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A Review on the Renewable Energy Resources for Rural Application in Tanzania

Mashauri Adam Kusekwa

Electrical Engineering Department, Dar es Salaam Institute of Technology, Dar es Salaam, Tanzania

1. Introduction

United Republic of Tanzania with a surface area of about 945,087 square kilometres is located in East Africa bordering the Indian Ocean to the East, Mozambique, Malawi and Zambia to the South, The Democratic Republic of Congo (DRC), Rwanda and Burundi to the West and Uganda and Kenya to the North. The country has a population of 41,915,799 [Economic survey, 2009], of which 21,311,150, equivalent to 50.8 percent are female, while 20,604,730 equivalents to 49.2 percent are male. Tanzania mainland has a population of 40,683,294, while Tanzania Zanzibar has a population of 1,232,505. Population distribution shows that 31,143,439 people, equivalent to 74.3 percent of the population live in rural areas, while 10,772,360 people live in urban areas. The population is based on the growth rate of 2.9 percent per annum estimated during the 2002 population and housing census of 2002. Geographically, the country lies between Latitudes 1-12°S and Longitude 20-41°. Climatically, the country is tropical, hot with arid central plateau surrounded by Lake Victoria in the North-West, Lake Tanganyika in the West, temperate highlands in the North and South; the Coastal plain facing the Indian Ocean and Mount Kilimanjaro being the highest mountain in Africa. About 62,000 square kilometers [Casmiri, 2009] of the land is covered by water, including the three fresh-trans-boundary lakes of Victoria, Tanganyika and Nyasa. Woodlands account for more than 33,500 square kilometers and arable land; land suitable for agriculture is concentrated in Southern, North-East and Central part of the Country, covering more than 44 million hectares.

1.1 Background

Energy is an essential factor in both livelihoods and industrial development. An increase in unsuitable use and excessive consumption of energy has been causing not only local pollution but also global environmental problems such as global warming and climate change. In addition; fossil energy sources such as coal, oil, etc are so limited, if energy security is not fully ensured, such unsuitable use may pose a significant threat to economic activities and even to people's lives. Therefore, to realize sustainable development, a stable energy supply is important as well as an improvement in energy related environmental problem. Renewable energy resources and technologies are one of kind of approaches that if well utilized can play part in enhancing energy security and avoidance of environmental problems emanating from fossil energy sources.

Renewable is a term used for forms of energy which are not exhaustible by use over time. It means that the renewable sources can be regenerated or renewed in a relatively short time. This section focuses on leading renewable energy sources in Tanzania. The leading sources are a result of the assessment conducted in the country. The following are leading renewable sources: biomass, solar, hydropower, wind, solar and geothermal. However, hydropower as one of the leading renewable energy sources in the country is not discussed in this chapter. In general, the sources of renewable energy can be divided, according to their origin, into natural renewable sources i.e. wind, solar, geothermal etc., and renewable sources resulting from human activity which include: biomass including landfill gas and industrial heat recovery.

The energy balance of the country shows that biomass use accounts for 88 percent of energy consumption in particular in the rural area [Magesa, 2007]. The majority of the rural population relies on biomass as fuel for cooking. Biomass is followed by Petroleum (7 percent), gas (2 percent) etc. Summary of the primary sources in the country is given in Table 1.

Petroleum exploration efforts have been made in the past and are still going on but so far no oil has been found. Therefore, the country relies exclusively on imports of its oil whereby the transport sector consumes more than 40 percent of all petroleum imported. At present, only 70 percent of the demand for petroleum fuel is met. The increase in importation of petroleum products and continuous rise in oil price is heavy burden for the country. With the introduction of right policy, regulation and incentives, the country has a potential of substituting a large percentage of the imported fuel with Biofuel that could be produced within the country.

