Chapter 7
Options and Challenges

7.1 Introductory Remarks

So far the discussion has exposed energy and some of the important resources in most countries and regions of Africa and it is evidently clear that Africa is endowed with abundant energy resources, both fossil-based and renewable energy. To illustrate this fact, we look at Table 7.1 that summarises the available energy resources and Table 7.2 that gives examples of the quantities of these resources in some African countries. These two tables are but expansions of data given in Chap. 1.

Table 7.1 lists only sixteen countries out of 54 in the whole continent without including at least other ten or so countries with significant energy resources. These include; Namibia, Sudan, Benin, Republic of Congo, Chad, Zambia, Mozambique, Uganda, Ivory Coast, and Equatorial Guinea, which also have some quantities of these resources. If solar and wind were included, then most, if not all, African countries would be listed as having sufficient quantities of exploitable energy resources.

Again some countries with either oil or gas or both such as Uganda and Kenya where oil was recently discovered are not on the list (Table 7.2) because the accurate quantities of available reserves have not been determined. Ethiopia which does not have significant amount of fossil-based fuels such as oil and gas has recognized the need to generate its electricity using cleaner renewable energy sources such as solar and wind. Namibia is not endowed with fossil-based fuels either and is already planning to produce a quarter of its electricity requirement from solar energy by 2015 when a large solar power facility will have been completed. These are good steps towards sustainable energy developments and compliance with international environment protection targets. South Africa, on the other hand, has enough coal to last several years, but, in the same spirit of environmental concerns, it has planned to develop other renewable sources which by 2030 should produce at least 18,000 MW of electricity. Solar energy is almost

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Table 7.1 Examples of countries having fossil-based and other energy resources (populations figures are 2014 estimates)

Country	Population in millions	Energy resources
Libya	6.2	Oil, gas
Nigeria	178.5	Oil, gas, coal, hydro
Algeria	40	Oil, gas, coal
Angola	22	Oil, gas
DRC	69.4	Oil, gas, hydro
South Africa	53	Coal, hydro, oil, gas
Cameroon	23	Oil, gas
Tunisia	11	Oil, gas
Egypt	83.4	Oil, gas, hydro
Morocco	33.5	Oil, gas
Ghana	26.4	Oil, gas, hydro
Ethiopia	96.5	Geothermal, hydro, coal, shale oil
Zimbabwe	14.6	Geothermal, coal, hydro
Kenya	45.5	Oil, geothermal, hydro
Gabon	1.7	Oil, gas
Tanzania	50.5	Gas, geothermal, hydro

Table 7.2 Available quantities of oil and gas in some African countries (2013 estimates)

Country	Oil/million barrels	Gas/billion Cu Ft	PV/MW	Wind/MW
Libya	44,000	NA	5	
Nigeria	37,200	180,000		
Algeria	13,400	148,600		10
Angola	13,500	10,950		
Egypt	4400	85,800	5	660
Sudan	6000	3000		
DRC	3180	3000		
Gabon	2000	970		
Cameroon	200	4455		
Tunisia	430	4475	4	154
Ghana	660	800		
Morocco	100	50		1000
Equatorial Guinea	1800	1300		
Mozambique		4500		
Ethiopia			5	171
Namibia		2200	80–100	

everywhere throughout the year in Africa while wind speeds along the African coastline from the Mediterranean Sea, Atlantic Ocean, round to the Indian Ocean and up to the Red Sea are sufficiently suitable for the development of wind farms.

The highlands inside the continent also have suitable wind speeds for wind farms. A few African countries have proved the efficacy of some of these renewable energy technologies by establishing wind farms and solar energy systems. However, looking at Table 7.2, it is obvious that despite the abundance of solar and wind energies, Africa is lagging behind in their developments and applications.

It is also apparently clear that there are many challenges in making the right choices that would lead to higher level of self-sufficiency in energy. These include technical, institutional, legislative, and socio-cultural considerations and for any approach to succeed, locally available resources must be the foundation on which the plans should be based. In addition, Africa needs to get rid of resource management styles that tolerate nepotism and tribalism, which have encouraged corruption and theft of public resources.

Sadly, the huge hydro potential in the Democratic republic of Congo, which is capable of supplying electricity to the whole of Sub-Saharan Africa, has not been exploited in a region where access to electricity is still among the lowest in Africa and so is in dire need of electricity. Similarly, geothermal potential in the Great Rift Valley of Eastern Africa has not been fully tapped, except for the small quantity used in Kenya and Ethiopia.

Co-generation potential especially in the existing agro-based industries is another area that has been largely neglected in Sub-Saharan Africa where there is adequate biomass and agricultural wastes that could be used for electricity generation. In addition to these resources, Africa has other minerals such as gold, diamond, copper, uranium, etc., which can be traded to raise income for electricity generation and other development needs.

Having identified various energy resources in different regions of Africa, it is clear that Africa is blessed with substantial quantities of oil, gas, coal, solar, wind, geothermal, hydro and biomass energy potentials. These energy resources constitute the continental advantage that can be used to accelerate Africa's economic development. Chapter 6 discussed some of the energy conversion technologies as areas that pose both challenges and opportunities in African energy sector.

Experience and technical details can be sourced from elsewhere if necessary but the core resources must remain local. In this regard, renewable energies particularly solar, biomass, wind and small hydro potentials, which are fairly well distributed in Africa, would play a very crucial role as energy resources not only in the continent but also for those countries that are not endowed with conventional energy sources. As has been noted, rural settlements in the developing countries are generally not planned and are therefore randomly distributed without any consideration to the fact that there may be need to share some facilities. Every family is on its own and struggles to make the best use of whatever resource is available within easy reach. This style of living does not encourage the development of sophisticated and efficient techniques that require the concerted effort of members of the community. As a result, people tend to continue with the old traditional and often inefficient methods of meeting their needs and therefore the efforts are usually limited to the essential basic requirements. It is for this reason that rural household energy

supplies are restricted to cooking and lighting because individual families do not have the capacity to acquire suitable energy for other applications.

These features clearly point at renewable sources and decentralised systems as the most suitable energy arrangements for the rural areas. Even if power companies were to extend the national grid lines to every household in the rural areas, the cost of electricity would be too high for the people to afford at the present poverty levels. Further, maintenance and service costs would also be too high for the utility companies due to large distances that would have to be covered by the technicians to reach isolated villages. Consequently, the reliability of supply would be very low and this would erode the users' confidence in such sources of energy and force people to resort to other means of getting energy and, most likely, they would revert to the old practices. Such a trend of events cannot be generalised for all the rural areas since settlement distributions and living conditions vary from place to place and from country to country. But the fact that decentralised energy systems hold the key to rural electrification still remains. The readily available energy sources such as solar, small hydro, wind and biomass are the best choices for rural applications and they also offer the best decentralised supply technologies. However, it is important to first and foremost obtain accurate data on their distributions and potentials to facilitate proper identification of pioneer development and growth centres where they can be managed by small rural units such as households, villages, or other organised community structures. Similarly, the ownership and management responsibilities can be placed at these levels with local village chiefs and other leadership structures given the responsibility to ensure that the facilities are properly operated and regularly serviced. In doing this, the systems are likely to be sustained if the users value the services provided.

It is however important to identify suitable nucleus units where community energy facilities can be established to initially provide highly desirable services and also demonstrate the viability of such resources. The services can thereafter be extended to the surrounding communities based on demand and existence of appropriate management structure. Such core units could be schools, hospitals, and organised community centres. Participation of the communities is therefore an important prerequisite for the success of these decentralised systems. However, because of the growing population and increasing demand for energy, supply of energy by these facilities should be reviewed every few years to assess their suitability and adaptation to the changing circumstances. If for a particular area the population density has increased to a level where centralised facility can be more effective, then they can be replaced by introducing more suitable systems including extension of national grid power lines to the area. It is in this context that rural electrification can be expected to succeed and there are no better decentralised sources than solar, wind, small hydro, agro-based co-generation and biomass. All these are renewable energies with both socio-economic and environmental advantages that can give the desired and sustainable impetus for rural development.

