55455

E

Distr.: LIMITED

ECA/SDD/CSD.3/5
29 August 2003

UNITED NATIONS
ECONOMIC AND SOCIAL COUNCIL

Original: ENGLISH

ECONOMIC COMMISON FOR AFRICA

Third Meeting of the Committee on Sustainable Development

Addis Ababa, Ethiopia
7-10 October 2003

Reports on selected themes in natural resources development in Africa: Renewable energy technologies (RETs) for poverty alleviation

Table of contents

Pages

Executive Summary

Energy-poverty nexus has been analysed by a number of authors and relevant institutions and international organizations. Most of the reports emphasized the importance of improving access to modern energy services for the poor as a means of helping them escape from poverty. The role that improved access to energy services could play in poverty reduction efforts was further recognized when the Ninth Session of the UN Commission for Sustainable Development (CSD-9) stated that: "To implement the goal accepted by the international community to halve the proportion of people living on less than US$ 1 per day by 2015, access to affordable energy services is a prerequisite."

Poverty is a complex and multidimensional phenomenon, which has no precise definition. It can be conceptualised in a number of ways. In economic terms, income poverty means surviving on an income of less than US$1 per day; while in social terms, poverty is defined as the deprivation of material requirements for minimal acceptable fulfilment of human needs, including food. From a sustainable development perspective, poverty is defined as the denial of various choices and opportunities basic to human development.

It is also possible to identify an energy dimension to poverty. Energy poverty is thus defined as the absence of sufficient choice in accessing adequate, affordable, reliable, high quality, safe and environmentally benign energy services to support economic and human development. While energy is not in itself a basic need, it is required as a critical input for providing other essential human needs. Consequently, the satisfaction of the basic human needs and poverty alleviation efforts cannot be achieved without improving access to better energy services.

For people living in poverty, the most pressing priority is the satisfaction of basic human needs, which includes access to food, shelter, water supply and sanitation and other services that will improve their standard of living, such as health care, education and better transport. In this regard, aaccess to modern energy services can contribute to poverty alleviation by (i) improving the quality of life through better lighting, access to cleaner cooking fuels and safe drinking water; and (ii) improving effective delivery of social services through ensuring reliable heating, lighting, refrigeration of vaccines and other medicines, and sterilization of equipment in health centers, as well as providing lighting to schools, thereby allowing people to study at night, and improving their employment prospects.

Access to affordable and reliable energy services can also play a crucial role in underpinning efforts to achieve the Millennium Development Goals (MDGs). The goal of halving poverty by 2015 will be achieved only if affordable and reliable energy supplies are provided to increase production, income and education; create jobs and reduce daily grind involved in having just to survive. Halving hunger will require the provision of adequate energy services for more food production throughout the food chain. Increasing access to safe drinking water will require the provision of adequate energy services for pumping and boiling water. Ensuring gender equity in education cannot be achieved as long as girl children are drawn from school to collect traditional biomass fuels for family subsistence.

Renewable energy technologies (RETs) have the potential to help improve access to energy services for the poor people living in rural areas of sub-Saharan Africa. There is a variety of mature or near-to-mature technologies that can convert biomass into more convenient energy carriers, such as gaseous and liquid fuels, process heat, motive power or electricity, which can be used in energy-efficient conversion devices (cookstoves, electric lamps, motors, refrigerators, etc.) to provide energy services. Almost all renewable energy sources (biomass, solar energy, wind power, and small hydropower) can be converted into the most versatile of energy carriers, electricity.

Renewable energy-based technology (RET-based) systems could contribute to providing improved energy services for the rural poor thereby alleviating poverty in sub-Saharan Africa. However, widespread diffusion of RET-based systems faces strong institutional, technical and financial barriers that need to be overcome for any effective contribution to poverty alleviation. One of the most challenging barriers is the high initial cost of RET-based systems compared to conventional energy options. In order to bring the costs within the reach of many low-income people, it is necessary to spread the high initial costs of RET-based systems over a reasonable period of time while putting in place innovative financing mechanisms targeting the poor.

Financial arrangements for increasing affordability of RET-based systems can be made through improved access to microcredit. Microcredit is an effective way to provide households and small businesses with access to capital via loans that typically include flexible repayment schemes, fee schedules that match customer income stream, and longer loan repayment terms. In this regard, access to finance needs to be made available not only to end users, but also all the way along the service chain to organizations that help to manufacture, install and maintain the energy services.

Subsidies have often been used as a government policy instrument to facilitate access to energy services for low-income consumers. Lower income rural households will only benefit from access to RET-based energy services with targeted policies, including subsidy policies. In this regard, governments should implement well-targeted subsidies, the so-called "smart subsidies", as exemplified by the subsidizing policy applied to the World Bank sponsored *Uganda's Energy for Rural Transformation (ERT).*

Experience in sub-Saharan Africa shows that the introduction and success of any renewable energy technology is, to a large extent, dependent on the existing government energy policy and strategies. The existing regulatory framework is often the major barrier to widespread diffusion of RET-based systems. There is need for creating an enabling policy environment that help mobilize resources and encourage private sector participation in the application and dissemination of the most promising RETs.

Many RET-based energy projects have failed in the past because of inadequate local skills and knowledge to select technology that is appropriate to the needs of poor people and to keep it in good running order. It is also important that the poor have access to information on the availability and use of alternative energy sources to help them make the right choice of energy services and to inform them on how to use these energy sources more efficiently. Training local people to install, operate and maintain energy service technology is important to ensure their reliable operation.

Therefore, the choice of RET-based systems for dissemination and development in sub-Saharan Africa should take into account the existing technical knowledge and local industries. Technologies that can improve existing methods and build on already established industries are likely to be successfully disseminated. Some RET-based systems, such as wind pumps, small hydro, and improved cookstoves, can be build on local knowledge and skills, with the possibility of manufacturing them locally, thereby giving opportunities for employment and enterprise creation. These technologies can also become self-sustainable in the long term.

A new strategy that could facilitate access to RET-based energy services in rural areas would include:

(i) *Use of full range of "energy services"* without limiting available options to a single technical option such as PV systems;

(ii) *Use of intermediaries* who have or are able to obtain the technical and other expertise to identify and support local providers of energy services;

(iii) *Use of a wide range of service providers* by involving a wide range of suppliers including NGOs, local authorities, community groups and small and micro- enterprises (Sees);

(iv) *Consider providing different categories of service* so that a wide range of consumers can receive a service at a price they can afford;

(v) *Combine financial support with technical and management support*, as experience over the past years suggest that successful support to Sees needs to go beyond the provision of credit; and

(vi) *Use of a range of financial instruments* that would include loans, partial guarantees, revolving funds, and "group guarantees", such as those provided by women's group, and equipment leasing.