Source of Energy	Composition in percentage[%]
Petroleum	7
Electricity	1.4
Renewable (Solar, Wind, etc)	1.3
Biomass	88
Others (e.g. Coal)	0.3
Gas	2
Total	100

Table 1. Primary Energy Sources (April 2011)

Renewable energy can effectively solve the problem of global warming and climate change being experienced in the country; in addition, renewable energy technologies can create jobs to young graduate and hence reduce poverty. Promotion of renewable energy technologies has not progressed easily in the country due to economic inefficiency when competing with traditional energies of oil and natural gas. There are two premises from which to promote renewable energy technologies on a large scale use. First, is diversification of the risk to the environment and social-economic activities; secondly, to increase stable energy supply and enhance energy security of the country. Use of renewable energy technologies in the country will have a positive impact on social-economic development of the country in the future. This chapter focuses on assessment of renewable energy technologies as an alternative approach in electrifying rural Tanzania. In rural Tanzania, there is still an excessive demand and dependence upon traditional energy use. Developing appropriate technologies, efficient

extraction of energy from renewable energy sources and use of modern renewable energy technologies to store the generated energy in more efficient manner that has a significant potential to mitigate climate change, offer a sustainable energy supply, create jobs, reduce poverty and achieve a sustainable development.

2. Available energy resources in Tanzania

A large portion of the United Republic of Tanzania remains un-electrified. The vast part of the country has vast reserves of natural energy resources including water, natural gas, coal, wind, solar, ocean waves, uranium and even geothermal energy. If these resources could be harnessed they could meet the ever-growing demand of electricity for many years to come and create opportunities to export electricity to neighbouring countries. In the following section, available energy resources in Tanzania is presented

2.1 Hydropower

Hydropower currently contributes more than 50 % of electricity generated in the country. Given that supply is not meeting demand; deliberate efforts are needed to be taken to look for other sources. Large areas of the country are supplied with power from hydro stations which include Hale, Kidatu, Kihansi, New pangani Falls, Mtera and Nyumba ya Mungu. Large reservoirs are located at Mtera, Kidatu and Nyumba ya Mungu with storage Capacity of about 4,200 Million cubic metres [Casmiri, 2009] while Hale, Pangani fall and Kihansi have three head ponds with a total capacity of 2.26 Million cubic metres. Electricity generated from hydropower is given in Table 2. The re-filing of the above mentioned reservoirs depends on the availability of sufficient rainfall from various basin including Rufiji, Ihefu and Pangani basins. Therefore, the contribution of hydropower to the energy mix of the country varies according to climatic conditions.

Energy Source	Plant Name	Installed Capacity [MW]
Hydropower	Kidatu	204
Hydropower	Kihansi	180
Hydropower	Mtera	80
Hydropower	New Pangani Falls	68
Hydropower	Hale	21
Hydropower	Nyumba ya Mungu	8
TOTAL		561

Table 2. Electricity Generated from Hydro Source (Source TANESCO, 2009)

Future hydropower projects under plan are given in Table 3
Hydropower resources currently contribute more than 50% of electricity generated in the country. It is a leading renewable energy resource. However, electricity generated from hydropower highly depends on weather conditions. Due to climate change being experienced in the country, it has been observed that the pattern of rain in the catchment

area is not consistent; hence the level of water in all the dams used to generate electricity is falling. This trend has affected distribution of electricity in the country. TANESCO, the Government owned utility company responsible for transmission and distribution of electricity has resorted to introducing load shedding. Hydropower is a leading renewable energy resource in the country but it cannot guarantee sustainable supply of electricity. Other resources are needed to supplement energy during drought. Renewable resources such as biomass, wind, solar, geothermal, etc., must be exploited as supplement to hydropower resources.

2.2 Natural gas

The country has abundant natural gas reserves in the coastal basin that are estimated at more than 45 billion cubic metres [TIC, 2007]. Significant gas discoveries have been made on the coastal shores of Indian Ocean. Four discoveries of natural gas fields so far have been established in the vicinities of Songo Songo Island (about 250 km south of Dar es salaam in 1974), Mukuranga (about 60 km South of Dar es Salaam, in December 2007), Mnazi Bay (about 450 km south of Dar es Salaam in 1982) and Kiliwani North (about 2.5 km South East of Songo Songo Island in April, 2008), but only two gasfield i.e. Songo Songo and Mnazi Bay are producing. Songo Songo gasfield was estimated at 810 billion standard cubic feet, while proven, probable and possible reserves stood at 1.1 trillion standard cubic feet. Mnazi bay gas reserves are estimated at 2.2 trillion standard cubic feet. The gas from Songo Songo Island is transported by pipeline to Dar es Salaam where it is distributed to electricity generation plant and industries especially cement industry. Natural gas supplied to Songas Power Plant generates about 200 MW of electricity. The generated electricity is fed into the National Electricity grid and distributed to end users by TANESCO. In 2010, TANESCO started operating its own plant at Ubungu to generate 102 MW from natural gas. Symbion Power Plant is a private company using natural gas to generate 112.5 MW. Tegeta is generating 45 MW from natural gas. It is anticipated that in the near future more IPPs will generate power using the same gas from Songo Songo gas field.