There may be arguments against these energy resources but the fact still remains that under the present rural situation, they can be developed and used where the people live and with good possibility for community participation that is needed for

successful application and sustainability. To prepare the ground for this success, suitable socio-political environment must be established to regulate the process so that some reasonable level of quality control and safety procedures are established. This may require the introduction of new legislations and the establishment of institutional frameworks that would specifically handle rural energy development. All the new arrangements must also fit into the current energy initiatives such as the independent power production regulatory measures. In addition, there is greater need for effective coordination between national industrial energy needs and rural energy requirements. The two energy supply objectives cannot be achieved by a single provider without the risk of ignoring one and this has been the situation that has stifled past rural energy development strategies. The high concentration of industries in the major towns and their regular large payments to the utility companies are too attractive for a power distributor to consider the cumbersome management of rural energy networks.

Different but well-coordinated approaches should be used in order to succeed in both fronts and in this regard co-generation should be a rural renewable energy initiative that can link well with national energy supply network. Similarly, small hydro power generating facilities should be considered under rural energy initiatives but designed to link with national network as and when necessary. Some of these, depending on the situation, can be completely decentralised with localised supply networks while others would necessarily be limited to households, village, small organized communities and institutions. Unlike urban energy supply systems, rural energy supply requires a lot more involvement by the users because distribution is individual-centred and not "area" focussed like the urban system. The individual consumers must therefore take some responsibilities. This is one of the reasons why some level of community ownership in a participatory sense is important for the sustainability of rural energy supply systems. Small systems like photovoltaic lighting units and biogas plants, which can be owned and operated by a single household should be actively promoted by providing appropriate incentives to the users in the form of technical assistance, subsidy or tax rebates. Other incentives such as school fee waivers and subsidized medical treatment can also be considered. These are strategies that would very quickly sensitise rural communities to develop clean energy culture that would eventually move them away from reliance on raw biomass energy. The policy would also instil in people the energy conservation practices that would make significant contribution in reducing emission of greenhouse gases into the atmosphere as discussed in the previous sections of this book.

7.2 Human Resource Development

Most of the renewable energy technologies have been developed to a level at which they can satisfactorily serve the intended purposes in developing countries. Unfortunately for Africa, like any other developing region, research and

development of these technologies were done elsewhere without any meaningful participation at the local level. Most of them found it easy and less expensive to engage in the low level traditional biomass-based technologies such as charcoal and wood stove developments, which have not made any significant impact in energy use patterns. Attempts to develop and use biogas and gasification conversion processes have not worked well while the use of energy from co-generation facilities has been restricted by energy control regulations. This means that a lot of studies will have to be done to prepare the ground for proper and effective response to energy policy changes and technology transfer processes. Many renewable energy technologies particularly photovoltaic technology and large wind generators will have to be transferred into the region. Technologies that are not so complicated like solar water heaters, solar cookers (household and institutional), small hydro, and wind machines should be developed by local personnel using locally available materials. Local skills should be developed and used in all installations and maintenance of renewable energy technologies. In order to achieve this, it is necessary to instil some energy culture in people so that the society becomes conscious of how to use and conserve energy from different sources. It is also necessary to develop the critical mass of human resources, which in this context includes manpower, skills, knowledge, and accumulated experience in dealing with all aspects of renewable energy technologies at all levels from craftsmanship to skilled applied scientists who can spearhead further developments and modifications suitable for local conditions. These people must be deployed in positions relevant to their training backgrounds. Placing skilled personnel in positions where they can effectively apply their professional knowledge is very crucial in any development process.

This is perhaps one area where most African leaders have shot down renewable energy initiatives as they use political interests and ethnic considerations in appointing qualified people to positions of influence. The result of this is that a lot of people are given positions in which they do not use the professional skills acquired during the many years of training. In many instances, the morale and work ethics are eroded by appointing a relatively less qualified person as the head of more qualified and experienced colleagues. These practices are more effective in retarding technological development than any form of corruption and any wise leader must avoid them completely. Development in the region has severely suffered from this practice particularly in Sub-Saharan Africa where it has been the norm in government ministries and departments. Consequently, the government receives inappropriate advices that lead to wastage of scarce resources in addressing misplaced priorities to the extent that even general repair work and routine maintenance become expensive and difficult to carry out.

One example of this vice is the small hydro facilities that were introduced in some countries by colonial settlers. A good number of such facilities could not continue operating because of the so-called lack of qualified personnel to maintain them. A study carried out in Uganda confirmed this at a time when there were many highly qualified Ugandans in various branches of engineering (mechanical, electrical, civil, etc.,) working in various government offices. Thus, human resource

development does not mean beginning to train people on renewable energy technologies today but starting with proper assessment and meaningful deployment of those already available, and they are many. Since the 1970s quite a significant number of many Africans have been trained on various types of renewable energy technologies and therefore a very effective taskforce for the development of renewable energy technologies can be very quickly constituted.

In addition to this, it is important to set up at least one centre of excellence in research and development of renewable energy technologies in each country. Such centres should be primarily charged with the responsibility of carrying out research and development work on renewable energies but should also be in a position to provide data and investment guidelines on renewable energies. Some suggestions on how such centres can be established with the prevailing limited resources are discussed in the next section. To build the capacity for the centres and bring them to effective productive levels, there would be need to fine-tune existing renewable energy technology courses in institutions of higher learning in the region. Renewable energy technologies have been fairly well developed and therefore the centres should not waste resources trying to re-invent the wheel but should focus on resource identification and technology adaptation to suit local socio-economic and resource accessibility circumstances. This task is important and enormous and should not be left to the leadership of such centres alone to decide. The activities must address national energy development goals as set out in each national development plan and this means that they should have adequate annual budget allocation in which disbursement of funds is based on the progress made in achieving the set goals. In this regard contract research and technology developments, with measurable achievements, should form the basis of the activities in these centres and government ministries and departments should be the main sources of these contracts. These activities should be linked with those of the private sector particularly non-governmental organizations at the dissemination stages.

All these will call for the establishment of suitable regulatory framework to ensure that procedures and requirements are followed and fulfilled and that adequate resources in both manpower and facilities are made available for this. The efforts of many non-governmental organizations in the 1980s and 1990s on the development of renewable energy technologies would today have made a greater impact in the region than they did if they had been given organized institutional backing beyond mere lukewarm non-interference attitude. Theoretical policy changes that are prominently presented in official documents without the necessary structures on the ground will not lead to the solutions of rural energy supply problems. There is need to do more in the form of institutional arrangements that would effectively link the demand side with supply strategies and use decentralised renewable energy programmes as the principal means to satisfy the requirements.

Conditions for environmental protection could be used as indicators for choosing the method and source for energy production so that independent power suppliers are guided accordingly. This is not a new concept as it has been used by many developed nations to encourage independent power producers to develop solar and wind energy systems. For example, Germany, which is one of the world's leading

nations in the use of wind energy is also very conscious and strict on environmental protection laws and regulations and uses these principles through appropriate legislation and institutional arrangements, to encourage independent power producers to use renewable energy sources. A similar institutional approach in Africa would not only encourage independent power producers to turn to renewable energies but would also encourage more active local participation in the development of these technologies.

Existing energy related organizations should be strengthened and used as energy development focal points. In Africa, regional approaches to energy issues preferably with coordination of regional bodies such as ECOWAS in West Africa, EAC in East African and various regional Power Pools should be used to improve the region's energy infrastructure. Again, these institutions would require suitably qualified personnel who can achieve the objectives. The linkages and experiences gained by non-governmental organizations can serve as useful tools for better networking and information exchange on renewable energy technologies. When compiling an inventory for renewable energy resources, it is important to include detailed information on institutions and agencies involved in energy development issues such as training, dissemination, energy technologies, energy policy studies as well as their potential and socio-cultural constraints. Such information would encourage exchange of experiences, research collaboration, dissemination, and training capabilities on a regional basis so that larger markets and standardization procedures are developed. This is expected to attract both local and foreign investors and facilitate cost-effective exploitation of the region's huge renewable energy resources.

