evaporation of a liquid working fluid. The **vapour obtained expands in a reciprocating or rotating engine, or steam turbine** doing useful work. From the engine, it flows into a heat exchanger, in which it condenses; the condensate is reinjected by a pump into another heat exchanger in which it evaporates closing the cycle. Various types of solar engines have been developed to drive water pumps or electrical generators.

Fig. EWIII-13 shows a solar water pumping system driven by a solar engine.

PARABOLIC MIRROR COLLECTOR

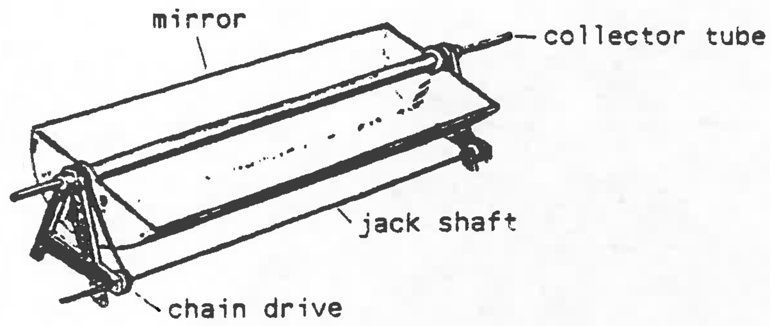


FIG. EWIII-12a

FRESNEL LENS COLLECTOR

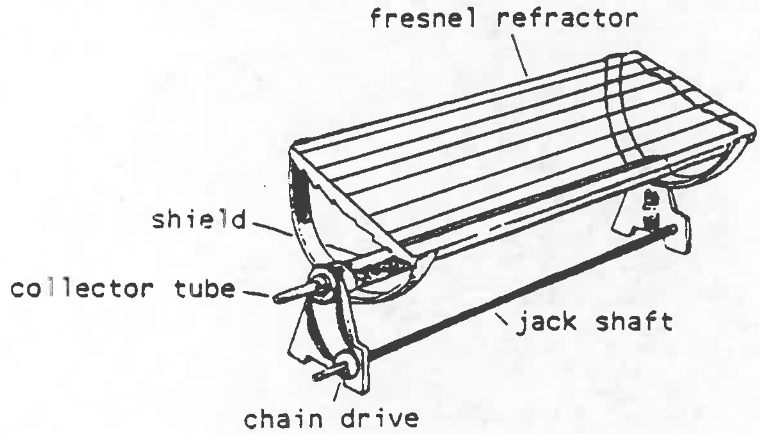


FIG. EWIII-12b

COLLECTOR WITH MIRROR STRIPS, FIXED IN A MOVING FRAME

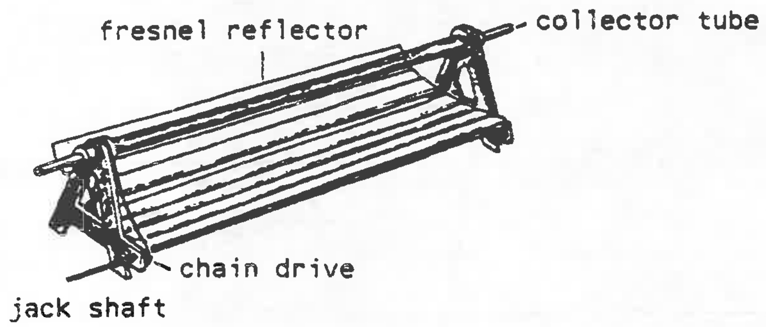


FIG. EWIII-12c

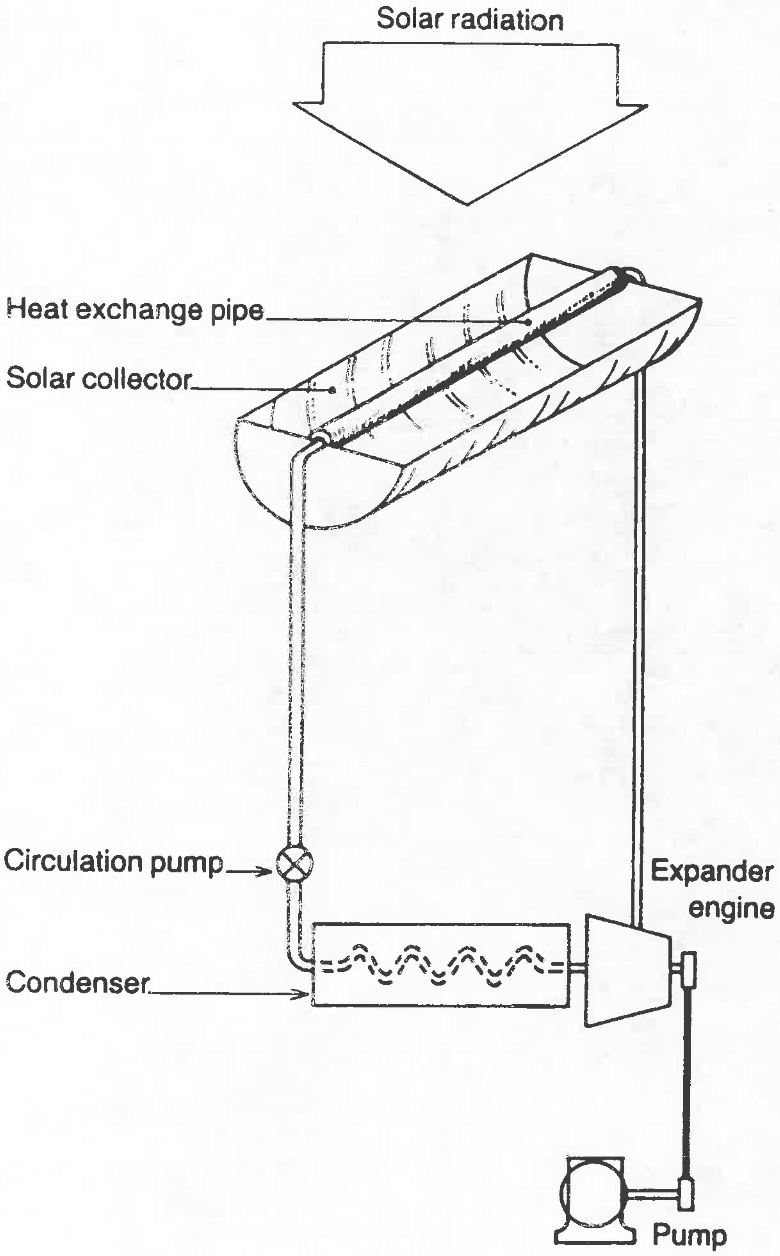

Solar radiation
Heat exchange pipe
Solar collector
Circulation pump
Expander engine
Condenser
Pump

FIG. EWIII-13

Photovoltaic systems are today more competitive.

2.2.2 Solar refrigeration and air-conditioning

Air-conditioning means the treatment and handling of air to obtain well-defined values of temperature, humidity, velocity and purity of the air in a given space. Only the cooling aspect will be considered here, so that solar refrigeration and space air-conditioning can be associated. The temperature is generally lower in the case of refrigeration, especially if one is speaking of ice production or most cases of food preservation. Well-defined values of temperature and humidity could not be obtained in the case of air-conditioning without an external source of energy to operate fans, pumps and control systems.

Solar refrigeration **can be achieved through a solar engine operating a conventional compressor**, or **through an absorption machine** heated by solar energy.

The system is complex and it requires an external power source to operate pumps and control circuits. A block diagram of this system is shown in Fig. EWIII-14.

2.2.3 Solar power plant (Tower type)

The simplest system **consists in reflecting the sun's rays and concentrating them into a boiler in which a fluid circulates**; hence the conversion of solar energy into thermal energy is effectuated by a mirror-field boiler system. The mirror field consists of an ensemble of rotary specular surfaces (Heliostats) and represents the reflector of the optical system; the receiver boiler positioned at the focus of the optical system permits the transfer of the reflected energy to the working fluid with consequently evaporates. The vapour is used to drive a turbine connected to an electrical generator (Fig. EWIII-15).

Solar generated electricity with this system is still too costly. The advanced technology involved needs the availability of highly skilled operators. The system can be used for the production of high-level power (1 Megawatt or more) and can be justified only where the electricity produced is integrated into one utility grid. Such a system, as a consequence, is not recommended for isolated or rural communities.

2.2.4 Photovoltaic electricity generation

It is possible to **convert solar radiation directly into electricity** without passing through thermodynamic and mechanical systems by using **solar cells.**

BLOCK DIAGRAM OF A SOLAR REFRIGERATING SYSTEM

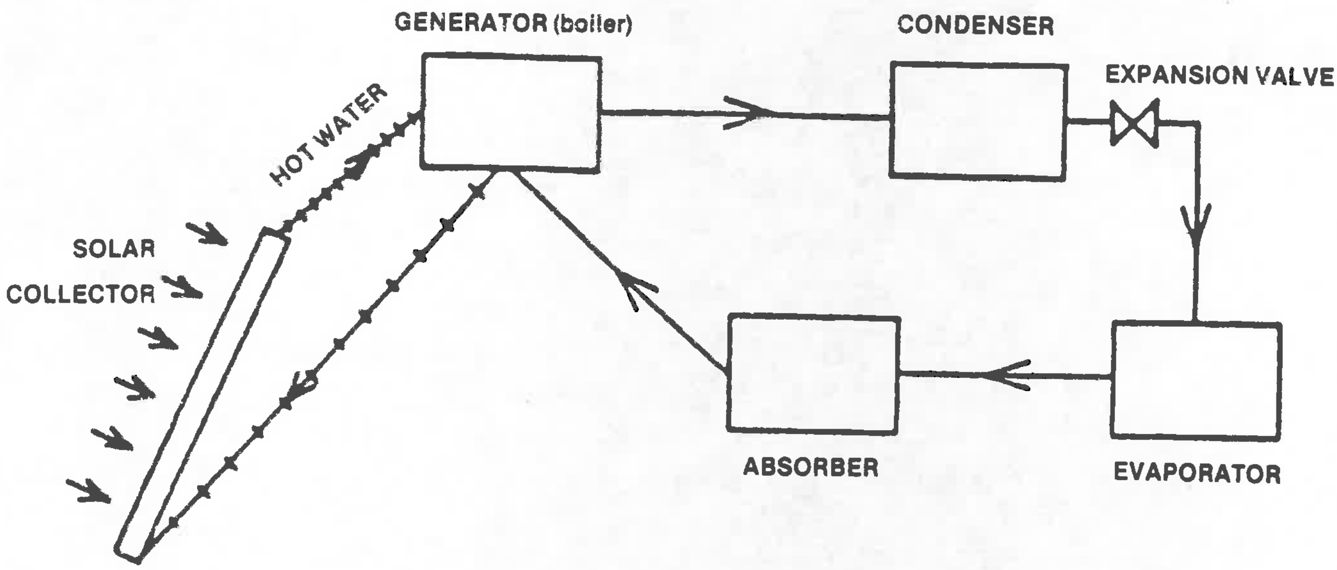
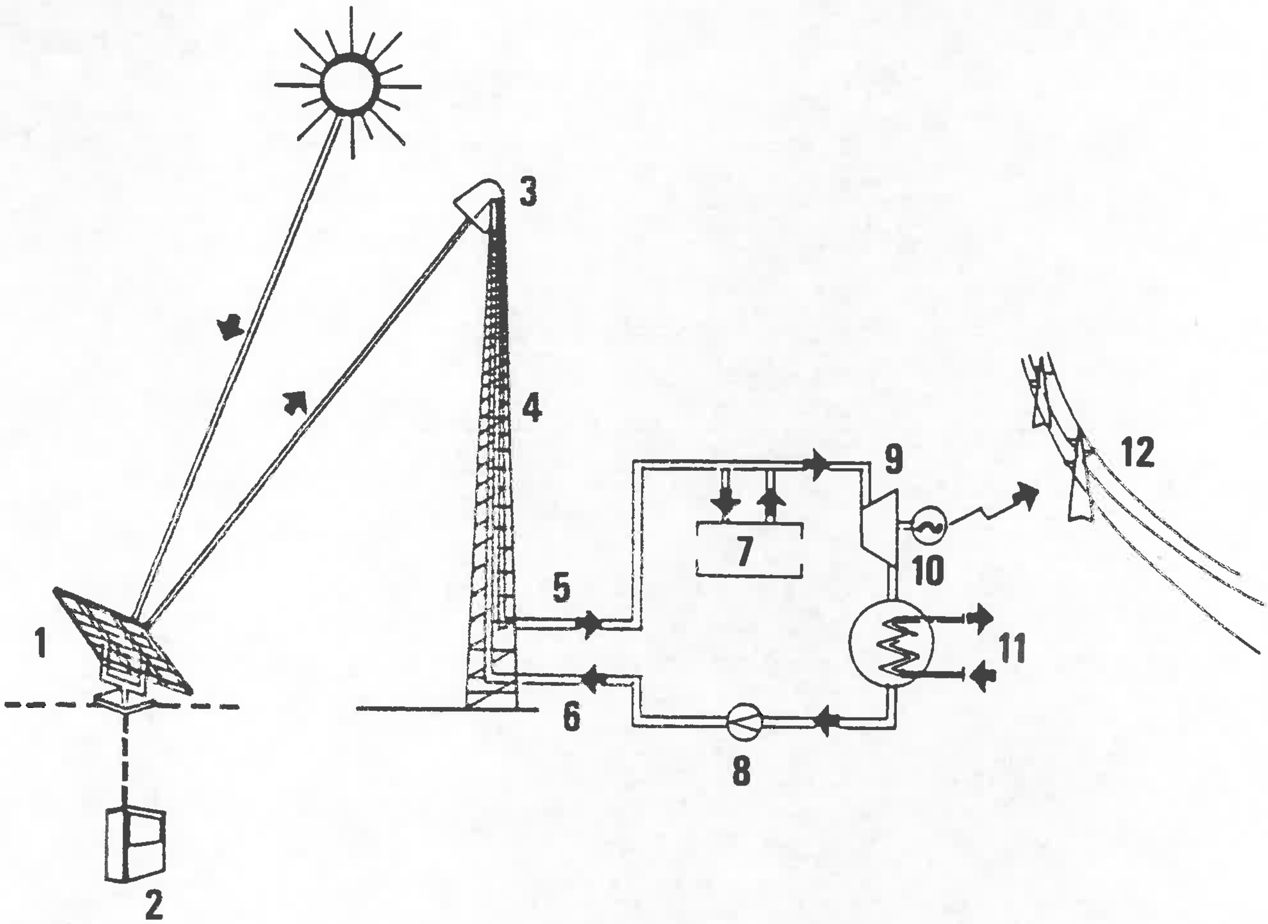


FIG. EWIII-14

CENTRAL RECEIVER SOLAR POWER PLANT



1 · HELIOSTAT
2 · CONTROL CENTER
3 · RECEIVER
4 · TOWER
5 · STEAM
6 · WATER
7 · STORAGE
8 · FEED WATER PUMP
9 · TURBINE
10 · ALTERNATOR
11 · CONDENSER
12 · GRID

FIG. EWIII-15

. The **photovoltaic cell** is an electronic component fitted with semi-conductors in which the absorption of photons (the elementary particles of light) creates free electrons and "holes". These electrical charges are separated out and collected by a top grid and a base contact. This primary electrical circuit is connected to other cells and thence to an external load. In this way, light is converted directly into electricity without using any moving parts, without applying heat, and without causing pollution (Fig. EWIII-16).

. The **module.** To get sufficient power and voltage, several cells have to be interconnected. These groups of cells are encapsulated in sealed modules which protect them from dampness, impact and nuisance (Fig. EWIII-17).

. **Module assembly.** Modules may be mechanically and electrically arranged into panels, which may themselves be grouped into arrays. In an installation, a group of arrays constitutes the array field.

. **Electricity storage.** Very often, particularly for lighting, the greatest need for electricity arises outside periods of sunlight, and it is therefore essential to store the current which is produced. It is also the case that storage makes it possible to satisfy sudden power demands at a level far in excess of what a photovoltaic system can supply at any given moment.

. **Storage devices.** These are usually lead batteries, and less usually nickel cadmium batteries. Their storage capacity is enough for two to three days of normal consumption without charging, and up to even ten days for installations where a wide margin of safety is needed.

. **Charge and discharge control.** This protects batteries against over-charging or excessive discharging, and prolongs their useful life (5 to 7 years).

If necessary, an inverter can be used to convert the direct current (dc) generated by the photovoltaic system into a standard alternating current (ac) suitable for industrial use.

As already discussed, a photovoltaic system includes a photovoltaic electricity source and loads. In some cases, this arrangement can be conceived with an auxiliary generator of a power ranging from 5 to 10 kVA, or connected to the grid.

Photovoltaic systems are ideal for community use to supply, for instance:

. water pumps;
. lighting systems;
. telecommunication systems;
. refrigerators;
. cooling systems;
. and all other systems which require electricity supply.

THE SOLAR (PHOTOVOLTAIC) CELL

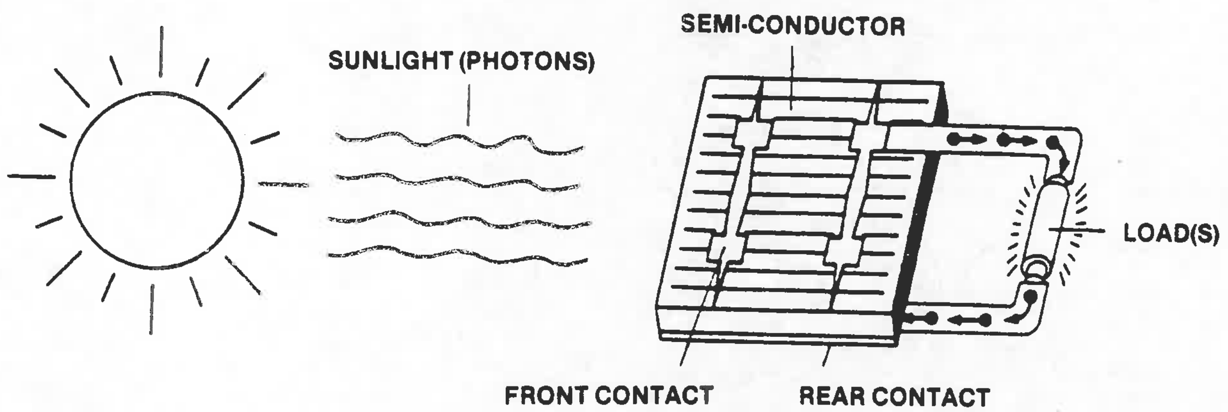


FIG. EWIII-16

A PHOTOVOLTAIC SYSTEM

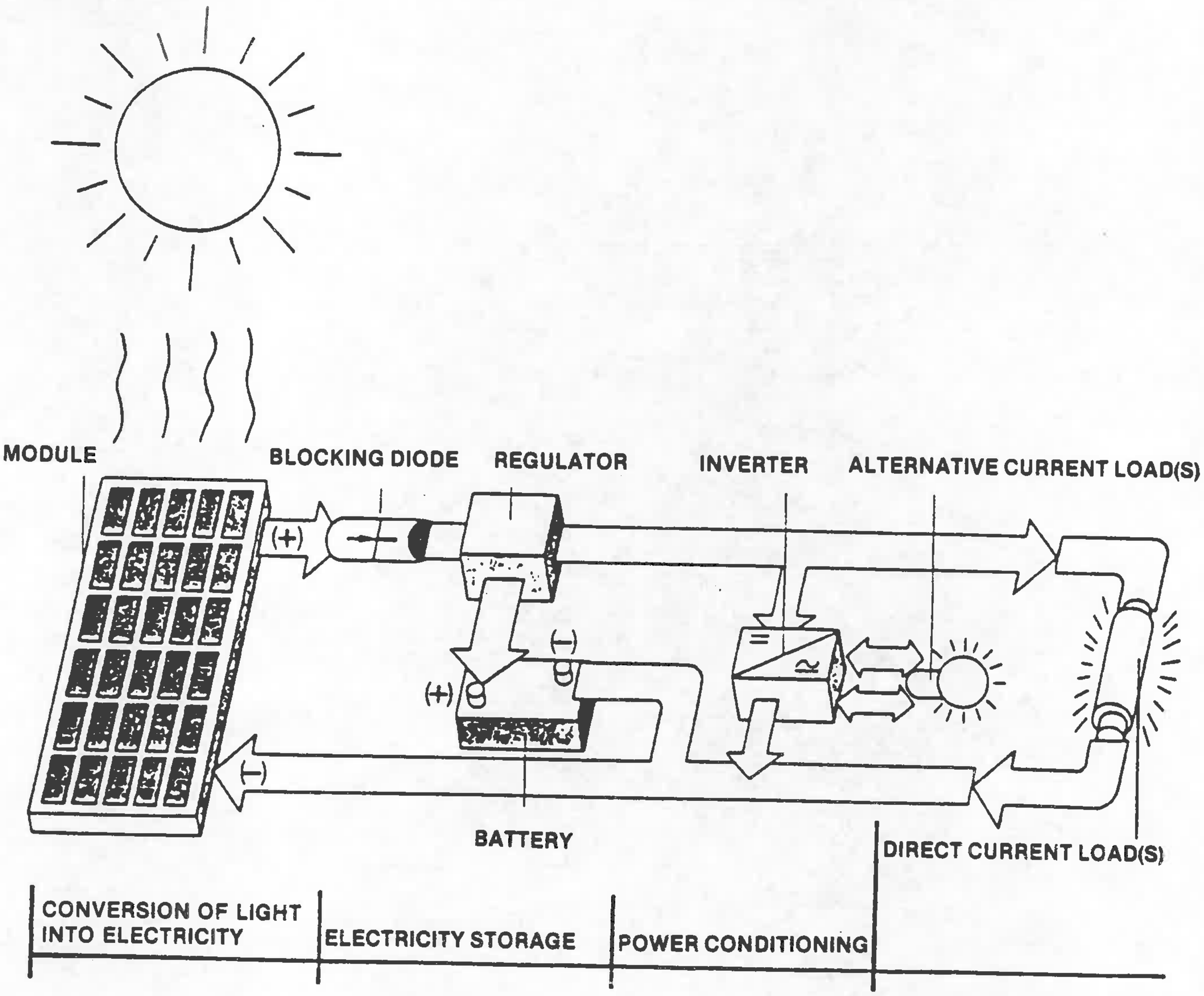


FIG. EWIII-17

The **extraordinary simplicity** of a solar-photovoltaic system would make it a highly desirable energy system, both in developing areas and in industrialised nations. The attractions of photovoltaic arrays include the absence of moving parts, very slow degradation of properly sealed cells, possibility for modular systems at sizes from a few watts to megawatts, and extreme simplicity of use.

Up to now, however, high costs of development and fabrication of solar arrays have discouraged widespread application. There is evidence that, with appropriate technological development and mass production techniques, the cost of solar arrays can be lowered to the point where a complete system - solar conversion, power conditioning and transmission/distribution - can compete on a life-cycle cost basis with other large-scale energy-system alternatives, and perhaps be even useful in small-scale applications in remote rural areas.

3. SMALL-SCALE HYDROELECTRICAL GENERATION

3.1 INTRODUCTION

Hydropower is a renewable source of energy which offers a number of advantages: it is **non-polluting, reliable, multipurpose** (irrigation, electricity generation,....), **easy to exploit**, potentially available in a large part of the world. Where the resource exists, hydro-electricity is far and away more economical and flexible than any other form of energy.

Small power stations are ideal to supply electricity to populations living in rural or remote areas; they require feeding by a simple water flume and can be installed as part of a scheme for irrigation, flood control or water storage.

Roughly speaking, there are **three levels** of small-scale power plants, considered according to their installed capacity:

micro-hydro: installations with a power capacity from a few watts to 100 kW

mini-hydro: installations with a power capacity from 100 kW to 1000 kW

small-hydro: installations with a power capacity from 1000 kW to 1500 kW.

3.2 THE HYDROPOWER STATION

A small-scale **hydropower station** includes the following main components (Fig. EWIII-18):

TYPICAL HYDROELECTRIC INSTALLATION

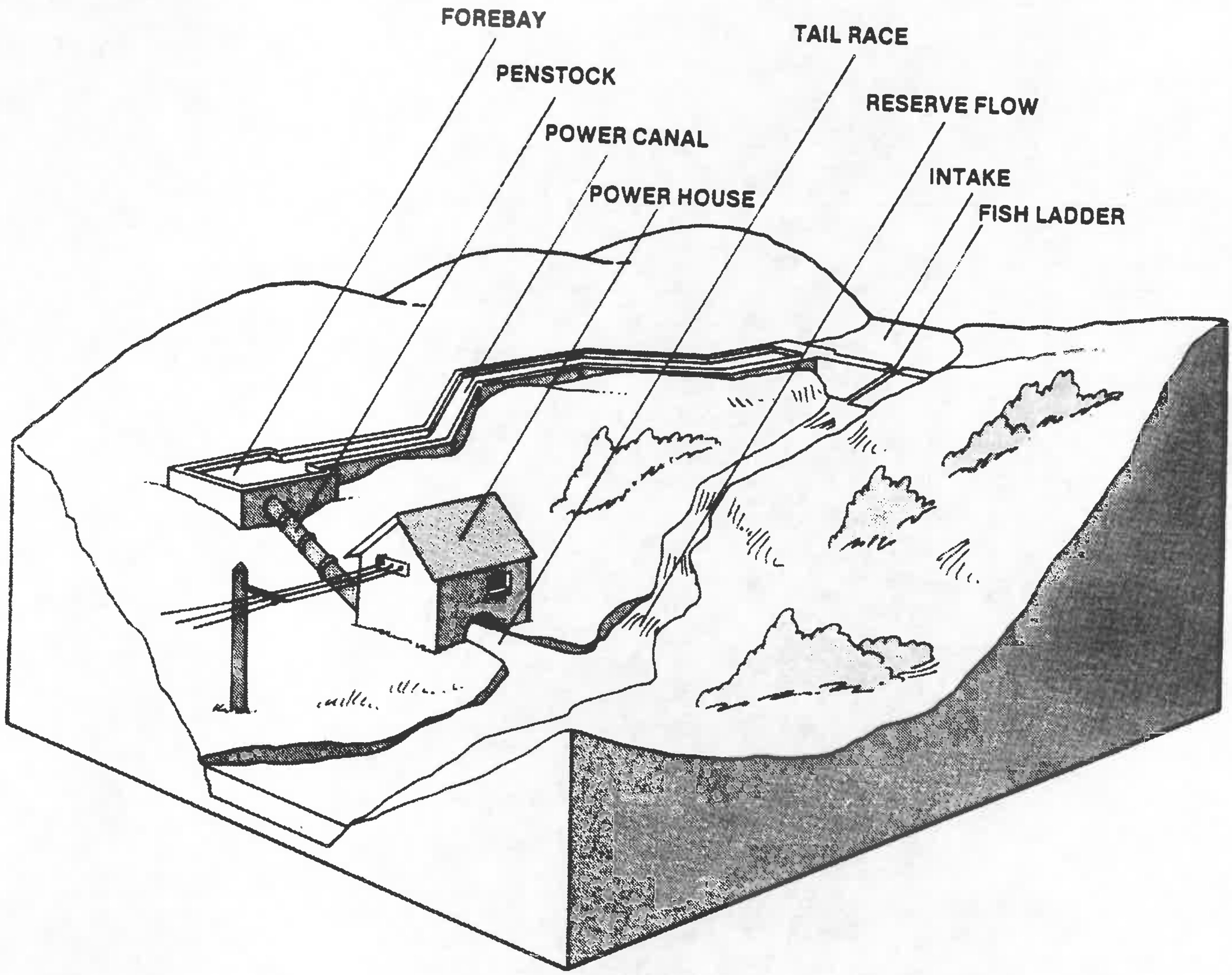


FIG. EWIII-18

- an **intake** of a shape and size suited to the nature of the terrain or river bed. It is built in rip-rap, gabions, earth, masonry, concrete, etc. The intake can also be connected to an irrigation canal or a drinking-water piping system;

- a **feeding flume** made of earth or concrete, or a metal or plastic penstock (pipe) which is fitted with a grating to keep out solid objects; in some cases a desanding pool also needs to be installed to reduce the presence of sand in the water which can damage the turbines;

- a **sluice valve system** to protect against flooding, to close off the water flow, or to stop the turbine running;

- a **connection system** with a penstock which supplies the turbine directly;

- a **turbine**, like the paddle wheel of a water mill, which transforms the water energy into mechanical power suitable for driving an electricity generator. Various types of turbines are designed according to the site, and water head and flow characteristics;

- a **generator** which produces electric power;

- a **control system** to control the electric generator as a function of the water supply conditions and consumer demands;

- a **power house** where turbine, generator, control devices and where necessary an output step-up transformer are located;

- a **transmission line** to deliver electric power to users.

3.3 POWER GENERATION

The **amount of power generated** by a hydroelectric installation is determined by the **flow rate**, by the **head** or level different between the penstock inlet and the turbine outlet, and by the efficiency of the turbine.

A very approximate formula to give a rough estimate of the generating potential of a small hydro scheme is:

$$P = \eta CHQ \simeq 5HQ$$

where:

P = output power in kilowatts (kW)
H = net head of water in metres (m)
Q = flow rate in cubic metres per second (m^3/s)

C is a constant ($\approx$ 9.810 kg/m^2s^2)
η is hydropower system efficiency

η.C can be assumed $\approx$ 5 taking into account that for small rural systems the total efficiency is around 50% (for large unit efficiency this will vary from 70 to 99%).

Many countries have precise data on the flow and regime of their rivers over several years. There are also many simple ways of measuring these flows accurately enough without the need for sophisticated apparatus. And lastly, rainfall statistics can also help to define a river's average flow rate by reference to the surface characteristics of the drainage basin.

It is also essential to study the average slope of a river in order to establish its fall.

Moreover, surveying the terrain (its permeability, geological structure, stability and so on), as well as studying the local materials resources, will help to establish the right method of construction for the intake or dam.

Even though hydroelectricity is perfectly clean and free from pollution, a small power station must still meet a certain number of constraints. At the cultural level, using local materials and construction methods will usually help such installations to blend into their surroundings.

From the standpoint of noise, carefully chosen materials and well insulated buildings should be adequate to deal with the main nuisance. From the biological point of view, the installation should be designed to allow for fish migration.

3.4 TURBINES

A **hydraulic turbine** is a **rotating machine driven by a stream of water under pressure** from a penstock or from a forebay. The potential and kinetic energy is then converted into mechanical energy of rotation by means of a freely revolving wheel fitted with blades, buckets or vanes.

The flow is directed at the wheel by a nozzle or an injector allowing the flow to be adapted to the mechanical power required by the electrical equipment being driven.

Various types of turbine are available, allowing every sort of adaptation to the characteristics of the head of water:

- **Axial-flow turbines** (for moderate heads of water): In such turbines, the flow passes between the guide-vanes and is guided axially against fixed blades;

. **Kaplan turbines** (for moderate heads of water);

. **Francis turbines** (for medium-power heads of water);

. **Pelton turbines** (for high water heads);

. **Banki Mitchell turbines** (for medium-power heads of water);

. **Turgo turbines** (for high water heads).

Fig. EWIII-19 shows various types of turbines.

3.5 POWER GENERATORS

Generators convert the mechanical energy produced by the turbine **into electrical energy.**

There are **two types** of generating equipment, depending on the characteristics of the grid to be served:

. the **synchronous generator**, generally serving a self-contained or autonomous network, but equally appropriate for high-tension units above 2,000 kW linked to the grid. These are the most widespread type of generator;

. the **asynchronous generator** is most commonly used for hooking up to the general grid. Magnetising this machine involves keeping it supplied with a power input taken either from the mains or from capacitors connected in parallel.

3.6 CONTROL SYSTEMS

Generators must satisfy the demands made upon them by the mains grid.

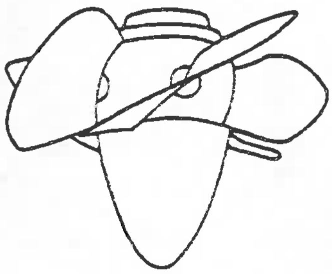
In the case of a power station linked to an interconnected high-tension grid, the frequency and tension of the grid, as well as the speed of rotation of the turbo-generator set, are practically constant. The question of control is then little more than a matter of regulating the flow at the turbine.

In the case of a power station serving an autonomous network, maintaining the frequency and volume to within technically acceptable limits requires a continuous balancing up between the power being delivered and the power being demanded by the grid. This balancing can be taken care of by two methods of control:

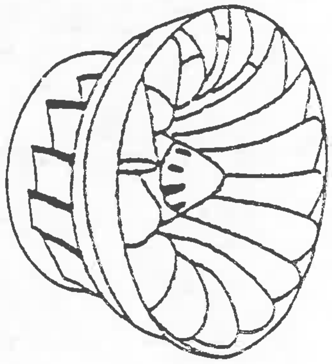
. controlling the consumed flow (hydraulic control);
. control of the electric load.

TYPES OF HYDRAULIC TURBINES

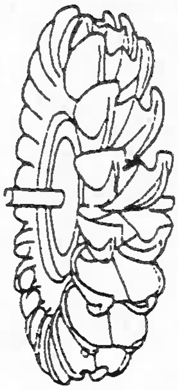
KAPLAN TURBINE



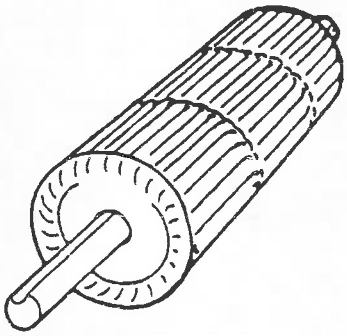
FRANCIS TURBINE



PELTON TURBINE



BANKI MITCHELL TURBINE



TURGO TURBINE

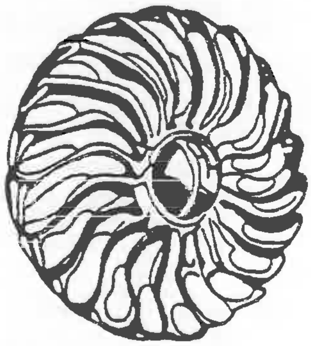


FIG. EWIII-19

Present-day techniques make it possible to automate the operation of a small power station at a minimum cost and high efficiency and reliability.