Energy Source	Plant Name	Installed Capacity [MW]
Hydropower	Stiegler’s Gorge	2,100
Hydropower	Mpanga	165
Hydropower	Ruhudji	358
Hydropower	Rumakali	222
Hydropower	Lukose & Masigira	118
Hydropower	Rusumo Falls	21
TOTAL		2,984

Table 3. Future Hydropower projects (Source EWURA Annual Report 2008/09)

In Mtwara the same gas is extracted at Mnazi bay and is used to generate electricity to Mtwara and Lindi Regions. The two regions are not connected to the National electricity grid. Electricity generation from natural gas is increasing and it is anticipated that in the near future, natural gas will replace hydropower as source of electricity generation in Tanzania. Electricity generated from natural gas is given in Table 4.

Energy Source	Plant Name	Installed Capacity [MW]
Natural gas	Songas	200
Natural gas	TANESCO	103
Natural gas	Symbion	112.5
Natural Gas	Tegeta	45
TOTAL		460.5

Table 4. Electricity Generated from Natural gas Source (Source TANESCO, 2011)

Future thermal power projects under plan are given in Table 5

Energy Source	Plant Name	Installed Capacity [MW]
Natural gas	Kinyerezi	240
Coal	Kiwira 1	200
Coal	Mnazi Bay	300
Coal	Mchuchuma	400
Coal	Ngaka	400
Natural gas	Dar es Salaam	100
HFO	Nyakato	60
TOTAL		1,700

Table 5. Future Thermal Power generation from coal and natural gas (Source MEM 2011).

2.3 Coal

Coal is another resource of primary fuel available in the Country. Coal is found in Kiwira, Mchuchuma and recently in Ngaka. It is estimated that the country has more than 1,200 Million metric tons of coal. Kiwira coal mine supplied between 4-6MW of electricity to the grid annually when it was working; However, now it is closed. Current plan is to revamp the mine so that it can be able to generate power so as to curb power shortages especially during drought seasons when hydro plants are affected. About 1.5 million tons per annum are expected to be mined at the Mchuchuma coalfield where about 400 MW thermal power plants will be built in an effort to increase reliability and security of grid power. Ngaka mine is also expected to be functional in the near future. Apart from grid electricity generation, coal is used in some industries such as cement and paper mills. However, its use is still low. In this aspect its contribution to energy mix of the country is almost negligible.

2.4 Petroleum

The consumption of petroleum and related products in Tanzania is about 1.54 million cubic metres annually [Casmiri, 2009]. Petroleum is imported from the Persian Gulf and the Mediterranean region. Most of petroleum depots are in Dar es Salaam near the Dar es Salaam harbour. From Dar es Salaam petroleum is transported to up-country regions via trunk roads and some areas by Tanzania Railways. Therefore, for the country to have access to petroleum products, infrastructures such as trunk roads, railways should be passable throughout the year regardless of climatic conditions.

Imported petroleum and related products are widely used in the transport and industrial sectors. It is also used for generating electricity in isolated grid-diesel power stations that have an installed capacity of about 21 MW and are located in Songea, Masasi, Tunduru, Kilwa Masoko, Mpanda, Kigoma, Biharamulo, Ikwiriri, Mafia and Ngara. Petroleum and related by-products are imported and distributed by private companies regulated by the Energy and Water Utilities Regulatory Authority (EWURA) which has the authority of monitoring performance and standards with regards to quality, health, safety and environment, licensing, tariff review of electricity and price control.