Difficulties in financing renewable energy initiatives have been a major inhibiting factor in the development and application of renewable energies. It is therefore necessary to establish easy and flexible financing mechanisms specifically for renewable energy technologies. There are a number of ways in which this could be achieved but it would be important for such structures to include credit schemes, higher taxes on fossil fuels, and attractive tax rebates or wavers on renewable energies. It is also worth considering the establishment of national fund for renewable energy developments. There have been, in many African countries, fuel taxes, which are paid at the petrol or gas stations whenever one buys fuel. A good fraction of this money should go into the development of local energy resources so that the tax is justified by using it in a way that enhances patriotism. This could be done through contributions to the renewable energy fund or by putting it into a revolving fund to facilitate easy and flexible financing of renewable energy programmes including support to sympathetic credit institutions. The process of administering such funds involves accurate assessment of the need and circumstances of the applicants and therefore would be more effectively handled by local institutions that understand both cultural and social factors that have implications on ability to respond to loan repayment obligation. Financing arrangements are very sensitive matters that, if not well managed, can kill even the best initiatives and so the regulatory mechanisms for controlling this aspect must be effective and just. Obviously there would be need to establish or reorganize existing institutions that

would devote adequate time and resources, in a coordinated framework, in order to satisfy both renewable energy developers and users. It is through all-round coordinated and concerted efforts that the success of renewable energy technologies can be realized in Africa. The challenge is therefore focusing on three major areas: (1) formulation of suitable renewable energy policies that would encourage the development of renewable energy technologies; (2) establishment of institutional framework for effective monitoring and coordination of renewable energy activities including the enforcement of quality control measures; and (3) constitution of easy and flexible financing mechanisms to provide the impetus required in the whole process. These should be viewed and accomplished in the background of well-documented data on all aspects of renewable energies including national and regional distributions, economic viabilities, potentials and possibilities of modular developments. It is expected that the local human resources would be developed in all these areas and effectively deployed appropriately. Many of these issues have not been properly addressed because there is not enough skilled manpower that could formulate suitable and implementable policies for the rural conditions. Human resource development must therefore be seen in its entirety to ensure that every initiative gets the desired support from all relevant sectors.

7.3 Biomass: The Challenges

Although various authorities in each African country have not given biomass the recognition it deserves, it is however widely accepted that it plays an important role in the developing countries in general, and that its use is not by choice but a survival means for the poor rural communities. It is a reliable source of energy that does not have to be stockpiled in large quantities as it can be obtained on a daily basis. In spite of its importance, biomass has generally been ignored in official energy planning strategies and yet its use is associated with environmental problems, whose impacts affect the whole nation. Furthermore, it can be depleted if its regeneration is not carefully planned and this would have far reaching consequences on the environment such as soil degradation and changes in weather conditions that would have adverse effects on agriculture. There have been a number of activities on agro-forestry and tree planting in general but not specifically for energy purposes and in many cases the ministries of energy in the region were not actively involved. The evidence that biomass use far exceeds its natural regeneration is common knowledge and so is the undesirable impact of its careless and unplanned use. Biomass is also used for construction and it is also destroyed to give way for new settlements and agricultural land. All these activities are increasing the demand for it while its supply is diminishing. This is definitely a very dangerous trend.

In addition, its use is a great health hazard to the women and children who use it for cooking. Burning of biomass, particularly firewood and charcoal, is associated with emissions of carbon dioxide and the toxic carbon monoxide. Users of these

fuels are therefore regularly exposed to the risks of developing diseases that affect respiratory system. The common practice when these fuels are used indoors into simply let the smoke find its own way out of the room. There is virtually no attempt to vent the smoke out of the room. Indoor air pollution from smoke is suspected to be the major cause of respiratory diseases that kill a large number of women and children in Africa. In addition to this, the emitted carbon dioxide and carbon monoxide are well known greenhouse gases that cause undesirable increase of global warming.

The other concern regarding the use of biomass is the rate at which deforestation and land degradation is taking place. In recent years, the escalating oil and electricity prices and their intermittent supply in many areas encouraged many institutions to turn to wood and charcoal. In Kenya alone, more than two million tons of fuel wood is consumed per year. This is based on a modest estimate of about two kg of fuel wood per household per day. Large institutions like hospitals and colleges use between 5 and 10 tons of fuel wood per month and this raises the estimated figure by more than 100,000 tons/year further increasing the total annual fuel wood consumption in the country. Regeneration is difficult to accurately assess, but it is obvious that it does not match consumption rate and therefore there will be an imminent fuel wood crisis if nothing is done to slow down consumption rate and to intensify regeneration activities. It is generally accepted that, for the purposes of comparing consumption rate against existing wood reserve, ten tons of fuel wood is equivalent to clearing one hectare of forest, but this depends on the forest density, which is very low in many parts of Africa. The unfortunate situation is that the already visible land degradation and deforestation in the region have not been given adequate attention from the energy point of view. They are normally assumed to be the responsibilities of the ministries in charge of agriculture and natural resources while energy-related health hazards associated with fuel wood use are handled by the ministry of health. Under this arrangement, it is very difficult to implement preventive measures because energy consumers will continue with their practices as if these matters do not concern them.

There are, however, a number of options in addressing the problems associated with biomass energy use. Developing an energy-sensitive culture in which energy conservation and application risks are well understood by the society is the foundation on which all energy issues should be based. Alongside this development should be the introduction of efficient methods of converting energy from one form to another especially biomass conversion processes as well as promoting use of efficient stoves. Improved charcoal kilns should be more aggressively pursued and once the technology is widely understood, the use of inefficient techniques should be banned. But first, the organization of charcoal production must be improved to a level where use of these improved conversion technologies can be effectively practiced. Tested and successful kilns such as the Katugo and Mark V in Uganda and the oil drum in Kenya and any other traditional kiln in other regions should be carefully re-examined and their improved versions promoted. The stoves that use charcoal and wood should be comprehensively re-analysed with a view to promoting efficient models. Special attention should be given to those stoves that have

had a measure of success in the region such as the Kenyan Ceramic Jiko (KCJ) and the maendeleo wood stoves. These stoves have proved that they have significant desirable advantages such as less consumption of fuel and achievement of more complete combustion of fuel than the traditional stoves. Similarly, improved institutional stoves should be seriously considered at national levels and the governments should assist in their promotion, dissemination and use, particularly in government rural institutions. At the same time, the governments should support efforts to develop stoves and devices that can use other types of energies especially solar and fuel briquettes. In this regard, use of biomass fuels should in future be restricted to high temperature heat requirements, which cannot be achieved through alternative rural energy sources. Low temperature needs such as water and space heating should be achieved by other means and not from biomass fuels.

At a larger industrial scale, biomass is an important energy for co-generation and also for biogas and producer gas production. Of these applications, only producer gas may require wood. The other processes make use of animal wastes and agricultural residues and so the risk of running short of supply is very low. The cows, chicken, and other animals will always make their wastes available for a biogas plant while for co-generation by sugar millers, bagasse is the main waste and is always available in large quantities to generate electricity for the industry and the surrounding communities. The full regeneration cycle of sugarcane, which produces bagasse, is between 15 and 20 months and given that the milling capacity of the factory is known, it is possible to determine the size of the sugarcane farm that can adequately and continuously serve the factory for both sugar milling and co-generation activities. Sugar milling enterprises are some of the agro-based industries with the lowest failure risks and this has been demonstrated in some African countries where despite civil wars and adverse direct political interference that forced many industries to close down, sugar millers survived. There are many cases where they were mismanaged and plundered but they still went through all these successfully—a proof that these are the types of industries that are suitable for the unpredictable African political conditions.

With the additional economic empowerment in co-generation and role as independent power producers, these establishments are sure to create a significant economic impact in the rural areas and enable the communities to broaden their energy options beyond biomass. At least the few rural elite will quickly move from biomass to electricity, LPG and kerosene for cooking. The improvement of the economic status of the rural people will enable them to acquire the capability of switching to cleaner modern energy technologies and increase artisanal job opportunities. The economies of many African states depend mainly on agricultural outputs such as coffee, sugarcane, tea, pyrethrum, cloves, cocoa, cereals that double as staple foods as well. Co-generation is an industrial activity that is economically viable for agro-based industries especially sugar processing industries, which have large amounts of industrial waste in the form of sugar cane bagasse. Thus co-generation is a rural-based industrial undertaking that has the highest potential for improving rural electrification. Its advantages include a wide range of choices regarding the location of the factory that automatically leads to the spontaneous

development of new human settlements and vibrant trading centres that create income generating opportunities for the local people. Such new settlements can serve as the nucleation centres for rural electrification. With the two industrial outputs of the processed goods and electricity, the companies are sure to make profits at lower prices of their products and the factory need not be too large. Local investors would therefore be encouraged to establish medium or even small-scale agro-processing industries with commercial power generation components. The diversification of electricity generation using various renewable energy sources would create opportunities for broad-based rural energy development programmes.