I. Introduction

1. Energy and poverty have figured in many policy documents and statements made by agencies such as the World Bank (WB, 2001), the United Nations Development Programme (UNDP, 2001), the World Energy Council (WEC, 1999), the International Energy Agency (IEA, 2002), and the UK's Department for International Development (DFID, 2002). Most of these reports emphasize the importance of improving access to modern energy sources for poverty alleviation.

2. In September 2000, the UN General Assembly adopted the Resolution on the United Nations Millennium Declaration setting up the Millennium Development Goals (MDGs) to reduce poverty. Furthermore, the Ninth Session of the UN Commission for Sustainable Development (CSD-9) stated in April 2001 that: "To implement the goal accepted by the international community to halve the proportion of people living on less than US$ 1 per day by 2015, access to affordable energy services is a prerequisite."

3. It is generally accepted that energy is not in itself a basic need, but it is required as a critical input for providing other essential human needs such as adequate food, clean water, health care, education, shelter, and employment. People do not need energy *per se*, but they need the benefits and services that energy can provide. Therefore, satisfying the basic human needs and poverty alleviation cannot be achieved without improving access to better energy services[1].

4. Most of African least developed countries (LDCs) have been facing low and stagnant growth in securing access to modern energy services. Most of poor people in sub-Saharan Africa still rely on traditional biomass for cooking and heating. Due to extreme poverty and lack of access to modern sources of energy, more than 80% of the overall African population, mostly the poor strata, rely on biomass to meet its household energy needs, particularly for cooking and heating.

5. However, the fact that the majority of low-income people in Sub-Saharan Africa will continue to rely on biomass for their basic energy needs for the foreseeable future is not, in itself, a cause for major concern. What is worrisome is the way in which biomass is used, and the technologies and applications used in its combustion. This is what links biomass use to poverty in many developing countries. There are many cost-effective and more efficient technologies that could be applied to convert biomass and other renewable energy resources into modern energy carriers, such as electricity, gaseous and liquid fuels, thereby contributing to poverty reduction and supporting sustainable livelihoods.

6. This paper is based on a review of the available literature on energy and poverty, including the role that renewable energy technologies (RETs) could play in reducing poverty in developing countries. It will consider issues such as poverty and energy dimension of poverty, linkages between energy and poverty reduction and renewable energy technologies (RETs) for improved rural energy services, as well as making RETs work for the poor in Africa.

---

[1] *Energy services* are referred to as the desired and useful products, processes, or services that result from the use of energy, such as cooking, water heating, lighting, refrigeration, water pumping, etc.

II. General considerations on energy and poverty

II.1 Understanding poverty

7. Poverty has no precise definition. It is a complex, multidimensional and context-specific phenomenon related to the inadequacy or lack of social, economic, cultural and political entitlements. Traditionally, poverty has been defined in terms of shortfalls of consumption or income. It thus has become common to establish an income-based or consumption-based *poverty line*, which is usually set against the cost of a basic diet for a group and/or the combination of dietary needs and a few non-food essential items. One commonly used income-poverty definition is subsisting on US$1 per day or less.

8. Another approach links poverty to basic human needs. Poverty is then defined as the deprivation of material requirements for minimal acceptable fulfilment of human basic needs, including food. This concept of deprivation goes well beyond the lack of private income: it includes the need for basic health and education and essential services that have to be provided by the community to prevent people from falling into poverty. It also recognizes the need for employment and participation.

9. A relatively new approach to defining poverty is based on the human capability concept. This approach defines poverty as the absence of basic human capabilities to function at a minimally acceptable level within a society, or a person lacking the opportunity to achieve some minimally acceptable levels of these functionings. The functionings can vary from physical ones as being well-nourished, being adequately clothed and sheltered and avoiding preventable morbidity, to more complex social achievements such as taking part in the life of the community.

10. This human capability concept of poverty matches the description of *human poverty* developed in UNDP reports whereby *poverty* is defined as the denial of various choices and opportunities basic to human development (UNDP, 1997; UNDP, 2001). Deprivation of opportunities and choices basic to human development can be considered as more relevant than poverty of income, as it focuses on the causes of poverty and leads to strategies of empowerment and other actions to enhance opportunities for everyone.

11. Recognizing the poverty of choices and opportunities implies that poverty must be addressed in all its dimensions. For this reason, the *Human Development Report 1997* introduced a *Human Poverty Index (HPI)* in an attempt to bring together in a composite index the different features of deprivation in the quality of life to arrive at an aggregated judgement on the extent of poverty in a community. HPI uses indicators of the most basic dimensions of deprivation: a short life, lack of education and lack of access to public and private resources (measured by access to health services and to safe water, combined with the prevalence of malnutrition).

12. According the World Development Report 2000/2001, poverty encompasses not only material deprivation (measured by an appropriate concept of income or consumption), but also low achievements in education and health. However, it is generally admitted that poverty is an outcome of economic, social and political processes that interact and reinforce one another in ways that can worsen or ease the deprivation poor people face every day.

13. For example, improving health outcomes not only improves well-being, but also increases income earning potential. Increasing education not only improves well-being; it also leads to better health outcomes and to higher income. Increasing people's voice and participation not only addresses their sense of exclusion; it also leads to better targeting of health and education to their needs. Understanding these complementarities is essential for designing and implementing programmes and projects that help people escape poverty.

II.2 Energy dimension of poverty: energy poverty

14. Energy poverty has been defined as the absence of sufficient choice in accessing adequate, affordable, reliable, high quality, safe and environmentally benign energy services to support economic and human development[2]. Energy poverty interacts with other manifestations of poverty, including lack of access to essential human services as highlighted in Box 1 below.

Box 1: Energy as a contributor to essential human services

Reliable and affordable energy supplies are absolutely required to meet even the most basic human daily needs of the world's poor people. These include:

- *Cooking*: Energy for cooking (and heating in cold climate) is one of the life's most basic needs. It is estimated that approximately 95% of staple foods (such as rice, grains, green bananas, etc.) need cooking before they can be eaten.
- *Safe drinking water*: Supplying safe water would not be possible without energy for pumping, and clean fuels for boiling water. Without energy for pumping and/or boiling ware, people would be often forced to rely on water from streams polluted by cattle or human effluent.
- *Lighting*: Energy for lighting allows people to study and/or carry out income-generating activities at night.
- *Health care*: Energy is needed for powering vital equipment in rural health centers such as refrigeration for vaccines and other medicines, sterilization of equipment, and lighting, as well as transport facilities.
- *Education*: Energy is needed to provide lighting in schools, allowing extended classes and power modern learning equipment such as overhead projectors and computers.
- *Communication*: Electricity supply is required for powering radio and/or TV sets, as well as information and communication technology (ICT), that are necessary for households, farmers, schools, and others living in remote areas to access critical information.
- *Agricultural needs*: Many crops need processing, such as grain milling for flour, so that they can be used for the preparation of food. Without mechanical power, this can be an enormously time consuming, almost back-breaking task, particularly for women and girl children.