3.7 TECHNO-ECONOMICAL CONSIDERATIONS

Today, the technology for harnessing water power has a long and successful history and is mature. Standard equipment used is very reliable, is relatively simple to maintain, and has a long service life. The question to be asked is therefore not whether small hydro plants are technically feasible in the rural context of developing countries, but rather whether it is economically feasible to install and operate such plants. The question of the amount of initial investment is of major importance and, in addition, a number of other factors often affect economic viability. Some of these factors are the following:

- The **low-load factor**, often met in existing stations associated with poor plant utilisation, is resulting in insufficient returns on the invested capital.

- Where the development of all forms of hydropower is the responsibility of a single government agency, small hydropower is often neglected in the face of large-scale projects, where often all human resources available are required. Also, where the same procedures in planning, procurement and licensing are applied as for big projects, small hydro is at a disadvantage.

- The fundamental issue that a small power station is most effectively managed (and perhaps owned) by a small, local organisation, is sometimes forgotten. Experience shows that if stations are centrally managed and staffed by employees of a central government agency, such stations tend to run up high operating costs in terms of salaries, per diem and hardship allowances for operators brought in from outside. Locally trained staff should be in charge of the plants.

- High cost of equipment for civil works has long been a major constraint. Standardisation of equipment and indigenous manufacturing can contribute to cost reduction.

- Another problem is that engineer involved in hydro projects are very often trained abroad, where little of direct relevance to rural situations is taught. Such people are very often unaware of local possibilities and skills, a situation that can only be changed "on the job" in active project implementation with local participation, including women.

THE MOST IMPORTANT GEOTHERMAL FIELDS IN THE WORLD

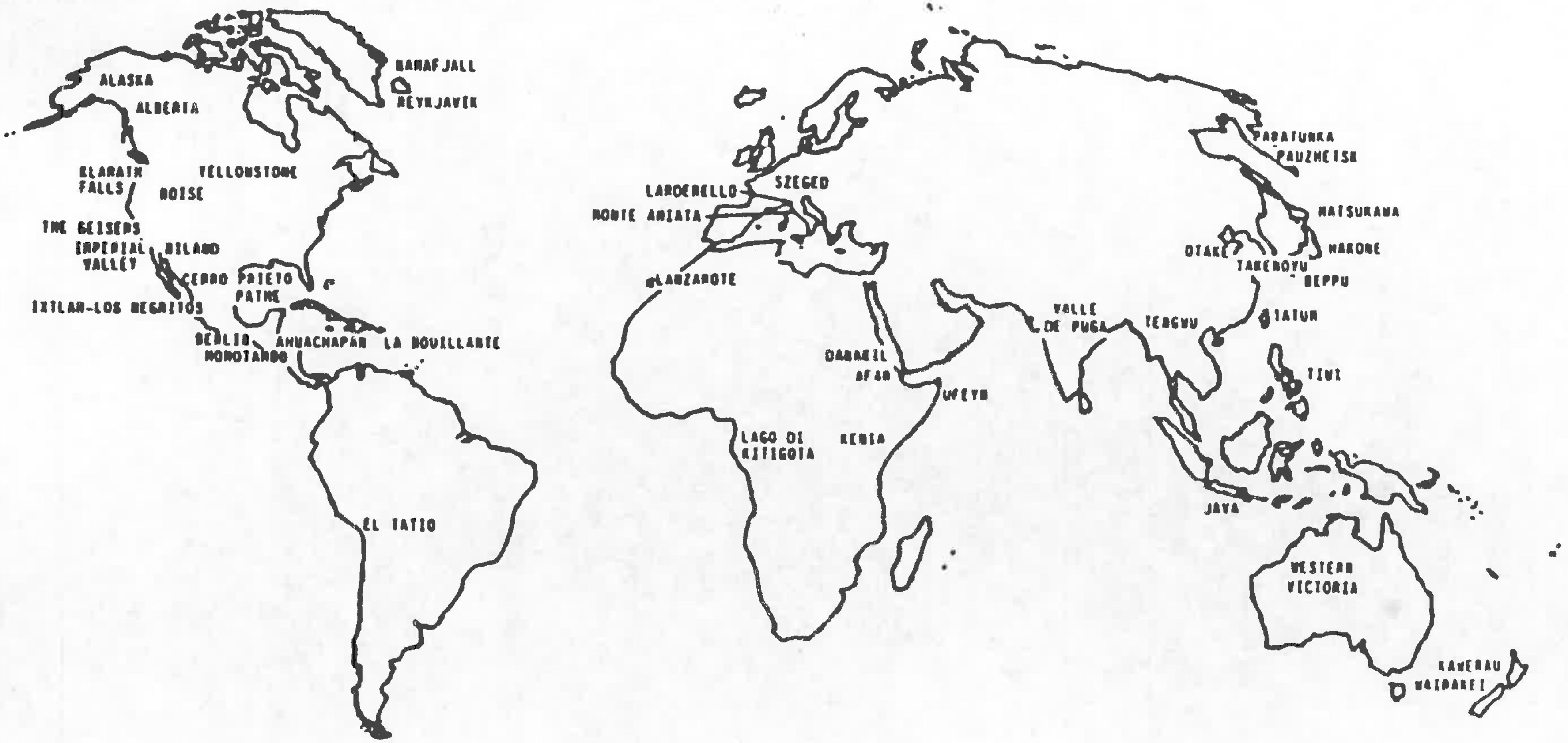


FIG. EWIII-20

GENERAL SCHEME OF A VAPOUR GEOTHERMAL SYSTEM

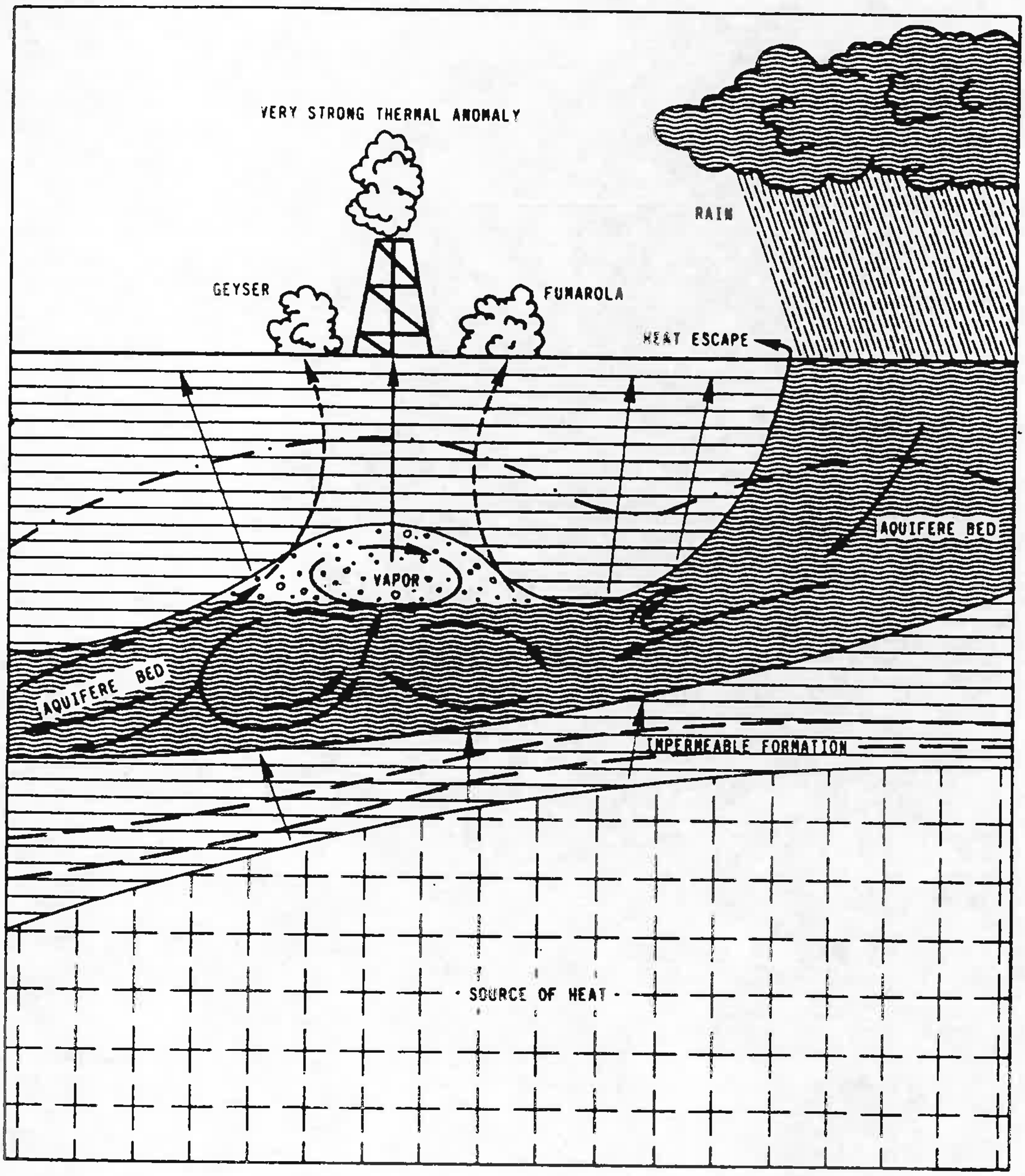


FIG. EWIII-21

The potential of geothermal energy would be far greater if heat could be extracted from **hot dry rocks** which do **not** naturally contain water. Such rocks occur almost all over the earth, not just in seismic zones.

Hot dry rocks must first be shattered to make them porous. Then cold surface water is pumped down one hole, allowed to percolate through the hot rock, and pumped back up to a second hole.

If the technique can be developed at an economic price, geothermal energy could be harnessed **practically worldwide.**

So far, drilling and heat extraction are only practicable down to about 3 kilometres, but this is expected to increase.

The total energy available as hot water or steam down to 10 km is around 4×10^{21} joules. The figure would be thousands of times greater if hot dry rocks could be exploited.

4.2 HYDROTHERMAL SYSTEMS

The geothermal systems that can at present be commercially exploited are:

- **Hot water systems** which contain water at 50°C to 100°C and can be used for space heating and low-temperature agricultural and industrial applications. A hot water reservoir can be of commercial interest if it is located less than 2,000 metres deep.

- **Liquid dominated systems** (high temperature) which contain pressurised water, at a high temperature (more than 100°C) and a limited quantity of steam. Since the liquid is stored in a natural reservoir covered by an impermeable rock layer, it cannot escape to the earth's surface since it is kept under pressure in the reservoir. These geothermal systems can be exploited through drilling and are economically convenient for electric power generation and industrial processes.

- **Vapour dominated systems**, which produce dry and in general superheated steam, mixed with small quantities of other gases (CO_2, H_2S). These systems are typically suitable for electric power generation; in fact the steam can be used to feed a steam turbine which drives an electrical generator.

There are other geothermal systems which are not so far commercially exploited:

- **hot dry rocks**, which require the creation of an artificial geothermal reservoir;

- **geopressurised systems**, in which water is found at a temperature between 150 and 200°C trapped in sedimentary rocks.

4.3 TECHNO-ECONOMICAL CONSIDERATIONS

Techniques for developing geothermal resources are very **similar to those for oil**. But since the energy content of water at high temperature (i.e. 300°C) is less than a thousandth that of oil, far less money can economically be spent on exploration and drilling.

It is generally not worth transmitting geothermal heat for long distances. Hot water or steam **must be used near the source** before it cools. The cheapest geothermal sources are in volcanic areas and these are mostly in developing countries.

One of the most promising uses of geothermal energy is in electricity generation.

A present estimate indicates that approximately 5000 MW represent today the geothermal electrical power installed in the world. Fig. EWIII-22 shows the world distribution of geothermal electrical generating capacity.

The first experimental geothermal electricity station was built in Larderello, Italy, in 1904, with a full-sized plant completed in 1913.

As Fig. EWIII-22 shows, **USA, Italy and the Philippines** together now have almost three-quarters of the world's current geothermal electrical generating capacity.

Today, only 28% of global geothermal power plants are in the Third World. By the year 2000, 36% will be in the Third World, almost entirely in **Central America**.

By the year 2000, the **USA, Japan and Mexico** will contain over three-quarters of the world's geothermal electricity capacity. (Naturally, these figures are based on plans announced so far; other countries are likely to decide to exploit geothermal power between now and the end of the century.)

In small countries, geothermal power can make a large contribution to national energy needs. In the Caribbean, a geothermal steam field is being developed by France in Guadeloupe, and in St Lucia a similar development is being backed by the UK.

Most **geothermal water** is below 150°C and so is **not normally hot enough to generate electricity**. It can only be used for bathing, to heat buildings, to warm greenhouses or outdoor crops, or as pre-heated water for boilers. Fig. EWIII-23 shows which countries were in 1980 using **low-temperature geothermal heat**: Japan, Hungary and Iceland together made up 85% of the total.

Whenever possible, **geothermal sources** have been **used** to **generate electricity** in **medium-sized** (10-100 MW) **turbogenerators** near to the

GEOTHERMAL ELECTRICAL GENERATING CAPACITY 1980 AND 2000 (estimated)

	1980		2000	
	MW	%of world total	MW	%of world total
USA	923	38	5824	33
Japan	168	7	3668 +	21
Italy	440	18	800	5
New Zealand	202	8	382 +	2
USSR	5	0	310	1
Turkey	0.5	0	3101	1
Iceland	32	1	68 +	0
France	0	0	15 +	0
TOTAL NORTH	**1771**	**72**	**11217**	**64**
Mexico	150	6	4000	23
Philippines	446	18	1225 +	7
El Salvador	95	4	535	3
Costa Rica	0	0	380 +	2
Nicaragua	0	0	100	1
Indonesia	0.25	0	92 +	0
Ethiopia	0	0	50	0
Kenya	0	0	30 +	0
Chile	0	0	15 +	0
TOTAL SOUTH	**691**	**28**	**6427**	**3**
WORLD TOTAL	**2462**	**100**	**17644**	**100**

FIG. EWIII-22

INSTALLED LOW - TEMPERATURE GEOTHERMAL CAPACITY IN 1980

	FOR BATHING		FOR OTHER PURPOSES		TOTAL	
	MW	%	MW	%	MW	%
Japan	4394	82	81	3	4475	56
Hungary	547	10	619	23 1/2	1166	15
Iceland	209	4	932	35	1141	14
USSR	0	0	555	21	555	7
Italy	192	4	73	3	265	3
China	7	0	144	5 1/2	151	2
USA	4	0	111	4	115	1
France	0	0	56	2	56	1
Czechoslovakia	8	0	35	1 1/2	43	1
Romania	0	0	30	1 1/2	36	0
Austria	3	0	2	0	5	0
TOTAL	5364	100	2644	100	8008	100

FIG. EWIII-23

well site. In the past, **150°C** was the minimum geothermal temperature that could be used for generating electricity. There are manufacturers who now produce bladeless turbines designed to use geothermal water and steam as cool as 100°C for electricity production.

Geothermal energy can also be used in **industrial processes**. The US Government is spending almost $1 million on eight projects from metal processing to mushroom growing, mainly in western USA.

The **technology** to **exploit the heat in hot dry rocks** is still at an **early stage**. The principle is simple. Two holes are drilled down to the required depth. The space between them is shattered by explosives and/or water pressure (hydrofracturing - an established techniques used by the oil industry to encourage oil flow). Water is then passed down one hole, and brought back up the other as steam.

If successful, this technology may make geothermal energy practical almost worldwide. But the investment costs could still be high. The other problem with dry rocks is lifetime. The original crack surfaces would cool rapidly, and power output could in practice decline sharply after a relatively short period of operation.

The main factors affecting cost are the temperature of the hot water or steam, and its depth. Deeper wells cost more to drill and have higher maintenance costs, but they tend to yield hotter, drier steam than shallow wells. Dry steam allows more efficient generating plant.

The World Bank's figures, from actual projects, include the cost of delivering in bulk electricity to major customers. They show **geothermal electricity** to be **cheaper than electricity from wind or solar power**, cheaper than nuclear power (except large multiple units), cheaper than small-scale hydroelectric power, and cheaper than most oil-generated electricity.

But large-scale hydropower and gas-generated electricity come out cheaper than geothermal.

Geothermal energy, which strictly speaking is **neither new nor renewable**, is technically and economically feasible in areas where hot water and steam exist near the surface, and where there is a demand for heat or electricity. Development will normally be large-scale and capital-intensive. For these reasons, geothermal energy is **unlikely to be of much use in the rural Third World**; in urban areas, it will only be useful in special circumstances.

But for some semi-industrialised Third World countries in seismic zones, without other cheap resources, it could play a big role.

A final consideration is that geothermal energy use has some **environmental problems**, chiefly the release of sulphurous gases to the atmosphere, and the discharge of warm water, often containing a high level of dissolved solids, to rivers. In practice, air and water pollution has so far not proved a problem, at any geothermal site. Waste water can normally be reinjected into the ground, in some cases after removal of commercially-valuable potassium salts.

5. WIND ENERGY SYSTEMS

5.1 INTRODUCTION: WIND CHARACTERISTICS

The winds of the earth are caused primarily by unequal heating of the earth's surface by the sun. The solar radiation is absorbed and reflected differently by various parts of the atmosphere and by the different types of surface.

The redistribution of the incident solar radiation causes low and high-pressure areas in the atmosphere, which force the air to move towards zones of low pressure; hence the solar radiation is converted into kinetic energy of the wind.

The **main characteristics** of **wind** can be summarised as follows:

- wind is **low-density fluid**; for this reason, the physical dimensions of any device able to convert its kinetic power into a useful form are large in comparison to the amount of power produced;

- wind is **random** in **speed** and **direction**; only average wind speed and directional distribution on a yearly base is repetitive within acceptable limits;

- the **power density** of wind decreases with the air density (i.e. at higher altitude);

- the amount of power available in a freely-flowing wind stream of cross-sectional area A is equal to this area twice the velocity of the windstream V, times the kinetic energy of a unit volume of the wind stream; in other terms, the power that can be obtained varies in proportion to the cube of the wind speed.

5.2 WIND ENERGY TECHNOLOGIES

Part of the **kinetic energy of wind** can be **captured by a rotor and converted into mechanical or potential energy**. The major drawback of a wind power system stems from the nature of the source - wind has a low power density and wind speed and direction are highly variable. Therefore, wind power systems are best for applications which can tolerate varying power input such as pumping water from wells, the traditional windmill application in many parts of the world. The power that can be achieved by a wind system is proportional to the cube of the wind speed and the square of the windmill-diameter:

$$P = \eta C\ d^2\ v^3$$

in which:

P = theoretical wind power (kW)
d = windmill diameter (m)
v = wind speed (m/sec)
C = constant = (5.10^4 kg/m^3)
η = windmill efficiency (20-40 per cent)

The effect of wind speed on windmill power output is visualised in Fig. EWIII-24.

There are **three principal dimensions** to wind energy technology, namely:

a) **type of machine**, for example, horizontal axis, from sail and multibladed to fast-running rotor types, and vertical axis from Savonius to fast-running Darrieus and variations;

b) **application**, for example, water pumping water desalination, heating, cooling, autonomous electric power generation, power generation with grid connection;

c) **size of machine**, for example, small (less than 10 kW), medium (10-100 kW), medium-large (100-1000 kW), large (more than 1 MW).

Sail mills, multibladed mills and Savonius rotors are mostly rated at less than 10 kW. They have a high solidity and are not suitable for scaling up to larger sizes. They are mainly used for direct water pumping where there is a premium on considerations such as simple construction and a high starting torque. Low solidity wind turbines, both horizontal axis and vertical axis, exist in all sizes and are used primarily for electric power generation.

5.3 TYPES OF WIND ENERGY COLLECTORS

Many types of wind energy collectors have been devised. It is said that more patents for wind systems have been applied than for nearly any other type of device. Basically, almost any physical configuration which produces an asymmetric force in the wind can be made to rotate, translate or oscillate and power can be extracted. Of course, technical and economical feasibility should be deeply studied for each configuration.

Machines using rotors as wind energy collectors may be **classified in terms of the orientation of their axis of rotation** relative to the windstream, i.e.:

- **Horizontal-Axis Rotors** (Head-on) - for which the axis of rotation is parallel to the direction of the windstream; typical of conventional windmills.

POWER GENERATION VIA WIND MACHINES

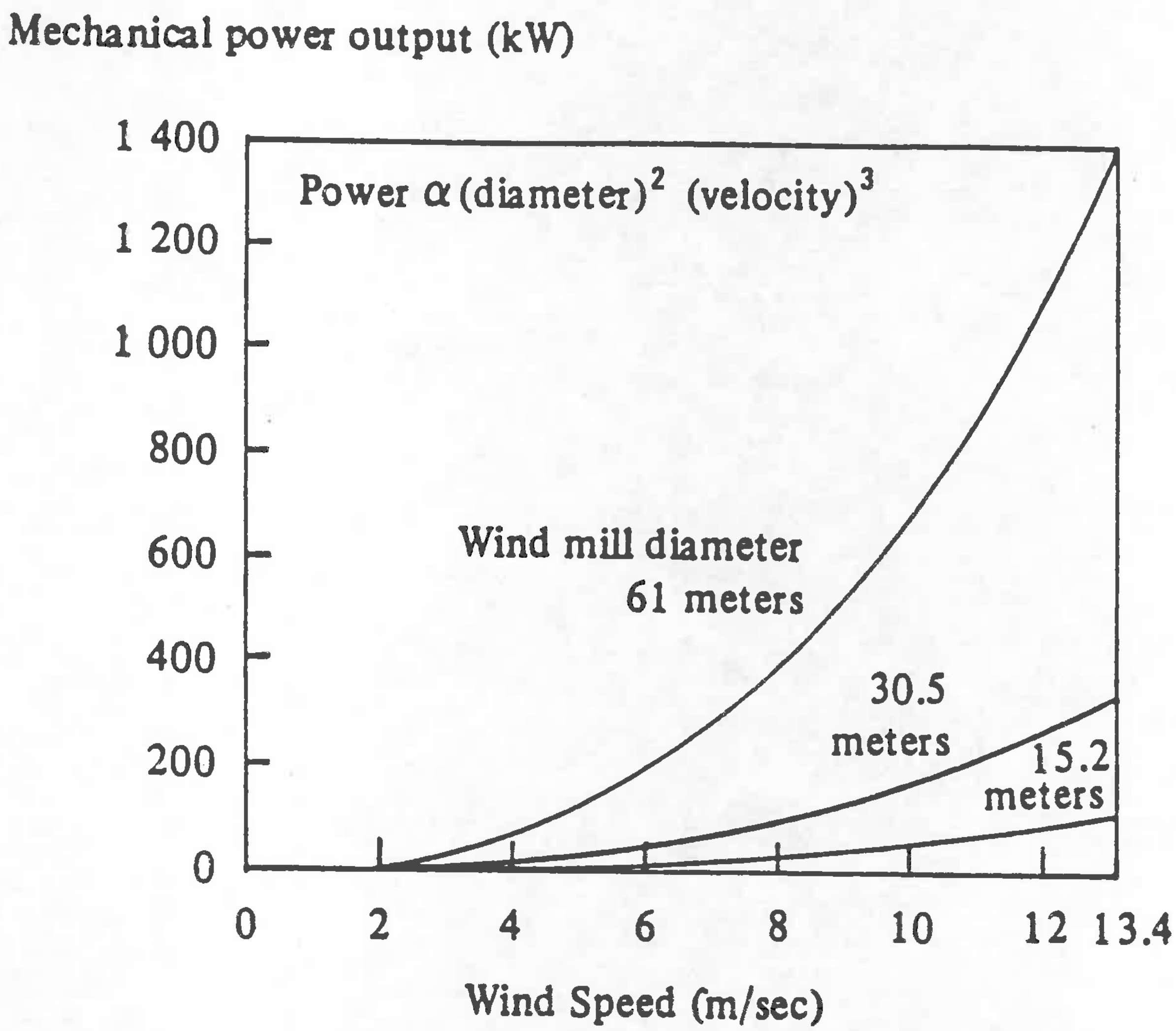


FIG. EWIII-24

- **Cross-Wind Horizontal-Axis Rotors** - for which the axis of rotation is both horizontal to the surface of the earth and perpendicular to the direction of the windstream, somewhat like a water wheel.

- **Vertical-Axis Rotors** - for which the axis of rotation is perpendicular to both the surface of the earth and the windstream.

In addition, a number of types of translational wind machines have been devised, including the **sailing ship** itself; sailing ships carry **water-driven turbines** mechanically connected to an electric generator; as well as **land vehicles driven by sails** or solid airfoils on a closed track or roadway, with their wheel mechanically linked to an electric generator. Other types of translational devices have been designed to produce **power by oscillating in the windstream.**

Still other types of wind energy conversion devices are being developed that use no moving parts, such as devices that use differential cooling in a windstream to generate electricity by means of the Thomson thermoelectric effect.

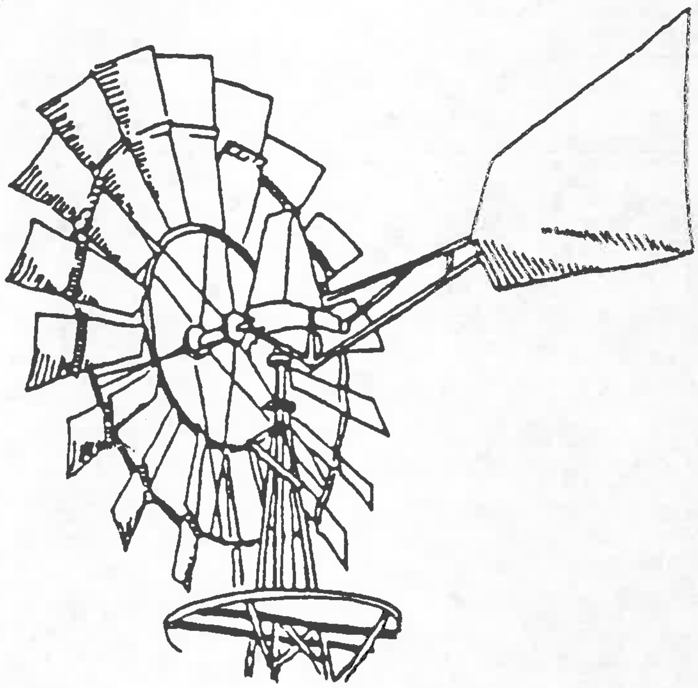
5.3.1 Horizontal-axis rotors

Horizontal-axis rotors (Fig. EWIII-25) can be either **lift** or **drag devices.** Lift devices are generally preferred since, for a given area, many times more force can be developed by lift than by direct drag. In addition, a drag device generally cannot move faster than the wind velocity. Thus a lifting surface can obtain high tip-to-wind speeds and, consequently, a higher power-output-to-weight ratio and a lower cost-to-power-output ratio. Systems can be designed with different numbers of blades, ranging from one-bladed devices with a counterweight, to devices with large numbers of blades (i.e. up to 50 or more). Such systems often use canted blades to reduce the bending loads on the roots of the blades. Some horizontal-axis rotors are designed to be yaw-fixed, i.e. they cannot be rotated around a vertical axis perpendicular to the windstream. Generally, this type would only be used where there are prevailing winds from one direction. Most types are yaw-active and will "track" the changing direction of the wind. Small systems are usually designed to yaw using a tail-vane whereas larger systems are normally servo operated.

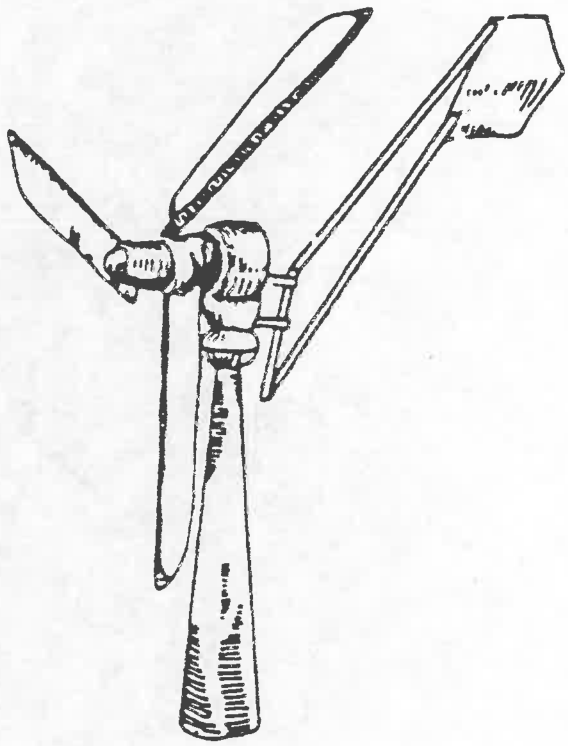
A number of means are used to prevent a propeller from overspeeding in high winds, including feathering of the blades, flaps rotating with the blades, or flaps on the blades themselves, as well as devices that turn the propeller sideways to the wind using pilot vanes set parallel to the blades.

Some blades are directly coupled to the output of the system through a shaft on which the rotor is mounted. Others use a circular rim attached to the blade-tips to drive a secondary shaft that is mechanically connected to an electric generator or other form of power output.

TWO TYPES OF HORIZONTAL-AXIS ROTORS



Multi-blade rotor



High-speed rotor

FIG. EWIII-25

Some horizontal-axis rotors are designed with blades that rotate in front of the towers, with respect to the direction of the windstream. These are called up-wind rotors. On the other hand, rotors that are designed with the blades rotating behind the tower are called down-wind rotors.

5.3.2 Vertical-axis rotors

In general, **vertical-axis** rotors have a major **advantage** over horizontal-axis rotors. They do **not** have **to be turned to the wind** as the direction of the windstream varies. This reduces the design complexity of the system and decreases gyro forces on the rotors, when yawing, that stress the blades, bearings and other components used in horizontal-axis rotor systems.

Various types of vertical-axis panemones have been developed in the past that use drag forces to turn rotors of different shapes. These include those panamones that use plates, cups, or turbines as the drag device, as well as the **Savonius** S-shaped cross-section **rotors** (Fig. EWIII-26), which actually provide some lift force but are still predominantly drag devices. Such devices have relatively **high starting torques**, compared to lift devices, but relatively **low tip-to-wind speeds** and **low power outputs** per given rotor size, weight and cost.

Another type which is now considered to be a potential major competitor to the propeller-type systems is the **Darrieus rotor** (Fig. EWIII-26).

These rotors are lift devices, characterised by curved blades with airfoil cross-sections. They have relatively low starting torques, but high tip-to-wind speeds, and therefore have relatively high power outputs per given rotor weight and cost. Various types of Darrieus rotor configurations have been conceived and designed to operate with one, two, three or more blades.

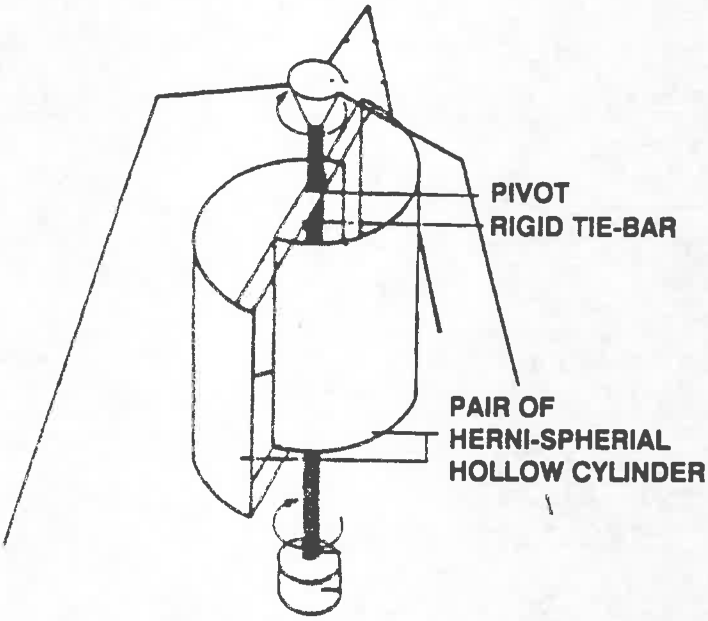
Darrieus rotors can also be combined with various types of auxiliary rotors to increase their starting torques. However, such additions increase the weight and cost of the system, so tradeoffs in these characteristics must be considered in developing an optimum design for a given application.

Other types of vertical-axis rotors include Magnus Effect rotors typified by the "Madaras" or "Flettner" designs that consist of spinning cylinders (Fig. EWIII-27). When operated in a windstream, translational forces are produced perpendicular to the windstream by the Magnus Effect. Such a device can be used as a sail to propel ships or land vehicles.