Production of producer gas at commercial level mainly for decentralized rural electricity generation for localized power supply to villages and market centres will also improve rural economic status of the people and uplift their lifestyle. Independent power producers, particularly indigenous groups or companies should be encouraged to participate in the development and promotion of such enterprises. Producer gas technology requires too much attention and specialized knowledge to succeed at household level and so focal units should be, among others, organized villages and market centres where the economic scale of the system is viable. The best focal units would be schools, hospitals and any other organized rural entities. Biogas, on the other hand, is a household energy technology where its management and use are a family concern. The possibility of mismanagement and irresponsible use increase with the number of people using a common unit and therefore the responsibility of managing and using biogas plant should be kept at a family level. Statistical data collected in East Africa indicate that more communal biogas plants are generally poorly managed than those owned by individual families. Biogas plants managed by institutions have also performed relatively better than the communal ones. There are also indications that portable biogas that can be used by those who do not have their own plants would be more attractive and would enable the governments to reduce importation of liquefied petroleum gas (LPG) in the region.

Technologies that would make this possible should form part of the energy training programmes in institutions of higher learning particularly those institutions which are already engaged in various aspects of animal production such as Sokoine University of Agriculture in Tanzania and Egerton University in Kenya. Other government institutions, which have animal and poultry farms, should be the first to establish biogas plants for both demonstration and normal application purposes. Waste treatment lagoons in municipalities, rural industrial establishments, hospitals, etc., would be more useful if modified to act as biogas plants to provide energy to those living close to them. Such biogas production methods have been successfully applied in many parts of the world including the United States of America. One advantage of doing this is that it also helps in ridding the surrounding of the strong smell from these usually exposed lagoons. The actions on the waste by microorganisms that participate in the production of the gas results into final stabilized slurry with soft smell and good soil conditioning qualities.

Socio-cultural bottlenecks regarding the use of human waste should be identified and appropriate measures put in place to overcome them. Another aspect of

biomass energy, which requires considerable attention, is the production of fuel briquettes from agricultural residues and other biomass wastes. Although the technology of producing fuel briquettes is known and has been used in the region, there has not been a serious attempt to develop special stoves that can efficiently use this form of fuel. A number of people have used ordinary wood or charcoal stoves to burn fuel briquettes while such stoves are not suitable for briquettes and so their poor performance discouraged many users. The development of fuel briquette stoves is a task that should be given more attention by energy specialists and research institutions. The absence of such stoves has hampered the wide scale use of the already existing fuel briquette machines. This is just one good example of how poorly renewable energy development has been coordinated in the region because briquette machines should have been introduced together with some prototype stoves but it appears that the machines were promoted in isolation and so people did not understand their importance. At some stage, some unfocussed proposals were made about the stove but there was no concrete research and development work done on it and the idea faded away as quietly as it came. There is need to formulate an integrated approach in the development of renewable energy strategies for Africa in order to find the right mixture of approaches that would produce the best result.

It is a fact that the position of biomass as an important energy source will continue for many years to come and therefore ways of efficient use, conservation, and regeneration should be considered and indeed included in all rural energy planning processes. It is also true that there are a variety of biomass wastes that are not being used as energy sources. Their application should be developed to an economically attractive level for the rural situations where they are abundantly available. Some of these wastes are regarded as environmental pollutants when they could be used to provide the much-needed heat energy. While advocating for improved and attractive use of biomass fuels, it should always be remembered that the consumption of biomass is associated with emissions of carbon dioxide, which is one of the most effective greenhouse gases. Therefore all biomass applications should give due considerations to the environmental impacts of using it as fuel and appropriate measures incorporated to address this. The situation, at present and in the foreseeable future, is that the use of biomass as a major energy source for the rural communities will continue and therefore it is unthinkable to neglect it in the planning and development of energy resources.

African energy policy makers and planners must directly address it and endeavour to put in place institutional, financial and consumption strategies that can effectively and efficiently guide its sustainable use. To achieve this, it will be necessary to develop and promote other renewable energy resources in order to ease the pressure on biomass. In this regard, it is important to note that much of the biomass energy is for heat requirements and not electricity or lighting and so the efforts to ease the pressure on biomass should first and foremost consider rurally affordable renewable heat sources. If this heat is to be obtained from electricity, it must be almost as cheap as biomass fuel and the payment terms must be easy and based on consumption and not anything else that would raise the cost.

The other alternative is to improve the economic status of the rural population to a level where they can afford more expensive energies. This is a task that cannot be achieved overnight and will take several decades. Whatever the choice, biomass regeneration efforts must be intensified and addressed through appropriate programmes that would promote reforestation and agro-forestry activities. This means that nationwide culture of tree planting should be revitalized and balanced against other land-use patterns especially those that arise due to increased population pressure. Experience gained in previous tree planting programmes should be used in making the right choices of tree species that would not interfere with other vital land use activities such as agriculture and livestock production.

Two other aspects of biomass energy that might in the near future play key roles in the transport sector are power alcohol and bio-diesel. Global petroleum politics is getting more and more interesting and is apparently the source of modern international conflicts. Nations are already getting concerned about access to oil products as global reserves continue to decrease and while the demand is going up. This situation should be of grave concern to the developing countries, which have neither the gun nor the money to secure oil supply. The survival of such countries may well be determined by their own ability to use appropriate technologies to convert biomass materials into liquid fuels that can be used in industrial and transport sectors. In East Africa, Kenya has had some experience in power alcohol production and should strive to remove the bottlenecks associated with its production in order to make it an economically viable energy source. As for bio-diesel, many African states have no experience with its use or production but the potential for producing bio-diesel crops exist. This will however require adequate investment in relevant research and development to establish the characteristics of suitable crops and efficient oil extraction methods.

7.4 Solar Energy Applications: The Constraints

In general, household energy requirements, rural or urban, are for high temperature heat and lighting. Household appliances and home entertainment are the pleasures of those who can afford energy beyond heating and lighting needs. Home entertainment however, has more energy source options (in the form of dry cells and lead acid batteries) than lighting or heating. Both these needs can be met through photovoltaic and thermal conversions of solar energy into electricity and heat respectively. These two processes can be achieved independently using different specific techniques and this is a characteristic of sunlight that makes it an important energy resource for the rural situation in which two different sources of energy (wood and kerosene) are normally used for cooking and lighting. Indeed a few rural families are already using solar energy for lighting and there is also another small number using solar cookers.

The biggest constraint in the application of solar energy is that it is available only during daytime and yet energy requirement is more critical during the night.

Suitable deep discharge batteries are readily available but they substantially increase the cost of solar photovoltaic systems because they are used together with additional system components such as charge controllers. The applications of photovoltaic solar systems are therefore limited to middle and high income groups who can afford to buy them. One 50 W panel, which can provide lights for a family of 4–6 people living in a four-roomed house costs about US$ 200, which comes to about US$ 400 together with the basic components like battery, charge controller, light bulbs, cables and the necessary circuit components. Over 90 % of the rural population in Sub-Saharan Africa have an average monthly income of less than US $ 50 and cannot afford to buy the systems unless some easy and flexible payment arrangements are provided. The region lacks suitable financing mechanisms such as hire purchase, loans and subsidies through which the low income groups can afford to purchase solar lighting systems. A few financial institutions that have provided credit facilities were faced with problems and costs of tracing defaulters and had to withdraw the service. Existing financial institutions therefore are not willing to get involved in short or long term financial arrangements with individuals whose occupations are not clearly defined. The problem is also compounded by the fact that the majority of the rural population do not have legally bound and credible employers through whom they can repay loans and credits.

Another discouraging factor is the instability and irregularity of income for most people in the rural areas due to the temporary nature of their employments. Rural establishments such as sugar factories, hospitals, and schools take advantage of the high rate of rural unemployment to engage workers on temporary and casual terms with very low wages. The low income and unstable employment situation make it very difficult to find slow-moving items in the local market particularly the more expensive and non-essential goods. Consequently, renewable energy devices such as solar photovoltaic panels are not readily available in the rural markets. Most PV stockists are operating in large cities and towns and so are far removed from the typical rural population, and indeed, many of the people who are already using PV systems are those who are fairly well informed or whose relatives are familiar with the technology. So there are two factors that inhibit the use of solar PV systems. One is the price which many people cannot afford under single payment terms even though, in the long run, it turns out to be almost comparable to other sources that are considered to be cheap. The second one is lack of information on how to correctly use a PV system within its own technical limits. A number of people have been disappointed by PV systems because of incorrect use that overloads the system to the extent that power is exhausted too fast making it unlikely to recharge to full capacity the following day. Often the system is also used during daytime and so denying the battery the energy for full recharge.

