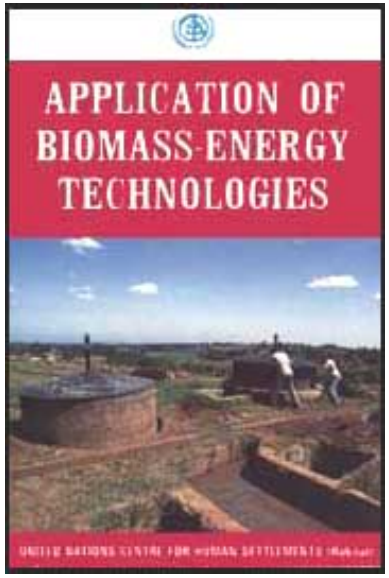

Application of biomass-energy technologies (1993) (Habitat)

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Foreword

The availability of energy and the security of its supply are of paramount importance to all human communities. Unfortunately, in most countries - both developed and developing current energy markets ignore the social and environmental costs and risks associated with fossil-fuel use. If externalities such as employment, import-substitution, energy security and environment are considered, then biomass systems compare very favourably with fossil-fuel systems.

Biomass currently accounts for about 14 per cent of the world's energy supply and is the most important source of energy for three quarters of the world's population living in developing countries. With increases in population and per capita demand, and depletion of fossil-fuel energy resources, the demand for biomass energy is expected to increase rapidly in developing countries. Even in developed countries, biomass is being increasingly used. For example, the United States of America now has 9000 MW of biomass power plants and Sweden, which derives 14 per cent of its energy from biomass has plans to increase it further as it phases down nuclear and fossil-fuel plants into the next century. With technologies available today, biomass can provide modem fuels such as electricity and liquid fuels, in addition to more traditional cooking fuels, and this energy can be produced and used in an environmentally sustainable manner, while emitting no net CO_2.

Yet. biomass energy continues to receive the lowest priority in energy planning in developing countries. Many factors contribute to this: the unreliability of

production and consumption statistics; the uncertainty of production costs which are quite site-specific; its diverse sources and end-uses; and its interaction with land uses.

Integrating biomass energy in national energy planning and policy-making on an equal footing with other energy sources will not be easy and will require concerted action at national and sub-national levels. A reliable information base will have to be developed on the supply and utilization of biomass energy in the country; the policy environment must be made responsive to the needs of the biomass-energy sector, research, development and engineering efforts will have to be stepped up in required areas; and the commercialization of biomass technologies will have to be promoted through selective and well-targeted subsidies and fiscal and other forms of incentives.

These are some of the recommendations of an Expert Group Meeting recently organized by UNCHS (Habitat) to promote commercialization of biomass technologies in developing countries. The present publication brings together, in an edited form, the contributions of several eminent experts commissioned by the Centre on different biomass-energy technologies. The publication forms a part of the Centre's continuing efforts to promote wide dissemination and commercialization of renewable energy technologies - an area of expressed concern in chapter 7 of Agenda 21 on sustainable human settlements development. I am confident that the case studies presented in this report and the policy options suggested in the light of these experiences will prove useful to policy-makers, researchers and potential entrepreneurs.

UNCHS (Habitat) acknowledges the contributions of Professor D.O. Hall, Dr. B.K. Kaale, Dr. S. Karekezi and Dr. N.K. Ravindranath in the preparation of this publication.

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Introduction

Biomass is considered to be one of the key renewable energy resources of the future at both small- and large-scale levels (Johansson et al, 1992). It already supplies 14 per cent of the world's energy, and the many future projects being assessed, if implemented, could increase the role of biomass in the overall energy system. On average, biomass produces 38 per cent of the primary energy in developing countries (90 per cent in some countries), where it is the largest single energy source. Biomass energy is likely to remain an important global energy source in developing countries well into the next century. A number of developed countries also use biomass quite substantially, e.g., the United States of America which derives 4 per cent of its total energy from biomass (nearly as much as it derives from nuclear power), Sweden 14 per cent and Austria 10 per cent (Hall et al, 1992b).

Biomass is generally and wrongly regarded as a low-status fuel, and rarely finds its way into energy statistics. Nevertheless, biomass can lay claim to being considered as a renewable equivalent to fossil fuels. It offers considerable flexibility of fuel supply due to the range and diversity of fuels which can be produced (Jones, 1989). It can be converted into liquid and gaseous fuels and to electricity via gas turbines; it can also serve as a feedstock for direct combustion in modern devices, ranging from very-small-scale domestic boilers to multi-megawatt size power plants.