Source: Adapted from a number of relevant publications

15. According to a report of the International Energy Agency (IEA)[3], sub-Saharan Africa has the lowest electrification rate of any major world region with only 23% of its population having access to electricity. Generally, more than 500 million Africans are still without access to electricity. Statistics show that more than 83% of the Africa's population living in rural areas has no access to electricity, while more than 92% of rural sub-Saharan Africa' s population is still without access to electricity.

---

[2] The Gender-Energy-Poverty Nexus: Finding the energy to address gender concerns in development, DFID Project CNTR998521, by Joy S. Clancy and Margaret Skutsch and Dr Simon Batchelor

[3] World Energy Outlook 2002 – Chapter 13: Energy and Poverty

16. It is also indicated that over half of all the people relying on traditional biomass fuel for cooking and heating (some 2.4 billion) live in India and China, but the *proportion* of the population depending on biomass is heaviest in sub-Saharan Africa. In most of the least developed countries (LDCs) in sub-Saharan Africa, nearly all rural households use traditional and unprocessed biomass for cooking, while most of urban households use charcoal.

17. Heavy reliance on traditional biomass fuels and limited access to modern sources of energy such as electricity and petroleum-based fuels (LPG and kerosene) cannot help poor people escape from poverty. Without access to affordable modern energy sources, it is virtually impossible to carry out productive economic activity or improve healthcare services and education. Box 2 below gives some highlights on impacts of biomass use.

Box 2: Impacts of over-dependence on biomass energy on the poor

Extensive use of biomass and lack of access to modern fuels can result in the following:

- *Time spent gathering fuels*: The widespread use of wood fuel and charcoal can result in scarcity of local supplies. This forces poor people (usually women and girl children) to spend hours gathering firewood far away from home. This reduces the time that people could have devoted to other productive activities, such as farming, education and other income-generating activities.
- *Gender inequality*: The majority of all people living in poverty are women. Women place a high value on improved energy services because they are the primary users of household energy. Women are most likely to suffer from health effects of inefficient use of traditional biomass fuels and cooking methods.
- *Health*: The inefficient household biomass combustion results in high indoor air pollution, which is harmful for women and young children. Health impacts of indoor air pollution include: acute respiratory infections, adverse pregnancy outcomes, chronic obstructive lung disease, and several types of cancer. It is believed that acute respiratory infection is the primary cause of morbidity and mortality in children under five.
- *Agricultural productivity*: Use of agricultural residues and dung as fuel for cooking reduces agricultural productivity, because they are also widely used as fertilizer. Therefore, heavy reliance on these biomass fuels to meet the cooking and heating needs of the poorest households will result in reduced availability of organic fertilizer.
- *Environment*: Intensifying biomass utilization can have multiple impacts on the environment, such as soil erosion and loss of nutrients as biomass is repeatedly harvested and poor rural households use agricultural residues and dung as fuels. Sacrificing tree cover and soil quality may leave poor rural households impoverished and more susceptible to economic or environmental shocks.

Source: Adapted from the IEA's World Energy Outlook 2002: Energy & Poverty

III. Linkages between energy and poverty reduction

III.1 Current pattern of energy use in rural Africa

18. The bulk of energy consumed by rural poor households is derived from locally available traditional biomass fuels in the form of wood fuel, agricultural residues and dung. Cooking accounts for between 90 and 100% of household energy consumption[4]. The rest is the energy consumed for lighting, provided either by firewood (cooking fire), kerosene lamps

[4] The Challenge of Rural Energy Poverty in Developing Countries; WEC/FAO, October 1999

and candles. Space heating is required in areas with cold climates, and is often catered for by energy used for cooking.

19. The most common method of cooking with traditional biomass fuels throughout rural areas in SSA countries is the open heart or *three-stone fire*, which typically transfers only 5-10% of the fuels' energy content into the cooking pot and is responsible for harmful indoor air pollution. Improving combustion efficiency through use of "improved" cooking stoves could thus result in fuel savings and help alleviate the adverse impact on health of women and children and other damaging effects of traditional biomass energy use.

20. The predominance of traditional biomass fuels as the dominant source of energy for cooking, despite its inefficiency and harmful health effects, could be attributed to its availability as a "free" source of energy. In most cases, firewood is collected and not purchased. However, gathering firewood requires large amounts of human energy and time, and the burden tends to fall more heavily on women and children. It is estimated that, in rural sub-Saharan Africa, many women carry 20 kg of firewood daily over a distance of 5 km on the average.

21. Although lighting uses relatively limited amount of energy, it is an important household energy service. Kerosene is the most widely used modern energy source for lighting, but its use involves relatively high costs for kerosene lamps and fuel. Firewood is another important fuel for lighting, particularly for the poorest households, because it does not require additional investment. For high-income households, electricity (either from the grid, diesel generators or PV systems) is an option; but electricity is not a ready option for low-income households for lighting due to its high up-front costs (electric light fittings).

22. Energy and power are needed at all stages of agricultural production, including land preparation, cultivation, irrigation, harvest, post-harvest processing, storage, and transport of agricultural inputs and outputs. Despite the many advantages that could be gained from it, the degree of agricultural mechanization is generally low in most of SSA countries.

23. Limited use of mechanized agricultural practices in Africa means that the bulk of agricultural energy input for the basic agricultural activities is provided by human and animal power. The heavy reliance on human labour, particularly women, combined with low calorie intake may explain the low and declining levels of agricultural productivity in much of sub-Saharan Africa. Animal power can alleviate human drudgery and increase agricultural production, as it can provide transport, pull implement, lift water, and power crop processing.

24. Small-scale rural industries are comprised of agro-based (food processing, fish smoking, beer brewing, tobacco curing, tea drying, etc.), and non agro-based industries (brick making and charcoal production, small-scale mining, pottery, blacksmithing, carpentries and village workshops). The energy needs of rural industries comprise lighting, process heat, motive or shaft power and electricity. Traditional biomass fuels remain the major source of process heat for most rural industries, while a steady transition from traditional to modern energy sources is taking place with increases in rural electrification and greater availability of other commercial energy sources.