A system thus used would not satisfy the demands of the user. It is therefore necessary to educate people to understand that a PV system cannot be used in the same way national grid electricity is used. People must understand the various reasons for energy conservation particularly the prudent use of renewable energies. The location of supply points and unavailability of technically qualified personnel to give the correct information on application also, to some extent, limits the use of

PV systems. Surprisingly, even PV systems that were installed in institutions have also been misused and many of them are no longer operational. The various non-governmental organizations that promoted renewable energy technologies in the region considered PV systems as a purely business concern and therefore did not carry out any organized promotional activities such as proper application procedures. The commercial PV dealers who were expected to promote their use also did nothing to let people know about their use. Incidentally, even international development agencies that supported local non-governmental organizations were very hesitant in supporting the dissemination of PV systems. They instead chose to support wood energy technologies especially those that focused on charcoal and wood stove developments. The logical policy would have been to support viable initiatives that would reduce the pressure on biomass and fossil fuels and solar energy provided the best opportunity for this. Admittedly, the marketing of PV systems in the region is reasonably developed but they are considered as slow moving items and therefore are not stocked in large quantities.

Given the past experience and the knowledge on existing drawbacks in various energy systems, non-governmental organization are now well placed to conduct effective information dissemination on PV systems while at the same time setting up demonstration units in strategic centres such as schools, rural grocery stores, etc. It is not expected that the price of PV systems will drop to affordable levels for the rural peoples in the near future and therefore deliberate efforts must be made to establish infrastructure for easy and flexible financing systems as the basis for widespread application of PV systems. This is an important prerequisite for the success of PV systems applications in the rural areas and it demands going down to the bottom of the community to deal directly with individual users. Cooperative societies would be in a better position to provide suitable financing programmes but most of them have failed to meet the expectations of members and are struggling to survive. Furthermore, memberships of cooperative societies are open to those who have regular monthly incomes and whose employers can manage the check-off loan repayment system for the society. The majority of the rural population do not have regular incomes and are generally engaged in some sort of vague and weak self-employment—a condition that is not catered for by cooperative societies.

Above the community level, national governments have not given solar energy sufficient support to compete favourably with other energy resources. Great attention and huge foreign currency and budgetary allocations are effectively given to oil and large centralized power generation facilities that benefit less than 25 % of the total population and almost nothing is given to the development of renewable energy technologies that would benefit everybody. The examples of this are abound not just in Africa but also in many developing countries. For economic reasons, the action may be right but it needs to be balanced with the people's energy supply aspirations. This is a remarkably great contrast to what is happening in the developed economies where there are wider energy options but still they put a lot of emphasis on renewable energies. In these countries, significant support is given to both research and application of renewable energy technologies. The support includes tax rebates, attractive energy buying price from independent power

producers using renewable resources, which in effect means subsidizing renewable energies, and significant renewable energy research grants to research institutions including universities. There are also scholarships available for those who wish to study renewable energy technologies at postgraduate levels. These are some of the approaches that should be considered in Africa in addition to institutional arrangements. It is not right to import solar energy conversion devices when the capacity can be developed to locally produce them. Africa receives more solar radiation than those countries that supply PV systems to the region and it is possible to correct this anomaly simply by shifting the emphasis to renewable energies.

As mentioned earlier, solar energy has another attractive aspect, that is, it can be converted directly into heat, which is another common form of energy in great demand. There are two levels at which this can be applied: the low and high temperature applications. Low temperature applications include water heating, space heating, and drying of agricultural products in order to prolong their storage life. The technologies for these applications are very simple and quite a good number of them have been developed in Africa and are in use. However, low temperature applications are not priority requirements as people can do without such heating devices by using open air sun drying. The climatic conditions in the region do not demand regular space or water heating except in a few highland regions where night temperatures can go down as low as 10 °C. But such areas normally have abundant woody biomass for general heating purposes. Furthermore, water heaters are not suitable for rural use because they require pressurized water supply source that can force water to flow through the heater located on the roof of the building. More than 90 % of the rural houses are not supplied with pressurized piped water. People normally fetch water from nearby streams, rivers, shallow wells, or springs using portable water containers. Most solar water heaters that are in use in the region are installed in the cities and large towns where pressurized piped water facilities are available. Therefore the fact that these technologies are not used widely in the region is not a cause for concern since the rural living circumstances are not suitable for their application.

The second level is the high temperature application, which is mainly for cooking and water boiling. Most water sources are contaminated and therefore drinking water must be boiled to avoid water-borne diseases. These are the two main areas that consume a lot of biomass energy in the rural areas and so the use of solar energy to meet these needs would be a great relief on biomass. Solar cookers have been developed in the region and various designs are in use. However, the majority of the people have not been sensitized enough to appreciate this source of energy and exiting technologies for harnessing it. The available solar cookers are not as expensive as other solar devices and therefore financing should not be an issue since most rural people can afford to acquire them. So far solar cooker production centres are very few and demonstrations are usually done in scattered isolated places so that most people have remained unaware of this alternative way of cooking. The second constraint is that cooking during daytime is an activity that people would like to conduct quickly and at a particular interval of time between more pressing daily responsibilities. Night cooking is also done quickly in the early

part of the night to save on energy for lighting and also to have more time to rest and therefore a fast-cooking device is desirable. Solar cookers are generally slow and the availability of direct sunlight when needed is not assured. Night application of solar heat is currently not viable since effective high temperature storage systems are lacking. These characteristics and lack of energy control have inhibited their wide scale use in the region. In addition, using them require too much attention as they have to be regularly moved to face the sun all the time in order to constantly receive maximum direct sunlight. Some of their designs such as the more efficient ones that use parabolic reflectors to concentrate sunlight on to the pot are not convenient to use, particularly for preparing some traditional foods. There is therefore need to carry out more educational and promotional activities on them and also encourage further research on user-friendly designs and materials with high thermal conversion efficiencies.

These improvements should be conducted alongside training programmes that would enable existing local stove manufacturers to include solar cookers as one of their products. Thus there is still a lot that needs to be done on solar cookers before they can make any significant impact on rural energy scene. In general, for the conversion of solar radiation into high temperature heat the challenge is to come up with suitable designs that can meet the traditional cooking practices. The technology itself is simple and has proved that the devices can achieve sufficient high temperatures so there is no problem with the technology itself. On the other hand, conversion of sunlight into electricity is more complicated since it requires the development of suitable semiconductor materials that can be used to make solar cells. The solar cell manufacturing technique, from raw material processing to actual cell production requires specialized knowledge and use of high precision equipment. With committed support from the national governments, the region can develop the required technical skills and acquire the equipment to produce solar cells locally.

The situation outlined above clearly indicates that solar energy constraints fall into the following four areas:

- Awareness: Many people in Sub-Saharan Africa including policy makers are not aware of the potential benefits of solar energy systems and so there has neither been any attempt to provide extension services nor promotion campaigns in the public sector. All these have been relegated to the private sector, which is more concerned about making profit than spending on awareness campaigns.
- Affordability: Acquisition of solar systems needs large capital that most people in the rural areas do not readily possess and there are no financing mechanisms in the rural areas for it.
- Standard of solar system components: Some solar energy components available in the market are of low quality due to lack of enforceable standards. This, in addition to their high costs, has discouraged potential users.
- Technical capability: Poor installation and maintenance done by untrained technicians result into malfunctions that lead to disillusionment and loss of confidence in the systems.

Solar energy promotion in the region must consider ways of removing these constraints.

7.5 Wind Energy Challenges

Wind energy like hydropower is not easy to efficiently convert into heat unless it is first converted into electricity through a generator. But it is quite suitable for performing mechanical work such as water pumping or grain grinding. Although wind is available everywhere, its strength varies with time and from location to location. The success of its exploitation is therefore highly site specific so that the study of wind conditions for the site must be carried out over a long period of time before a suitable machine can be installed. In addition to this the machine must be designed for the intended function. For water pumping, high torque is required to turn the blades so that the pump receives enough energy to move through all its mechanical linkages. If the machine is to be used for electricity generation then high-speed machines are required. Thus it is important to match wind turbine to the prevailing wind regime at the selected site. Failure to do this can result into inefficient operation of the machine. The diurnal and seasonal variations of wind speeds at a given location also mean that the machine will not operate all the time. Electricity from a wind generator without storage facility is therefore unreliable but wind is still a better alternative than solar because it can operate day and night. For water pumping, the intermittent operation may not be a serious drawback since the water is pumped to a storage tank from where it is drawn only when needed. However, knowledge of wind regimes, regular up-dates of this information and its availability to both policy makers and energy experts in the whole region are important prerequisites for wind energy development.