Still other types of vertical-axis rotors have been conceived that use ducts and/or vortex generator towers, augmented by shrouds or

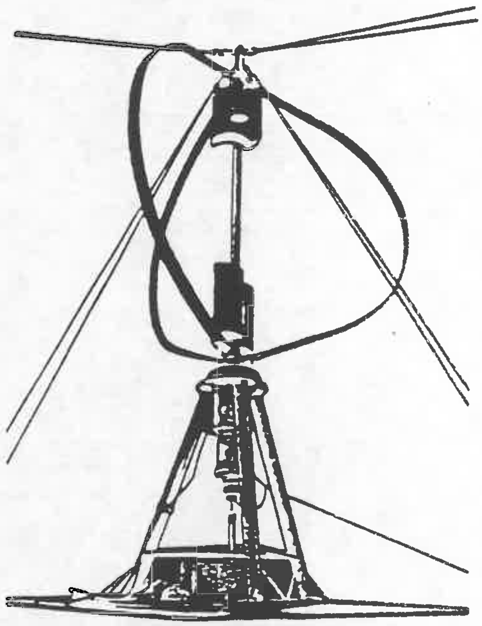
TYPES OF VERTICAL-AXIS ROTORS

SAVONIUS ROTOR



CHARACTERISTIC:
- SELF-STARTING
- LOW SPEED
- LOW EFFICIENCY

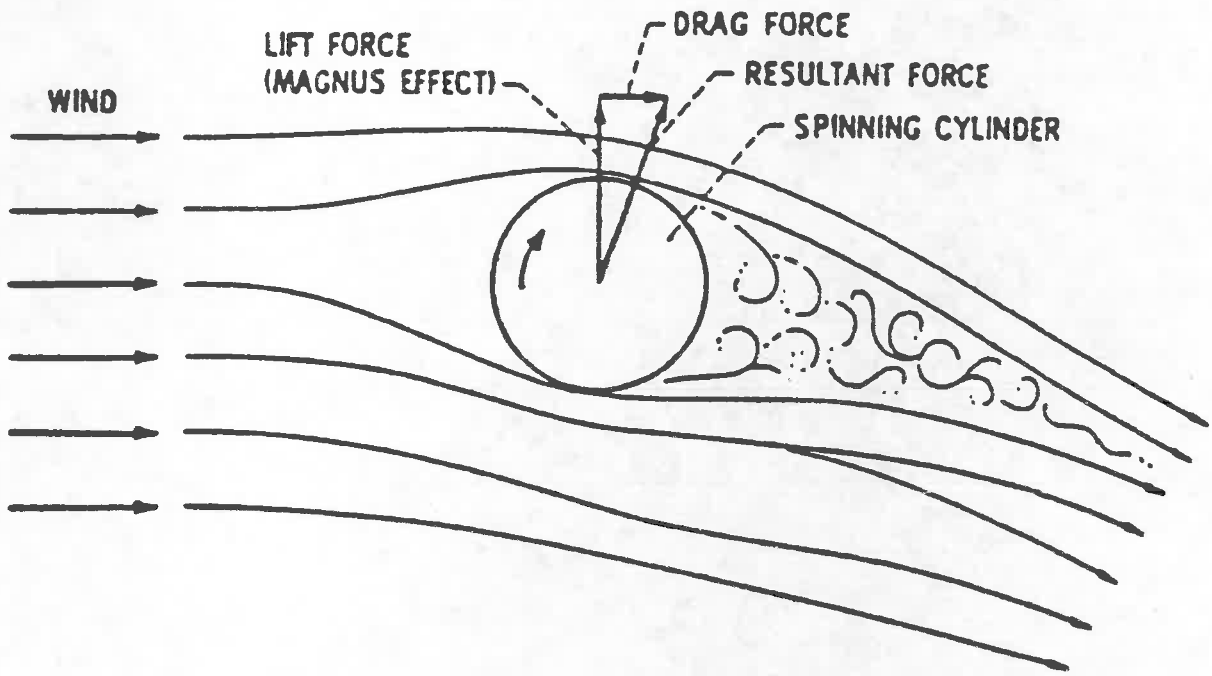
DARRIEUS ROTORS



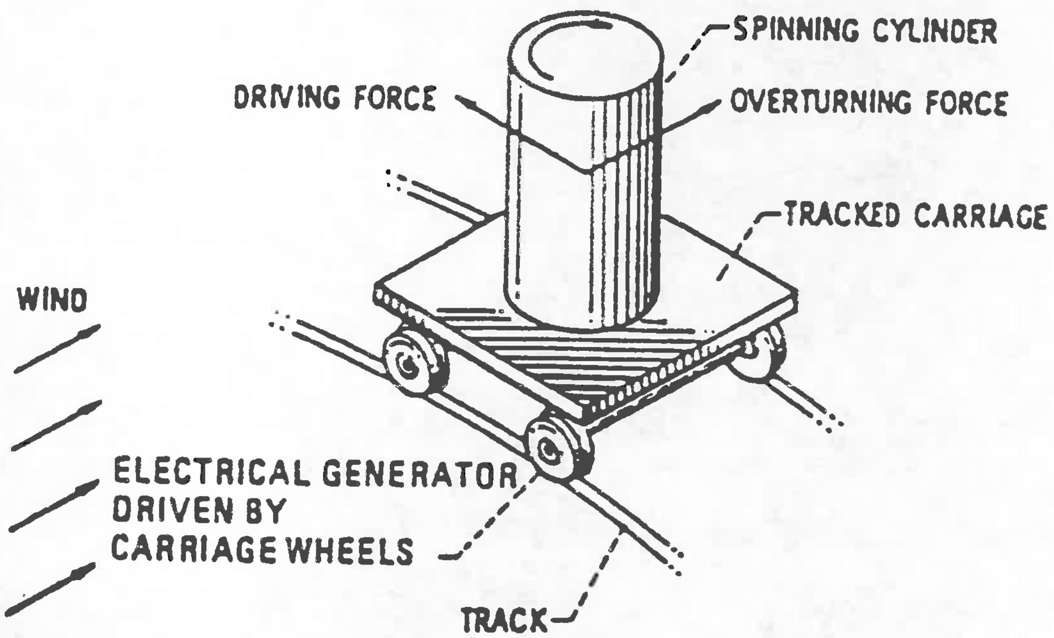
CHARACTERISTIC:
- NOT SELF-STARTING
- HIGH SPEED
- HIGH EFFICIENCY
- POTENTIALLY LOW CAPITAL COST

FIG. EWIII-26

VERTICAL-AXIS TURBINE



THE MAGNUS EFFECT



THE MADARAS CONCEPT FOR GENERATING ELECTRICITY

FIG. EWIII-27

diffusers to deflect the horizontal windstream to a vertical direction and increase its velocity, sometimes with the addition of heat, either by direct solar insolation or by burning a fuel of some type, in the final extension. The latter becomes, in effect, a gas turbine.

In conclusion, while many types of configurations can be conceived, the primary consideration is the amount of energy, per unit system cost, that is derived at a given wind speed.

5.4 TYPES OF APPLICATIONS

Energy extracted from the wind is initially transformed into mechanical motion: rotary, translational or oscillatory. The resulting mechanical work can be used to pump fluids or can be converted into electricity, heat or fuel.

5.4.1 Wind energy driven water-pumping systems (wind pumps)

A small windmill with direct mechanical drive to a water pump is an old technology, and commercial machines are still in extensive use in many parts of the world, including Argentina, Australia and South Africa. In most cases, the water is pumped whenever the wind blows and is stored in a tank for use as needed. Careful matching of the windmill to the pump characteristic is important and the windmill, pump and storage must be treated as a system.

The conventional multibladed windmill is a type that has been widely used for this purpose in the past, but because of economic and financial reasons it has found no widespread application in developing countries. In the past few years, some new all-metal multibladed windmill designs have been developed, which, compared to the traditional multibladed windmills, are considerably lighter in weight, simpler to construct and have a slightly higher overall efficiency. These windmills, after adapting the design to locally available materials, can be manufactured in simply-equipped workshops and are cheaper than commercially available mills by a factor of 2 to 4. A number of these windmills are operating in pilot projects, for example in India, Kenya, Pakistan, Peru, Tunisia and Sri Lanka. Experience within these projects is showing that extensive field testing is essential and is resulting in a number of design modifications to ensure the reliability of the machines.

Under certain circumstances, it is convenient to use an electrically coupled wind pump, which consists of a wind-driven electrical generator connected to an electric pump via a transmission line. This has a number of potential advantages:

a) greater flexibility in siting the wind machine in relation to the well;

b) use of high capacity submersible or shaft-type centrifugal pumps instead of piston pumps;

c) wind turbines are becoming available for pumping powers up to 100 kW or more and can be used in large irrigation projects;

d) wind turbines can be used in connection with a rural electricity grid so as to permit continuous pumping, but with reduced grid electricity consumption.

Besides the design of all-metal windmills, improved types of sails and/or wooden windmills have been developed in e.g. Colombia, India and The Netherlands, to try to meet the demands of the subsistence farmer. These mills, which can be fabricated in village workshops, are very much cheaper than commercial mills, even allowing for replacement of sails every two years. Drawbacks of this type of wind pump are relatively low efficiencies and relatively high time requirements for operation and maintenance.

5.4.2 Wind energy driven electricity generation (wind generators)

Autonomous wind power systems in the range of 10-1,000 kW, with diesel back-up and possibly hydroelectric storage, are already an economic alternative to conventional diesel generation for isolated communities in good wind regimes. With existing technology, the wind turbine cannot replace the diesel but can be used to give significant fuel savings.

High-speed wind rotors are mechanically connected to electrical generators; in small installations, usually a dc (direct current) generator can supply directly dc appliances and can be stored in batteries.

Large installations generally drive ac (alternating current) synchronous generators; in this case the generated electricity can be used directly or (most often) fed directly into the power network through a voltage step-up transformer.

A number of large-scale generating systems are now operating in the world, such as:

. 250 kW horizontal-axis - Oltramont Pass (California)
. 200 kW horizontal-axis - Clayton (New Mexico)
. 230 kW vertical-axis (Darrieus) - Magdalene Island

For this level of power, the technology is still too sophisticated for implementation in developing countries, but future use might not be very far away; research is proceeding fast.

Small generating systems are however commonly used and are cost effective in many countries.

5.4.3 Direct heat applications

Mechanical motion derived from wind power can be used to produce heat from the friction of solid materials, or by the churning of water or other fluids, or by the use of centrifugal pumps. This heat may then be stored in materials having a high heat capacity, such as stones, eutectic salts, etc., or the heat may be used directly for such applications as space heating, industrial processes, crop drying, etc.

5.4.4 Other applications

Wind energy transformed into electrical energy can be stored in the form of the mechanical motion of a flywheel or as hydrogen and oxygen gases derived from the electrolytic dissociation of water. The hydrogen and oxygen can be stored in liquid form in tanks, or in gaseous form in tanks, caverns, depleted natural gas wells, etc. The stored hydrogen can be used either as a fuel for direct space heating or industrial process heat, or it can be reconverted to electricity through the use of fuel cells, gas turbine generators that burn hydrogen, or by other means.

Wind power can also be used to compress air for use in various applications, including the operation of a gas turbine for generating electricity during the peak demand periods of a public utility system.

5.5 TECHNO-ECONOMICAL CONSIDERATIONS

Wind energy conversion systems are primarily characterised by the intermittent nature of the wind, which is their source of energy, and by the fact that their power output varies with both the swept area of their rotors and the cube of the wind velocity. Because of this cubic relationship between output power and wind velocity and the fact that the wind is not steady, the actual power output of wind machines, over a long period of time, may be significantly higher than the power output estimated from the average wind speed over that time. Exact siting is critical, since the wind velocity increases with height above the ground level. Local anomalies in wind speed occur both because of increased rates of flow over or around smooth hills and other objects and because of decreased rates of flow caused by nearby trees, buildings and other obstructions.

Furthermore, there are limitations on the size and power output of a wind energy system because of limitations on strengths of materials, which, in turn, limit the size of blades, bearings, tower heights and other critical system components. As a result, if a large capacity for generating electricity (e.g. 100-megawatt power capacity) is required, either the system must be composed of a number of interconnected, dispersed wind units of relatively small size, e.g. up to several megawatts each, or large-scale wind-powered vortex generator systems might be developed for this type of application.

There appear to be important advantages to using wind-derived energy in combination with energy derived from other sources, such as conventional fuels, sunlight, ocean thermal differences, bioconversion fuels, etc.

Since the wind blows intermittently in most locations, there may be a need to store wind energy over long periods of time, perhaps up to ten days or more, if the energy is being used for isolated applications requiring continuous power. The cost of providing sufficient storage capacity for such applications can be reduced if the wind-derived power is interconnected with other sources of power. For instance, since in most locations the wind often blows when the sun is not shining, and vice versa, a system using wind energy collectors and sun energy collectors, e.g. solar photovoltaic arrays or solar thermal collectors, in combination, can be expected to require less energy storage capacity than systems that use these types of collectors singly. Fig. EWIII-28 shows alternatives for converting and storing wind energy.

Large numbers of dispersed wind units tied into the same grid network can also be used to reduce storage requirements for base-load applications served by the grid, since wind speeds can vary considerably over large areas at any given moment in time.

The **technology** is **available today**, but while it is **simple** and easy to operate **for small systems** (installed power a few kW), it becomes extremely **sophisticated** and **costly**, and **difficult** to operate when **large powers** are **involved**.

6. BIOMASS-BASED ENERGY SYSTEM

6.1 INTRODUCTION

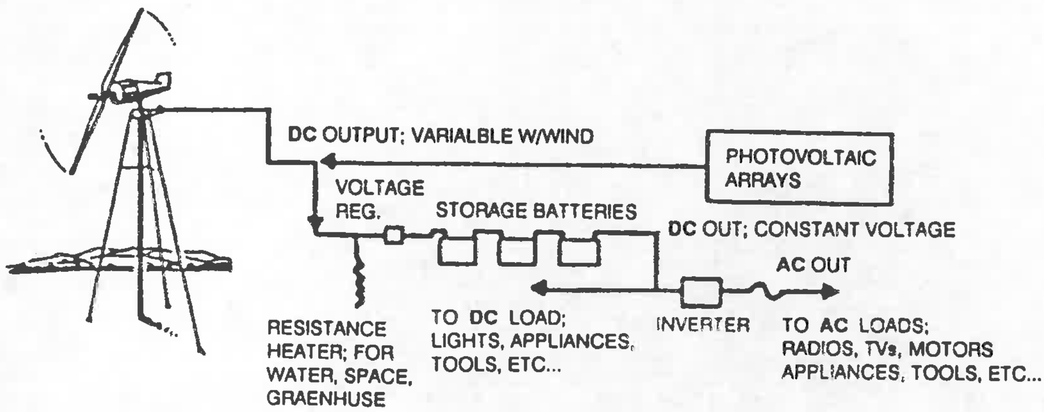
Biomass is represented by the entirety of vegetable and animal organisms referred to a given unit; by extension it also includes the transformation products of such organisms.

Biomass is a very important source of energy; in fact, about 13% of the world's primary energy is derived from biomass.

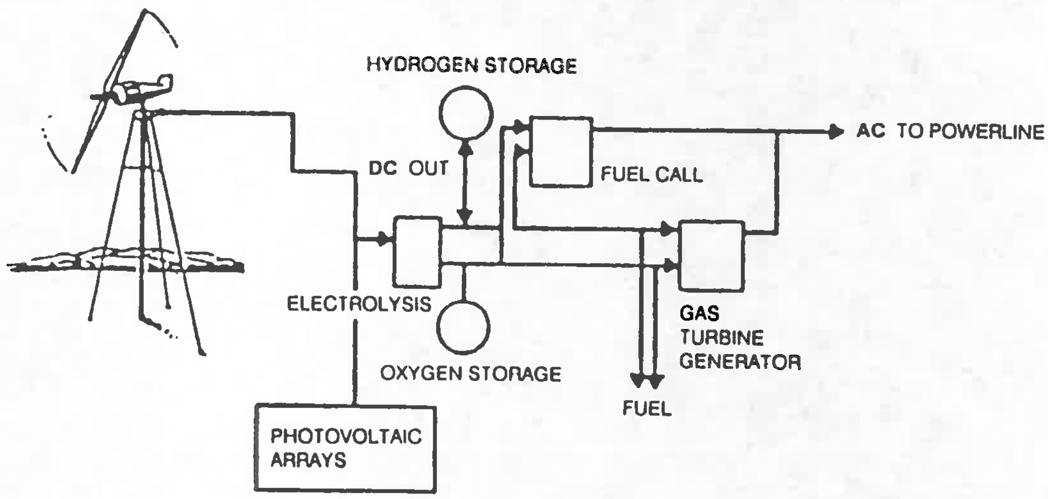
Essentially, the **energy content of biomass is produced by the photosynthetic process.**

Plants can be regarded as "solar collectors" that convert the sun's energy into chemical bonds between carbon and hydrogen by a process known as photosynthesis, as indicated in the following formula:

SYSTEM WITH BATTERY STORAGE



SYSTEM WITH HYDROGEN STORAGE



SYSTEM WITH FLYWHEEL STORAGE

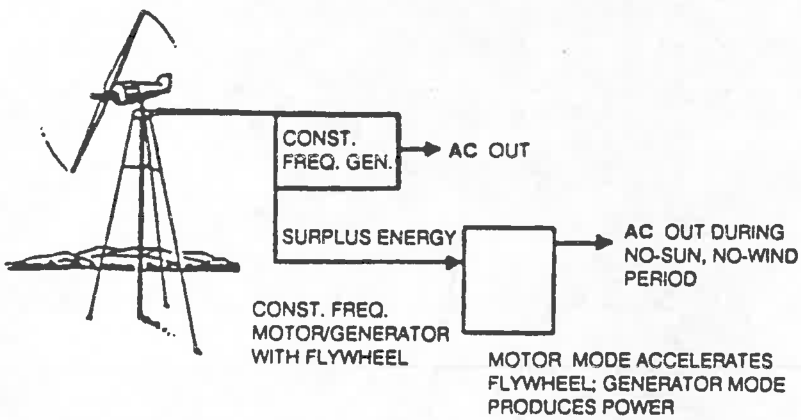
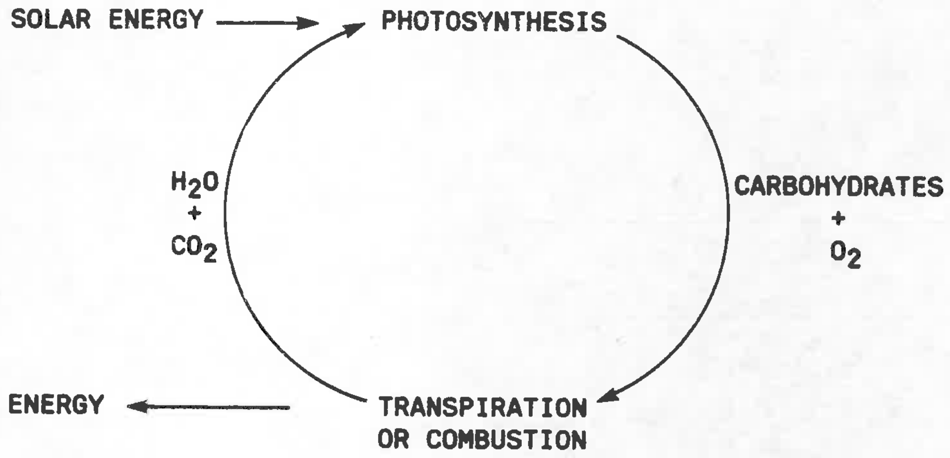


FIG. EWIII-28

$$6\ CO_2 + 6\ H_2O + \text{photons} \rightarrow C_6H_{12}O_6 + 6\ O_2$$



35% of solar radiation is reflected back into space by the outer layers of the atmosphere; 17.5% is reflected back by the inner layers of the atmosphere. Only 47.5% of the total solar radiation falls on the whole of the earth's surface: its amount is $3 \cdot 10^{24}$ J/year.

40% of such radiation, however, has not enough energy to overcome the threshold of photosynthesis (0.7 V): this is lost in the form of heat.

Therefore only 28% of solar radiation can be converted by photosynthesis, whose theoretical efficiency is only 33%. The maximum efficiency is 10% - i.e. 10% of the total solar energy which falls on the earth's surface can be transformed by photosynthesis.

The maximum photosynthetic efficency of the various types of agricultural cultivations is 1% on average. This figure may rise to 2.2-2.8% in some cases, such as for sugar cane and Napier grass, while some very special plants (e.g. water hyacinth - Eichornia crassipes) reach as much as 8%.

In temperate climates, this 1% efficiency can provide a maximum of 20-30 tonnes/hectare/year of dry matter. This biomass corresponds to 75 million Kcal/ha/year, or 7.5 tonnes of oil equivalent (toe). In the tropics, these figures may even be twice as high.

The factors that limit the production of dry matter are:

- temperature: in temperate climates, the optimum temperature for C_3-type plants is 15-25°C. In the tropics, it is 30-40°C for C_4-type plants (zea mais, sugar cane, sorghum);
- the number of hours of daylight (photoperiod);
- light intensity;
- the amount of rain or snow reaching the ground (precipitation);
- evaporation and transpiration (the mean annual amount of precipitation lost);
- characteristics of the soil;
- cultivation methods.

Fig. EWIII-29 gives some samples related to soil bioproductivity and photosynthetic efficiency of selected crops.

The actual and **potential availability of biomass** in a given area, which is the basic data for the assessment of its energetic exploitation, should be drawn up from a number of appropriate activities, such as:

. Elaboration of **thematic cartography**: subject maps and inventories are the basic means used for illustrating the availability of biomasses (example: forest biomasses).

. Elaboration of **potential soil use map**: which includes intrinsic production capacity of the soil and energy required for such production.

. Elaboration of **forest map**: which includes extent of wooded areas, composition (types of trees, bushes, shrubs, etc.), forms of management.

These maps are prepared from air photos and by means of ground surveys (example: biomasses formed of farming wastes).

. Filling in of information and elaboration of a **system for the provision of environmental data**: including discrete files, and numerical models for type of population, forms of management, structural types, density, potential soil use.

. **Forest inventories**: indicating the features and the available amount of each single wood species considered, the yielding features of the soils considered, the guidelines for forestry interventions (supply and deforestation, forestry improvements, etc.).

As regards the **measurement of biomass**, this can be done on a **volume** (m^3) or **weight** (kg or tonnes) basis.

The former is little affected by moisture content, while the contrary is true for weight. Weight should preferably be stated on an oven-dry

THE EARTH'S BIOPRODUCTIVITY

cereal crops as a whole	max.productivity tonnes/ha/yr	photosynthetic efficiency%
grassland/prairie	22	0.7
evergreen forests	22	0.7
deciduous forests	15	0.5
savnnah	11	---
oil palm	40	1.4
tapioca (cassave)	38	1.1
sugar cane	64	1.8
maize	86	0.8
rice	22	0.7
Napier grass	85	2.4
Beet	31	0.9
Fast-growing poplars	28	o.9
Fast-growing pines	18	0.7

FIG. EWIII-29

basis. Biomass production may then be expressed in volume per ha (hectare) (10,000 m³) and per year (m³/ha.year) or oven-dry weight per ha and per year (tonnes/ha.year).

Yield is the total production between planting and harvesting and is expressed in m³/ha or tonnes/ha.

Energy content varies with moisture content; "air-dry" biomass usually contains some 30 to 50% of moisture (of the dry weight).

Fig. EWIII-30 shows the various possibilities of biomass energy conversion.

The **energetic exploitation of biomass** can occur through two main processes:

. **thermochemical process**
. **biochemical process.**

The former utilises biomass with a moisture content lower than 50% and a C/N ratio (carbon/nitrogen ratio) exceeding 30, using **direct combustion and pyrolysis.**

Direct combustion is the oldest and simplest process for exploitation of biomass energy. At present, it is often used to feed boilers for the productionb of steam for driving generator turbines.

Pyrolisis is a biomass **vacuum distillation process**; if the temperature of the reaction is maintained around 400-500°C, then the process is defined as carbonisation and produces charcoal with liquid and gaseous tractions. At higher temperatures, in the range of 1000°C, the process, defined in this case as gasification, converts the whole original biomass and by-products into synthetic gas with a heat value of about 1,200 kCal/Nm³.

This gas can be used to supply a combustion engine (OTTO cycle) driving a generator for the production of electric power, or pumps, etc.

The **process of biochemical conversion** uses biomass with moisture contents exceeding 50% and a C/N ratio lower than 30%, and includes fermentation and anaerobic digestion.

The former consists of enzymatic conversion in ethylic alcohol, starting from sacchariferous solutions of various origins (i.e. agricultural wastes).

The latter, **anaerobic digestion**, is a process of fermentation of organic matter in the absence of oxygen by means of anaerobic bacteria; it produces biogas with a heat value of 5,500 kCal/Nm³ and digested mud with very high fertilising properties.

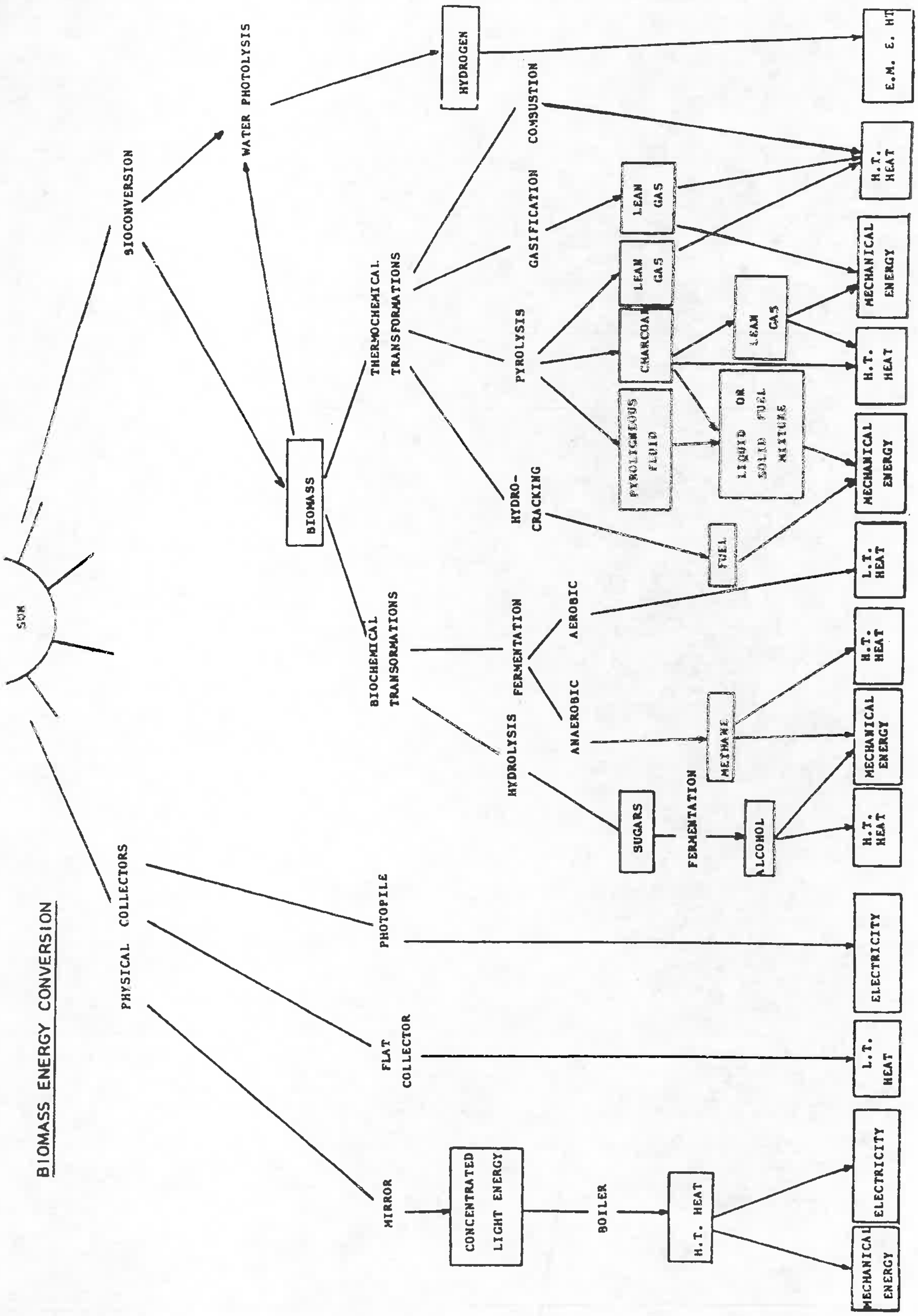

BIOMASS ENERGY CONVERSION
SUN
BIOCONVERSION
WATER PHOTOLYSIS
HYDROGEN
E.M. E. HT
BIOMASS
THERMOCHEMICAL TRANSFORMATIONS
COMBUSTION
GASIFICATION
PYROLYSIS
HYDRO-CRACKING
LEAN GAS
LEAN GAS
CHARCOAL
LEAN GAS
PYROLIGNEOUS FLUID
LIQUID OR SOLID FUEL MIXTURE
FUEL
H.T. HEAT
MECHANICAL ENERGY
H.T. HEAT
MECHANICAL ENERGY
L.T. HEAT
BIOCHEMICAL TRANSFORMATIONS
FERMENTATION
AEROBIC
ANAEROBIC
HYDROLYSIS
METHANE
SUGARS
FERMENTATION
ALCOHOL
H.T. HEAT
MECHANICAL ENERGY
H.T. HEAT
PHYSICAL COLLECTORS
PHOTOPILE
ELECTRICITY
FLAT COLLECTOR
L.T. HEAT
MIRROR
CONCENTRATED LIGHT ENERGY
BOILER
H.T. HEAT
ELECTRICITY
MECHANICAL ENERGY

FIG. EWIII-30

6.2 THERMOCHEMICAL CONVERSION PROCESSES

6.2.1 Direct combustion

Direct combustion is the oldest and simplest means for the energy exploitation of biomasses. It is suitable for low moisture substances with a high carbon content. According to the final use of the energy produced, its combustion can be achieved:

- in small capacity fireplaces or stoves (less than 10,000 kCal/h) when this energy is used for household purposes (cooking, hot water for sanitary facilities and room heating);

- in large and small capacity boilers for industrial applications (hot water, steam or hot air production).

6.2.1.1 Boilers

Various types of boilers (with different types of furnace, operating modes and stoked fuel) are available on the market today:

- horizontal flue (fire-tube) boilers, with injection combustion on the grate. The boiler can be stoked with combustible waste, to be integrated with fuel oil;

- vertical flue boilers, with injection combustion on the boiler grate. Loading can only be mechanical and this boiler type will be stoked with small-sized vegetable residues;

- tangential injection boilers which can be stoked either by hand or mechanically with regular-sized biomass;

- boilers with separate furnace ahead. This type of boiler is used particularly with moist biomasses of variable grain size; they are stoked by hand.

The combustion efficiency of the above-mentioned boilers, defined as the ratio between calories produced (heat output) and the energy content of the fuel matter, is about 70%; but it can reach even higher values.

Some European boiler manufacturers have developed boilers in which cereal straw bundled into large or medium-sized bales can be used as fuel. Facilities include crushing, transport and feeding systems, together with suitable safety and monitoring equipment.

Boiler capacity (output) may range between 10,000 and 15,000 kCal per hour up to several million kCal/h.

6.2.1.2 Stoves

Stoves are well-known devices; therefore the following paragraphs will mainly discuss efficiency.

Present-day cooking stoves mostly involve low-combustion efficiency, since most of these systems consist of a few stones placed side by side or rudimental stoves derived from drums, tins or other salvage material. To overcome this low combustion efficiency (η = 5-10%), some simple and cheap modifications should be introduced that would allow reduction of the specific fuel consumption, such as:

- the construction of suitable fireplaces with local materials (like clay or ceramic stones), but built to convey the heat more rationally to the user so as to reduce heat loss (η = 15% approx.);

- the adoption of suitable cooking vessels so as to ensure a better exchange surface (η = 15-20% approx.).

A large number of projects are under implementation, and others already completed, for improved cooking stoves and are the object of a consistent bibliography; for this reason, this topic is not extensively discussed in this modular unit.

One point should be underlined: many projects failed because they were not adopted to the local social characteristics of the users, mainly women, in spite of their good technological quality. Fig. EWIII-31 shows a few types of improved cooking stoves.

6.2.2 Pyrolysis

Pyrolysis is an airless distillation process of organic matter. If the temperature is lower than 400-500°C, pyrolysis is called carbonisation. Charcoal, gaseous fuels and liquid fuels are obtained from the biomass stoked into the reactor (such as heavy or light oils).

When the temperature reaches 1000°C and water, air and oxygen are present, complete gasification of the biomass is achieved with the sole production of fuel gas.

Reactors used for carbonisation or gasification processes are diversified according to the physical characteristics of the treated material, the production capacity of the system, the final usage of the fuel produced and the methods suitable to supply the necessary process heat. Charcoal is produced by various techniques. The benefits and drawbacks of three pyrolysis systems are reported in table 1.