III.2 Access to energy services and the MDGs

25. Energy plays a critical role in underpinning efforts to achieve the MDGs and improving the lives of poor people across the world. Although the Millennium Development Goals (MDGs) do not make any specific reference to the role of energy to reduce poverty, access to energy services is a crucial element in achieving the goals. The link between access to energy services and poverty reduction can be highlighted as follows:

- *Halving poverty by 2015* will not be reached without energy to increase production, income and education, create jobs and reduce the daily grind involved in having just to survive.
- *Halving hunger* will not come about without energy for more food production throughout the food chain (ploughing, planting, harvesting, processing and marketing).
- *Improving health and reducing death rates* will not happen without energy for refrigeration of vaccines and other medicines needed for the prevention and treatment of diseases and infections in health centers/clinics and for vaccination campaigns.
- *Supplying safe water* will not be possible without energy for pumping and clean fuels for boiling water.
- *Gender equity in education* cannot be achieved as long as girl children are drawn from school to collect ever-scarce traditional fuels for family subsistence.

26. Consequently, the role that energy services can play in helping to achieve the MDGs and improve the lives of the poor, as well as the direct and indirect energy-poverty links can be outlined as follows:

(i) To halve extreme poverty:

- Access to energy services facilitates economic development, including micro-enterprise, increased productivity from use of machinery, income-generating and livelihood activities from extended lighting, and improved local employment creation.
- Access to clean and efficient fuels reduce the large share of household income spent on cooking, lighting and space heating.
- Access to modern energy services can also assist in bridging the "digital divide" from ICT.

(ii) To reduce hunger and improve access to safe drinking water

- Energy services can help improve access to pumped drinking water and cook food since the majority of staple foods (such as rice, grains and green bananas) need to be cooked.
- Energy services can also improve productivity throughout the food chain (tillage, planting, harvesting, processing, transport, etc.), and reduce post harvest losses through better preservation (e.g., drying and smoking).
- Energy for irrigation helps increase food production and access to nutrition.
- Clean water helps improve health.

- Increased health and nutrition open up opportunities for employment and income generation.

(iii) To reduce child and maternal mortality and diseases

- o Energy services are needed to provide access to better healthcare facilities, including lighting operating theatres, refrigeration of vaccines and other medicines; sterilization of equipment and transport to health centers/clinics.
- o Electricity in health centres keeps them open at night;, helps retain qualified staff and allows equipment use, including vaccination and medecine storage for prevention and treatment of diseases and infections.
- o Access to energy services can help in the provision of nutritious cooked food, space heating and boiled water thereby contributing towards better health.
- o Access to modern energy services can also help improve health condition of women and children because:

  - Gathering traditional fuels and preparing food expose young children to health risks and reduce time spent on child care; and
  - Excessive workload and heavy manual labor (carrying heavy loads of fuelwood and water) may affect a pregnant woman's general health and well-being.

(iv) To achieve universal primary education and promote gender equality and empowerment of women

- o Energy services reduce the time spent by women and girl children on basic survival activities, such as gathering firewood, fetching water, cooking inefficiently, crop processing by hand, manual farming work, etc.
- o Good quality lighting in households permits home study.
- o Lighting in schools allows evening classes and helps retain teachers, especially if their accommodation has electricity.
- o Reliable energy services offer scope for women's enterprises.

IV. Renewable energy technology options for improved rural energy services

27. Renewable energy sources (including biomass, solar, wind, and hydropower) can be harnessed to help meet basic energy needs in rural areas through the application of relevant energy conversion technologies. There is a wide variety of technologies available or under development which can provide reliable and sustainable energy services from renewable energy sources, but the stage of development and the competitiveness of these technologies differ greatly. All renewable energy sources can be converted to electricity, but only a few of them can produce liquid and gaseous fuels as well as heat directly.

IV.1 Biomass energy technologies

28. Biomass energy has the potential to be "modernized", i.e., produced and converted into more convenient forms such as gaseous and liquid fuels. It can also be useful in processing heat or electricity. There is a variety of technologies, which can convert solid

biomass into clean, more convenient, energy carriers. Most of these technologies are commercially available today, while others are still in the development and demonstration stages. A brief description of the most promising technologies is presented below.

IV.1.1 Direct Combustion

29. Direct combustion remains the most common technique for deriving useful energy from biomass for both heat and electricity. Small-scale biomass technology systems used to provide heat for households needs for cooking and heating, or for income-generating activities (tobacco curing, fish or meat smoking, brick making, pottery, blacksmithing, etc.) are of interest for the rural poor. Small-scale biomass combustion for cooking and heating purposes can be improved through promotion of improved cooking stoves, which attempt to overcome the drawbacks of traditional cooking stoves by improving heat transfer to the pot thereby increasing efficiency and reducing indoor air pollution.

30. The predominant technology for electricity generation from biomass, at scales above one megawatt (1 MW) is direct combustion of biomass in a boiler to produce steam, which is then expanded through a turbine. The typical capacity of existing biomass power plants ranges from 1 to 50 MWe with an average around 20 MWe. In some agro-industrial installations, waste heat from the turbine can be recovered and used as process heat, the so-called co-generation, which has been developed in most of sugar refining industries (e.g., Mauritius). ***However, such examples of large-scale applications of biomass combustion technologies are of little relevance to alleviating poverty***.

IV.1.2 Gasification

31. Combustible gas, (or *producer gas)*, can be produced from solid biomass through a thermo-chemical process called *gasification*. This involves burning biomass in an enclosed reactor/container or *gasifier*, without sufficient air for full combustion. There are two major types of biomass gasification technologies: (i) fixed bed gasifiers, in which air passes through a packed bed of fuel blocks; and (ii) fluidized bed gasifiers. Currently, gasification in fixed bed gasifiers appears to be the most viable option for biomass-based power generation for capacity of up to 500 kW.

324. Producer gas can substitute fossil fuels in a number of applications, such as (i) direct heat applications where the gas is burned directly in a boiler, furnace or kiln to provide heat; and (ii) shaft/electrical power applications where the gas is used to run dual fuel diesel engines. For electricity production, producer gas can be used in modified diesel engines, where it can replace 70-80% of the diesel fuel required to run the engine. These biomass gasifier/engine systems hold promise of supplying motive power and electricity to isolated and remote areas of developing countries where grid connections are either unavailable or unreliable. However, problems related to gas cleaning requirements, relatively high costs and the need for careful operations have limited the systems' large-scale operations.

IV.1.3 Biogas technology

33. A methane-rich combustible gas, known as *biogas*, can be produced from biomass through a biological conversion process called *anaerobic digestion*. This process takes place inside an airtight container, known as a *digester*. Biogas can be burned directly providing energy for cooking and lighting, or used indirectly in a dual fuel engine to produce electricity

or shaft power. Biogas is most commonly produced using animal manure, mixed with water, to make the slurry introduced in the digester. The nitrogen-rich effluent released from the digester after biogas production is usually used as fertilizer.