Wind pump technology is relatively simpler than wind generator and there is adequate local expertise in Africa to produce and manage them. The problem at the moment is that the demand for wind pumps is very low and therefore the manufacturers tend to produce them on order. This is partly due to the high cost of the machines and partly due to limited use of groundwater, the long distance from water points and land ownership issues. The use of wind generators is even more limited and there are no well-established local manufacturers and so there is need to aggressively develop the capacity to design, construct and install wind generators of different sizes and for various applications.

The polytechnics and institutes of technologies should have more practical approach to the development of appropriate energy devices particularly wind, solar and hydropower conversion machines. People living in the developing countries quickly get into new ideas by copying examples and so these institutions must lead by producing and using these devices for people to develop confidence in them. If necessary, an authority should be established to ensure that these technologies are developed and, first and foremost, used by the same institutions. This is one way of developing new technologies and promoting their application at the same time and

it goes down well with the African customs, which believe that a visitor would be easily encouraged to eat your food if you are also eating it. The present institutes of technologies and polytechnics should be strengthened and refocused to effectively pursue their original mandates, which included design and fabrication of energy devices. Practical use of the technologies they develop should also be part of their mandate.

Their capacities with respect to qualified staff and well-equipped workshops should be the first priority in all technical institutions in the region. To provide incentives and attract dynamic students to these institutions, it may be necessary to expand opportunities for skill development so that technically smart students can develop their capacities beyond artisanal level. The need to do this was recognized many years ago and indeed the establishment of universities of technologies was proposed but unfortunately, regional and ethnic politics allowed such universities to revert back to normal traditional university disciplines and completely abandoned the original mandate. Thus, proper management of and commitment to relevant educational and training systems would enable the region to adequately address technology development issues so that such simple energy technologies like wind turbines, hydro turbines, solar energy conversion and other related devices can be locally produced and promoted.

Thus capacity building for home-grown technologies is the immediate step that should be taken by African countries if any significant step is to be made in technology development in general. It is through human resource development for renewable energy technologies that technicians, technologists and engineers can be produced to sustain any desired renewable energy programmes. Many of the renewable energy projects in Sub-Saharan Africa were managed by expatriates through donor-funded programmes and most of them could not be maintained after the experts left. This is an expensive experience that should be avoided in any future renewable energy programmes.

Medium and high income groups owning properties in the rural areas should also be encouraged to use renewable energy technologies even though they can afford the readily available but equally expensive energy resources. But this can only succeed if security of supply is assured and the supply is reasonably priced to attract the consumers. In this regard it is important to address the following constraints facing dissemination of wind energy technologies:

- High capital cost that makes wind energy less attractive compared to oil-powered generators;
- Inadequate data on wind regimes in the region;
- Limited after-sales service;
- Lack of awareness about the environmental and economic benefits of wind technology;
- Lack of enforceable standards to guarantee quality; and
- Lack of user friendly credit schemes and financing mechanisms.

7.6 Small Hydropower Systems

Large hydropower potentials in Africa have not been fully exploited because such developments are proving to be more and more expensive for the regional economies to absorb. For example, cases are known where some countries have stopped or avoided the development of some hydropower stations because the projects could not meet the least cost development criteria. It has been claimed that the cost of electricity generated from such projects, if implemented, would be higher than the current cost of electricity from other hydropower facilities. Sometimes such decisions are made when the government concerned had already spent some substantial amount of money on it. Such wastage of limited financial resources can be avoided if power development policies switched from large to small hydroelectric power development.

Africa has many permanent rivers whose volume flow rates are not sufficient for large hydropower stations but on which small hydroelectricity facilities can be established at affordable costs. Many sites suitable for this purpose have been identified and there are many others, fairly well distributed in the region, for which feasibility studies have not been done. The studies that have been done on the known sites were conducted by NGOs, environmentalists and individual researchers but the governments that are expected to have detailed information on these for prospective investors have not given this option some serious considerations. It is true that large and medium hydropower stations have given the region most of her electric energy—an energy form that is undoubtedly clean. However, times are changing and there are new issues that must be considered in developing more of such technologies.

The potential still exists but, as has been demonstrated by the Kenyan example and the Bujagali conflict in Uganda, the construction of large hydro dams for electricity generation is too expensive and involves a whole series of environmental questions. Some of these environmental considerations recognize the need to preserve some of these rivers for ecological, cultural, and biodiversity reasons. Obviously the alternatives to large hydropower technologies are many but most of them too have their environmental drawbacks and therefore energy technologies that can be appropriately scaled to avoid adverse impacts on the environment must be considered. So it would be unreasonable to argue for total exclusion of hydropower development because there are hydro technologies that can be used within reasonable environmental and ecological guidelines and small hydropower systems provide the best opportunity for this. Although the management of large state controlled hydro schemes suppressed the real demand for electricity through un-friendly policies, they have shown that they are not viable businesses as evidenced by their poor performance resulting into huge losses. Recent reforms are expected to correct this but there are indications that total privatisation of many of these utilities may not be possible since there are national security issues to be considered. It is therefore unlikely that opportunity for private sector in African electricity supply will go beyond the present constraints. The only ray of light in

this situation is seen in the development of mini hydro schemes. Better still, there are wide range of choices of small hydro technologies that can suit different river flow regimes. Some of these include low head, high head and free flow small hydro machines that can be used with minimal environmental impact. They also offer great advantages such as flexibility, potential to keep electricity cost low and socio-cultural acceptability. In addition, they are cheap to install and manage and can sufficiently meet the local needs within a simple distribution system.

The immediate priority is to identify locations of small hydro potential sites that are suitably close to active rural agro-based commercial enterprises such as coffee and tea processing centres, grain and milk collection points, and fish-landing beaches. Schools, health centres, and rural administrative centres should also benefit from such small hydropower systems. The major costs of small hydro machines are associated with the equipment itself particularly if imported. Every effort should be made to reduce the cost of the equipment and this can only be done if they are made locally. Local engineering farms, research, and development institutions should be encouraged to produce these machines by giving them appropriate incentives in the form of tax rebates, financial support for design and development costs and local market guarantee. Besides technical considerations, it is necessary, in general, to consider a broad range of issues in order to develop and successfully manage hydropower systems. Some information that would form the basis of these considerations are: need for power in an area; existing methods for meeting those needs; suitable energy mix for the prevailing circumstances of the people; environmental impacts of present and future methods of energy supply; the economics of possible energy choices; and priorities in technology and resource development. All these would require good planning and effective implementation strategies and not "Do It Yourself" attitude with which the authorities have treated rural energy supply in Africa.

The Vietnam experience in which it initially relied on imports from China and later learned to produce its own similar Pico hydro machines should be a good lesson for Africa. There are good opportunities in Uganda and other African countries, for example, where less than 5 % of the mini hydro potential has been developed. The factors for these opportunities include high cost of electricity from diesel and petrol generators due to high fuel prices; small hydro schemes are supported by local environmentalists; basic manpower is already available within local utility companies; low voltage mini hydro schemes favour rural conditions; and there is a fast-growing electricity demand. For example, Nebbe Hospital in Uganda and the surrounding settlements require reliable electricity for water pumping, refrigeration, theatre work, etc. There is a suitable mini hydro site close to Nebbe with a capacity to supply 40 kW, which would be enough for Nebbe hospital and the township. A number of such opportunities exist elsewhere within the region but there are neither community-based development plans nor any suitable policies to encourage commercial use of such facilities in a localised framework. For years, Nebbe spent large amounts of money running a generator that could only be operated for a few hours in order to keep the cost down while an un-developed cheap reliable alternative is in the vicinity.

7.7 Municipal Waste

For obvious reasons, clean energy demand in the urban centres is much higher than it is in the rural areas and is usually more than can be met by existing facilities. The generation of waste is also very intense in the urban areas due to high population density, intensive commercial and industrial activities. Managing this waste has been one of the major problems faced by practically all municipal authorities in the region. Its collection and disposal is not only a net revenue sink but is also too expensive. If properly managed, the waste can be turned into a useful resource that can generate some revenue for these municipalities. This would create the means and the need to improve sanitary facilities, which, in turn would reduce incidences of diseases that arise from filthy living conditions.