IMPROVED COOK STOVES

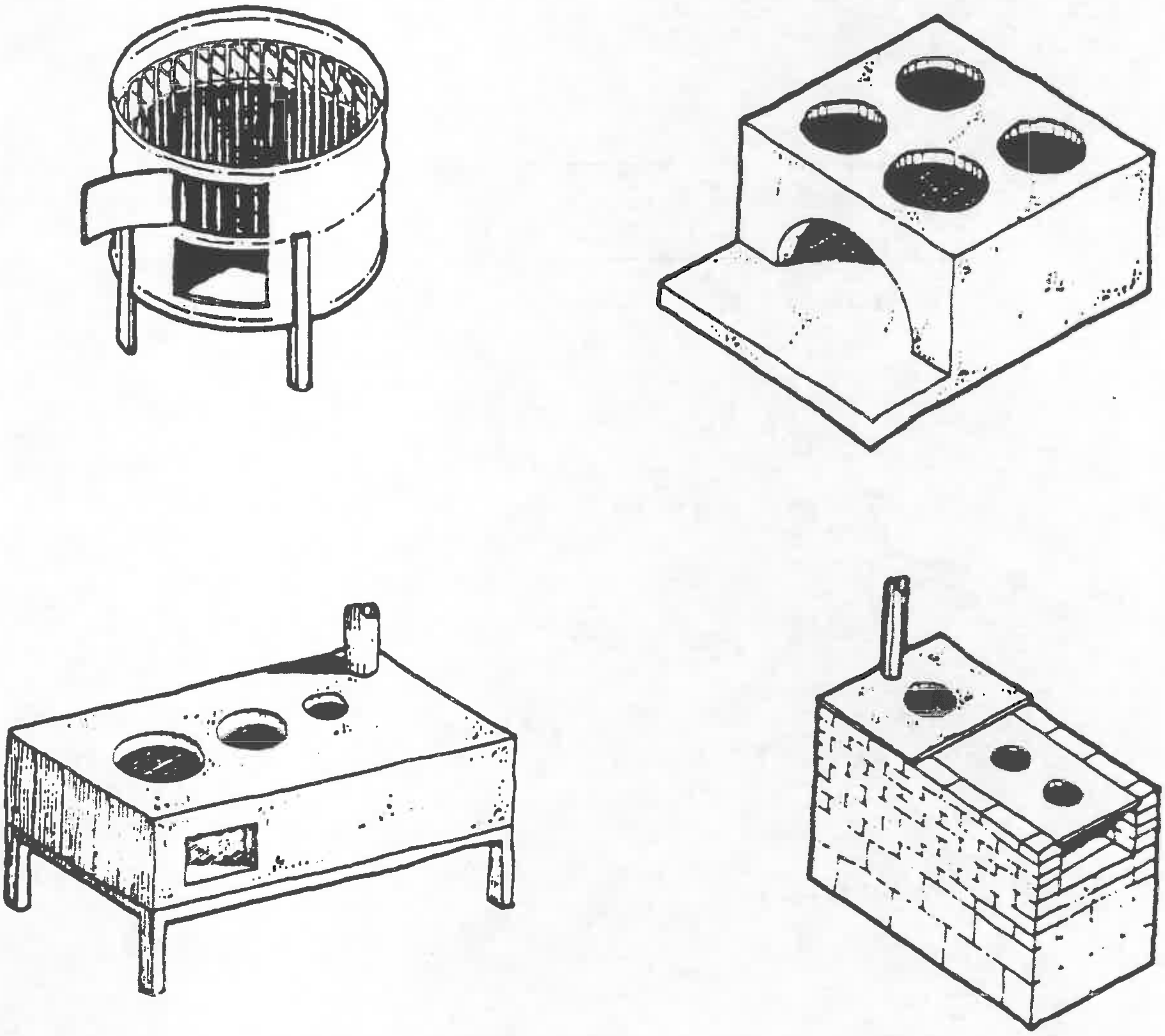


FIG. EWIII-31

TABLE 1
ADVANTAGES AND DISADVANTAGES OF CHARCOAL PRODUCTION IN A STEEL KILN AS COMPARED WITH A BRICKWORK KILN AND EARTHEN PITS

TERMS OF COMPARISON	PORTABLE STEEL KILN (OVEN)	EARTHEN PIT	BRICKWORK KILN
Cost ex-user site (US$)	5000	-	1000-2500
Internal volume (m^3)	6.5	8-30	50-130
Charcoal cycle (days)	3-4	20-30	9-25
Personnel	skilled	unqualified labour	unqualified labour
Mobility	yes	yes	easy to demolish and rebuild
Life (years)	1.5-4	-	8-10
Charcoal quality	good	acceptable	good
Average efficiency (% weight)	20	15	20
Carbonisation facility	simple	difficult	simple
Maximum size of wood in cm	30 x 5 x 5	without limits	200 x 30 x 30
Performance in rainy weather	good	poor	good
Overheating and accident tolerance	poor	fair	good

The adoption of more sophisticated systems would permit the achievement of better conversion efficiency values. For instance, 1000 kg wood which has a net heat value of 4.8 x 10^6 kCal/t and pyrolysis processed at about 400°C would give the products listed in table 2.

TABLE 2
AVERAGE PRODUCTS (OUTPUT) OBTAINABLE FROM
INDUSTRIAL PYROLISIS PROCESSES

PRODUCT TYPE	PRODUCT PER 1 t OF D.M. kg	NET HEAT VALUE kCal/kg	TOTAL ENERGY PER t OF D.M. ON 10^6 kCal
Coal	300	7200	2.16
Oil	200	4800	0.96
Gas	200	1900	0.38
Total	700		3.50

In this case, the conversion efficiency will be 70% approx.

It is possible to obtain this high efficiency because the condensable and uncondensable products are used to match the energy needs of the plant instead of being rejected to the ambient.

6.2.3 Gasification of ligneous products and agricultural waste

The gasification of ligneous cellulosic or carbonaceous materials is a well-established technology whose operating principles have been known for more than seventy years in industrialised countries.

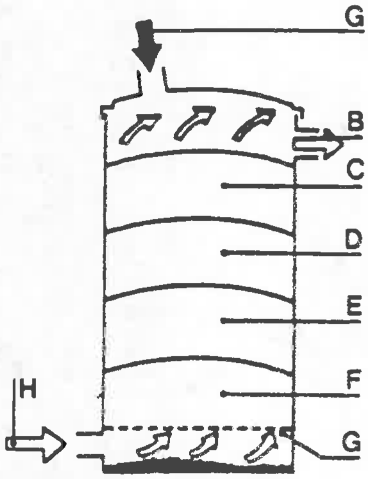
Gasification means partial combustion of ligneous-cellulosic or carbonaceous materials through a controlled introduction of oxygen in a vessel and consequent transformation of the original products into fuel gases.

In practice, gasification is a step forward in the pyrolysis process; in fact in the gasification process, the charcoal produced by pyrolysis is transformed partially into gas by partial combustion with oxygen or steam (see Fig. EWIII-32 for these types of gasifiers).

The chemical process on which gasification is based is also shown in Fig. EWIII-32.

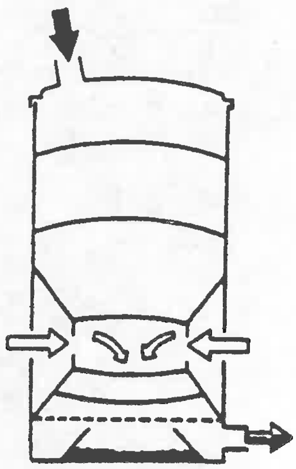
GASIFIERS

A updraught

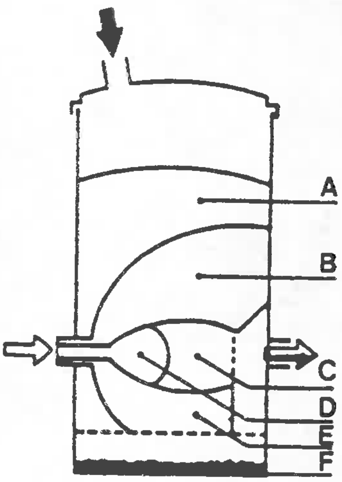


A BIOMASS
B GAS
C DRYING
D PYROLYSIS
E REDUCTION
F COMBUSTION
G GRATE
H AIR

B downdraught



C crossdraught



A MOISTURE DRAWN OFF
B TARS AND OTHER VOLATILES DRIVEN OFF
C C+2H – CH
C+H O – CO+H
C+CO – 2CO
D =O – CO
E BURNING CHAR
F ASCH

FIG. EWIII-32

The purpose of the process is to transfer the energy contained in a solid (the biomass) into a "producer gas"; since this is easier to transport and burn, and it can readily be used in an internal combustion engine.

Lignocellulosic substances have a high content of volatile solids (80% average) which facilitates the process; gasification is the decomposition of hydrocarbons into gas. The process starts in the absence of air, at more than 600°C, with slow combustion.

Combustion produces a gas (carbon dioxide) with a high heat value. Carbon dioxide can be reduced in the presence of the white-hot carbon. Carbon monoxide is in such a way obtained. During the process, pyrolegnous liquids and tars are obtained; the latter can be burned in the gasifier itself, especially when the gas must feed the engine.

The mean composition of the obtained gas is the following:

hydrogen (H_2)	12-18%
carbon monoxide (CO)	15-20%
methane (CH_4)	2-4 %
carbon dioxide (CO_2)	10-15%
nitrogen (N)	48-55%

Gas composition is influenced by the amount of air used during the process (generally 1/3 of the amount necessary for total combustion) since the air produces a high nitrogen content which remains in the gas.

The gas heat value is 1100-1350 kCal/Vm³.

Gasifier operating features

The gasifier utilises pyrolysis processing of vegetable matter by heating the gas obtained in the burner. Gas can be drafted in the same direction of the feeder wood or charcoal (down-draft gasifier) or in the opposite direction (up-draft gasifier). The heat value of the resulting gas is 1100-1350 kCal/m³ with an energy efficiency of about 75%. After cooling and filtration, the gas can be used for combustion fuel or as fuel for internal combustion engines. In this way it is possible to obtain shaftwork or electricity, according to the flowchart shown in Fig. EWIII-33.

In the latter case, by burning 1.3 kg of dry wood (20% humidity), 1 kWh with an energy output of 15% can be obtained.

Today, gasifiers are being produced in the Philippines - in its first year of production the Filipino firm of GEMCOR sold 850 small gasifiers: 450 rated at 12 kW to power the small inshore fishing boats called "bancas"; another 200 rated at 45 kW to power irrigation pumps; and the rest to run light commercial vehicles.

FLOWCHART OF ENERGY PRODUCTION FROM WOOD GASIFICATION

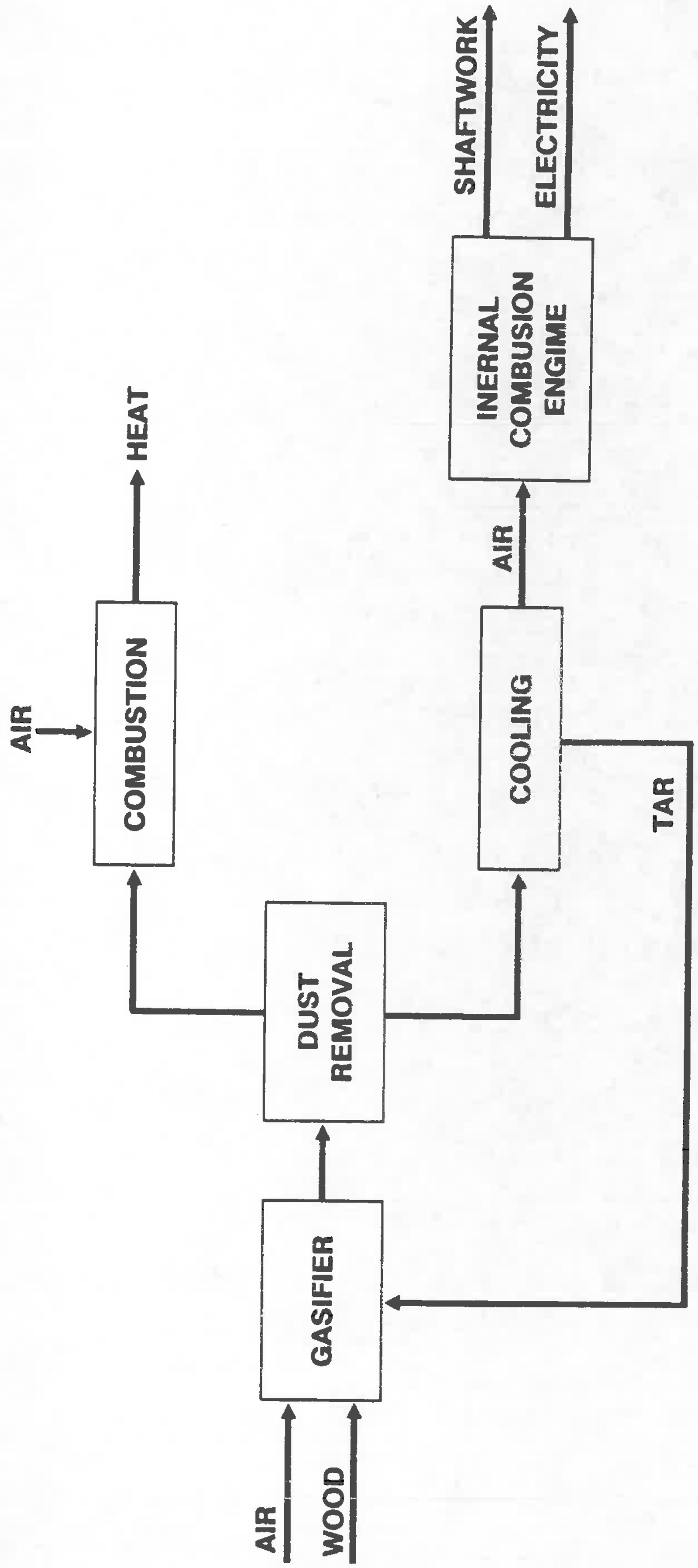


FIG. EWIII-33

In Brazil, some 60 companies are involved in gasifier technology. Gasifiers are being used to run vehicles, power furnaces and kilns and to produce lime (an industry in which it is claimed that gasifiers can reduce wood consumption from 2.5 to 0.8 tonnes of wood per tonne of lime produced). In Brazil, only charcoal is used as a fuel for gasifiers because this reduces the cost of the equipment - gasifiers using other fuels must be capable of getting rid of large quantities of sticky tar. Maize husks, wood waste in the form of chips or blocks and coconut shells can all be used to fire gasfiers. Research is still needed on more difficult fuels such as sawdust and rice husk briquettes.

In Paraguay, second-hand engines have been modified to run off producer gas. Since 1981, the Sapire sawmill - and the houses of nearby labourers - have been supplied by electricity generated in this way. This has saved substantial quantities of diesel fuel, which previously had to be purchased in the nearest town 100 km away.

6.2.4 Liquefaction

Liquefaction is a process which follows gasification; through the catalytic conversion of the gas produced, methanol or any other type of alcohol and hydrocarbon (indirect liquefaction) are obtained.

Research work actually tend towards the development of direct liquefaction; in this case, the process is conducted in a single reactor where the gasification phase is followed by catalytic liquefaction of the gas produced.

In presence of heat and a catalyst such as zinc oxide or a mixture of catalysts, the following reaction is carried out:

$$CO + 2H_2 \xrightarrow[\text{catalyst}]{\text{heat}} CH_3OH$$

<u>State of the art</u>

. **Indirect liquefaction**

For the conversion of synthetised gas into liquid fuels, vanguard technologies such as LURGI and ICI for the production of methanol, FISCHER TROPSCH/SASOL for the production of hydrocarbons, are available.
Other processes are at the study stage to improve the conversion yields.

. **Direct liquefaction**

The technique conducing towards direct liquefaction is still in its infancy since it involves a process which still presents many difficulties of a chemical nature.

6.3 BIOCHEMICAL CONVERSION PROCESSES

6.3.1 Anaerobic digestion

Animal, human and agricultural wastes can **produce biogas** through a **fermentation (digestion) process** occurring in an **environment** where there is **no oxygen** (anaerobic condition).

A good anaerobic digestion performance requires optimum environmental conditions for the bacterial flora, in particular for the most sensitive component: the methanogenic bacteria.

Rural areas have large supplies of agricultural residues and animal wastes - theoretically suitable for conversion into a usable source of energy. The process that appears to hold the greatest immediate potential for utilisation of these materials as sources of fuel is anaerobic fermentation. This process, also called **anaerobic digestion, converts** complex **organic matter to methane** and other gases (Fig. EWIII-34); it is developed in a device called a **digester**.

The digester can be fed with different biomasses: animal manure, human waste, soil, vegetal wastes and residues from agro-industrial production, algae, water hyacinth, etc.

Gas production has been found to vary significantly with the mixture of materials used. Experience has shown that gas production can be increased by mixing substrates that have a high carbon content with substrates containing nitrogen, and vice versa.

It has been found, as a matter of practice, that it is important to maintain a C/N ratio by weight (carbon/nitrogen ratio) close to 30 to achieve an optimum rate of digestion.

The table EWIII-35 shows a C/N ratio of a variety of raw waste materials. With the aid of the values presented in this table, waste materials that are low in carbon can be combined with materials high in nitrogen, and vice versa, to achieve the optimal C/N ratio of 30/1.

Temperature also has a significant effect on anaerobic digestion.

The digestion proceeds best at 30-40°C with a mesophilic flora, and at 50-60°C if a thermophilic flora is developed and adapted. The choice between medophilic and thermophilic operation will be made at the design stage and will be based upon climate and other considerations.

The digestion process occurs in a certain period of time (retention time) which depends on the type of material used.

As an example, for cattle manure kept in a digester at 30°C the optimal retention time is 30 days and the biogas produced amounts to 0.58 litres per day.

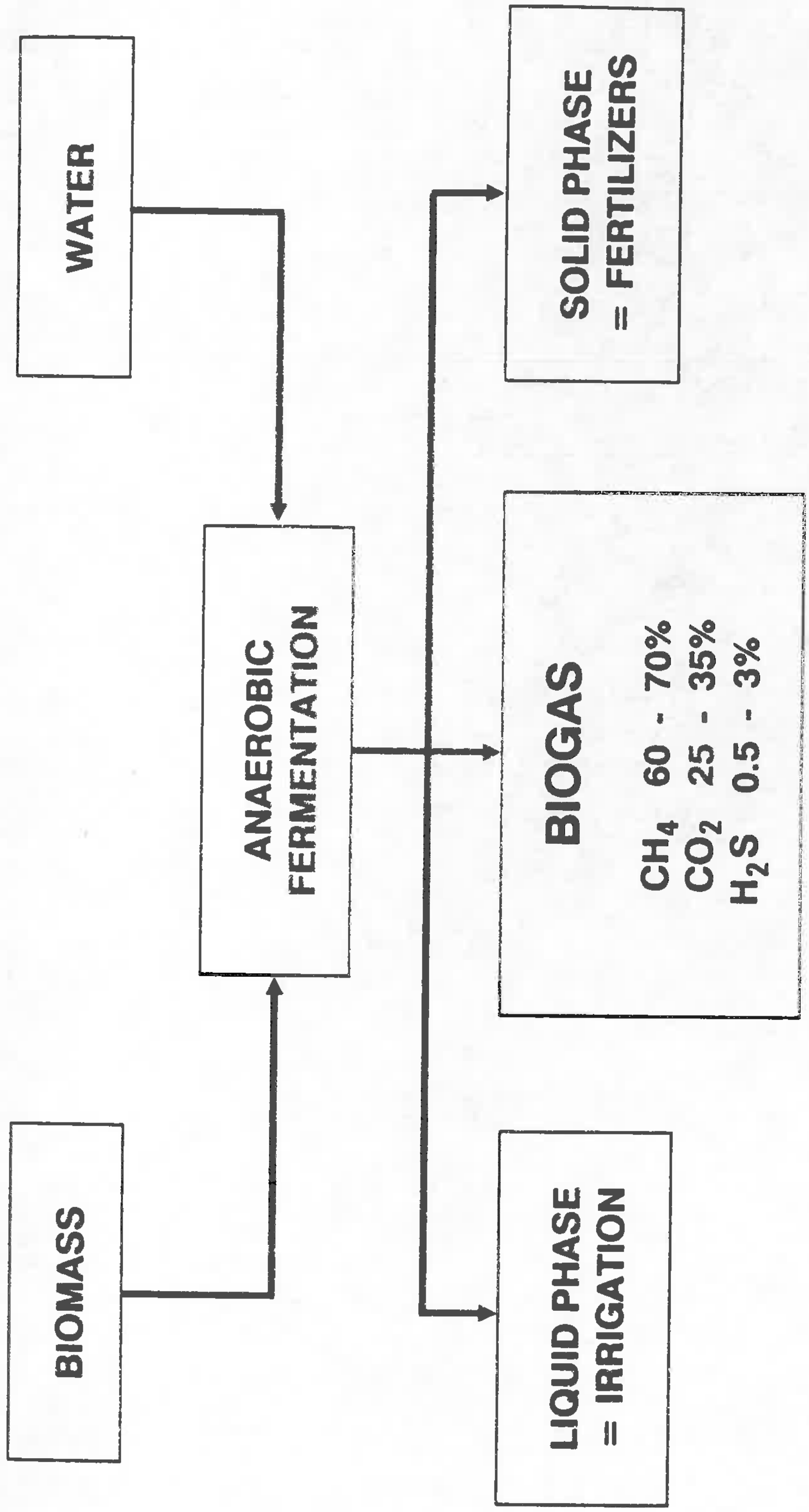

WATER
BIOMASS
ANAEROBIC FERMENTATION
SOLID PHASE = FERTILIZERS
BIOGAS
CH4 60 - 70%
CO2 25 - 35%
H2S 0.5 - 3%
LIQUID PHASE = IRRIGATION

FIG. EWIII-34

TABLE 1 - C/N mean ratio for some types of biomasses

Type of biomass		C/N
Animal wastes	urines	1
	blood	3-4
	meat wastes	5-6
Dejections	cows	22-28
	horses	22-28
	pigs	18-22
	poultry	13-17
	sheeps	20-24
	goats	20-24
	man	6-10
	sludge :	
	active	3-7
	primary	8-12
	cow manure with litter	28-32
Vegetables	potato leaves	18-22
	wheat straw	130-150
	maize cobs	60-65
	maize stalks	70-80
	bean straw	29-31
	peas stems and leaves	18-28
	broad bean straw	22-24

FIG. EWIII-35

6.3.2 Biogas

Biogas, which is **one of the products of anaerobic digestion,** is a composition of the following:

Metane (CH_4)	55 - 75%	(in volume)
Carbon dioxide (CO_2)	25 - 40%	(in volume)
Hydrogen sulphide (H_2S)	0.01 - 0.3%	(in volume)
Hydrogen (H_2)	0.0 - 10%	(in volume)
Hydrocarbons (C_nH_{2n+2})	0.5 - 3%	(in volume)

The **calorific value,** expressed in kcal/Nm³ (kilocalories per normal cubic metre), is 5400.

The characterisics of biogas are similar to those of natural gas, therefore it can replace natural gas.

Biogas can be used directly, or it can be purified by removing H_2S and CO_2. Desulphurisation is necessary to prevent corrosion when used in internal combustion engines.

Biogas can be **used for:**

- **Cooking**	1.5 - 2.0 Nm³/d for a family with 5 to 7 members
- **Direct lighting**	0.07 - 0.15 Nm³/h per 30-70 candles power
- **Absorption cooling**	0.08 - 0.10 Nm³ per dm² surface/d
- **Electric power generation**	0.60 - 0.70 Nm³/kWh
- **Engines** (η = 0.25)	0.45 - 0.50 Nm³ per HP per hour

Concerning the use of biogas for driving internal combustion engines, it is interesting to know the following information:

a) Electricity production: the power of generators driven by biogas can vary from 1.6 to 2200 kW.

b) Vehicles: there are tractors that can use biogas compressed in bottles.

Biogas production is continuous, whereas most of the uses are discontinuous.

In order to have at one's disposal a sufficient quantity of biogas per day, a suitable **storage system** is necessary to store a percentage of the biogas produced.

6.3.3 Biofertilisers: effects and consequences of organic fertilisers

The use of rural wastes for methane generation, rather than directly as fuels or fertilisers, yields several direct and indirect benefits.

The final result of applying anaerobically digested sludge to soil has better effects than those obtained from applying any other kind of organic matter. The humus materials formed improve physical properties of soil: for example, aeration, moisture-holding capacity, and water infiltration capacity are improved and cation exchange capacity is increased. Furthermore, the sludge serves as a source of energy and nutrients for the development of microbial populations that, directly and indirectly, improve the solubility, and thus the availability to taller plants, of essential nutrients contained in soil minerals.

6.3.4 Types of biogas generation systems

Anaerobic digestion can be performed in **two types of plants** which differ according to the biomass feeding system:

- **continuous plants**
- **discontinuous or batch plants.**

6.3.4.1 Rural-type digesters

Digesters which are simple to manufacture are:

a) Chinese-type digester
b) Indian-type digester
c) Plug-flow digester
d) Batch digester

a) <u>Chinese-type digester</u>: No sophisticated technology is needed to construct this digester. In China, there are approximately 1,500,000 digesters of this type. As shown in Fig. EWIII-36, it is constructed underground for better thermal insulation. Every day, a new load is added as a function of the retention time, and the corresponding output sludge is extracted.

This type of digester is recommended for families, and a 10 m^3 digester is usually constructed. To keep the gas pressure constant, it is necessary to install a pressure regulator.

If vegetable residues are used as digestible materials, they must be thoroughly broken up into small pieces, to avoid clogging the output tubes.

b) <u>Indian-type digester</u>: This is a vertical continuous digester with a floating cover that works as a gasometer.

CHINESE TYPE DIGESTER

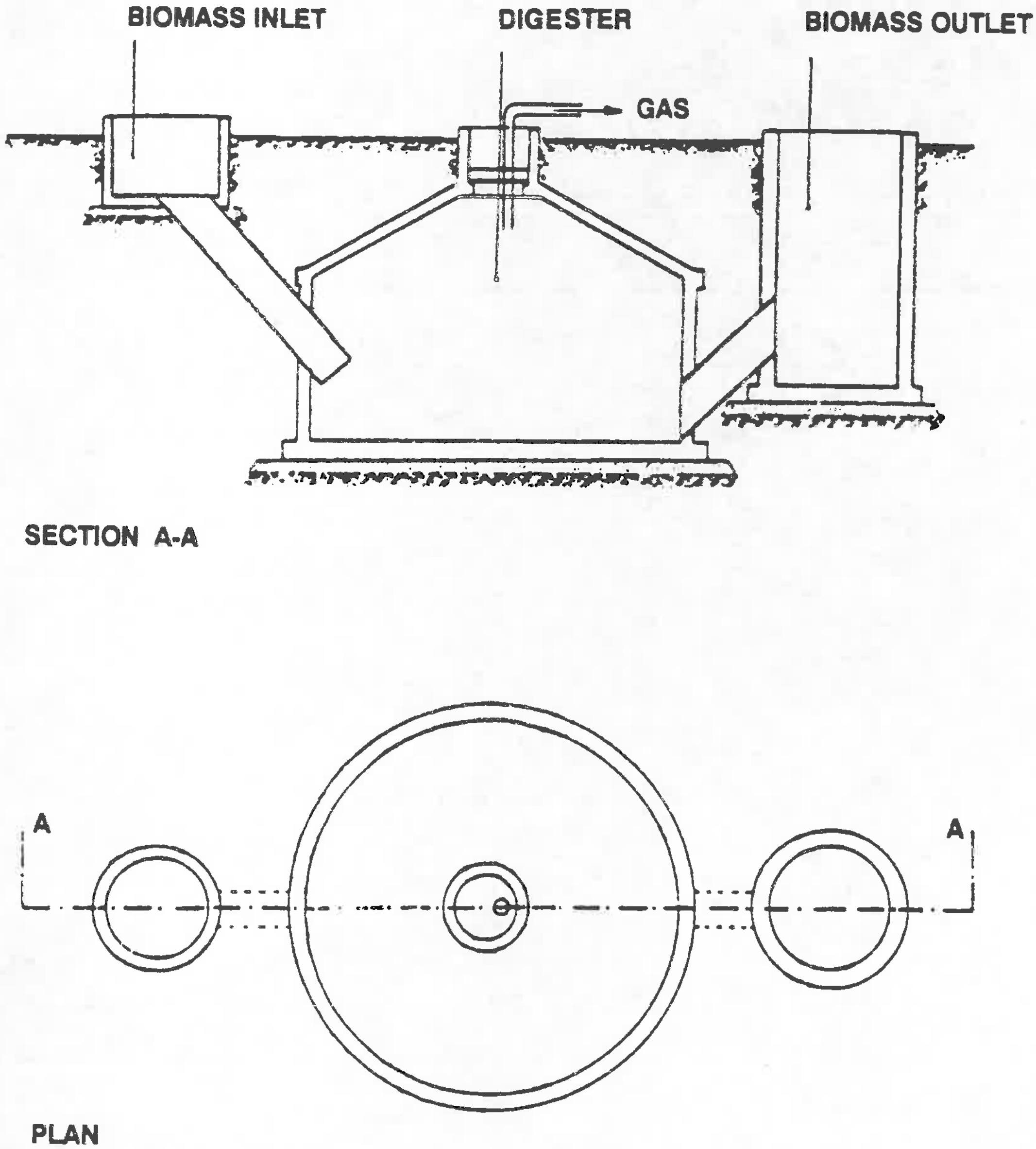


FIG. EWIII-36

The thermal insulation is not as effective as in the Chinese-type digester, and the internal heat is dissipated via the cover's surface.

Construction of this type of digester is easy, and is shown in Fig. EWIII-37. Local materials may be used: bricks, clay, sand. Its cost is reasonably low. The most expensive part is the gasometer, which must be able to move vertically in order to maintain a constant pressure. This pressure is a function of its surface and weight.

When vegetable residues are used, the instructions given for the Chinese-type digester must be followed.

The gas yield is approximately 0.20-0.30 Nm^3/m^3 of digester per day, with a retention time of 40 days.

The gas yield may be lower than in the case of the Chinese-type digester, due to the poor thermal insulation.

c) **Plug-flow digester**: The horizontal displacement digester by Fry (Fig. EWIII-38) is claimed to be economical and easy to install and operate. Elements of construction of this type of digester include: a long cylindrical metal drum or concrete pipe, lying horizontally on (or partially in) the ground, or a long rectangular tank with a flow-roof which may be made of concrete, iron or plastic. It is necessary to insulate this digester to minimise the thermal losses towards the environment. The roof has a dome for gas collection near the output tube of the digester.

The cover can also be made of plastic and/or elastomeric materials.

The total concentration of solids must be at least 10%.

Under optimal conditions of temperature and organic concentration, the gas yield can vary between 0.5-0.8 Nm^3/m^3 of digester per day.

The gas must be sent to a gasometer to avoid overflow of the sludge.

d) **Batch digester**: This type of digester is the simplest of all considering the method of construction and operation.

Generally, its shape is square or rectangular. Underground construction is suggested for better thermal insulation (Fig. EWIII-39).

This digester can receive all kinds of materials: when the materials loaded into the digester are finely broken up, the gas yield will be maximum.