Biomass-energy systems can increase the energy available for economic development without contributing to the greenhouse effect since biomass is not a net emitter of CO_2 to the atmosphere when it is produced and used sustainably. It also has other benign environmental attributes such as lower sulphur and NO_X emissions and can help rehabilitate degraded lands. There is a growing recognition that the use of biomass energy in larger commercial systems based on sustainable, already accumulated resources and residues can help improve natural resource management (Hall and Rosillo-Calle, 1991).

A. The need for modernization

Despite its wide use, biomass is usually used so inefficiently that only a small percentage of useful energy is obtained. The overall energy efficiency in traditional use is only about 5-15 per cent, and biomass is often less convenient to use compared with fossil fuels. It can also be a health hazard in some circumstances, for example, cooking stoves can release particulates, CO, NO_X formaldehyde, and other organic compounds in poorly ventilated homes, often far exceeding recommended WHO levels (Smith, 1987b). Furthermore, the traditional uses of biomass energy, i.e., burning animal dung and crop residues, are often associated with the increasing scarcity of hand-gathered wood, nutrient depletion, and the problems of deforestation and desertification (UNCHS, 1990). In the early 1980s, almost 1.3 billion people met their fuelwood needs by depleting wood reserves (WRI, 1988), whilst the worldwide impact of burning dung is estimated to reduce grain production by 20 Mt annually due to loss of fertilising capacity (Myers, 1984).

There is an enormous biomass potential that can be tapped by improving the utilization of existing resources and by increasing plant productivity. Bioenergy can be modernized through the application of advanced technology to convert raw biomass into modem, easy-to-use energy carriers (such as electricity, liquid or gaseous fuels, or processed solid fuels). Therefore, much more useful energy could be extracted from biomass than at present. This could bring very significant social and economic benefits to both rural and urban areas. The present lack of access to convenient energy sources limits the quality of life of millions of people throughout the world, particularly in rural areas of developing countries. Since biomass is the single most important energy resource in these areas its use should be enhanced to provide for increasing energy needs (Smith, 1987a). Growing biomass is a rural, labour-intensive activity, and can, therefore, create jobs in rural areas and help stem rural-to-urban migration, whilst, at the same time, providing convenient energy carriers to help promote other rural industries.

Enhanced biomass availability on a sustainable basis requires support and development of new biomass systems in which production, conversion and utilization are performed efficiently in an environmentally sustainable manner. Efforts to modernize biomass energy should concentrate on those applications for which there are favourable prospects of rapid market development, e.g., biogas, the generation of electricity from residues and biomass plantations through the gasifier/dual-fuel engines route or using advanced gas turbines fired by gasified biomass, and the production of alcohol fuels from sugarcane (Williams, 1989).

B. Experience from case studies

Over the last 20 years there have been numerous proclamations of failure and success of biomass schemes and projects. Much of the criticism has been warranted and has certainly helped focus attention on such projects' shortcomings and often uncritical acceptance. The designation "successful" to a project must be seen as relative to past failures and it does not imply that all components of a project are acceptable for any specific programme. Ideally, a successful biomass programme should show sustainability, replicability and flexibility, multiple benefits, and should also be economic when all costs and benefits, particularly the externalities, are considered.

The socio-economic and technological implications of the use of biomass technologies have been considered in this publication through several case studies. In most cases, the relevant authors have had long-term direct experience of evaluation at the local, national and international levels. Only such case studies have been selected for this publication where economic data are available in disaggregated form or the projects had been operating for a reasonable period, extending over at least several years. Particular attention has been paid to the modern attributes of biomass and to the opportunities for upgrading biomass production and use, highlighting the under-utilized biomass energy potential.

I. Woodfuel production technologies

A. Introduction

Woodfuel accounts for about 10 per cent of the total energy used in the world. It provides about 20 per cent of all energy used in Asia and Latin America, and about

50 per cent of total energy used in Africa (Arnold, 1991, Murray and De Montalembert, 1992). However, it is the major source of energy , in particular for domestic purposes, in poor developing countries: in 22 countries, woodfuel accounted for 2549 per cent, in 17 countries, 50-74 per cent, and in 26 countries, 75-100 per cent of their respective national energy consumption (UNCHS, 1984).