With appropriate management of municipal solid waste, it is possible to generate electricity using technologies that are already available in some developed countries. Instead of requesting international development agencies to assist in developing large hydro power plants, national governments should seek assistance to develop power generation facilities using municipal wastes, as this will improve both power supply and sanitary conditions for the poor urban population. The use of waste for electricity generation is a unique solution to both waste management and revenue problems. The challenge, however, is to improve waste collection and sorting in order to separate energy waste from the rest. There is also need to identify suitable energy generation technologies that would use municipal waste as feedstock. Another energy production possibility from municipal waste is to design wastewater treatment lagoons to produce biogas. This approach is different from the use of solid waste to generate electricity but energy linkages can be developed so that, although they operate as independent units, they supplement one another, if necessary. Regional authorities must begin to think of new technologies of turning waste into useful resources. This will go a long way in improving the environment in the crowded residential urban estates.

7.8 Policy Issues

Most countries in Africa are primarily concerned with the development and management of commercial energies: electricity and Petroleum fuels. However, in terms of energy accessibility, less than 10 % of the total population, particularly in the Sub-Saharan region, benefits directly from these energy resources. The rest of the people, mostly living in the rural areas, have to find and manage their own energy resources and the reasons for this go beyond accessibility and includes the relatively high costs and application safety. So there are the questions of poverty, temporary and poor quality of shelters and the lengthy process of preparing local traditional foods. Due to a number of constraints associated with these conditions, the people have no choice but to use the available energy resources that are easily accessible

and affordable within their territory and only biomass-based fuels particularly firewood fit into this category of energy, making it the natural choice. It is considered as a non-commercial energy source since it is largely collected from the neighbourhoods free of any charge. Many African countries have broad energy policies, which give guidelines on how both commercial and non-commercial energies should be managed to ensure that energy is available to everyone and that suitable arrangements are made to guarantee sustainability of all vital energy resources. On the question of accessibility, the policies seek not only to increase access to a greater number of people but also to improve services and efficiencies of energy technologies in order to protect the environment and reduce health hazards associated with energy use. This means that despite the wide gap of income levels of the people, everyone should have access to improved household energy services and efficient energy technologies. These policies have good intentions but unfortunately their implementation and hence achievement of the objectives come with costs that the people are expected to meet. Thus the majority of the people do not give any attention to these policies and tend to produce, exploit and rationally use their own energy resources as long as there is no objection from anyone. The relevant authorities seem to support this position by passively handling energy policy matters and doing almost nothing to diversify energy resources to increase options to the people.

In addition to health and environmental protection, the policies also cover gender and use of public forests. The policies specifically recognize the role of women in household energy management and seeks to improve their participation in energy development programmes and open to them ownership of energy resources at both demand and supply ends. It is therefore expected that deliberate efforts should be made to ensure that women participate in energy related education, training, planning, decision-making, and implementation strategies. But, in practice, this is not visible in energy management strategies. With regard to forest resources, the policies are concerned with sustainable exploitation without adverse impact on the ecosystems or reduction in biodiversity. All these policy provisions indicate that national energy concerns in the region only cover the following four issues:

- Improved access to energy
- Health
- Protection of forests
- Elimination of gender disparity in energy issues

The implications of these policies is that the use of various energy sources should not endanger the health and lives of people while keeping the environment, ecosystems and biodiversity protected from any form of degradation. The rights of women who are normally overburdened with the task of fetching biomass-based fuels are also recognized and it is expected that these would be protected through ownership rights.

It is important to trace the background of these policies in order to understand why the governments are cold about the development of renewable energies. Before 1979, there were few government departments with overall mandate on energy

issues. Energy matters were widely spread over a number of government ministries and, as a result, there was total lack of policy guidelines on energy development. When relevant ministries or departments were eventually established, budgetary allocations to them were very low and apparently this has not changed even where full Energy Ministries exist. It is for this reason that NGOs and the private sector in general became actively involved in the development of renewable energy technologies and their dissemination in Africa. Consequently, renewable energy activities (except large hydropower facilities) have followed an ad hoc path with very little input, if any, from national governments. Whenever they got involved in renewable energy activities, they did so because donors and the international community in general were interested in renewable energy applications, mainly for environmental reasons.

The main energy concern was in oil business and large electricity generation facilities and when renewable energies began to appear in the policy documents, it was because there was too much talk about renewables in the international forums, but at the national level, nothing was done to attract investors to renewable energies. To some extent, the monopolistic practices of government-controlled power utilities and multinational oil companies have stifled the official interest in renewable energies. To demonstrate this, we look at the Electricity Acts, which were basically formulated under very close supervision of the national utility companies and naturally gave the same companies power and authority to control a wide range of energy issues. These Acts prohibited commercial generation and sale of electricity directly to the consumers but gave the same utility companies the mandate to issue licenses for commercial electricity generation. The electricity thus generated under license would be sold to the same utility company, more or less, at its own price. This arrangement that made the utility companies the custodians of the Electricity Acts is the reason for lack of support for renewable energy development.

Such utility companies existed in many countries. Some examples were Uganda Electricity Board, Kenya Power and Lighting Company, Tanzania Electricity Supply Company and equivalent companies in countries such as Nigeria. The system made it extremely difficult to get the license and make profit out of electricity generation. Although these Acts have been reviewed, there are still many obstacles and constraints imposed through pricing and long bureaucratic processes for private sector investment on electricity generation. Thus the policy change and the inclusion of renewable energies in the policy documents is still not enough to address the entire energy situation.

There is need to turn the situation round and provide commercial incentives for power generation, particularly for use of renewable energy resources such as solar, wind, and small hydro schemes. National utility companies should be treated like any other service provider operating and obeying the provisions of the Act and not as the custodian of the Act, a facilitator and a competitor at the same time. Tanzanian government had made some bold policy steps to attract investors into the development of renewable energies by providing attractive financial terms for potential investors. It simplified procedures for investing in solar, wind, and micro

hydro schemes including a 100 % depreciation allowance in the first year of operation. There were also exemptions from excise duty and sales tax and concessionary customs duty on the first import of materials used in renewable energy projects. In addition, extensive guarantees were provided to investors under the investment promotion centres certificate of approval. There were other attractive terms on repatriation of income, ownership guarantees and dispensation of assets. These were all very positive steps towards the development of locally available renewable energy resources that should be emulated by the other states.

However, there is still a lot to be done to remove the control roles of national utility companies involved in the generation, distribution, and sale of energy and create an environment in which the policies can be implemented freely and effectively. As mentioned above, these policies, with the exception of a few initiatives, exist only as official records of intention but very little effort, if any, has been made to achieve them. Often, some of them are used to discourage potential new players. The fact that these policies came into being only recently also shows how passive the governments have been about the development of the energy sector. The question is whether the governments understand the reasons behind the on-going vibrant global energy politics and whether they are sensible enough to use the currently available resources to fully prepare for the imminent future energy shortages. A good policy, if implemented, can cushion some of the adverse impacts of global energy shortages.

For the developing nations, this needs effective mobilization of both domestic and external resources to increase investment in the development of local energy resources by deliberately creating conducive business environment for renewable energy technologies. This will further require efficient support from established institutional arrangement in which energy initiatives receive due attention without unnecessary bureaucratic procedures. In order to provide meaningful accessibility to energy, the governments must provide correct micro-economic facilities to both energy producers and consumers through balanced energy pricing that would satisfy the needs and circumstances of both parties.

Appropriate regulatory measures that would encourage people to adopt efficient energy production and clean energy use should be constituted and implemented at various levels. Development of local resources and financial incentives should form the basis of these initiatives. This will ensure that commercial energy companies, especially electricity generating and distribution companies, aggressively pursue network expansion policy as the only way of generating income and not through over-taxing a few consumers. However, it is worth noting that, in the past, the government-controlled utility companies received financial assistance from public funds but did not improve performance and coverage as was expected. Cases in which people paid for new line connections but had to wait for years to be connected were so common that consumers could not understand the business of such power companies. Such delays are today still very common despite the many promises and the new energy policies. This is yet another reason why it will be absolutely necessary to put more effort on policy implementation instead of spending time on policy formulations, which are eventually not enforced.