INDIAN TYPE DIGESTER

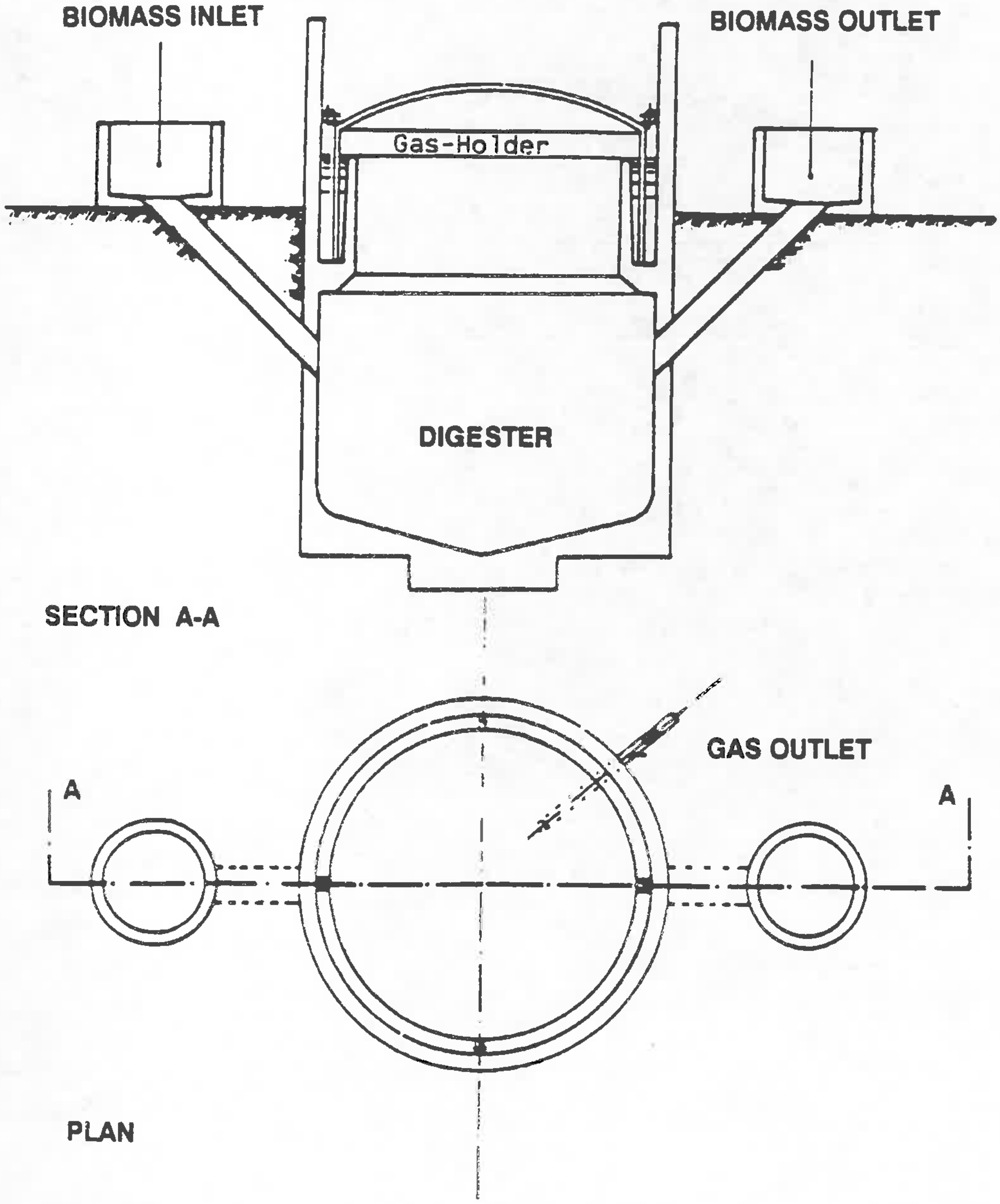
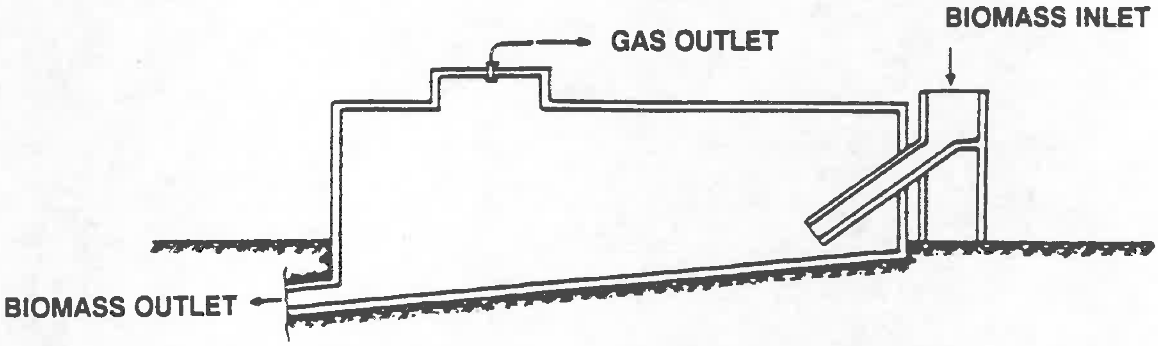
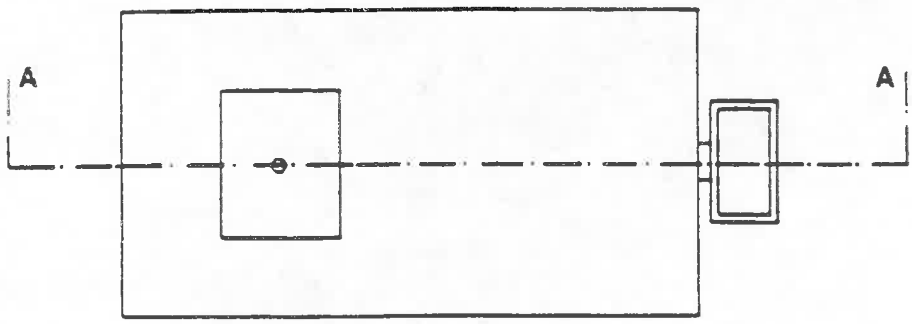


FIG. EWIII-37

PLUG-FLOW DIGESTER



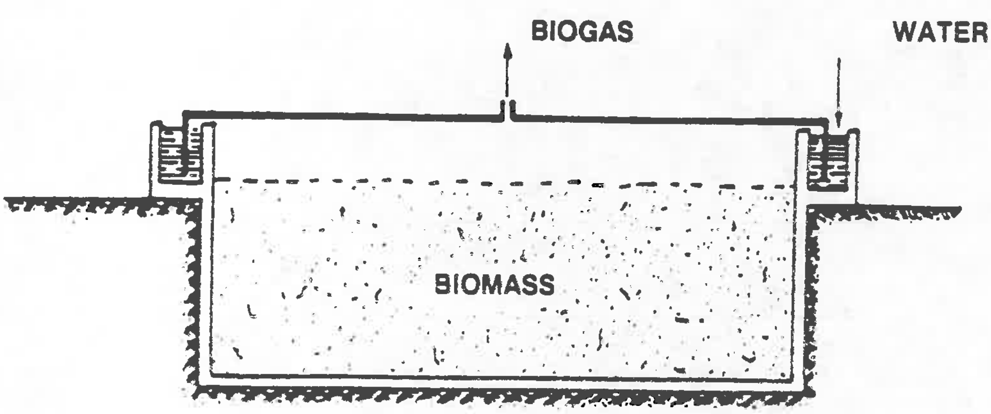
SECTION A-A



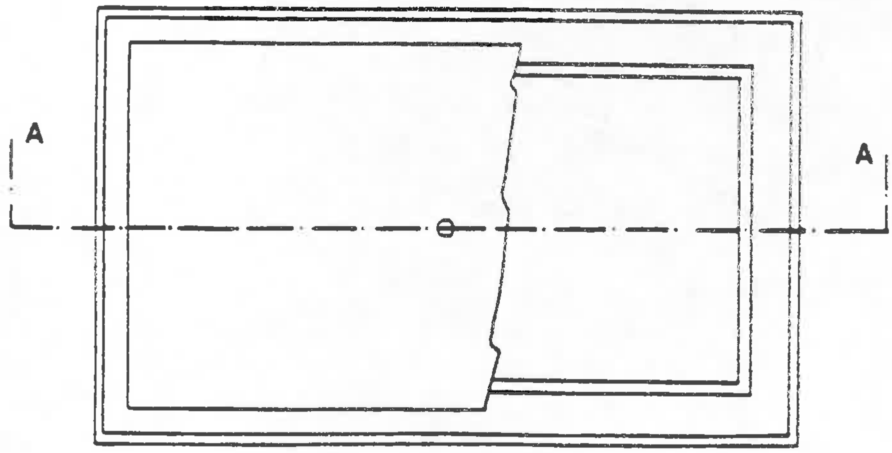
PLAN

FIG. EWIII-38

SATCH DIGESTER



SECTION A-A



PLAN

FIG. EWIII-39

"HIGH RATE" DIGESTER

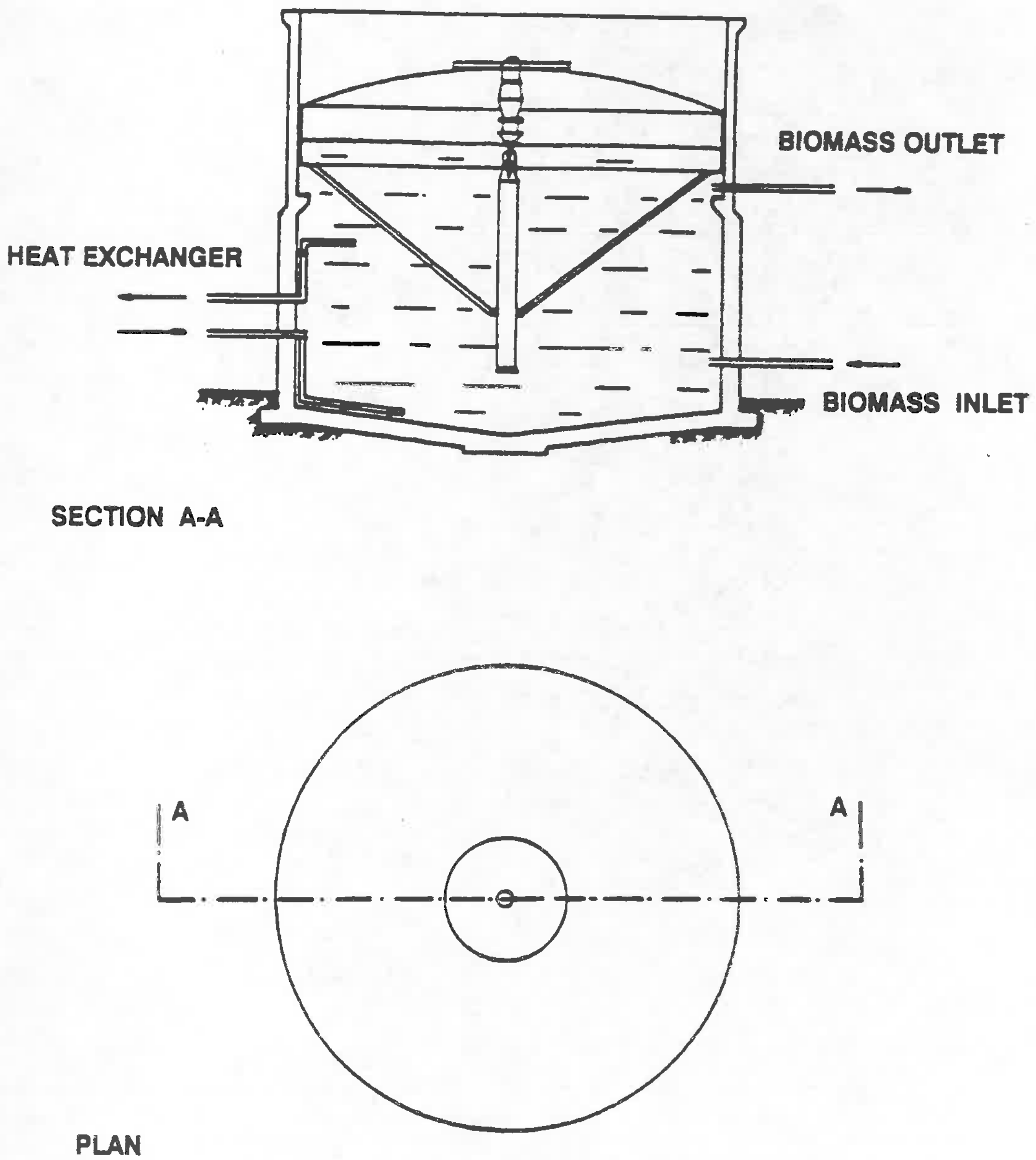


FIG. EWIII-40

Advantages and disadvantages between the continuous and discontinuous loading system for the anaerobic digestion process

System	Advantages	Disadvantages
Continuous	- Continuous operation - Constant gas production - Minimal handling - Tested experience - High production of biogas per unit volume - Suitable to handle large quantities of biomasses	- Continuous monitoring of physical and chemical parameters
Discontinuos	- Extremely simple in operation and use - Low initial investment and possibility to use local materials - Suitable for small quantity of biomasses - Suitable for use in remote regions	- Several reactors are needed for a regular production - Loading and unloading need manpower - Low production of biogas per unit volume

FIG. EWIII-41

kcal: kilocalories

kW: kilowatt

MW: megawatt

ac: alternating current

dc: direct current

Flat collector:

A plane device designed to capture the heat from solar radiation with the purpose of heating a fluid.

Greenhouse effect:

The phenomenon by which a greenhouse traps the sun's heat.

Focusing concentrator:

Solar collector in which a curved mirror surface concentrates the radiant energy from the sun onto a heat absorbing body.

Heat exchanger:

Device which enables the transfer of heat between two fluid streams at different temperatures.

Condenser:

Device which enables the condensation of vapour or steam, transforming it into a liquid.

Water head:

The difference in level (expressed in metres) through which water falls, producing useful kinetic energy.

Flow rate:

The amount of fluid (in litres or m^3) passing through a given cross-section in a unit of time (seconds).

Efficency η:

Ratio between the total output of useful energy from a process or system to the total energy input (expressed as a percentage).

Load factor:

Ratio between the amount of power effectively produced and the potential power production capacity of a system.

Calorific value:

The amount of heat produced when a unit of mass is completely burned.

Economic and Social Commission for Asia and the Pacific, Bangkok: Renewable Energy Planning: Methodological Aspects of Assessment of New and Renewable Source of Energy and Integrated Planning, Bangkok, 5-30 August 1985, United Nations, March 1987.

Meier, U. and Rentsch, U.: New and Renewable Energies, ENDA Third World Document Series, No. 20-81, September 1981.

Reddy, T.A. and Bouix, Ph. (Eds.): Solar Thermal Component and System Testing, Proceedings of the Fourth Asian School on Solar Energy Harnessing, Asian Institute of Technology, Bangkok, Thailand, 12-20 December 1985.

CESEN: Energia domani, No. 17, Genoa, Italy, July-August 1980.

Hofkes, E.H. and Visscher, J.T.: Renewable Energy Sources for Rural Water Supply, Technical Paper 23, International Reference Centre for Community Water Supply and Sanitation, The Hague, The Netherlands, 1986.

Agence française pour la Maîtrise de l'Energie: Small Hydro-Electric Power Stations, Paris, 1983.

Eldridge, Frank R.: Wind Machines, Report prepared for the National Science Foundation, 1975.

Food and Agriculture Organization of the United Nations: Wood for Energy, Forestry Topics Report No. 1, FAO Forestry Department.

Agence française pour la Maîtrise de l'Energie: Electricity from Sunlight, Paris, 1983.

1. LIST THE SOLAR SYSTEMS (THERMAL AND VOLTAIC) WHICH WILL BE OF DIRECT USE FOR WOMEN.

2. LIST THE HYDRO SYSTEMS WHICH WILL BE OF DIRECT USE FOR WOMEN.

3. LIST THE GEOTHERMAL SYSTEMS WHICH WILL BE OF DIRECT USE FOR WOMEN.

4. LIST THE BIOMASS BASED SYSTEMS WHICH WILL BE OF DIRECT USE FOR WOMEN.

5. LIST THE WIND DRIVEN SYSTEMS WHICH WILL BE OF DIRECT USE FOR WOMEN.

6. WITH REFERENCE TO THE ABOVE-MENTIONED SYSTEMS, INDICATE WHICH APPLICATIONS AND TECHNOLOGIES ARE MOST CRITICAL FOR THEIR USE BY WOMEN.

7. INDICATE WHICH APPLICATIONS AND TECHNOLOGIES ARE MOST SUITABLE FOR RURAL AREAS AND CONTRIBUTE BETTER TO THE IMPROVEMENT OF WOMEN'S SOCIO-ECONOMIC CONDITIONS IN YOUR COUNTRY.

NAME OF PARTICIPANT

....

INSTITUTION

....

OCCUPATION

....

COUNTRY

....

DATE

....

Mark the box which corresponds best to your opinion on each question.

1. Your professional interest in the particular topic included in this modular unit was:

   high ☐ ☐ ☐ ☐ low

2. The objectives of this module were:

   clear ☐ ☐ ☐ ☐ not clear

3. Would you say that the objectives of this module met all, some or none of your expectations?

   3.a) Which objectives were not met?

3.b) Explain briefly why the objectives were not met.

4. The contents of this module were:

well structured ☐ ☐ ☐ ☐ badly structured

4.a) If they were badly structured, explain why.

5. The terminology in this module was:

easy to understand ☐ ☐ ☐ ☐ hard to understand

6. The visual material (slides, drawings, diagrams...) used in this module was:

clear ☐ ☐ ☐ ☐ confused

useful ☐ ☐ ☐ ☐ useless

7. The checklists have covered the subject studied:

completely ☐ ☐ ☐ ☐ not at all

8. The checklists were:

useful	☐	☐	☐	☐	useless
too simple	☐	☐	☐	☐	too complicated
sufficient	☐	☐	☐	☐	insufficient

9. Studying this module enabled you to learn:

many new things	☐	☐	☐	☐	nothing new

10. The knowledge acquired through this module will, in your present profession, be:

useful	☐	☐	☐	☐	useless

11. The knowledge acquired through this module will, in the near future, be:
(Reply to this question only if the answer to question no. 10 is negative)

useful	☐	☐	☐	☐	useless

12. List the topics you would like to have treated more extensively:

1) ....

2) ....

3) ....

13. List the topics you would like to have treated to a lesser extent:

1) ....

2) ....

3) ....

14. List the topics not included in this module which you think are of particular interest to your profession:

    1) ....

    2) ....

    3) ....

15. List any suggestions for improvement of this training module:

    ....

    ....

    ....

    ....

    ....

    ....

This evaluation questionnaire should be sent to:

UN/INSTRAW
P.O. Box 21747
SANTO DOMINGO
The Dominican Republic

TRAINER'S GUIDE

HARDWARE

1. Overhead projector
2. Screen
3. Blackboard
4. Flipcharts (optional)

DOCUMENTS TO BE USED BY THE TRAINER

See "Module Structure", page 2

DOCUMENTS TO BE DISTRIBUTED TO TRAINEES

EWIII-1.1: Target groups

EWIII-1.2: Objectives

EWIII-2.1: Table of contents

EWIII-2.2: Text

EWIII-2.4: Glossary

EWIII-2.5: Bibliography

EWIII-3.1: Checklists on key issues for group work

EWIII-3.2: Evaluation questionnaire

KEY POINTS	TRAINING METHOD AND ACTIVITIES	DOCUMENTS TO BE DISTRIBUTED	AVA
	INTRODUCTION		
1. Objectives	Presentation	EWIII-1.1 EWIII-1.2	
2. The NRSE technologies	Presentation	EWIII-2.1 EWIII-2.2	
	PRESENTATION		
3. Solar energy systems	Presentation		EWIII-1
4. Passive thermal system	Presentation/ discussion		EWIII-2
5. Solar water heating	Presentation		EWIII-3, 4a, EWIII-4b
6. Solar cooking	Presentation/ discussion		EWIII-5, 6, 7
7. Water distillation	Description		EWIII-8
8. Crop drying	Description/ discussion		EWIII-9
9. Active thermal systems	Presentation		EWIII-10
10. Solar engines	Description		EWIII-11
11. Solar cooling	Description		EWIII-12
12. Solar power plant	Description		EWIII-13
13. Photovoltaic conversion	Presentation/ discussion		EWIII-14, 15
14. Techno-economical considerations for solar systems	Discussion		

KEY POINTS	TRAINING METHOD AND ACTIVITIES	DOCUMENTS TO BE DISTRIBUTED	AVA
15. Hydroelectricity generation	Presentation		
16. Hydropower stations	Description		EWIII-16
17. Hydroturbines	Description		EWIII-17
18. Techno-economical considerations for hydro systems	Discussion		
19. Geothermal energy systems	Presentation		EWIII-18, 19
20. Techno-economical considerations	Discussion		EWIII-20, 21
21. Wind energy systems	Presentation		
22. Wind energy technologies	Presentation		EWIII-22
23. Wind machines	Description		EWIII-23, 24 EWIII-25
24. Water pumping	Description/ discussion		EWIII-23, 24 EWIII-25
25. Electricity generation	Description/ discussion		EWIII-23, 24 EWIII-25
26. Techno-economical considerations	Discussion		EWIII-26
27. Biomass energy conversion	Presentation		EWIII-27, 28
28. Thermochemical process	Presentation		
29. Direct combustion	Discussion		EWIII-29

KEY POINTS	TRAINING METHOD AND ACTIVITIES	DOCUMENTS TO BE DISTRIBUTED	AVA
30. Pyrolysis	Description		
31. Gasification	Description		EWIII-30, 31
32. Liquefaction	Description		
33. Anaerobic digestion	Description		EWIII-32
34. Biogas	Presentation/ discussion		
35. Fertilisers	Presentation/ discussion		
36. Digesters	Description/ discussion		EWIII-33, 34 EWIII-35, 36 EWIII-37
	SUMMARY		
37. Key issue checklists	Group discussion	Checklist EWIII-3.1	
38. Presentation on checklists	Plenary discussion		
	MONITORING AND CONTROL		
39. Key issue checklists	The participants will work in small groups and discuss various proposals		
40. Module evaluation questionnaire	Individual activity	Questionnaire EWIII-3.2	

NAME OF TRAINER ....

COUNTRY .... DATE ....

AVERAGE EDUCATIONAL QUALIFICATIONS OF PARTICIPANTS ....

....

.... NUMBER OF PARTICIPANTS ....

Mark the box which corresponds best to your opinion on each question.

1. To what extent has the module achieved the objectives stated?

☐ over 80%

☐ 70 - 80%

☐ 60 - 70%

☐ 50 - 60%

☐ less than 50%

2. Did the objectives meet the needs of the group?

totally ☐ ☐ ☐ ☐ not at all

3. On the basis of the objectives stated, the subject matter is:

relevant ☐ ☐ ☐ ☐ irrelevant

4. The progression of the subject matter is:
(Give reasons for your answers)

too fast ☐ ☐ ☐ ☐ too slow

5. List the topics you would like to have treated in the package more extensively:

a) ....

b) ....

c) ....

6. List the topics you would like to have treated to a lesser extent:

a) ....

b) ....

c) ....

7. List the topics not included in this module that you think should be included:

a) ....

b) ....

c) ....

8. The technical quality of the audiovisual material was:

high ☐ ☐ ☐ ☐ low

9. The relevance of the audiovisual material was:

high ☐ ☐ ☐ ☐ low

10. The quantity of the audiovisual material was:

high ☐ ☐ ☐ ☐ low

11. The sound/slide package (where applicable) was:

too long ☐ ☐ ☐ ☐ too short

12. Your global evaluation, bearing the objectives and teaching resources of the module you have tested in mind, is:
(Give reasons for your answer)

excellent ☐ ☐ ☐ ☐ mediocre

After completion, please forward this document to:

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The Dominican Republic

EWIV-1: THE IMPACT OF SOLAR RADIATION WITH THE ATMOSPHERE

EWIV-2: THE TROMBE WALL

EWIV-3: TYPICAL CONSTRUCTION OF A FLAT-PLATE SOLAR COLLECTOR

EWIV-4: SOLAR WATER HEATER

EWIV-5: OVEN-TYPE SOLAR COOKER

EWIV-6: FOCUSING-TYPE SOLAR COOKER

EWIV-7: SOLAR COOKING WITH HEAT TRANSPORT AND HEAT STORAGE

EWIV-8: WATER DISTILLATION

EWIV-9: SECTION VIEW OF THE FRUIT AND VEGETABLE SOLAR DRIER

EWIV-10: SOLAR CONCENTRATORS

EWIV-11: BASIC CONFIGURATION OF A SOLAR THERMODYNAMIC PUMPING SYSTEM

EWIV-12: BLOCK DIAGRAM OF A SOLAR REFRIGERATING SYSTEM

EWIV-13: CENTRAL RECEIVER SOLAR TOWER POWER PLANT

EWIV-14: THE SOLAR (PHOTOVOLTAIC) CELL

EWIV-15: PHOTOVOLTAIC SYSTEM

EWIV-16: TYPICAL HYDROELECTRIC SYSTEM

EWIV-17: TYPES OF HYDRAULIC TURBINES

EWIV-18: THE MOST IMPORTANT GEOTHERMAL FIELDS IN THE WORLD

EWIV-19: GENERAL SCHEME OF A VAPOUR GEOTHERMAL SYSTEM

EWIV-20: GEOTHERMAL ELECTRICAL GENERATING CAPACITY

EWIV-21: INSTALLED LOW-TEMPERATURE GEOTHERMAL CAPACITY

EWIV-22: POWER GENERATION VIA WIND MACHINES

EWIV-23: HORIZONTAL-AXIS ROTORS

EWIV-24: VERTICAL-AXIS ROTORS

EWIV-25: MAGNUS EFFECT

EWIV-26: ALTERNATIVES FOR CONVERTING AND STORING WIND ENERGY

EWIV-27: THE EARTH'S BIOPRODUCTIVITY

EWIV-28: BIOMASS ENERGY CONVERSION

EWIV-29: IMPROVED COOK STOVES

EWIV-30: GASIFIERS

EWIV-31: FLOWCHART OF ENERGY PRODUCTION FROM WOOD GASIFICATION

EWIV-32: ANAEROBIC FERMENTATION

EWIV-33: CHINESE-TYPE DIGESTER

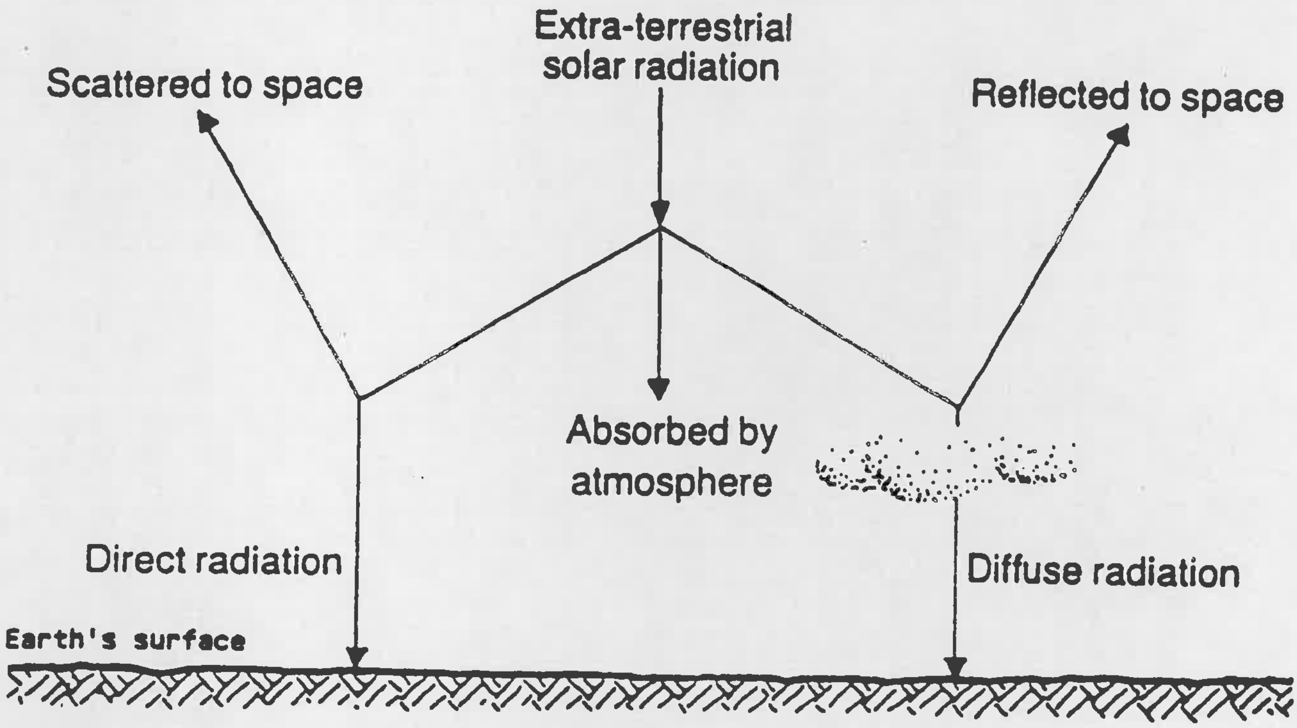
EWIV-34: INDIAN-TYPE DIGESTER

EWIV-35: PLUG-FLOW DIGESTER

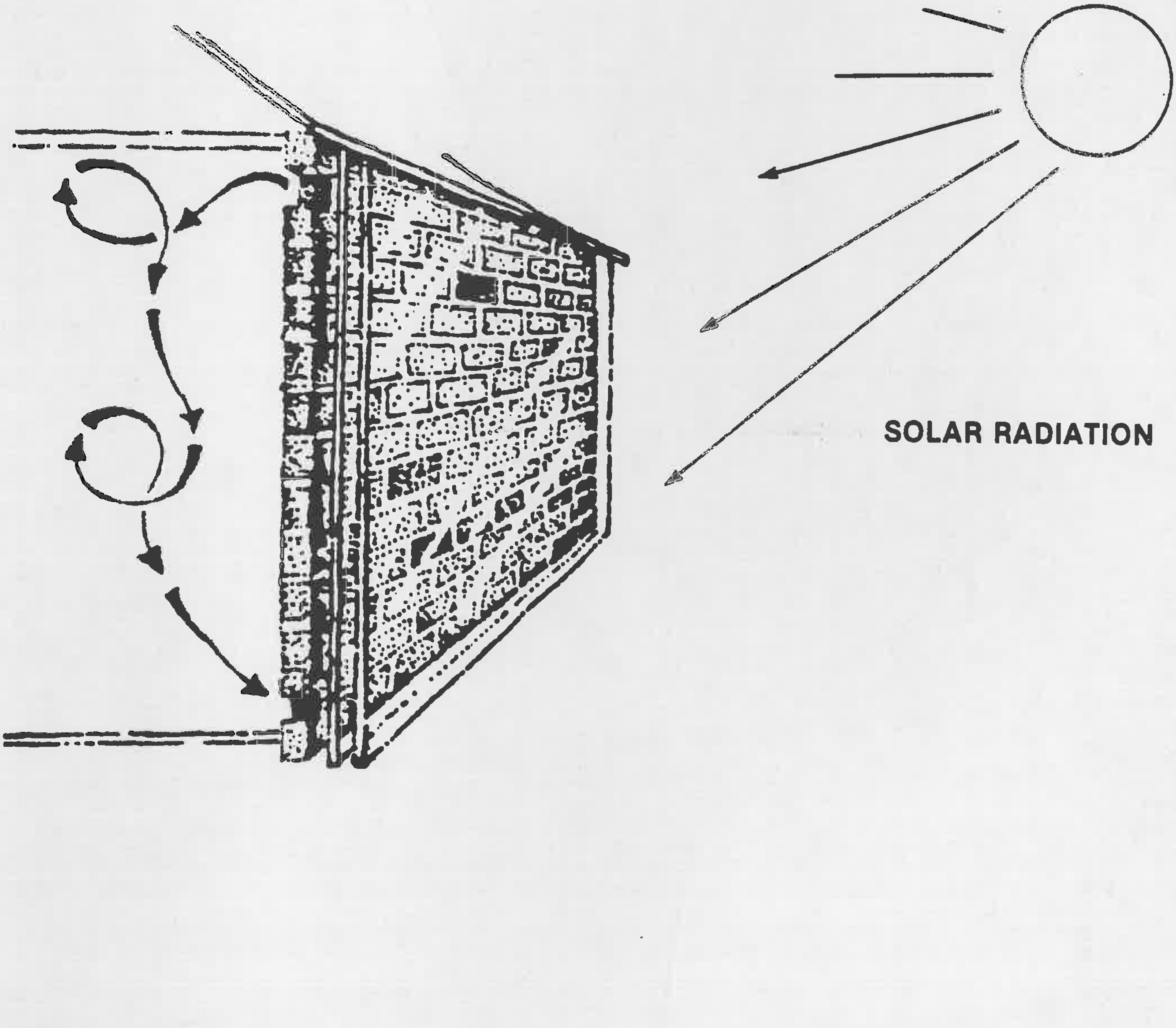
EWIV-36: BATCH DIGESTER

EWIV-37: HIGH-RATE DIGESTER

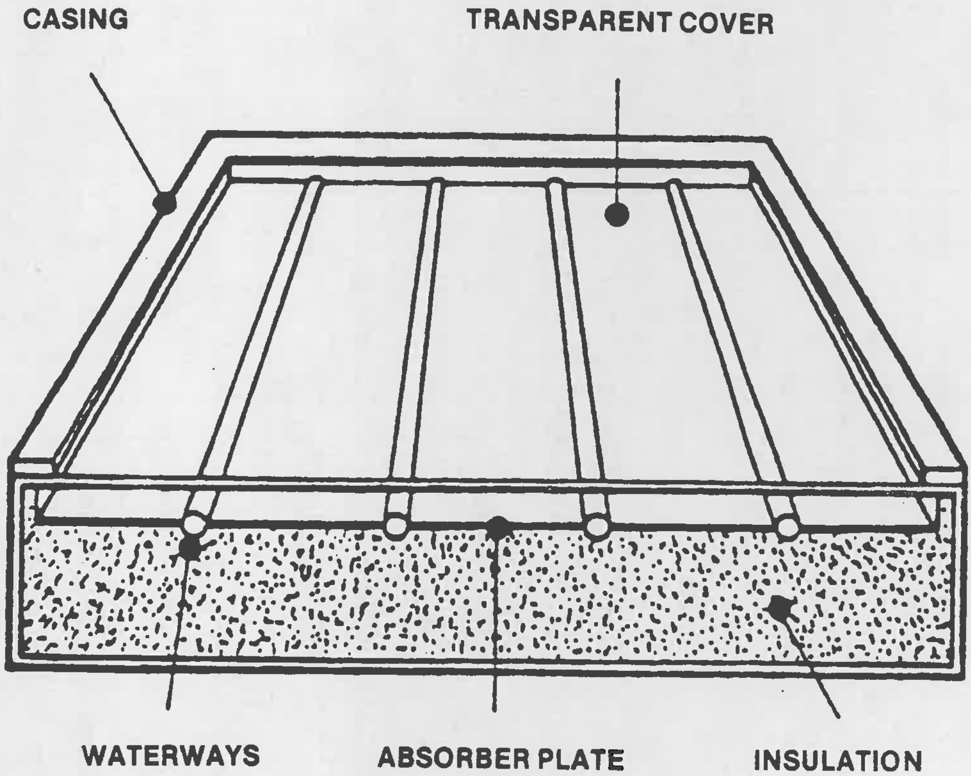
THE IMPACT OF SOLAR RADIATION WITH THE ATMOSFERE