More than half of the total wood harvested in the world is used as woodfuel (Eckholm, 1976). For specific countries, for example, the United Republic of Tanzania, the contribution can be as high as 97 per cent (Mnzava 1990).

Although woodfuel is the major source of energy for most rural and low-income people in the developing world, the potential supply of woodfuel is dwindling rapidly, leading to scarcity of energy and environmental degradation (UNCHS, 1990). It is estimated that, for more than a third of the world population, the real energy crisis is the daily scramble to obtain woodfuel to meet domestic use (Eckholm, 1975).

Current studies on woodfuel supply in developing countries have concluded that woodfuel scarcities are real and will continue to exist, unless appropriate approaches to resource management are undertaken (Arnold, 1991, SADCC Energy Sector 1992b). The increase of woodfuel production through efficient techniques, can, therefore, be considered as one of the major pre-requisites for attaining sustainable development in developing countries.

The following paragraphs describe the main points of case studies on woodfuel technologies which were conducted in eight Southern African countries, namely, Botswana, Lesotho, Malawi, Mozambique, Swaziland, the United Republic of Tanzania, Zambia and Zimbabwe.

B. Botswana

Botswana has a land area of 582,000 sq km. The most distinctive characteristic of the land is its aridity, with unreliable rains. The population of Botswana in 1991 was estimated to be around 1,370,000 with an average annual growth rate of 3.3 per cent. Over 90 per cent of the population depend on natural woodlands for fuelwood and poles. In the eastern part of the country, where most of the population is concentrated, woodfuel supplies are being rapidly depleted, with some areas experiencing acute woodfuel scarcity.

The main woodfuel production technologies used in Botswana include: establishment of woodlots by the Government and NGOs, individual tree planting, and management of the existing natural forest.

1. Establishment of woodlots

Establishment of community woodlots was introduced in 1970 and implemented mainly by the Forestry Unit, with financial support from the United States Agency for International Development (USAID). The main objective was to produce woodfuel and poles. The woodlots were supposed to be run by village development committees. However, there was little participation by villagers, and hence the method failed. Some of the reasons attributed to the failure of the community woodlots are: undefined distribution of the endproducts from the woodlots; lack of proper extension services to support the establishment of the woodlots; lack of experience by the local people on growing exotic species; and lack of short-term benefits to villagers commensurate with their efforts (Walker, 1990).

2. Individual tree growing

The Government and NGOs are encouraging individual tree growing through agroforestry. By the end of 1991, there were 12 government and seven NGO nurseries, which raised, in total, 300,000 seedlings for sale to individuals. Government nurseries supply mainly exotic species like eucalyptus species, while NGO nurseries tend to supply more indigenous species and fruit trees. The number of planted trees nationwide is low due to drought and the unavailability of seedlings. This has made

many people in Botswana conclude that management of natural woodlands, rather than planting of trees, is the only realistic option for supplying people with woodfuel and other forest products.

3. Management of natural woodlands

Walker (1990) reported that, in the past, local chiefs were very successful in managing natural woodlands in Botswana Conservation was encouraged through the deliberate use of existing taboos and beliefs. For example, the widespread belief that heifers belonging to persons responsible for cutting indigenous species, would only produce male calves was used to ensure such species were not cut.

After independence, the powers of chiefs in many areas were delegated to government officers who had little interest in managing the natural woodlands, thus leading to uncontrolled clearing of natural woodlands.

4. Role of NGOs in woodfuel production

NGOs have been more active in promoting and implementing tree-growing activities than the Government due to an acute shortage of official forestry staff.

An NGO, the Forestry Association of Botswana (FAB), has been leading in conducting forestry research on suitable woodfuel species, establishment of tree nurseries in rural areas, management of natural woodlands and creation of mass-awareness on the need to sustain tree-growing and environmental protection at the local level. FAB has also been involved in formulating the National Conservation Strategy of Botswana In addition, it has lobbied hard to influence national forestry policies and create awareness to the urgent need to strengthen the Forestry Unit in the Ministry of Agriculture.