There is a need to improve on the implementation of existing policies, this is to say, implementation efficiency must come first and this must be done in an environment of competition and operational self-sufficiency without expecting special "survival kit" from the government. The consumer, on the other hand, must be the ultimate beneficiary of the regulations and incentives through appropriate and effective policy enforcement. Due to the governments' past interest and stake in the utility companies, the common practice was to protect the companies and not the consumers and as a result the electrification process progressed at an extremely slow pace.

The inefficiency and irresponsible management by government departments affected other resources as well. The development of biomass resources, which had all the requirements for success, could not be sustained because the very people who were expected to enforce the policy on protection of forests and biodiversity also abused it. In Kenya, for example, the government protected all forests on trust land by posting government-appointed forest officers to all forested areas to ensure that the surrounding communities adhered to the laid down procedures for harvesting forest resources. But these same officers turned round and irresponsibly sold forest resources for their own benefits. The policies are still in force but most forests are gone. Similarly the policies on energy and gender; energy and health; and energy accessibility are still very much alive but they are not implemented. The point here, is that, as much as it is very important to have progressive policies, it is equally important to effectively implement those policies in order to achieve the desired goals.

The private sector and many policy analysts have in the past recommended aggressive long-term policies that demonstrate economic and environmental benefits of energy resources, particularly renewable energies, with emphasis on job creation and income generation but not much has been achieved. It would appear like most of these suggestions also died of the common disease like most of their predecessors: implementation deficiency.

The benefits of diversifying energy sources including long-term savings on oil imports do not make any sense to the rural poor peasant farmers whose energy needs are restricted to heat, which can be met by using biomass and rudimental devices. Their needs for services that require petroleum fuels are only occasional and so it is not easy for them to relate their lifestyle with electricity or oil. Therefore expecting them to participate in the implementation of policies, which do not lead them to viable alternative energies, is unrealistic. Thus energy policies that would broaden the choices must target the consumers and encourage energy use strategies that would provide both incentive and socio-economic empowerment. Consequently, poverty reduction, accessibility to energy, suitable pricing, and appropriate incentives must be properly integrated in the policy framework and effectively implemented.

One of the approaches would be to prepare and implement clear strategic programmes and regulations that encourage active participation of key stakeholders including a wide range of consumer categories such as church organizations, institutions, community-based organizations, NGOs, etc. All areas that are impacted

by energy use such as health, housing, and forestry and those that affect energy development and use such as energy technologies, financing, and community energy-use-culture must all be considered in the programmes. It is also necessary to recognize differences in zonal energy requirements and availability and make appropriate provisions for energy use that are specific to those regions and their energy endowments. Since poverty is a major drawback in diversifying energy choices, it would be necessary to include income generation, health, and gender issues in all energy programmes. In this respect, education, capacity building, and general awareness creation would form an important component of such initiatives. A good policy should encompass all key areas including but not limited to health, financing, safety, education, accessibility, incentives, good energy mix, buying and selling arrangements with independent power producers. But, most importantly, the policies must be aggressively implemented at all levels through well-planed energy development strategies.

A very dangerous trend that needs to be seriously considered is the continued reliance on firewood and charcoal. As population increases, the demand for land for food production and human settlement would substantially go up and inevitably there will be increased demand for firewood. There are several possible results of this; one is the increase in price of firewood, which will also have its own repercussions. Increased demand for firewood also implies increase in the level of poverty with dire social and economic consequences including insecurity. The firewood crisis may also adversely affect food supply as both food and energy production will compete for the little land available. It is therefore not wise to address the biomass energy problem by trying to increase its production to meet the demand. This option should be taken as a short-term measure but, in the long run, it would create a far bigger problem than can be imagined. There will be a limit to which available land can supply adequate biomass energy and every effort should be made to avoid getting to this limit and the only option is to consider developing other inexhaustible or more elastic energy resources to provide heat energy to reduce the demand on firewood. Thus, whereas it is important to plan for more biomass production for obvious reasons, it is also equally important to start looking for means of reducing pressure on biomass as an energy source. The use of raw biomass mainly as a source of heat energy is not only inefficient but also does not give the versatility that is needed from an energy source. In this regard, it is necessary to also consider technologies that would transform biomass into a more versatile energy source such as liquid or gaseous fuel, which can produce energy for both heat and lighting and provide energy to run machines as well. Attention should be turned to fuels like bio-diesel and co-generation technologies that effectively broaden the energy base. Use of municipal wastes for electricity generation should be given serious considerations. Such developments will encourage use of clean energy and stimulate growth of new urban settlements, which, in turn, may ease the pressure on agricultural land. Since there are numerous issues that need to be addressed by a progressive energy policy, it becomes necessary to identify and formulate them into broad energy policy objectives that can be achieved. The broad energy policy objective should be to ensure adequate and quality supply of energy

at affordable cost in order to sufficiently meet development needs while protecting and conserving the environment. Specific objectives that can be implemented with periodically measurable achievements are then formulated around this broad objective. Some of these are to:

- Improve access to affordable energy services;
- Enhance security of supply;
- Develop indigenous and renewable energy resources;
- Develop and instil energy efficiency and conservation practices as well as prudent environmental, health and safety measures; and
- Develop a broad spectrum of local energy options to facilitate optimum mix in various applications.

Any serious energy development strategy must first recognize the crucial role of energy as a tool for socio-economic and industrial developments so that energy analysis becomes part of every initiative. There are therefore a number of challenges in the implementation of energy policy. Some of these include but not limited to:

- Establishment of effective legal, regulatory and institutional frameworks for creating both consumer and investor friendly environment;
- Expansion and up-grading of energy infrastructure;
- Enhancing and achieving economic competitiveness and efficiency in energy production, supply and delivery; and
- Mobilization of resources for the required improvements in the energy sector.

In addition to these broad policy implications and challenges, there are issues that are pertinent to specific energy forms and sources such as electricity, petroleum, and renewable sub-sectors. These must also be addressed in the context of overall energy objectives for both medium and long-term strategies.

There are also institutional and management challenges that have affected the expansion of the power sector in the region but the single most crucial one is the persistent inability to establish management and technological framework for the development of non-hydro energy resources. As discussed elsewhere in this book, the power sector reforms that have been introduced in various countries since the 1990s have not produced the desired results. These reforms were mostly concerned about the removal of the monopoly of national power companies such as KPLC of Kenya, TANESCO of Tanzania, UEB of Uganda, and NEPA in Nigeria that controlled the generation, transmission and distribution of electricity in the respective countries. It is evidently clear that the removal of this monopoly by creating additional companies has neither encouraged diversification nor spurred the expansion of generation capacity. It was however hoped that the move would reduce the impact of rampant mismanagement in the power sector. This did not happen and there is a growing concern about the management structures of the power companies that accept political interference. The Tanzanian government attempted to address this problem by contracting a South African company to run TANESCO, but the new managers faced internal resistance by local workers. At the

end of the first two-year contract, a number of senior government officers were not convinced that the new managers improved the services. Despite the doubt, the contract was again renewed for another two years.

As much as there may be management problems in the utility companies, the solution to this may not be found in the management style but in the ability to diversify electricity generation. In fact, many industries have made great effort to persuade the governments to be more serious and supportive on this front. For example, Tanzanian industries have pushed for suitable incentives to be established for electricity generation using non-hydro energy resources in order to avoid frequent power shedding due to low water level in the hydro dams. Uganda government on the other hand is responding to the low power output due to drought by planning to procure about 100 MW of emergency thermal power supply. It is worth noting that Uganda's hydro power output relies on the level on water in Lake Victoria which had been significantly going down as a result of the 2005/2006 drought. Consequently Uganda's power generation had substantially decreased and this led to serious power rationing in the country. The impact of the drought was even more severe in Tanzania where hydropower generation level drastically dropped from about 560 MW to an all-time low of about 50 MW at the end of February 2006. The general decrease of power output in the region forced many industries to close down their operations.

7.9 Concluding Remarks

Having scanned the African energy situation in general, it is clear that, as much as there are circumstances peculiar to individual countries, the similarities especially within Sub-Saharan African countries outweigh the differences. However, the challenges and available opportunities in each country should be viewed with due consideration given to the prevailing national resource management environment. Many initiatives fail in Africa because of the many loop-holes in the management structures that allow corruption, theft, and mere selfishness to thrive. In addition to the negative impacts of these vices on the implementation activities, there is also general lack of institutional support for initiatives that would otherwise be very progressive. Thus these retrogressive practices put together simply stifle African energy development plans.

The information given in this chapter is a direct result of the authors' investigations and interpretation of African energy situation.