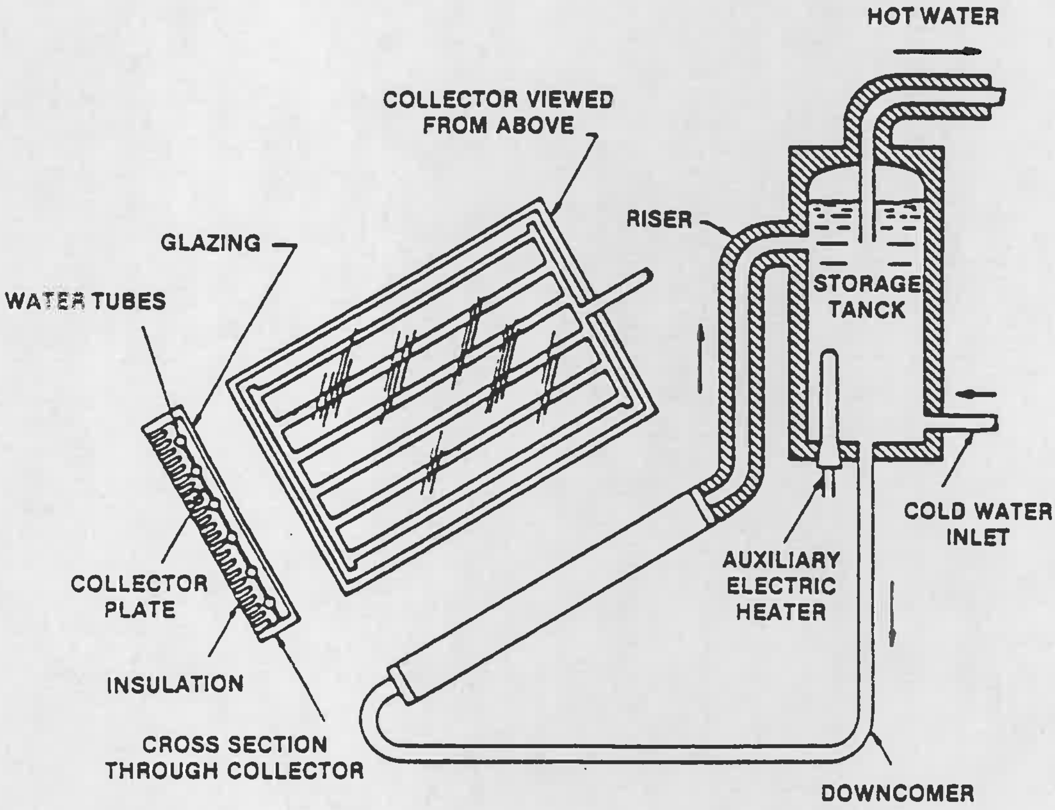
THE TROMBE WALL



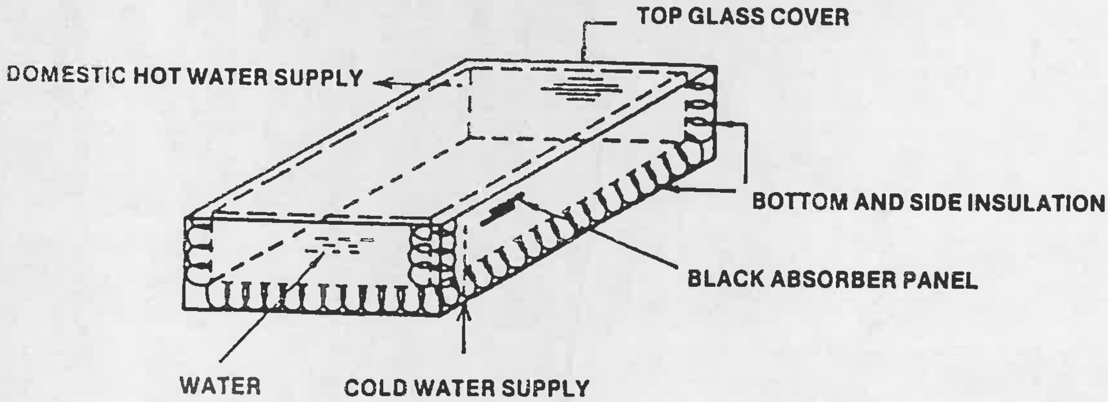
TYPICAL CONSTRUCTION OF A FLAT PLATE SOLAR COLLECTOR



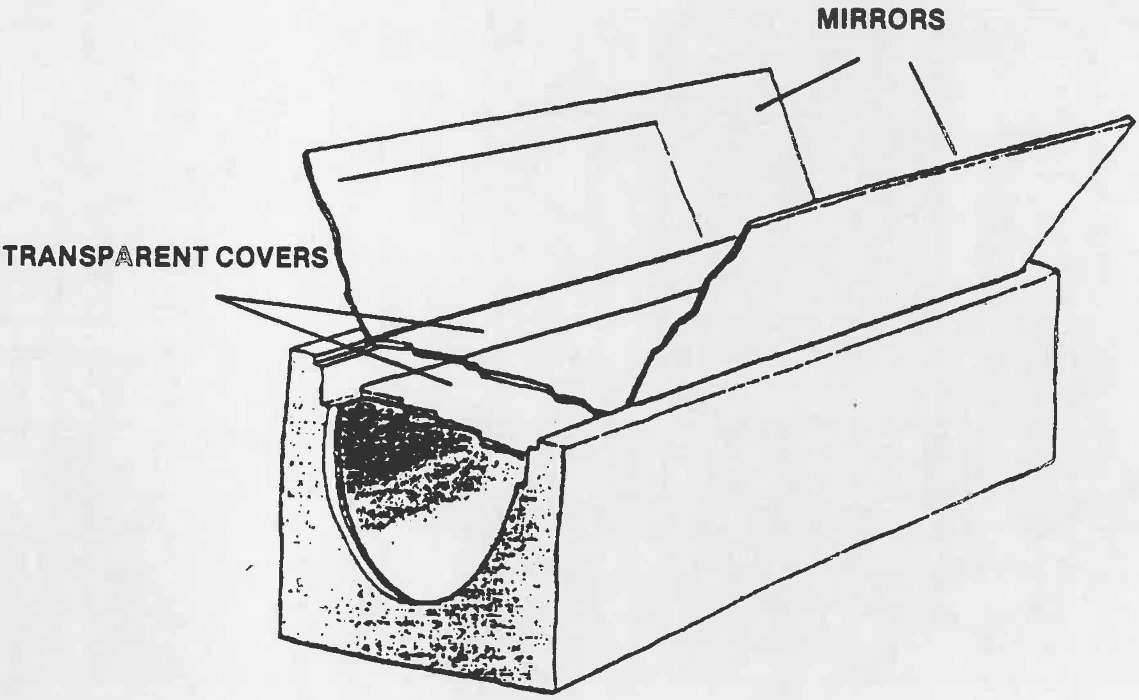
NATURAL-CONVECTION SOLAR WATER HEATER WITH STORAGE TANK



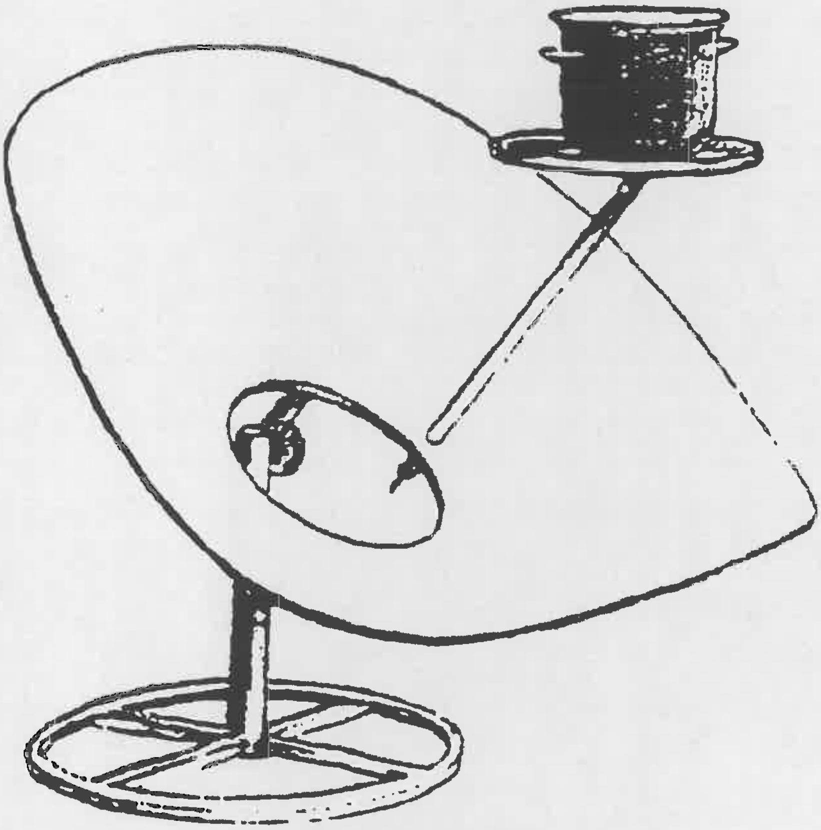
TANK-IN-COLLECTOR TYPE SOLAR WATER HEATER

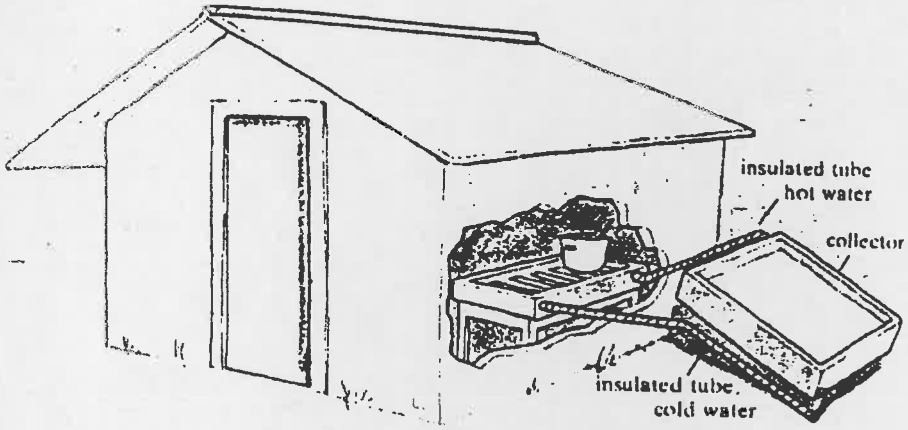


OVEN TYPE COOKER

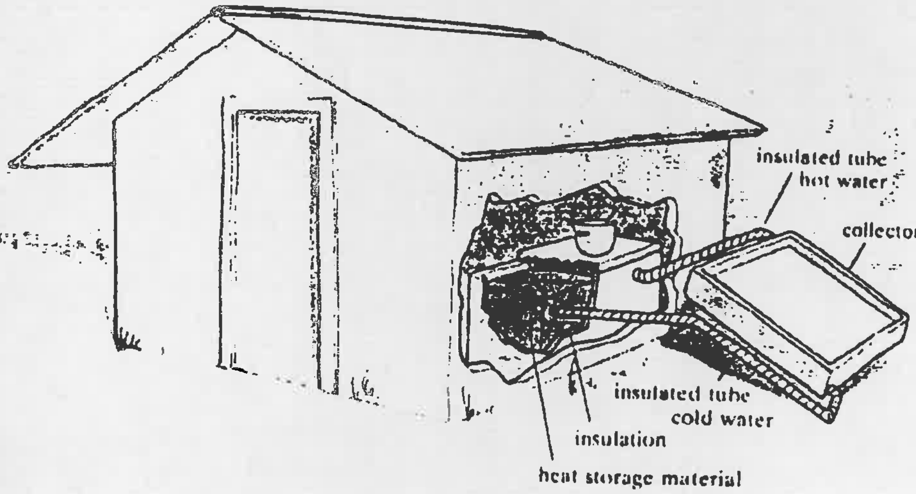


SIMPLE SOLAR COOKER



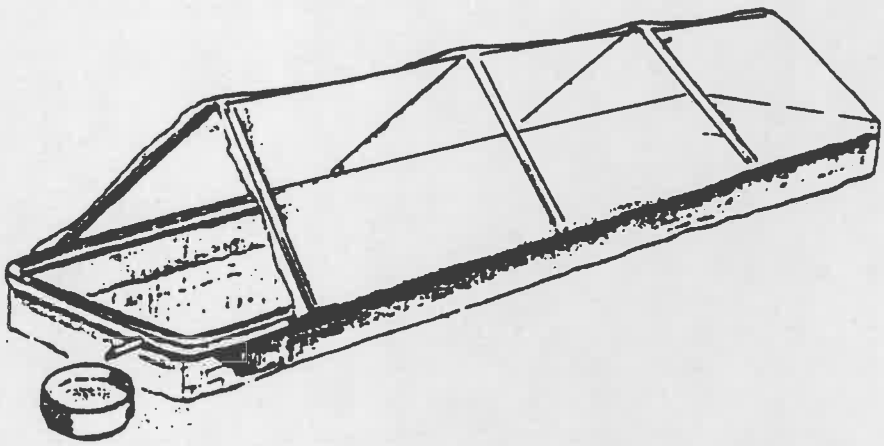


Solar cooking with heat transport.

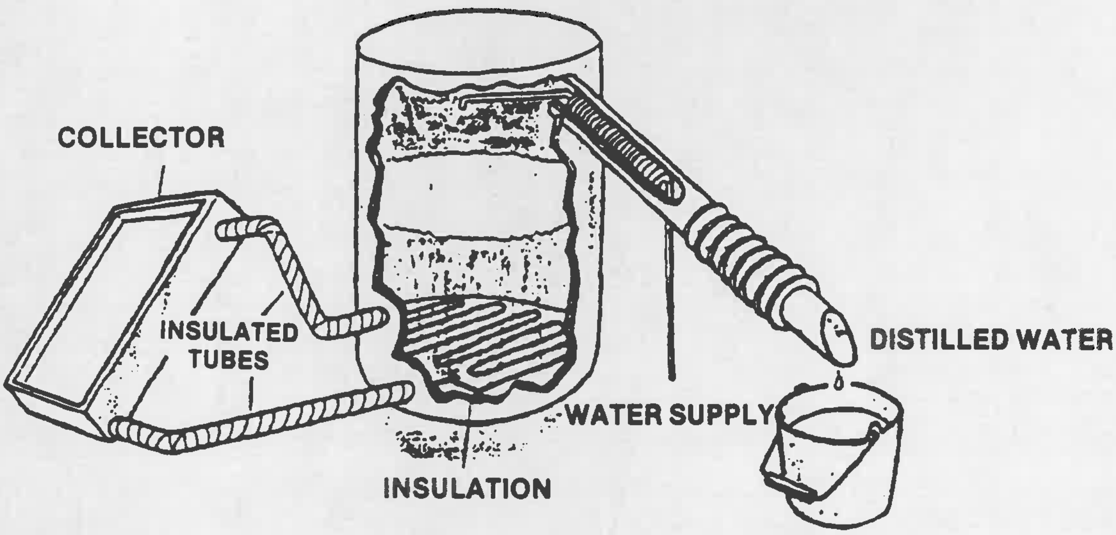


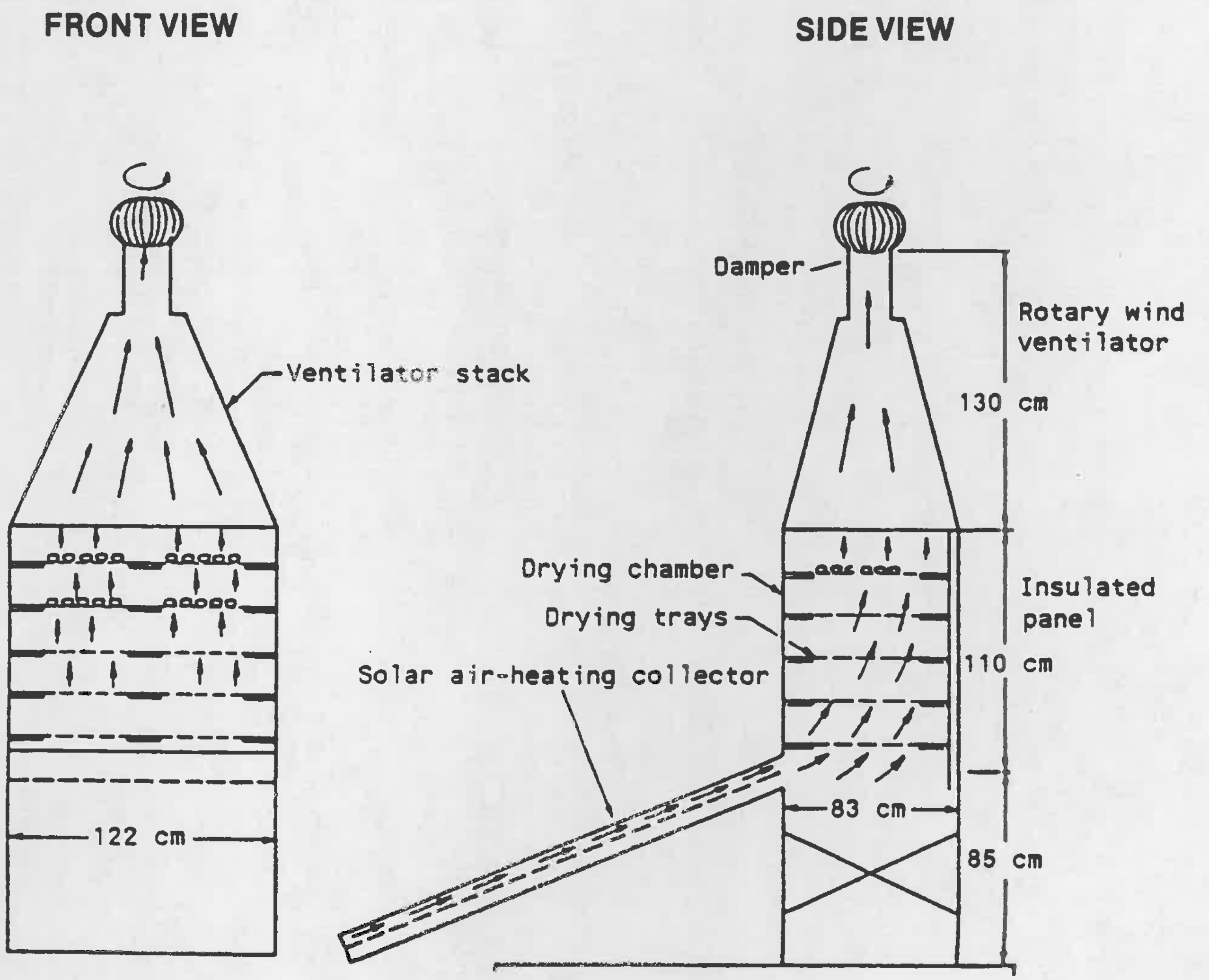
Solar cooking with heat transport and heat storage.

SIMPLE SOLAR STILL

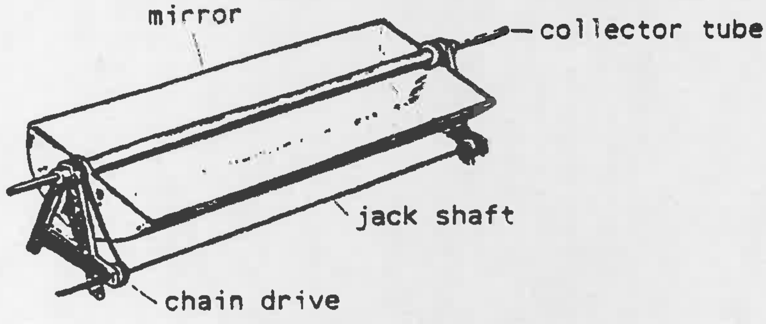


SOLAR DISTILLATION PLANT

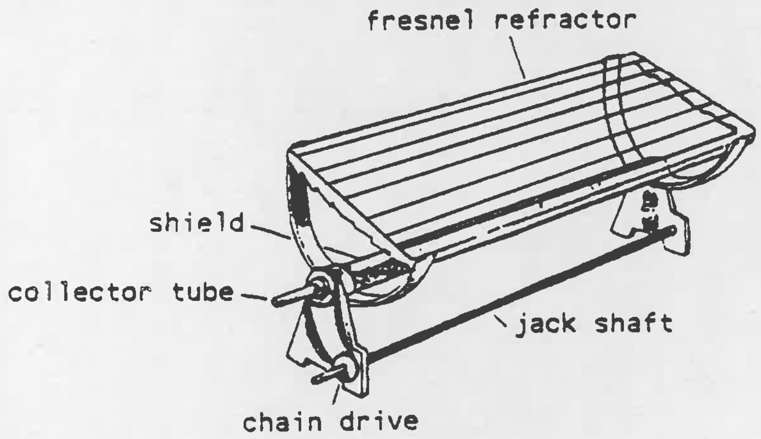



FRONT VIEW
SIDE VIEW
Ventilator stack
122 cm
Damper
Rotary wind ventilator
130 cm
Drying chamber
Drying trays
Solar air-heating collector
Insulated panel
110 cm
83 cm
85 cm

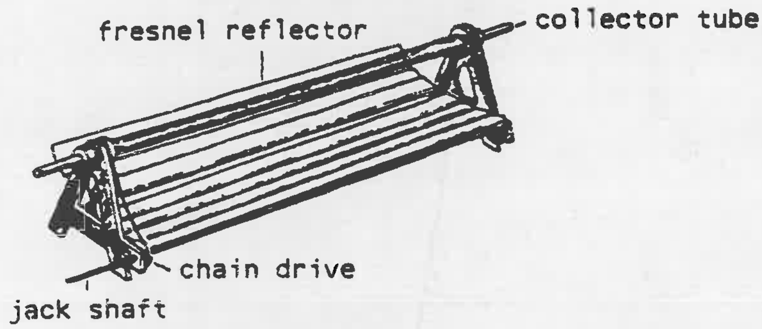
PARABOLIC MIRROR COLLECTOR

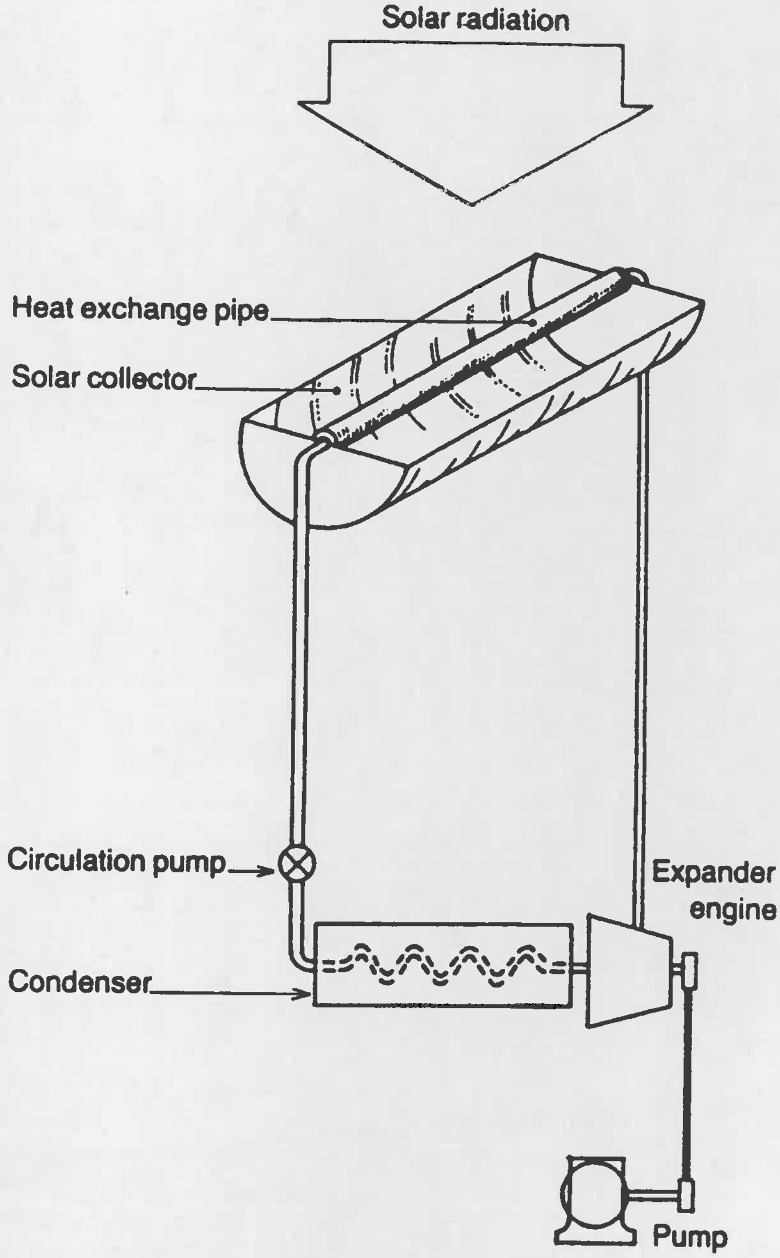


FRESNEL LENS COLLECTOR

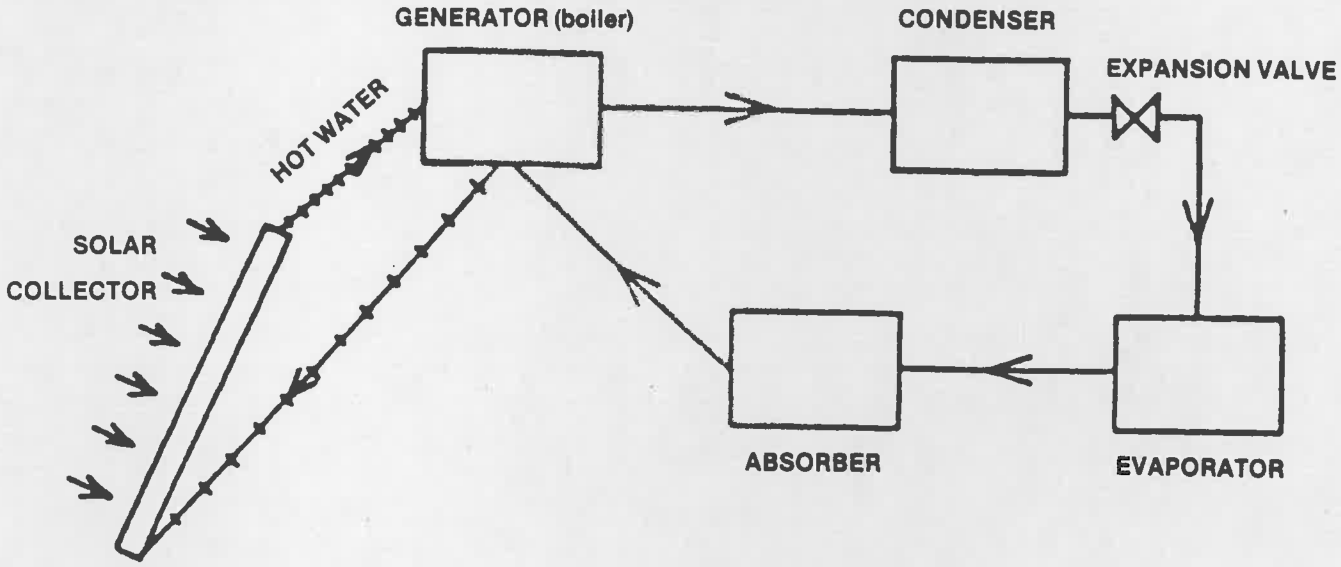


COLLECTOR WITH MIRROR STRIPS, FIXED IN A MOVING FRAME

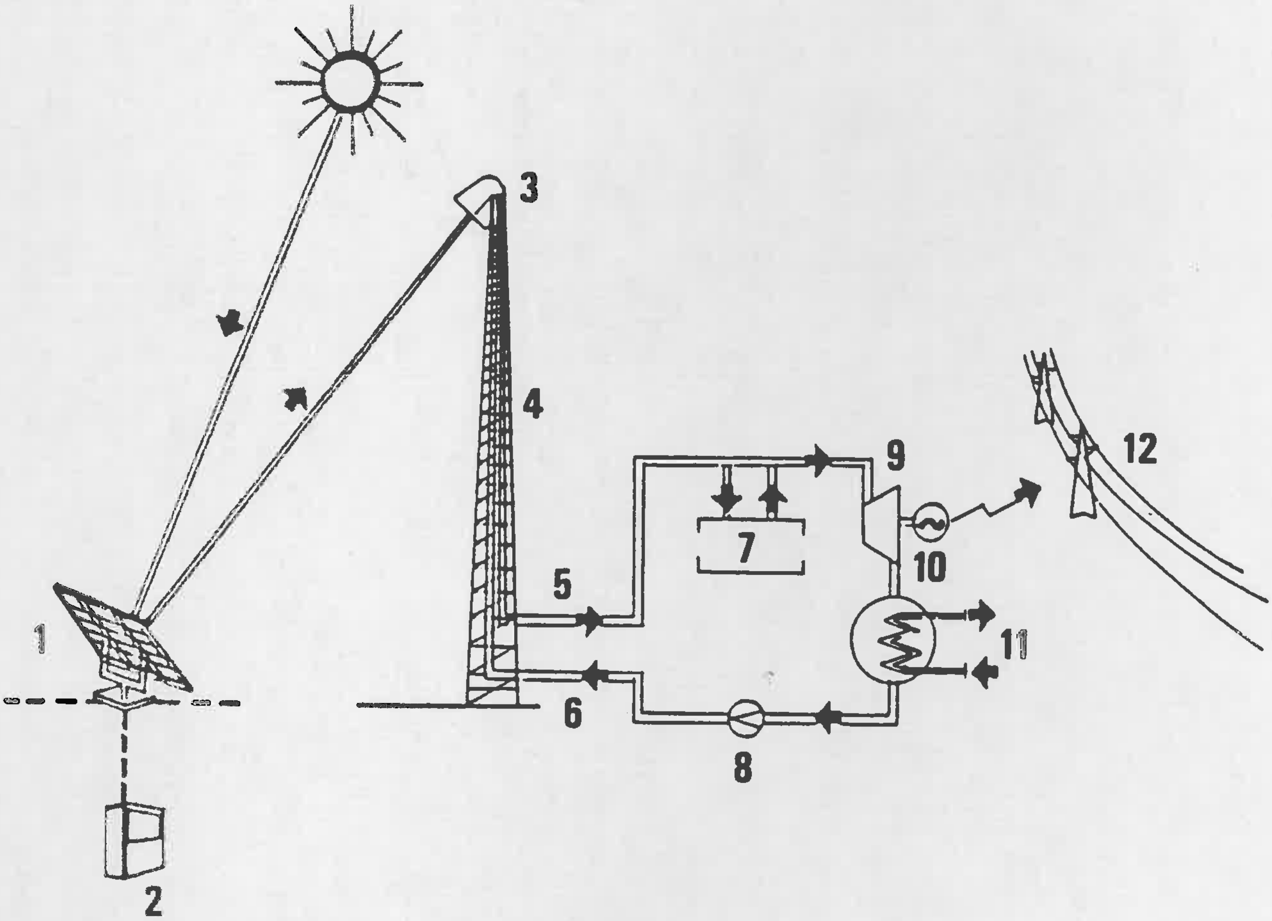



Solar radiation
Heat exchange pipe
Solar collector
Circulation pump
Condenser
Expander engine
Pump

BLOCK DIAGRAM OF A SOLAR REFRIGERATING SYSTEM

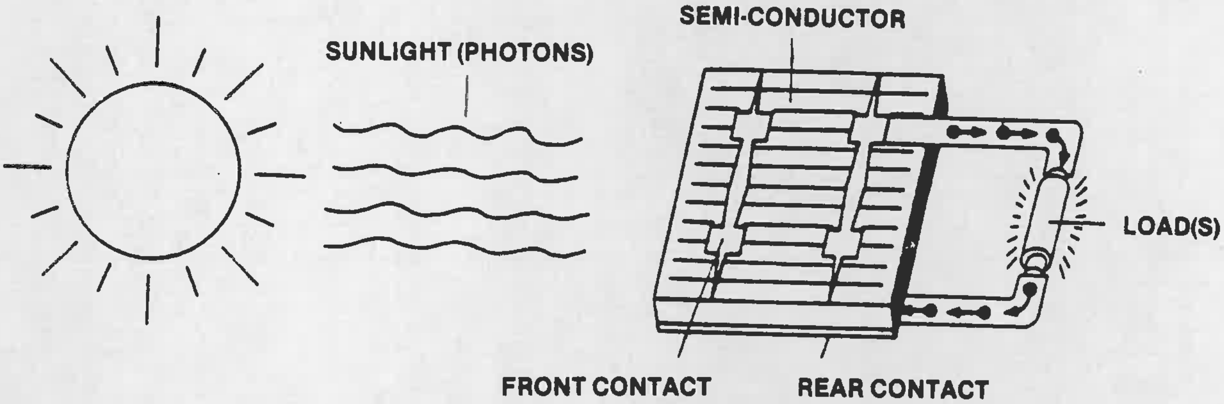


CENTRAL RECEIVER SOLAR POWER PLANT

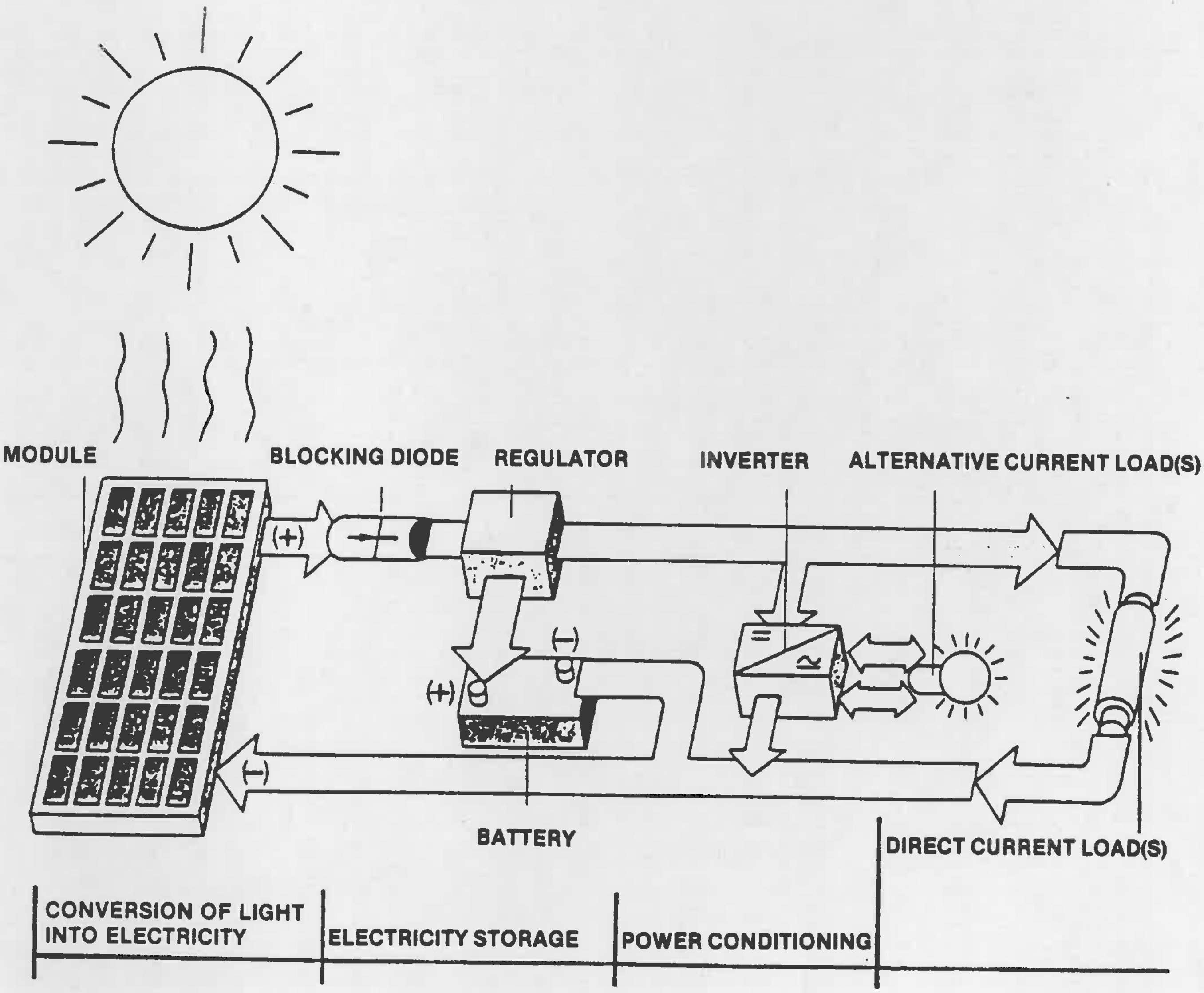


1 - HELIOSTAT
2 - CONTROL CENTER
3 - RECEIVER
4 - TOWER
5 - STEAM
6 - WATER
7 - STORAGE
8 - FEED WATER PUMP
9 - TURBINE
10 - ALTERNATOR
11 - CONDENSER
12 - GRID