C. Lesotho

Lesotho is a land locked country in the middle of the Republic of South Africa It has a total surface area of 30,350 square kilometres. The population of Lesotho in 1992 was estimated to be 1.9 million people with an average annual growth rate of 2.6 per cent (SADCC Energy Sector, 1992b)

Lesotho is largely a tree-less country, with no natural forest land other than shrub land. By mid- 1992, the total area planted with trees, through individual, school, and government woodlots was estimated to be around 20,000 ha, or 0.66 per cent of the country land area of which, only 9 per cent is suitable for permanent arable agriculture. About 80 per cent of the land is used as rangelands.

No individual or organization can own land in Lesotho, but people can acquire the right to use a piece of land for a specific purpose and for a specific time under customary law. The free grazing on agricultural fields after crop harvest make tree-growing by individual farmers almost impossible (Hall and Green, 1989).

Biomass fuels account for 88 per cent of the total energy consumed in Lesotho (in the rural areas, the proportion approaches 95 per cent), coal, paraffin, LPG and electricity accounting for the remaining 12 per cent. The main biomass fuels used and their contribution to the total national energy balance are: woodfuel, 62 per cent (mainly from shrubs), animal dung, 20 per cent and crop residues 6 per cent (MWEML, 1991).

The main woodfuel production technologies used in Lesotho are the establishment of woodlots and individual planting.

1. The Lesotho Woodlot Project (LOOP)

After the failures of a village tree-planting scheme of the 1940s, intensive establishment of woodlots for woodfuel and poles production was started again in 1973, when the Lesotho Woodlot Project was commenced by a private company, Anglo de Beers Forest Services Lesotho Ltd. The Overseas Development Administration (ODA) joined the LWP as a donor in 1974. The same year, the World Food Programme (WFP) provided additional support to the LWP through "food for work" (Green, 1990).

By the end of 1991, an area of about 10,250 ha of woodlots had been established in over 350 sites, as Government Forest Reserves. Some of the woodlots have now reached maturity. However, the Forestry Division is having problems selling wood from the mature woodlots due to the inaccessibility of the woodlots by trucks and lack of proper plans on how to sell the woodfuel. Furthermore, funds for re-establishing harvested woodlots are not available from local sources.

2. Individual tree-planting

The Lesotho Energy Master Plan of 1988 indicated that the country was experiencing acute energy scarcity for the household sector. To provide energy to the household sector, the Plan recommended that at least an equivalent of 7500 ha of woodlots be planted annually. To achieve this target, individual tree-planting on a participatory basis was emphasized. However, as stated earlier, due to uncontrolled grazing on crop land after harvesting, it has been difficult for individuals to grow trees on farmland successfully.

D. Malawi

Malawi, located in Southern Africa, has a total surface area of 119,140 square kilometres of which 20 per cent is water. According to the 1987 population census, the population of Malawi was 8.0 million people, with an average growth rate of 3.2 per cent

The country is divided into three administrative regions, the Southern Region, the Central Region and the Northern Region. Rapid population growth has created severe land pressure in the Southern and Central Regions, where deforestation caused by expansion of agriculture land and the supply of poles and woodfuel is reported to be high.

Woodfuel for about 93 per cent of the total energy used in the country. Due to the high share of woodfuel in the energy balance of Malawi, efforts have been initiated to sustain woodfuel production.

The main woodfuel technologies used include establishment of rural woodfuel projects, of large-scale plantations, government and individual tree nurseries, demonstration woodlots combined with research, individual tree-planting programmes, conservation of natural forests and provision of bonus for surviving planes.

1. The Rural Fuelwood Project

The first government project to address the problem of woodfuel scarcity in Malawi, the Rural Fuelwood Project, was started in 1976. It was funded by the Government of Malawi with additional funds from a British Government grant. The main objective of the project was to establish plantations for woodfuel and poles production.

To facilitate selection of appropriate tree species, the country was divided into eight silvicultural zones. Successfully growing species in each zone were surveyed, documented and disseminated to extension workers. Research on suitable woodfuel species continued as a routine forestry activity.

In addition, another project, the Rural Fuelwood and Poles Research Project was also started. The long-term objective of the project was to provide the basic

silvicultural information in order to promote rural afforestation for the sustained production of woodfuel and poles and to provide shade, fodder and soil improvement. It was financed by the Government of Malawi and the International Development Research Centre (IDRC) of Canada, which provided a grant of $Can500,000.