34. There are generally two types of biogas digesters: (i) fixed-volume digester, which produces a gas that has a variable pressure, depending on the amount of gas being produced; and (ii) fixed-pressure digester (also referred to as floating dome digester), which has a variable volume, and depends on the amount of gas being produced. The fixed-pressure digester has the advantage of being able to supply gas to appliances like a gas fridge or dual fuel generator, since they require a constant gas pressure.

35. Digesters can be built in virtually any size, from a small family-sized digester (1-2 m^3) producing just enough gas for cooking and lighting to a large community-sized digester of thousands of m^3 producing sufficient gas to generate electricity. The technical viability of biogas technology has been repeatedly proven in many field tests and demonstration projects, but numerous problems arose as soon as mass dissemination was attempted, particularly with regard to availability of digester feedstock (animal manure and water), and the high investment cost (US$300-500 for 1-2 m^3).

IV.1.4 Ethanol production

36. Ethanol is a liquid fuel produced by fermentation of sugars from sugar-containing biomass (e.g., sugarcane). It can also be produced from starch-containing biomass (e.g., cassava, corn, or potatoes). This process involves initial conversion of carbohydrates into water-soluble sugars before fermentation. Although ethanol production from sugar containing biomass can be considered as a well-established technology, research continues to find alternative production processes using less valued feedstock. Indeed, some of the biomass crops used as feedstock for ethanol production are high value staple foods in most SSA countries. In this regard, intensive research is being directed to ethanol production by *hydrolysis* of lignocellulosic biomass, a potential low-cost and efficient option[5]. Ethanol has proved to be an alternative source of liquid fuels for the transport sector in Zimbabwe, Malawi and Kenya.

IV.2 Micro-hydropower technology

37. Hydropower technology converts the gravitational energy of falling water into mechanical energy, and then from mechanical energy into electrical energy. Small-scale hydropower is often divided into three categories: micro hydro (less than 100 kW), mini hydro (100 – 1,000 kW), and small hydro (1 – 10 MW). Small-scale hydropower is now a mature technology that has been greatly improved by electronic load controllers, low cost turbine designs, the use of electronic motors as generators, and the use of plastics in pipe work and penstocks. Small hydropower can be one of the cheapest options for providing electricity to rural areas too remote to be connected to a grid.

38. Since the early 1980s, substantial efforts have been made to develop indigenous appropriate approaches to small hydro development. Many micro-hydro projects of less than 100 kW of installed capacity are of "run-of-river" type systems that require less extensive civil works and employ locally manufactured equipment. Experience from projects

---

[5] World Energy Assessment: Energy and the Challenge of Sustainability

implemented in Nepal emphasizes the importance of the participation of the local community, which reduces costs, enhances consumer satisfaction, and helps to provide a financially viable investment.

39. Depending on the end-use requirements, the output from the turbine shaft can be used directly as mechanical power or, alternatively, the turbine can be connected to an electrical generator to produce electricity. For many rural industrial applications, shaft power is suitable, for example, for food processing such as milling or oil extraction, sawmill, carpentry workshop, or small-scale mining equipment. However, many applications require conversion to electrical energy. For domestic applications, electricity is preferred. This can be provided either directly to the household via a small electrical distribution system, or supplied by means of batteries, which are returned periodically to the power station for recharging.

IV.3 Solar thermal energy technology

40. Solar energy can be converted directly into heat for low-temperature applications. Solar thermal technologies that have been disseminated in developing countries include solar water heaters, solar driers, solar cookers and solar stills. Solar water heating system is the most important application for low-temperature solar thermal energy conversion technology. A solar hot water system consists of three components: a solar collector, a storage tank, and a circulation system to transfer the heated water from the collector to the storage tank. In a solar water heating system, heated water is circulated naturally from the solar collector into the storage tank via the natural convection process called *thermosiphoning*.

41. Solar drying can help reduce post-harvest losses of agricultural products in rural Africa. Solar dryers consist of three main components: a drying chamber in which agricultural products are dried, a solar collector that heats the air, and some type of airflow system which can use natural convection or forced convection. Solar dryers can be classified as: direct solar dryers, indirect dryers, mixed mode dryers, and hybrid dryers (involving forced ventilation. In general, research has shown that solar dryers perform well and produce better results than the traditional method of drying crops in the open air. However, existing solar dryers are still too expensive for small farmers and are only affordable to middle to higher income farmers. Small farmers can, however, organize themselves in cooperatives in order to make such dryers affordable.

IV.4 Photovoltaic (PV) solar energy technology

42. Photovoltaics (PV) is a technology that converts sunlight directly into electricity. In a PV system, power is produced when sunlight strikes the semiconductor material and creates an electric current. The smallest unit of the PV system is a cell. Cells wired together form a module, and modules wired together form a panel. PV systems are a reliable, renewable, environmentally safe, and increasingly cost-effective technology for generating electricity for a wide range of applications for households and communities in the developing countries.

43. PV systems may comprise some or all of the following basic components: (i) *PV module or array of modules* and accompanying support structures; (ii) *power storage* (usually provided by batteries); (iii) *power conditioning equipment* (optional and typically includes inverters and control and protection equipment); (iv) *cables* (connecting the power supply to the storage media, conversion equipment, and appliances); and (v) *a load* (equipment being served by the power source).

44 The main applications of PV solar energy technology in developing countries include:

- *Community lighting*: PV-powered lighting, with battery storage, is used for community buildings such as schools and health centres to enable education and income-generating activities to continue at night time;
- *Households appliances*: Solar home systems can provide power for domestic lighting and other DC appliances such as TVs, and radios;
- *Refrigeration*: PV–generated electricity is particularly valuable for running refrigerators that preserve vaccines, blood, and other consumables vital to community health care programmes in rural areas;
- *Battery charging*: PV modules can be used to recharge batteries that power electric appliances ranging from flashlights and radios to television and lights; and
- *Water pumping*: PV is commonly used to supply water to villages and livestock, and for irrigation.

45 The total costs of a PV system depend on many factors aside from the basic hardware. However, the cost of PV array is a significant factor and will typically constitute 30% to 50% of the total capital outlay, with the balance-of-system (BOS) components contributing a similar amount. Costs for typical configurations are as follows:

- *A small solar home system* to power two or three fluorescent tubes, a radio and a black and white television – costs US$ 350 to US$ 700. This system typically requires a 50 Wp module and support structure, battery, wiring, and controls.
- *A PV-powered vaccine refrigerator* – costs US$ 2,000 to US$ 5,000. This system might require a 200 Wp array and would have a well-insulated case, a high-performance battery, along with cables and controllers
- *A roof-mounted community or school PV system* running lights, electrical equipment, and so on – costs US$ 10,000. The cost of the electricity produced by this 1.5 kWp (1,500 Wp) system would depend on the overall system efficiency, the resource availability, the lifetime of the system and the assumed discount rate.