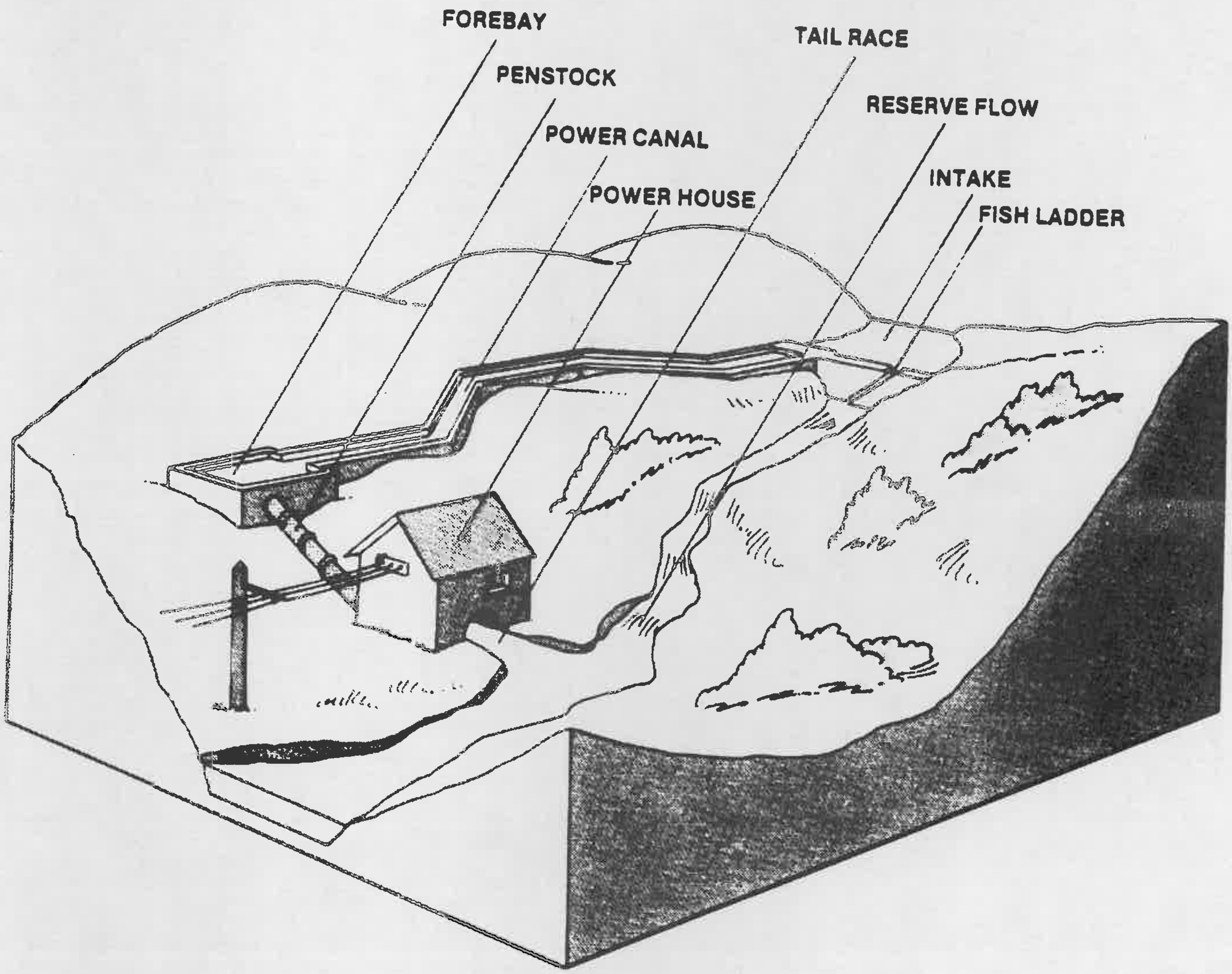
THE SOLAR (PHOTOVOLTAIC) CELL



A PHOTOVOLTAIC SYSTEM

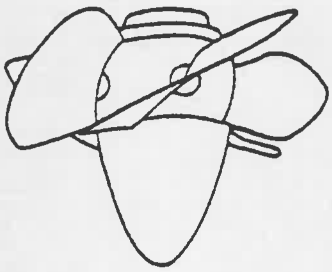


TYPICAL HYDROELECTRIC INSTALLATION

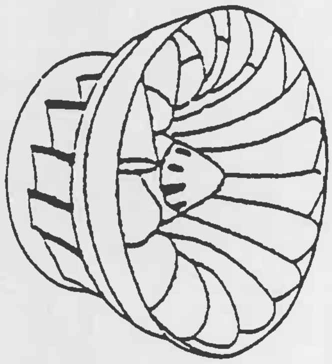


TYPES OF HYDRAULIC TURBINES

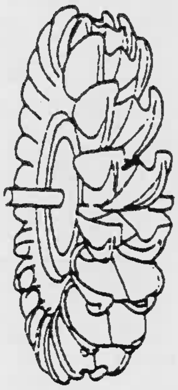
KAPLAN TURBINE



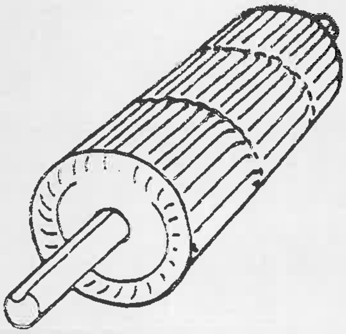
FRANCIS TURBINE



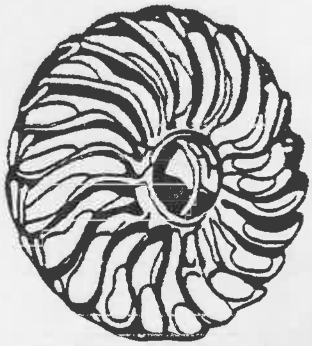
PELTON TURBINE



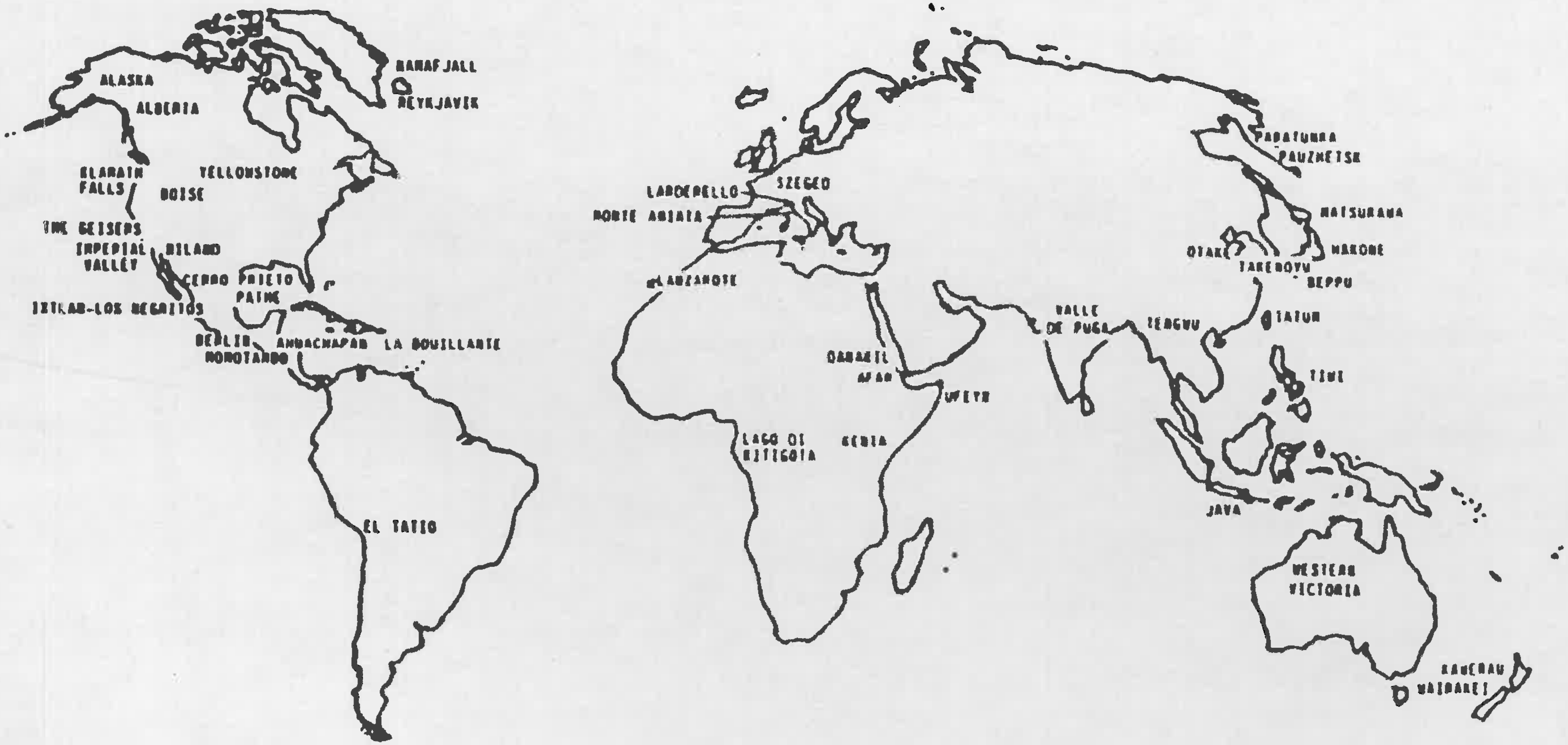
BANKI MITCHELL TURBINE



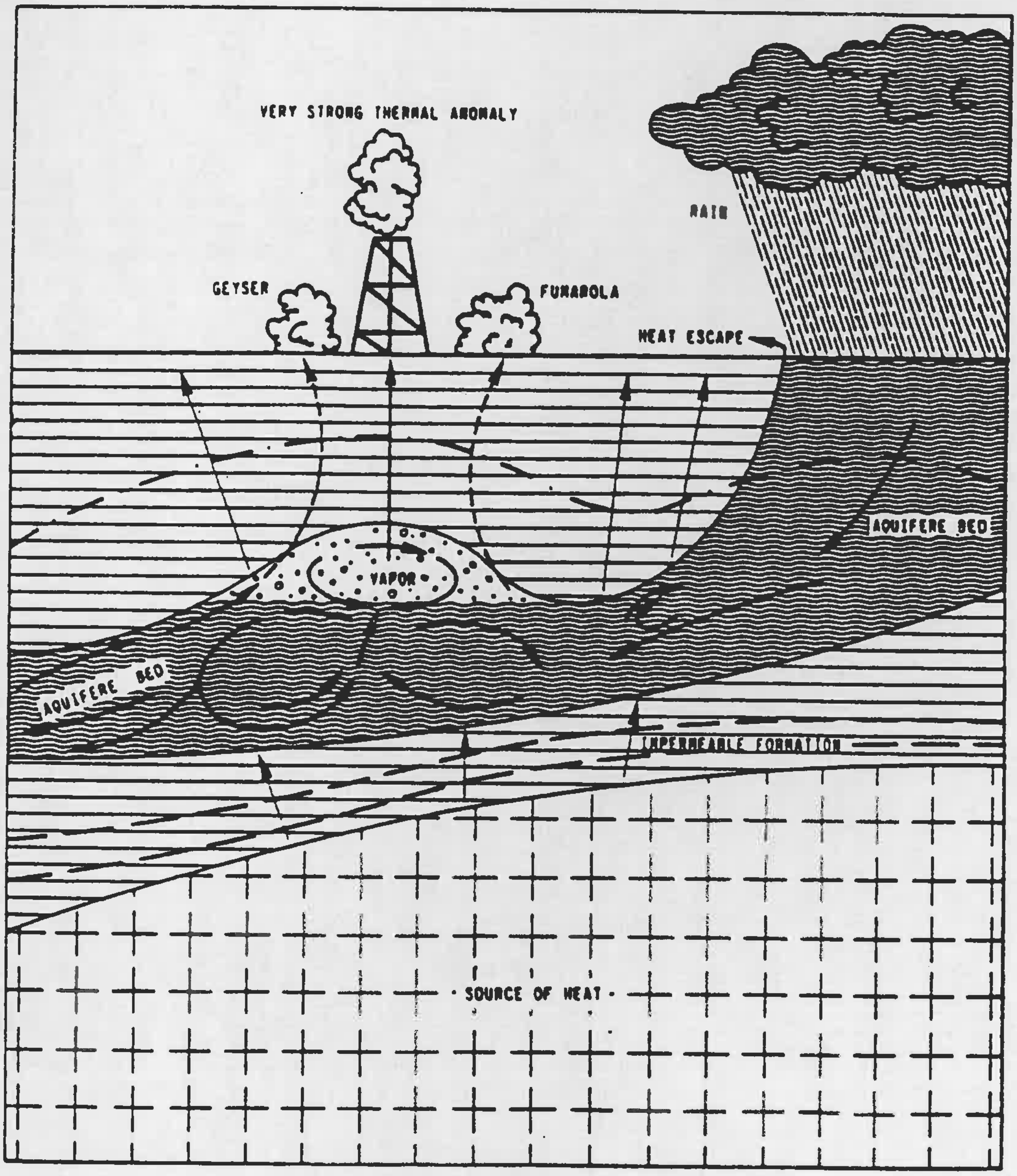
TURGO TURBINE



THE MOST IMPORTANT GEOTHERMAL FIELDS IN THE WORLD



GENERAL SCHEME OF A VAPOUR GEOTHERMAL SYSTEM



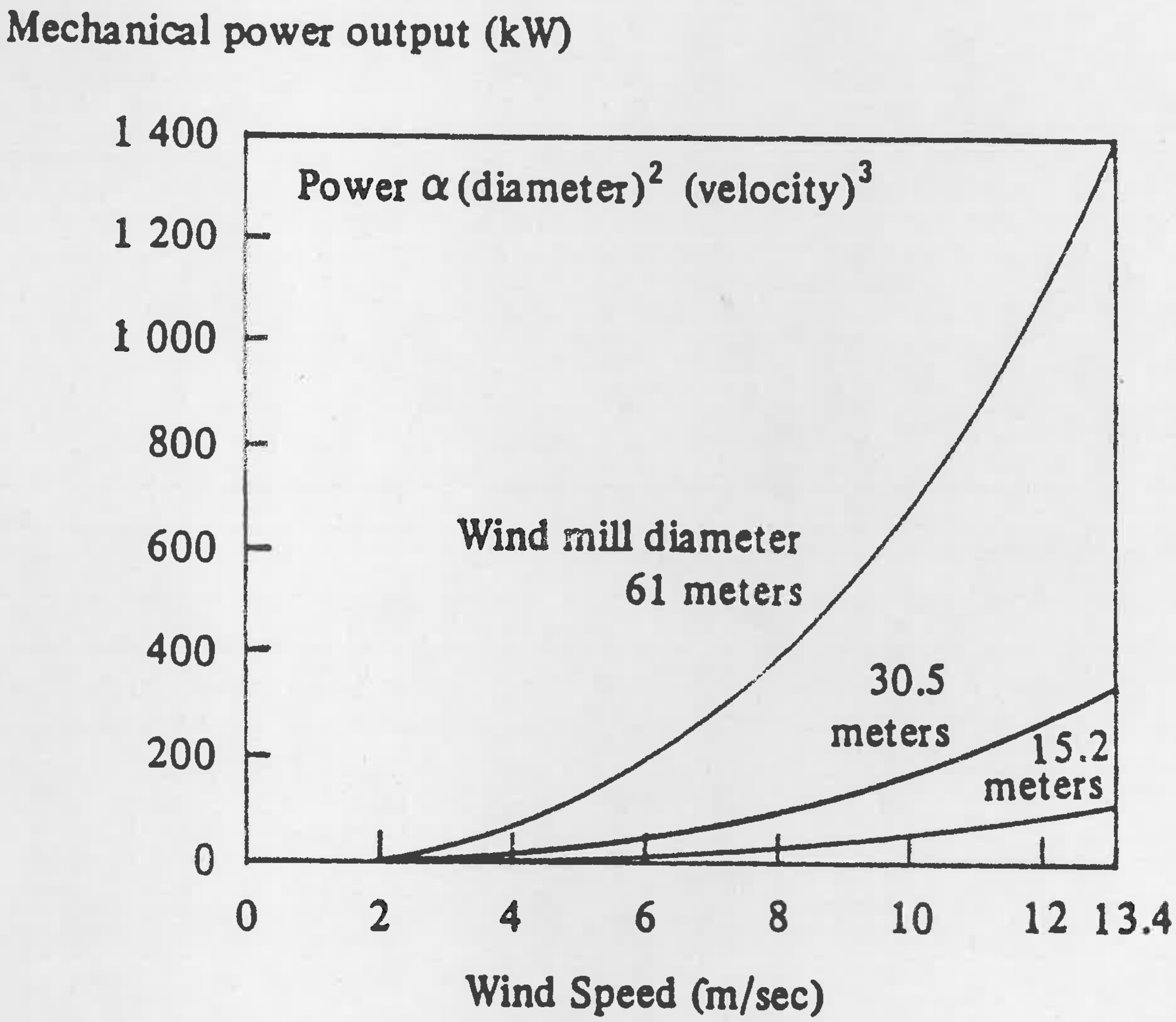
GEOTHERMAL ELECTRICAL GENERATING CAPACITY 1980 AND 2000 (estimated)

	1980		2000	
	MW	%of world total	MW	%of world total
USA	923	38	5824	33
Japan	168	7	3668 +	21
Italy	440	18	800	5
New Zealand	202	8	382 +	2
USSR	5	0	310	1
Turkey	0.5	0	3101	1
Iceland	32	1	68 +	0
France	0	0	15 +	0
TOTAL NORTH	**1771**	**72**	**11217**	**64**
Mexico	150	6	4000	23
Philippines	446	18	1225 +	7
El Salvador	95	4	535	3
Costa Rica	0	0	380 +	2
Nicaragua	0	0	100	1
Indonesia	0.25	0	92 +	0
Ethiopia	0	0	50	0
Kenya	0	0	30 +	0
Chile	0	0	15 +	0
TOTAL SOUTH	**691**	**28**	**6427**	**3**
WORLD TOTAL	**2462**	**100**	**17644**	**100**

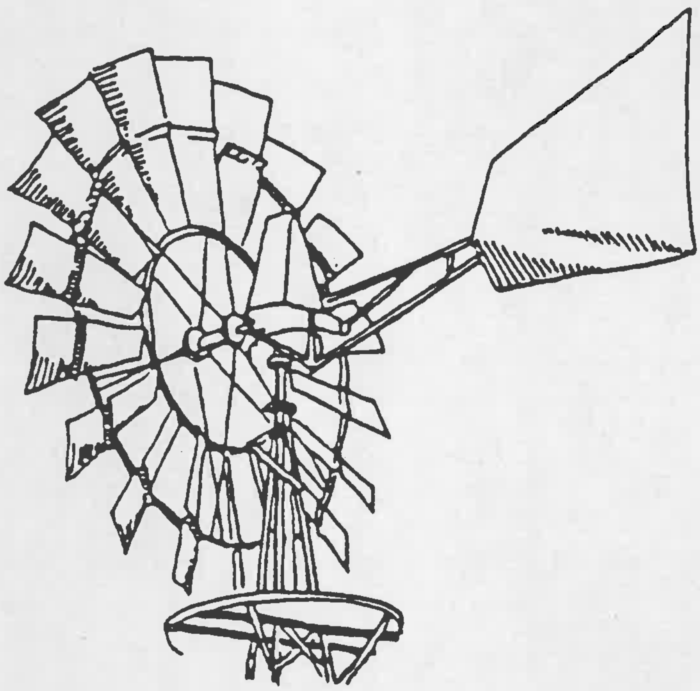
INSTALLED LOW - TEMPERATURE GEOTHERMAL CAPACITY IN 1980

	FOR BATHING		FOR OTHER PURPOSES		TOTAL	
	MW	%	MW	%	MW	%
Japan	4394	82	81	3	4475	56
Hungary	547	10	619	23 1/2	1166	15
Iceland	209	4	932	35	1141	14
USSR	0	0	555	21	555	7
Italy	192	4	73	3	265	3
China	7	0	144	5 1/2	151	2
USA	4	0	111	4	115	1
France	0	0	56	2	56	1
Czechoslovakia	8	0	35	1 1/2	43	1
Romania	0	0	30	1 1/2	36	0
Austria	3	0	2	0	5	0
TOTAL	5364	100	2644	100	8008	100