A total of 93 experimental plots were established at 73 sites in seven silvicultural zones. Of these, 48 sites were on communal lands used for grazing or denuded hill slopes, 20 on individual farmer's land and the remaining five in government forest reserves, as a safety measure against losses on the other sites.

Communal lands for establishing the trial plots were obtained through negotiations with chics and village headmen. Land in individual farms was obtained through negotiation with farmers, involving both wife and husband.

Paid labour was used for establishing and protecting the trial plots with some assistance from the community and individuals. The end-products of the trees belonged to those who had provided land, but they were not allowed to cut the trees without prior approval of forestry officers.

The project gave the following positive results:

- Support and land for tree-growing were obtained from the community and individual farmers because they had been consulted.
- It provided on-farm demonstration to farmers on the methods to grow trees and establish woodlots.
- It provided income to rural people, through employment by the project.
- It provided woodfuel, poles and local environmental protection.
- It provided some knowledge and experience of suitable exotic tree species for the areas covered by the trials.

2. The Malawi Wood Energy Project

The first large-scale woodfuel project in Malawi was the Wood Energy Project. which was started in 1979 with a World Bank loan of $US 10 million, and expanded in December 1986 with another World Bank loan of $US16.7 million. The main objective of the Project was to establish and develop a sustainable wood production programme to meet the current and future demands for woodfuel and construction poles, while conserving and ameliorating the natural forests and the environment. It aimed at increasing woodfuel production through government and private initiatives, enhance the economic utilization of woodfuels through the promotion of energy-efficient technologies, and improving natural ecosystems by offering efficient protection and management of the indigenous forests.

In the first phase, a total of 88 central-government nurseries were established by the end of 1988 which provided seedlings for establishing large-scale woodfuel plantations as well as for selling to farmers at a subsidized price.

By that time, a total of 15,000 ha of woodfuel plantations had been established by the Forestry Department using paid labour. The plantations were established close to urban centres, mainly in Lilongwe and Blantyre cities, with the main objective of providing woodfuel at affordable prices to urban low-income groups.

However, the first phase of the project proved to be a failure as, inspire of heavy subsidies, few farmers could afford the purchase of seedlings. Secondly, most of the farmers who planted trees indicated that their main objective was to produce poles for sale and for house construction and not for woodfuel. As long as free woodfuel was available from customary land forests, people did not feel compelled to plant trees except for sale.

The government woodfuel plantations under the monoculture production system proved to be very expensive, technically and financially.

Yields were low for most plantations: a mean annual increment of 4.6 m^3 per ha per annum was obtained against a planned increment of 10 m^3/ha/annum at a rotation of seven years. The plantations supplied less than 1 per cent of the wood consumed hence their contributions were insignificant.

These observations tend to suggest that large-scale plantations run by governments, might not be the best option for woodfuel production. On the other hand, tree-planting by the private sector, NGOs and the people themselves in participatory efforts appeared to be the most cost-effective way of growing woodfuel. However, the method required a catalytic support from the Government, through extension services and formulation of policies and laws which would promote and protect the interest of individual tree growers.

Wood from indigenous forests was regarded as a free commodity. To put a value to the wood, a pricing policy of woodfuel from indigenous forests was introduced, mainly to cover the cost of re-establishment of the trees (Nkaonja, 1990).

Lessons reamed from the first phase of the project and those collected by a special unit on social aspects related to woodfuel production were utilized in the implementation of phase two of the project started in 1987. The main differences between the two phases were:

- Less emphasis was placed in the second phase on large-scale government plantations and the main emphasis was directed towards tree-growing by the private sector on a participatory and sustainable system. The role of the Government and other funding agencies was limited to catalytic support.

- Small-scale farmers were encouraged to grow trees based on agroforestry practices.

- Large-scale tobacco farmers were encouraged to establish woodlots or woodfuel plantations to provide wood for tobacco curing.

- To intensify provision of extension services, the Malawi Forestry College and the Forestry Research Institute were strengthened, mainly through worker development. The key role of women in forestry development was emphasized. To enhance this key role, female student dormitories were constructed at the Malawi Forestry College to facilitate enrolment of female students.

- The private sector and individual farmers were encouraged to establish small-scale tree nurseries. Efforts were also made by the Government to decentralize its nurseries in order to locate them closer to the people. The 88 nurseries started under phase one were maintained and 60 new ones were added. Seedlings