IV.5 Wind energy technology

46. Wind energy systems convert the kinetic energy of moving air masses into mechanical or electrical energy. Two types of wind machines can thus be distinguished: windmills, which produce mechanical energy used mostly for pumping water in rural areas; and wind turbines, which generate electricity for households, villages or for connection to the utility grid. The power that can be generated from a modern wind turbine is practically related to the square of the wind speed, although theoretically, it is related to the cube of the wind speed. This means that a site with twice the wind speed of another site will be able to generate four times more energy.

47. Consequently, the availability of good wind speed data is critical to the feasibility of any wind project. Most commercial wind turbines operating today are placed at sites with average wind speeds greater than 6 m/s or 22 km/h, although annual wind speeds over 5.5 m/s can also b viable. Generally, annual average wind speeds greater than 4 m/s are required for small wind electric turbines, but less wind is required for water pumping operations.

48. Generating electricity from the wind is a mature technology and economically competitive with most fossil fuel applications. Wind power has proved to be very competitive with solar PV systems, biomass-based power systems, and diesel generators (see above), but is usually more expensive than micro-hydropower systems. Although wind turbines cost more initially than diesel generators, they are often much better from the user's point of view because they do not require high operational and maintenance costs (particularly fuel and parts) like diesel generators. Currently, the use of wind turbines for electricity production in Africa is limited (except for the "Alizés" small wind farm GEF-funded project in Mauritania). Under favourable circumstances, wind energy is economically competitive in comparison to conventional electricity generation.

49. Over the last 20 years, the cost of electricity from utility scale wind systems has dropped by more than 80%. In early 1980s, when the first utility-scale turbines were installed in the United States, wind-generated electricity cost as much as 30 US¢/kWh. Now, state-of-the-art wind power plants can generate electricity for less than 5 US¢/kWh in many parts of the United States, a price that is in a competitive range with many conventional energy technologies. The most economical applications of wind turbines is in groups of large machines (660 kW and up), called "wind farms", such as the eight 660 kW wind farm installed at Al-Koudia in Morocco. A number of other wind farms will be installed in Egypt and Morocco soon.

IV.6 Hybrid energy systems

50. A renewable-based hybrid energy system utilizes two or more energy (electricity) production technologies, usually solar PV and small wind turbines. The major advantage of wind energy is that its reliability is enhanced when used together with solar PV systems. Additionally, the size of the battery storage can be reduced, as there is less reliance on one technology for power production. In most cases, renewable-based hybrid energy systems involve a combination of a diesel generator with battery-inverted sub-system incorporating renewable energy sources like solar/wind/hydro. Coupling solar/wind/hydro based power system with diesel generators offer unique diesel fuel saving advantages while simultaneously ensuring reliable and least-cost power supply to isolated facilities or rural communities.

V. Making renewable energy technologies (RETs) work for the poor

V.1 Delivering improved energy services: Moving up the "energy ladder"

51. The "energy ladder" is a common concept used in household energy analysis, which implies that, as incomes rise and opportunities for using better technologies become available, people's preferences shift from traditional biomass fuels and inefficient cooking stoves to modern energy carriers and more convenient and energy-efficient end-use technologies that convert energy carriers into useful services. This means that people move up the energy ladder as their incomes grow.

52. In the past, many attempts to meet the energy needs of poor people have concentrated on their household requirements, such as cooking and lighting. These have often been referred to as "*consumptive uses*", even though lighting allows people to undertake income-generating activities (productive work) for extended hours, and cooking might include the

processing of food for sale. However, the most financially sustainable decentralized energy supply options to rural communities are likely to be those that provide mechanical power or electrical energy for productive enterprises ("*productive uses*").

53. Renewable energy technologies that can be used to meet household cooking needs, include: improved cooking stoves, solar cookers, and biogas. though producer gas is a clean cooking fuel, its use has not been promoted in most SSA countries. On the other hand, programmes for promoting and disseminating improved cooking stoves have been launched in sub-Saharan Africa since the 1980s, but have had mixed results. While improved charcoal cooking stoves targeting urban households have been successful, like the Kenyan *Jiko*, the Ethiopian Mirth, the Rwandese Rondereza and the Malian Mai Sauki, efforts to disseminate improved stoves for burning unprocessed biomass have somehow failed.

54. Biogas is the only biomass-derived modern energy carrier for household applications with which there is widespread experience. Experience of promoting small scale biogas technology in Africa at the household level has generally not met expectations, partly due to high capital costs and non availability of feedstock (animal manure and water) for the biogas digester. It is estimated that a family-sized digester would require an investment of US$ 300-US$500 and a minimum of two cows.

55. Rural households also need modern energy sources for lighting. As noted earlier, climbing the energy ladder for lighting means shifting from kerosene to gas lamps and finally to electric lights. Biogas can provide improved lighting than kerosene lamps, but electricity is much preferred because it can improve the quality of life by providing energy for both lighting and powering radio/TV. Because of the small amounts of electricity required, the most appropriate RETs for meeting household needs is solar PV technology through solar home systems (SHSs).

56. Although solar PV systems have been promoted in almost all African countries, widespread use of PV SHS has been limited due to high up-front costs. However, the Kenya experience provides a good example of success story as shown in Box 3 below.

Box 3: Private provision of PV systems in Kenya

The Kenya PV industry provides a model of sustainable, commercially-driven and PV-based off-grid rural electrification for consideration by other countries in sub-Saharan Africa. It is estimated that since the early 1990s, some 200,000 PV solar home systems (SHSs) have been installed, totalling more than 3.5 MWp (megawatts) of installed capacity, though most these are quite small. Since the late 1990s, sales of solar modules have remained over 20,000 systems per annum, representing a PV market worth more than US$6 million a year.

The Kenya PV market has grown in three stages. In the first stage, upper-middle class rural innovators as well as non-governmental organizations (NGOs) working in off-grid locations, installed complete PV systems (typically 40-100Wp with one battery powering five to ten lights and a B&W television) that generated demand for the technology. In the second stage, large numbers of rural people bought small (12Wp) PV panels costing less than US$50 (2001) with batteries, primarily to power TV sets. In the third stage, hire purchase and finance agencies entered the market, enabling lower-income rural families to buy systems on credit.