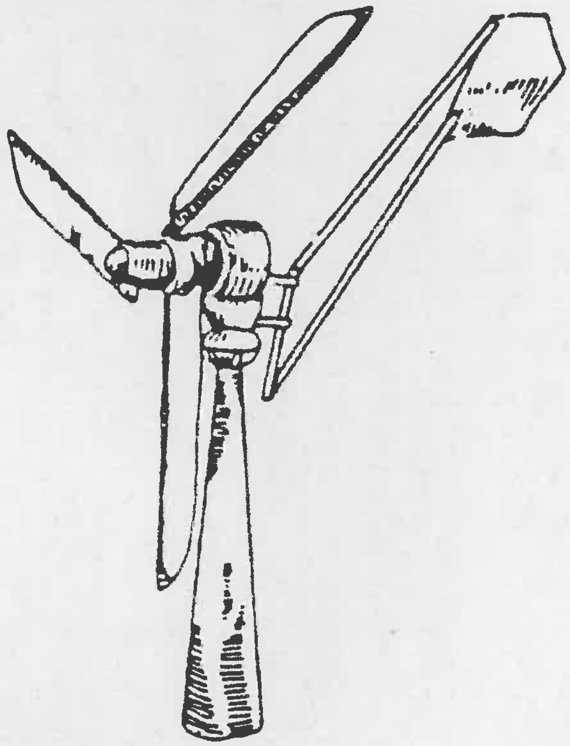
POWER GENERATION VIA WIND MACHINES



TWO TYPES OF HORIZONTAL-AXIS ROTORS



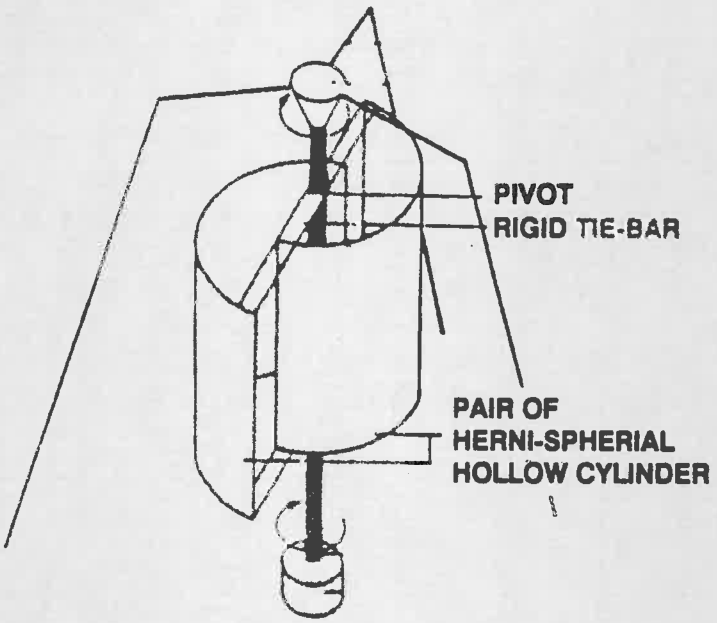
Multi-blade rotor



High-speed rotor

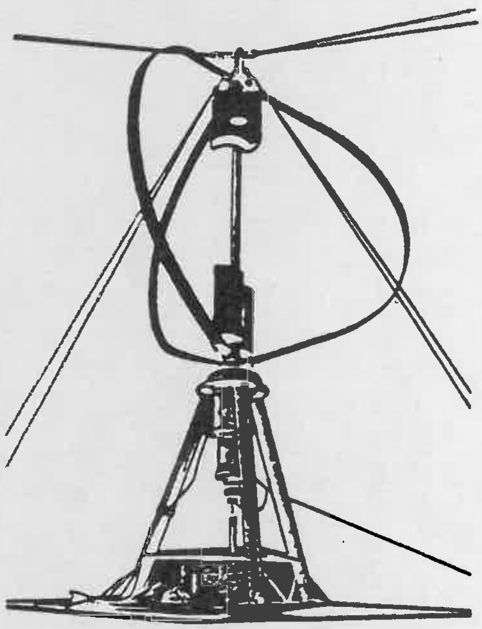
TYPES OF VERTICAL-AXIS ROTORS

SAVONIUS ROTOR



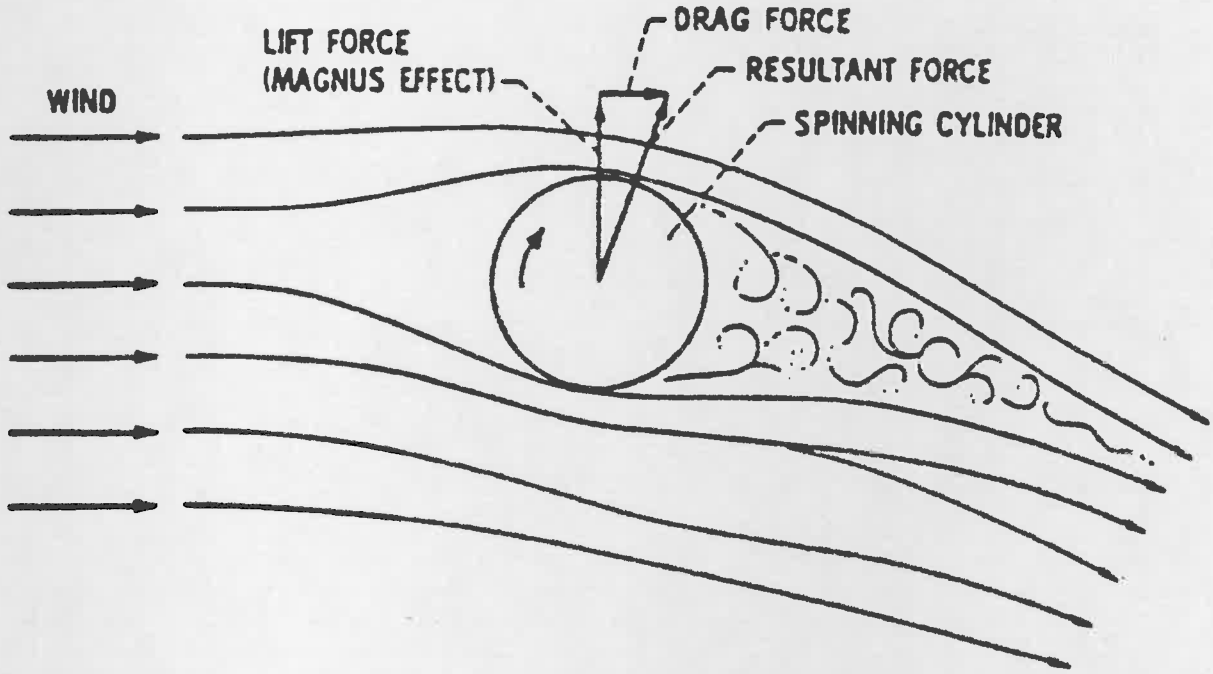
CHARACTERISTIC:
- SELF-STARTING
- LOW SPEED
- LOW EFFICIENCY

DARRIEUS ROTORS

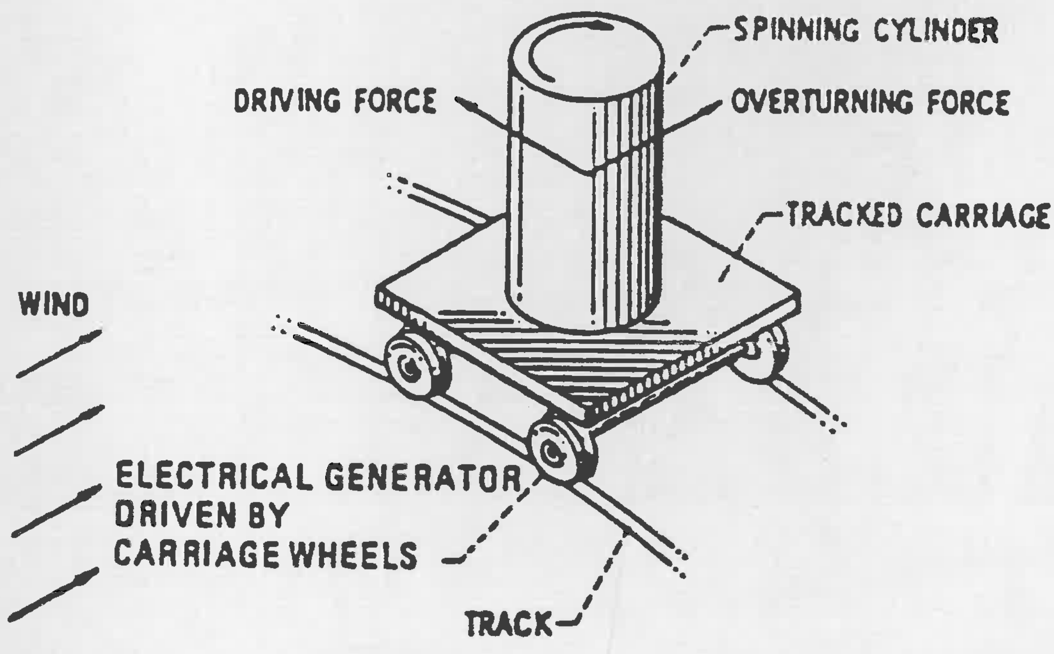


CHARACTERISTIC:
- NOT SELF-STARTING
- HIGH SPEED
- HIGH EFFICIENCY
- POTENTIALLY LOW CAPITAL COST

VERTICAL-AXIS TURBINE

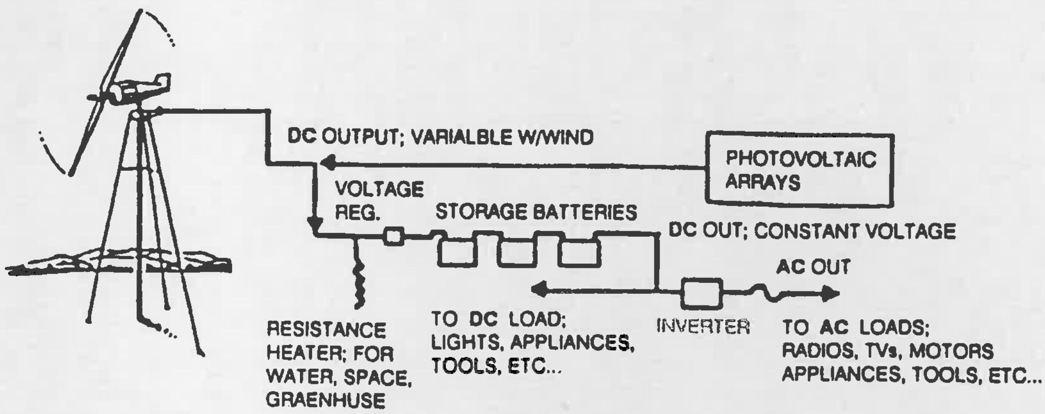


THE MAGNUS EFFECT

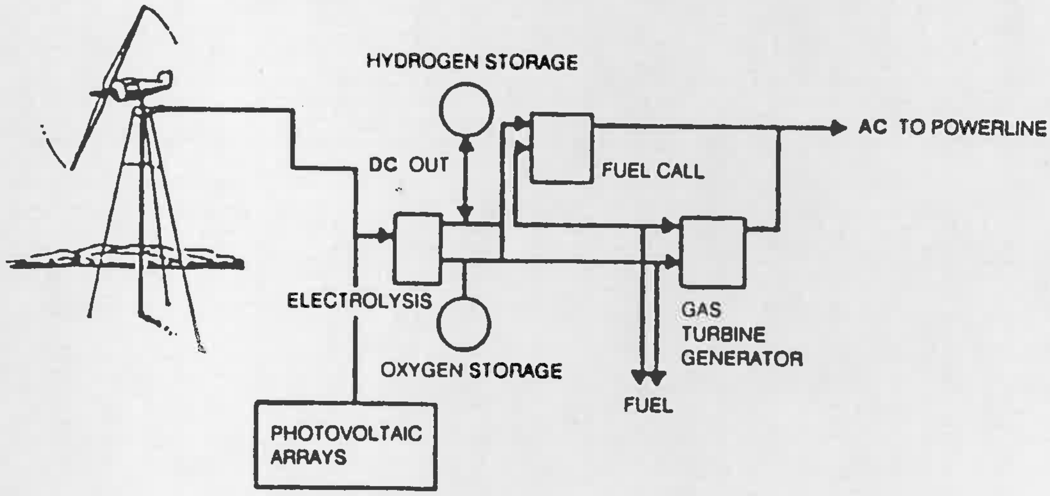


THE MADARAS CONCEPT FOR GENERATING ELECTRICITY

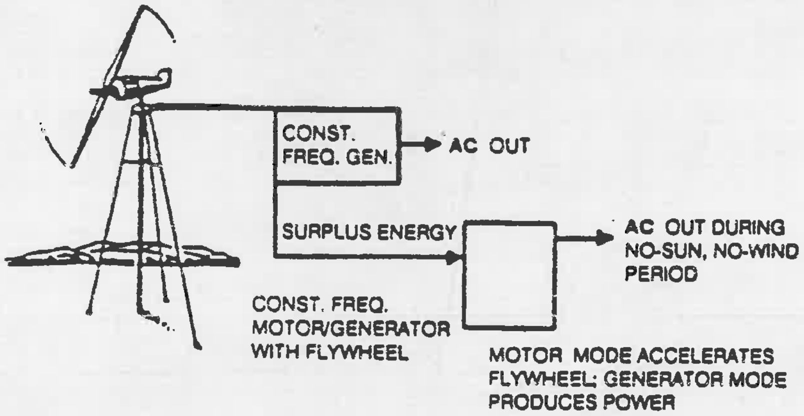
SYSTEM WITH BATTERY STORAGE



SYSTEM WITH HYDROGEN STORAGE



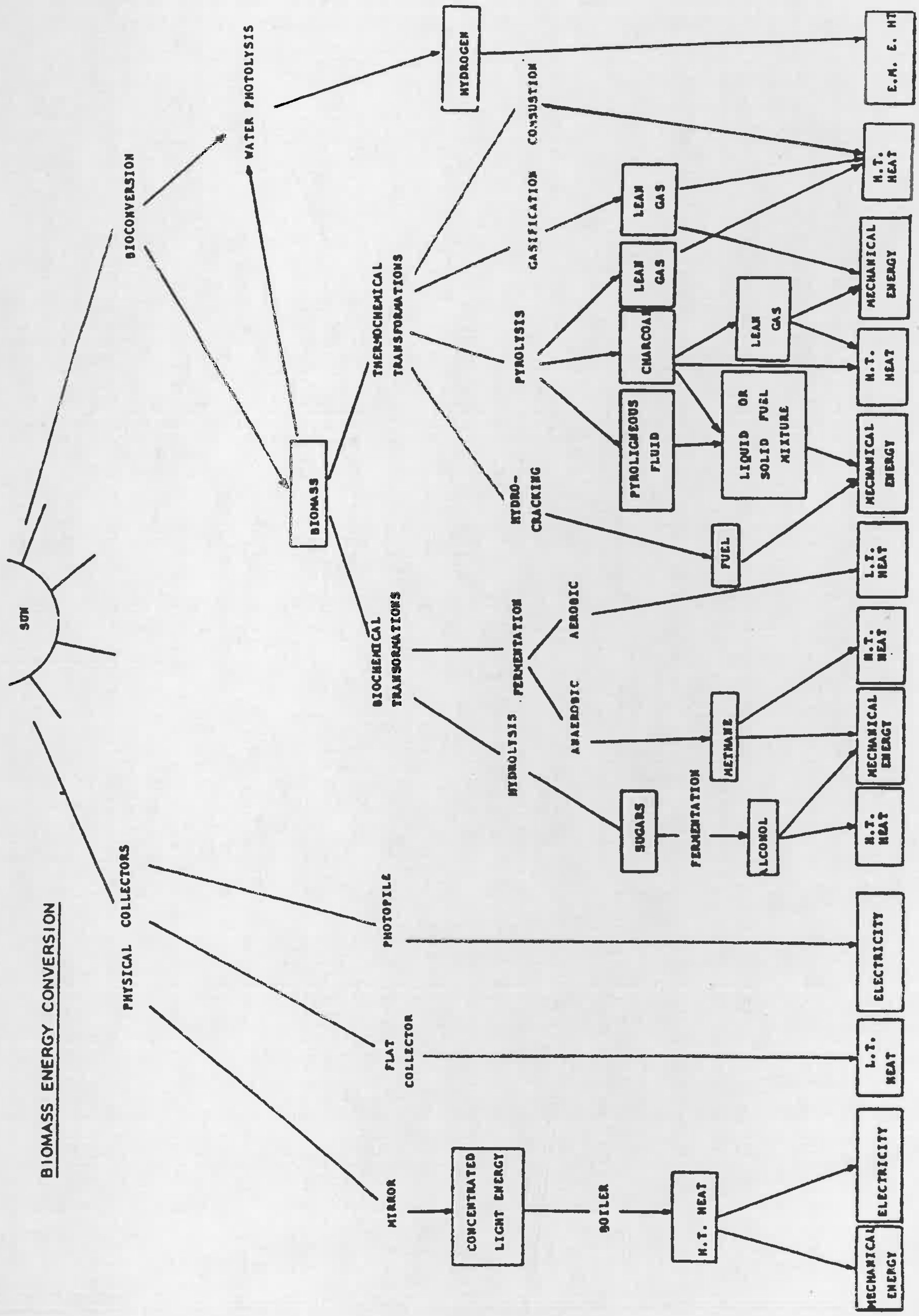
SYSTEM WITH FLYWHEEL STORAGE



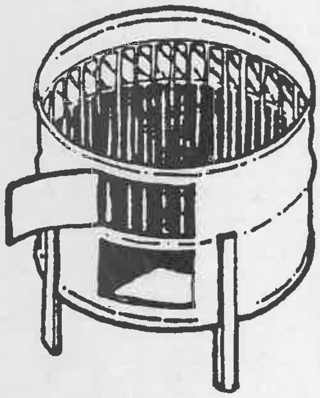
THE EARTH'S BIOPRODUCTIVITY

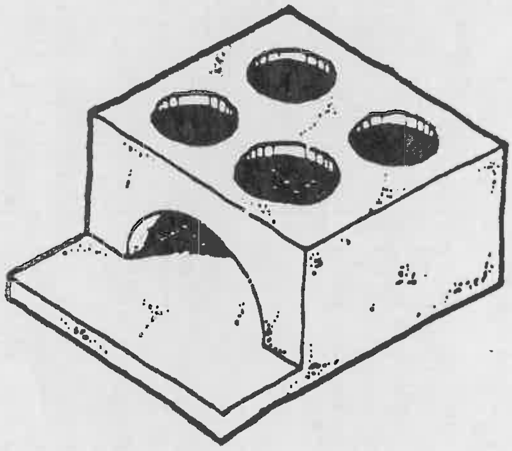
cereal crops as a whole	max.productivity tonnes/ha/yr	photosynthetic efficiency%
grassland/prairie	22	0.7
evergreen forests	22	0.7
deciduous forests	15	0.5
savnnah	11	---
oil palm	40	1.4
tapioca (cassave)	38	1.1
sugar cane	64	1.8
maize	86	0.8
rice	22	0.7
Napier grass	85	2.4
Beet	31	0.9
Fast-growing poplars	28	o.9
Fast-growing pines	18	0.7

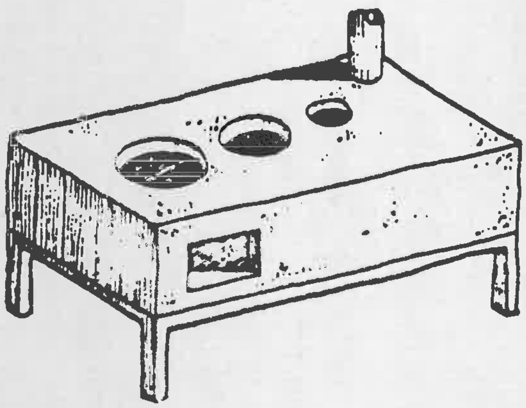
BIOMASS ENERGY CONVERSION

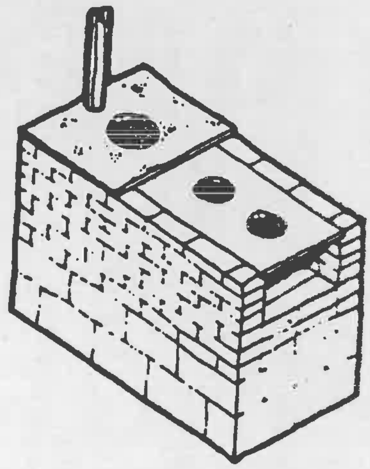


IMPROVED COOK STOVES



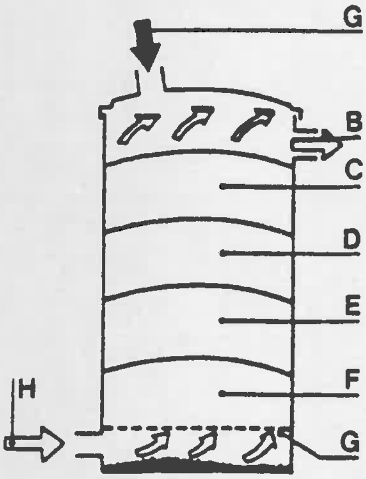






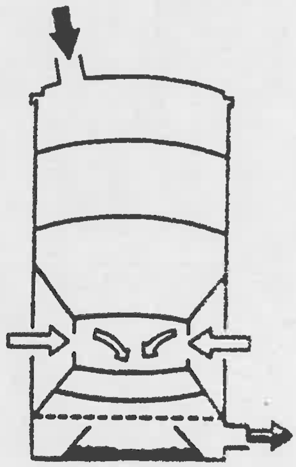
GASIFIERS

A updraught

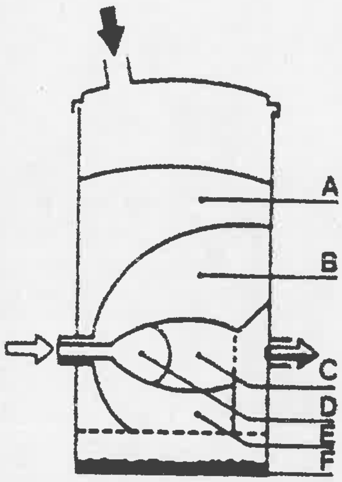


A BIOMASS
B GAS
C DRYING
D PYROLYSIS
E REDUCTION
F COMBUSTION
G GRATE
H AIR

B downdraught

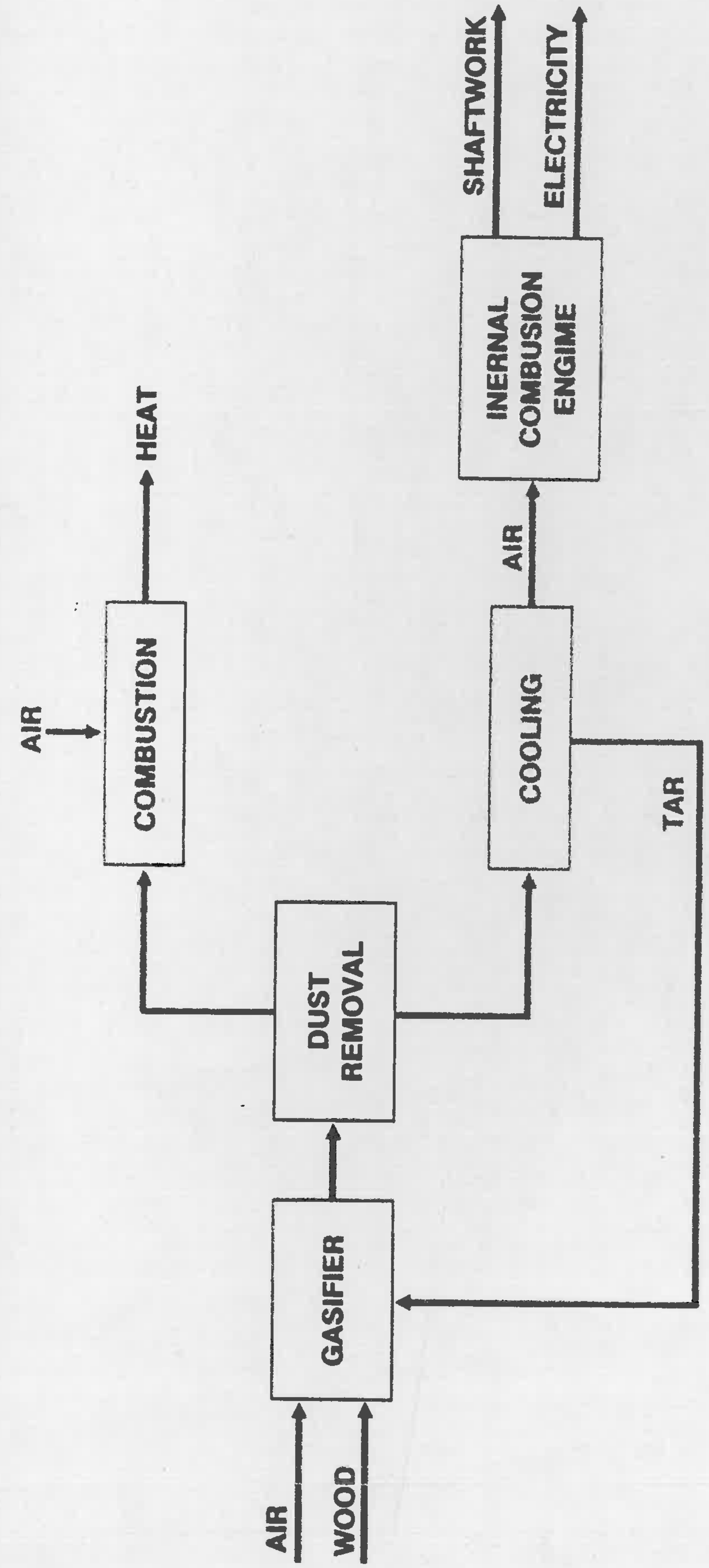


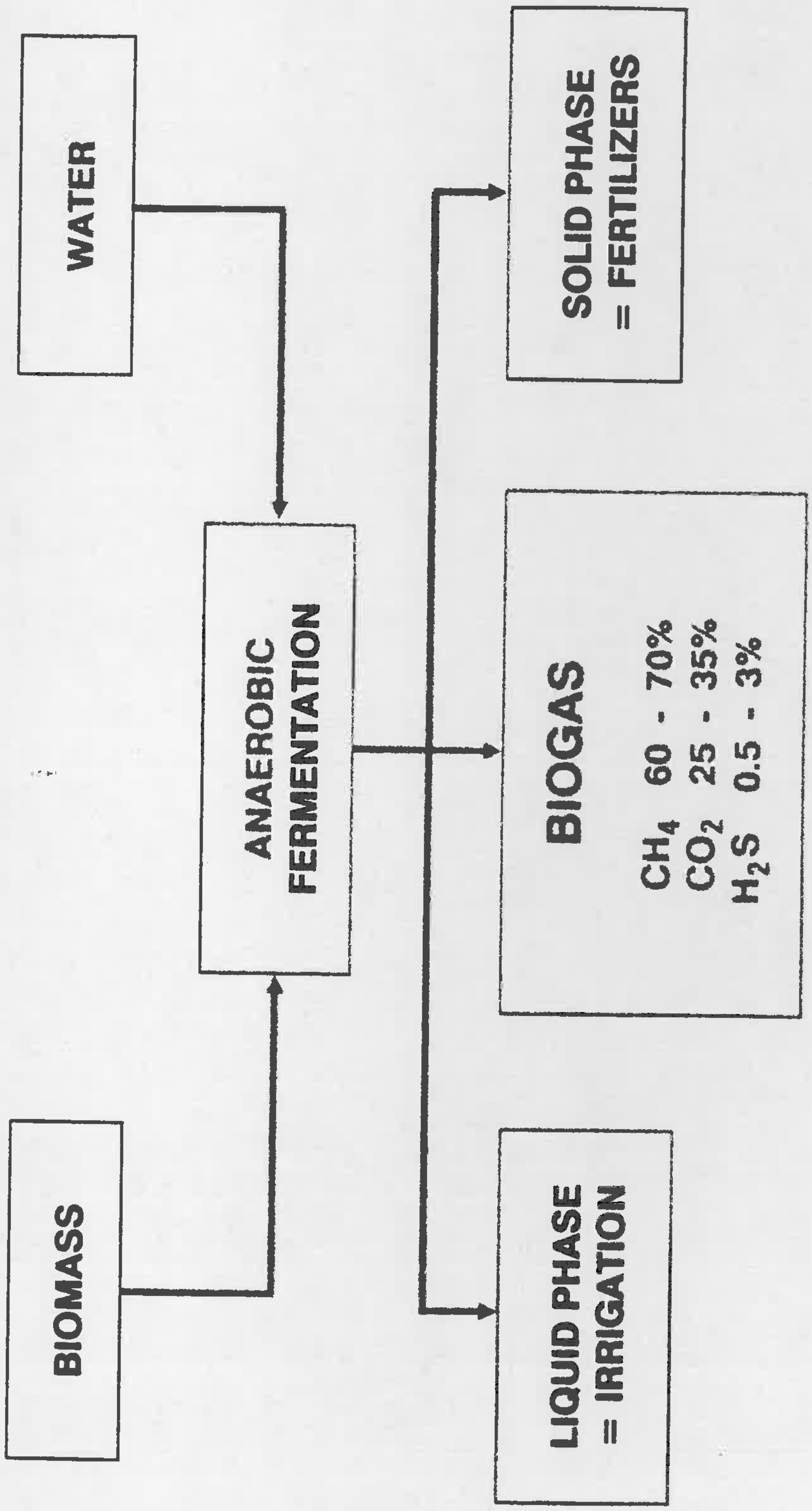
C crossdraught



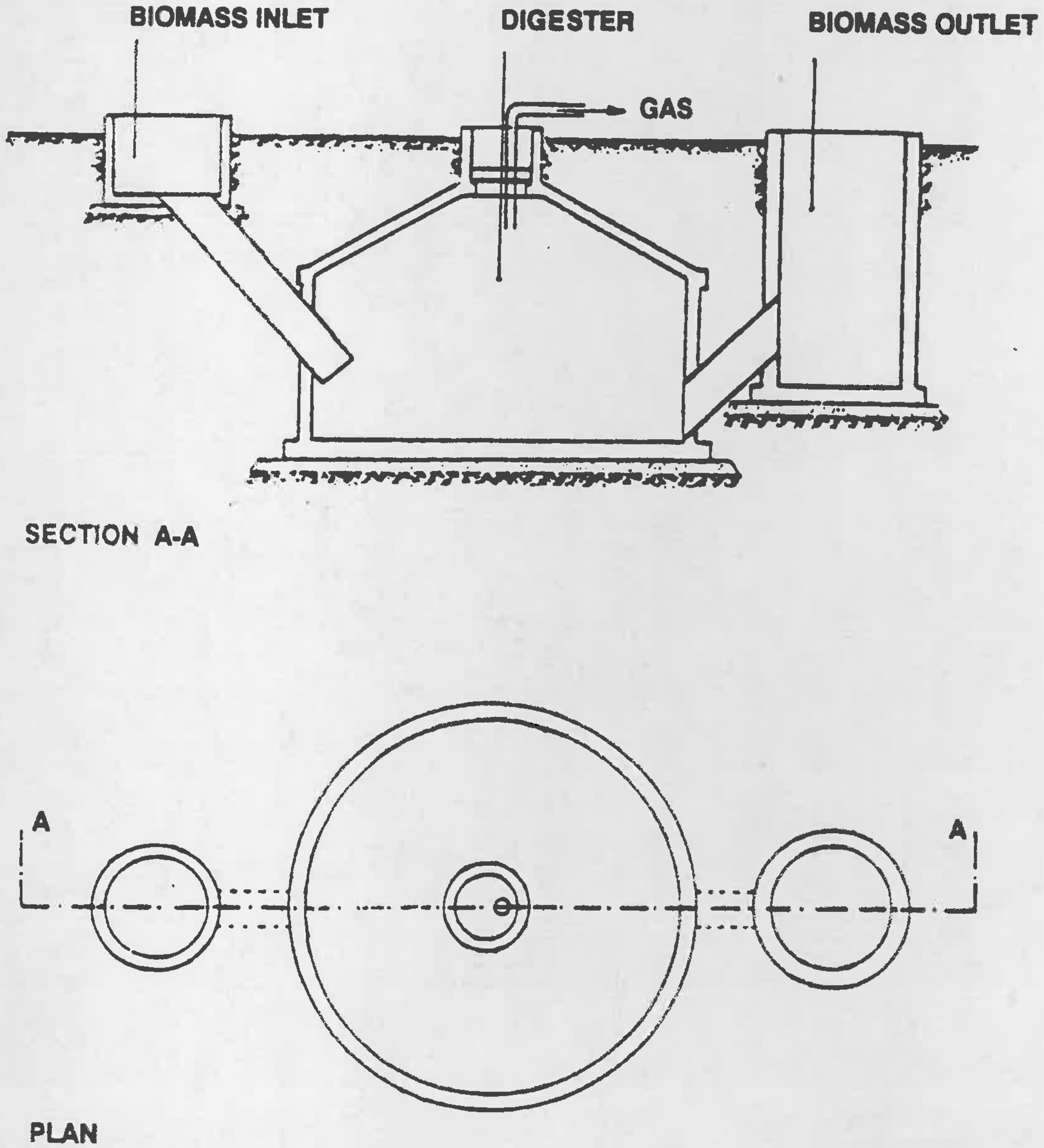
A MOISTURE DRAWN OFF
B TARS AND OTHER VOLATILES DRIVEN OFF
C C+2H – CH
C+H O – CO+H
C+CO – 2CO
D =O – CO
E BURNING CHAR
F ASCH

FLOWCHART OF ENERGY PRODUCTION FROM WOOD GASIFICATION

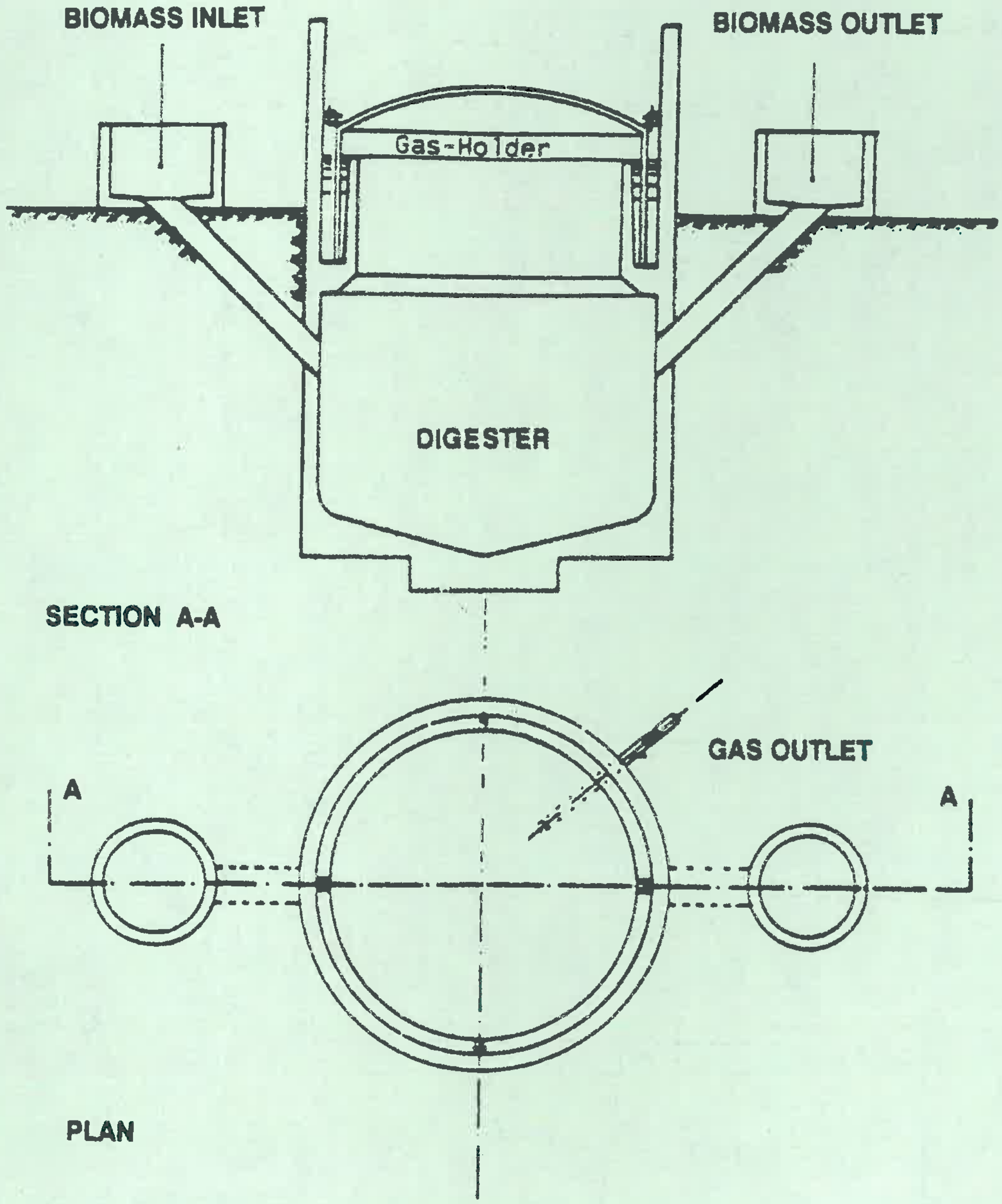



WATER
BIOMASS
ANAEROBIC FERMENTATION
SOLID PHASE = FERTILIZERS
BIOGAS
CH4 60 - 70%
CO2 25 - 35%
H2S 0.5 - 3%
LIQUID PHASE = IRRIGATION

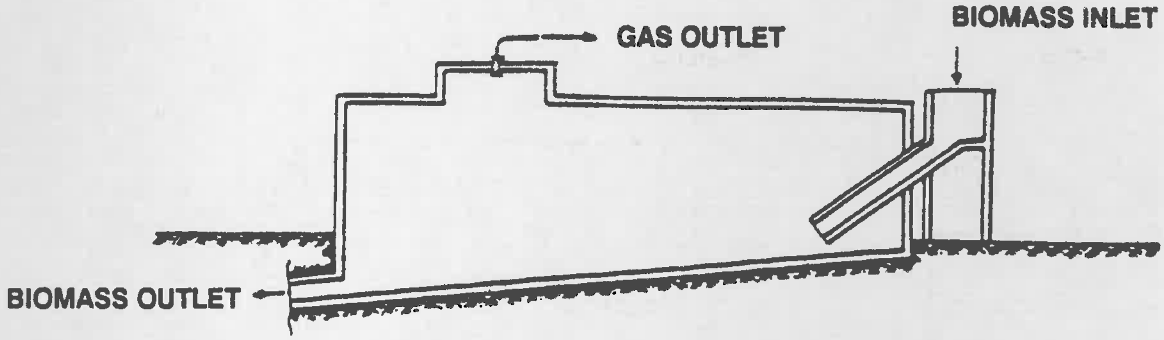
CHINESE TYPE DIGESTER



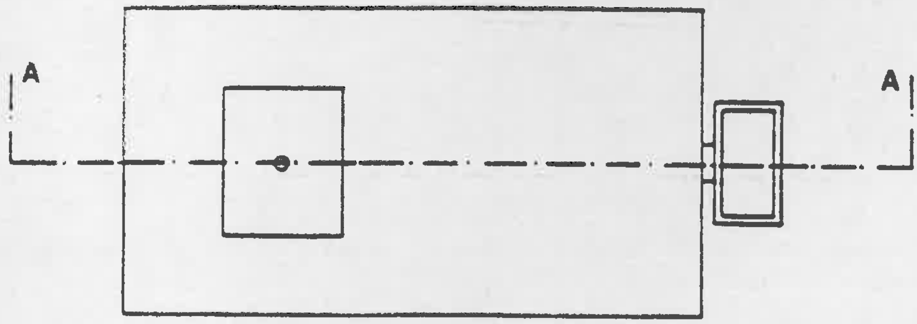
INDIAN TYPE DIGESTER



PLUG-FLOW DIGESTER

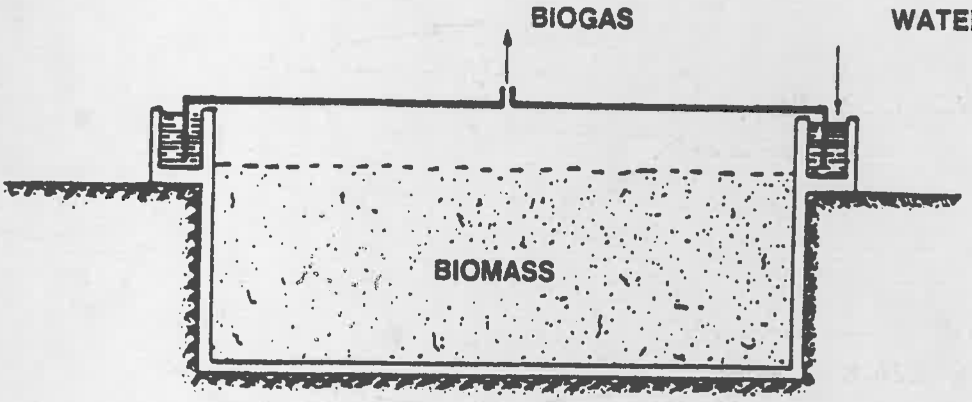


SECTION A-A

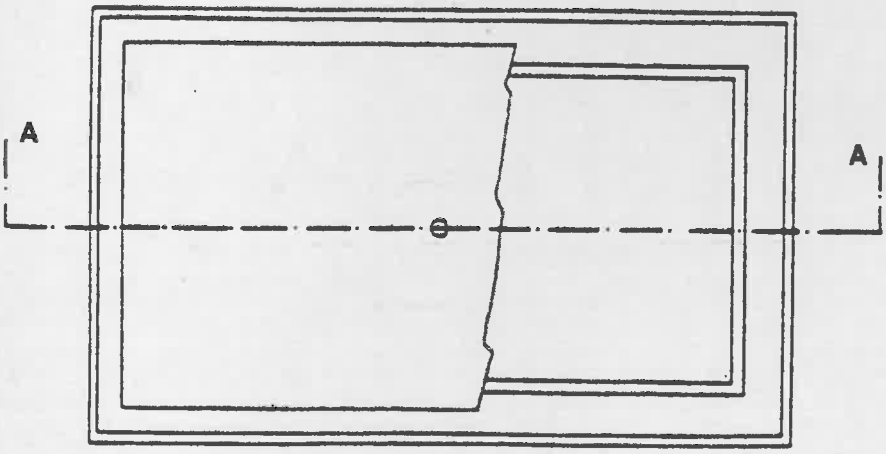


PLAN

BATCH DIGESTER

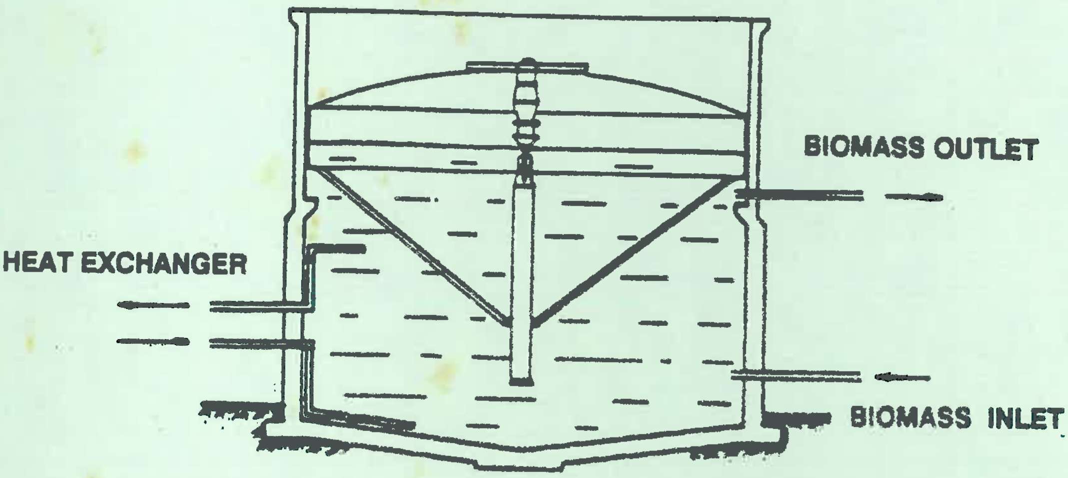


SECTION A-A

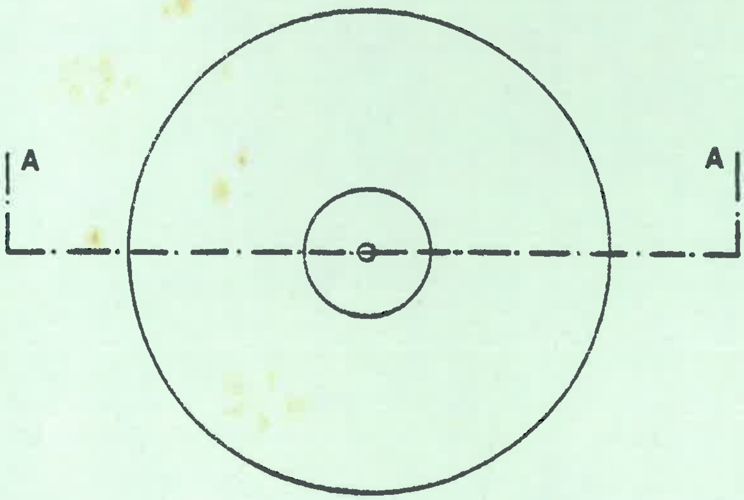


PLAN

"HIGH RATE" DIGESTER



SECTION A-A



PLAN