Today, the Kenya PV industry involves an increasing number of players, including importers (10-12 companies, many of which have turnovers above US$500,000), retailers, manufacturers, installers, battery charging stations and appliance sellers. People who purchase PV systems are interested in gaining power for TV, lighting and radio or music systems. Most of the buyers of PV systems are rural middle class people who have little hope in gaining access to the grid power, and who seek to improve performance of 12V DC lead-acid battery systems.

In conclusion, although low-cost provision of PV solar home systems has been successfully developed by the private sector in Kenya making Kenya PV industry a model of best practices in commercially-driven off-grid PV-based rural electrification programme, a number of market impediments have prevented PV systems from reaching the rural poor.

Source: Energy Services for the World's Poor: A World Bank Report; Mark Hankins, (2001)

57. The poorest people, who cannot afford to pay for energy services and must rely on free energy sources, can gain indirect benefits from energy services provided to the community. For example, where it is cost-effective to provide electricity to remote communities, providing energy for community facilities such as schools, hospitals, trade and community centres can benefit a wider cross-section of the community, even the poor are unable to afford household energy service themselves.

58. Improving access to modern energy services for the community can thus benefit rural poor people through improved social services, such as healthcare, education, drinking water supply and street lighting. Indeed, communities need energy services for many different activities and for many different sectors within the community, households, schools, medical centres, micro-enterprise development, and agriculture. Provision of energy services for community needs involves solar PV lighting, mini-grid supplied by RET-based power system, biomass gasifier/engine systems and windmills for water pumping for irrigation, etc.

V.2 Facilitating access to improved energy services through RETs

59. There is a variety of decentralized renewable energy technologies (RETs) that can complement grid extension efforts in the provision of modern energy services (electricity) to people living in rural areas. However, RET-based systems are yet to gain wide market acceptance and face barriers against widespread diffusion in rural communities of sub-Saharan Africa. These barriers can be of institutional, technical and financial nature.

V.2.1 Overcoming the initial cost barrier through innovative financing mechanisms

60. One of the most challenging barriers is that most RET-based systems have higher initial costs than their conventional alternatives, although the life cycle cost may be much less. But, people living in poverty primarily think in terms of the initial cost rather than the life cycle cost which ultimately results in lower energy prices and improved energy services. Therefore, in order to bring the costs within the reach of many low-income people, it is necessary to spread the high initial costs of RET-based systems over a reasonable period of time while putting in place innovative financing mechanisms targeting the poor.

61. Financial arrangements for increasing affordability of RET-based systems can be made through improved access to microcredit. Small loans, tailored to borrowers with limited ability to pay, are essential in making RET-based systems affordable and available. Microcredit is an effective way to provide households and small businesses with access to capital, via loans that typically include: flexible repayment schemes, fee schedules that match customer income stream, and longer loan repayment terms. In this regard, access to finance needs to be made available not only to end users, but also all the way along the service chain - to organizations that help to manufacture, install and maintain the energy services.

62. There are a number of models of microcredit that can be considered for financing RET-based energy services. These include:

- *Dealer credit*: A renewable energy supplier may find it beneficial to provide financing to the end user to increase sales potential. The supplier can finance this loan programme through supplier credits or revolving credit fund especially capitalized by a third party, typically a bank.
- *Leasing/Hire purchase*: Leasing or hire purchase is common among many small and mini-credit providers. Under this arrangement, the RET-based system remains the property of the lease agent, until the full cost of the system is recovered. A lease agent may be a microfinance institution (MFI), a non-governmental organization (NGO), a renewable energy equipment supplier, a utility, or a cooperative. Leasing creates a strong incentive for the lease agent to maintain the system, while the customer is still paying off the lease. Such a model was successfully introduced in Kenya for PV SHS.
- *Fee-for-service using ESCO*: Energy service companies (ESCOs) provide energy services rather than equipment sales. An ESCO can utilize either centralized or decentralized RETs, but it is most associated with decentralized technologies that are installed at the end-user's location. An ESCO may be a private company, a cooperative, a utility, or an NGO. The ESCO retains ownership of RET-based system indefinitely, and takes the responsibility for all maintenance, repair, and replacement tasks. The end-user pays the ESCO on a fee-for-service basis. This model was introduced in Zambia for PV SHS.
- *Fee-for-Service using Concession*: Concessions are an emerging opportunity to develop rural areas with RET-based systems using primarily private sector capital. Concessions can be a way to achieve economies of scale and offset transaction costs associated with purchasing individual RET-based systems. Example of Concession is the PV-based off-grid rural electrification programme in South Africa.

63. Transactions costs are also among the key barriers to affordability of RET-based systems, because they increase the price of the systems at all stages of the delivery chain. Developing RET-based energy supply options involves high costs including technology, financing, community development and management. Therefore, reducing transaction costs will lower the price of the energy system to the end user, expand the market and increase the impact of the programme. Microfinance institutions (MFIs) can lower transaction costs through economies of scale, and by simplifying transactions and externalising costs[6].

64. Subsidies have often been used as a government policy instrument to facilitate access to energy services for low-income consumers. Lower income rural households can only benefit from access to RET-based energy services with targeted policies, including subsidies policies. In this regard, governments should implement well-targeted subsidies, the so-called "smart subsidies". Smart subsidies have the following qualities: (i) they are *well targeted*; (ii) they *support least-cost options* for service; (iii) they *encourage commercial participation by the private sector*; and (iv) they are applied to *the front-end cost*. A good example of smart subsidies is the World Bank sponsored *Uganda's Energy for Rural Transformation (ERT).*

V.2.2 Improving the policy and institutional frameworks

65. Experience in sub-Saharan Africa shows that the introduction and success of any renewable energy technology is, to a large extent, dependent on the existing government energy policy and strategies. Since the choice of technology is based on the information which rural users have about their electrification status, governments need to set out clear guidance about these plans in order to support markets for RET-based energy supply options.

66. In most countries, markets can be distorted by aid-programmes that provide RETs at subsidized prices. These programmes can undermine the existing local market players who provide services at market rates. In addition, the existing regulatory framework is often the major barrier to widespread diffusion of RET-based systems, particularly with regard to conventional energy supply options. Taxes and subsidies applied to import of RET-based system components often undermine markets. There is, therefore a need to create an enabling policy environment that helps mobilize resources and encourages private sector participation in the application and dissemination of the most promising RETs.

67. With regard to institutional arrangements, governments can play a major role in increasing the efficiency of utilities and reducing the drain on public funds, notably through restructuring their national energy production and improving the way it is regulated. Regulatory policies for renewable energy should support independent power producers (IPPs) frameworks that provide incentives and long-term stable tariffs for private power producers. However, since there is little evidence that regulators have devoted sufficient attention to providing access to poor people to date, capacity-building among regulators would be essential.

---

[6] Sustainable Energy Strategies: Materials for Decision-Makers- Chapter 7: Financing for Sustainable Energy, a UNDP Report (2000)

V.2.3 Overcoming technical barriers

68. Many projects failed in the past because of inadequate local skills and knowledge in selecting technology that is appropriate to the needs of poor people and to keep it in good running order. It is also important that the poor have access to information on the availability and use of alternative energy sources to help them make the right choice of energy services and to inform them on how to use these sources more efficiently. Training local people to install, operate and maintain energy service technology is important to ensure their reliable operation.

69. Therefore, the choice of RETs for dissemination and development in sub-Saharan Africa should take into account the existing technical knowledge and local industries. Technologies that can improve existing methods and build on already established industries are likely to be successfully disseminated. Some RET-based systems, such as wind pumps, small hydro, and improved cookstoves, can be built on local knowledge and skills, and manufactured locally, thereby creating opportunities for employment and enterprise creation. These technologies can also become self-sustainable in the long term.

V.2.4 Strategy to promoting RET-based energy services in poor rural communities

70. A new strategy to facilitating access to RET-based energy services in rural areas[7] would include:

(i) *Use of full range of "energy services"* without limiting available options to a single technical option such as PV systems;
(ii) *Use of intermediaries* who have or are able to obtain the technical and other expertise to identify and support local providers of energy services;
(iii) *Use of a wide range of service providers* by involving a wide range of suppliers including NGOs, local authorities, community groups and small and micro- enterprises (Sees);
(iv) *Provision of different categories of service* so that a wide range of consumers can receive a service at a price they can afford;
(v) *Combining financial support with technical and management support*, as experience over the past years suggest that successful support to Sees needs to go beyond the provision of credit; and
(vi) *Use of a range of financial instruments* that would include loans, partial guarantees, revolving funds, equipment leasing and "group guarantees", such as those provided by women's group.

[7]Andrew Barnett, Innovating to deliver modern energy services to poor communities in developing countries: A Background Paper (2001 version)

VI. Conclusion

71. For people living in poverty, the most pressing priority is the satisfaction of basic human needs, which includes access to food, shelter, water supply and sanitation and other services that will improve their standard of living, such as health care, education and better transport. But it is generally recognized that although energy is not a basic need, it is required as a crucial input for providing other essential human needs. The satisfaction of the basic needs and poverty alleviation efforts cannot be achieved without improving access to better energy services.

72. Access to modern energy services can contribute *directly* to poverty alleviation by (i) improving the quality of life through better lighting, access to cleaner cooking fuels and safe drinking water, etc.; and (ii) improving effective delivery of social services through ensuring reliable heating, lighting, refrigeration of vaccines and other medicines, sterilization of equipment in health centers, as well as providing lighting to schools, thereby allowing people to study at night, and improving their employment prospects. Access to modern energy services can also contribute indirectly to poverty alleviation by improving productivity and enabling income generation through improved agricultural development (irrigation, crop processing, storage and transport to market), and through non-farming employment, including micro-enterprises.

73. Access to affordable and reliable energy services can also play a crucial role in underpinning efforts to achieve the Millennium Development Goals (MDGs). The goal of halving poverty by 2015 will be achieved only if affordable and reliable energy supplies are provided to increase production, income and education. Halving hunger will require the provision of adequate energy services for more food production throughout the food chain. Increasing access to safe drinking water will require the provision of adequate energy services for pumping and boiling water. Gender equity in education cannot be achieved as long as girl children are drawn from school to collect traditional biomass fuels for family subsistence.

74. Renewable energy technologies (RETs) have the potential to help improve access to energy services for poor people living in rural areas of sub-Saharan Africa. There is a variety of technologies that can convert biomass into more convenient energy carriers, such as gaseous and liquid fuels, process heat, mechanical power or electricity, which can be used in energy-efficient conversion devices (cookstoves, electric lamps, motors, refrigerators, etc.) to provide energy services. Renewable energy sources (biomass, solar energy, wind power, and small hydropower) can be converted into the most versatile of energy carriers, electricity.

75. RET-based systems can contribute to providing improved energy services for the rural poor and alleviate poverty in sub-Saharan Africa. However, widespread diffusion of RET-based systems faces strong institutional, technical and financial barriers that need to be overcome in order to improve their contribution to poverty alleviation. One of the most challenging barriers is how to overcome the high initial cost of RET-based system. This requires the creation of innovative financing mechanisms, such as microcredit, that can provide households and small businesses with access to capital, via loans that typically include flexible repayment schemes, fee schedules that match customer income streams, and longer repayment terms.

References and bibliography

Barnett A., 2000; Energy and the Fight against Poverty

Barnett A., 2001: Innovating to deliver modern energy services to poor communities in developing countries: A Background Paper

Biswat W. K. et al, 2001; Model for empowering rural poor through renewable energy technologies in Bangladesh

DFID, 2002: Energy for the Poor: Underpinning the Millennium Development Goals

DFID, 2003: The Gender-Energy-Poverty Nexus: Finding the energy to address gender concerns to development by Joy S. Clancy, Margaret Skutsch and Simon Batchelor

Greenpeace, 2001: Power to tackle poverty: Getting renewable energy to the world's poor

GTZ-Gate, 2001: Solar Drying Technology for Food Preservation

Hankins M.. 2001: The Kenyan PV Experience

IEA, 2002: World Energy Outlook 2002: Energy and Poverty

Karekezi S. et al, 2003: Renewable Energy in Africa: Limits and Prospects

Karekezi S. et al, 2000: Renewable Energy Technologies in Africa

Karekezi S. et al, 1996: Renewable energy technologies as an option for low-carbon energy future for developing countries: case examples from Eastern and Southern Africa

Lok-Dessallien R.: Review of Poverty: Concepts and Indicators

UNDP, 1998: Human Development Report 1997: Human Development to Eradicate Poverty

UNDP, 2000: Sustainable Energy Strategies: Materials for Decision-Makers, 2000

UNDP, 2001: Choices for the Poor: Lessons from national poverty strategies

UNDP, 2001: Choices for the Poor – Part 1: Policy Issues: Analysis of Poverty

WEA, 2000: World Assessment Report: Energy and the Challenge of Sustainability

WEA, 2000: World Assessment Report – Chapter 7: Renewable energy technologies

WEA, 2000: World Assessment Report – Chapter 10: Rural energy in developing countries

WEC/FAO, 1999: The Challenge of Rural Energy Poverty in Developing Countries

World Bank, 2001: World Development Report 2000/2001: Attacking Poverty