The current level of energy demand and supply in the country signifies low level development in the industry sector, transport, and commerce. Industry and urban households depend to a considerable extent on energy sources such as electricity and petroleum products which are either imported (petroleum) or generated in the country (electricity). Traditional segment of the economy, mainly rural households depend on biomass as the main source of energy. Semi-urban and urban dwellers also depend on biomass especially charcoal and firewood as a source of energy for cooking purposes despite the fact that a large number of households in this category have access to electricity. The demand for modern energy i.e. electricity is growing at a fast rate. From 1990-1998 demand for electricity rose by 4.45 %; from 2003-2006 demand rose by 8% despite a prolonged period of electrical power shedding due to drought and insufficient rainfall for hydropower catchments areas. The demand for electricity is expected to increase from the present value of 925 MW to at least 3,800 MW by 2025 [Msaki, 2006]. Despite low electricity consumption estimated at 14 % for urban areas and about 2% for rural areas, in general, supply is still unable to meet demand. This shortfall is attributed to the country's dependence on hydropower which in turn is affected by climate variation and climate change. To increase accessibility of electricity to both urban and rural areas necessary efforts are needed. In this aspect, the government decided to commit itself to facilitate the increase of use of renewable energy as an alternative solution for increasing accessibility of modern energy to rural areas. Therefore, a number of reforms i.e. legal framework measures, policies and strategies have been formulated and enacted to provide a constructive atmosphere for utilization of renewable energy resources in the country. The following are some of the policies and strategies adopted for the promotion and facilitation of an increased use of renewable energy within the country.

3. Legal framework and policies

Tanzania power sector has undergone through different turbulent periods, changes and reforms since the country attained its independence in 1961. Most of the changes and reforms have sent positive signals to those who are interested in developing or starting electricity project in the country. The changes and reforms include laying down a National Energy policy (NEP), Electricity Industry Policy and The electricity act of 2008, and guidelines for sustainable liquid biofuel development. Some of the legal framework and policies are elaborated in the following section.

3.1 National energy policy (NEP) -2003

The first national energy policy (NEP) for the Country was formulated in 1992. Since then the energy sector has undergone a number of changes, necessitating adjustments to the

initial policy. These changes include change in the way the role of the government from service provider to service facilitator, liberalization of the market and encouragement of private sector investment. With these changes, the energy policy of 1992 was replaced in 2003.

The objective of the 2003 NEP is to ensure availability of reliable and affordable energy supply and use in a rational and sustainable manner in order to support national development goals. The National Energy Policy of 2003 aims to establish energy production, procurement, transmission, distribution and end-user systems in an efficient, environmentally sound, sustainable and gender-sensitized manner.

Key objectives of the 2003 NEP regarding to Renewable Technologies (RT) and services include:

- Encourage efficient use of alternative energy sources.
- Facilitate Research and Development (R&D) and application of Renewable Energy for electricity generation.
- Facilitate increased availability of energy service including off-grid electrification of rural areas.
- Introduce and support appropriate fiscal, legal and financial incentives for Renewable Energy Technologies.
- Ensure the inclusion of environmental consideration in energy planning and implementation.
- Support Research and Development (R&D) in Renewable Energy Technologies.
- Establish norms, codes, of practice, standards and guidelines for cost-effective rural energy supplies and for facilitating the creation of an enabling environment for the sustainable development of renewable energy sources.
- Facilitate the creation of an enabling environment for sustainable development of Renewable Energy Sources.
- Promote entrepreneurship and private initiatives for the production and marketing of products and services for rural and renewable energy.
- Ensure priority on power generation capacity based on indigenous resources.

The policy encourages public and private partnerships to invest in the provision of energy services. It also seeks to promote private initiatives at all levels and stresses the need to make local and foreign investors aware of the potential of the Tanzanian energy sector. To implement the policy several laws have been enacted, among them are:

3.2 Rural energy act (2005)

The Rural Energy Agency (REA) and the Rural Energy Fund (REF) are autonomous bodies established under the Rural Energy Act no. 8 of 2005. The two bodies are monitored by the Ministry of Energy and Minerals (MEM). REA and REF are established to:

- Promote, stimulate, facilitate and improve energy access for social and commercial use in rural Tanzania.
- Promote the rational and efficient generation and use of energy.
- Utilize the rural energy fund (REF) to finance suitable rural energy projects
- Facilitate activities of key stakeholders with interest in generation and electrification of rural areas.
- Provide capital subsidies to rural energy projects through a trust fund
- Utilize the REF to finance viable rural energy projects.

- Allocate resources to projects in open and transparent manner and with well defined allocation criteria.

The act provides REF with funds from the following sources.

- Government budgetary allocation.
- Contribution from international financial organizations and other development partners.
- Levies of up to 5% on the commercial generations of electricity from the national grid
- Levies of up to 5% on the generation of electricity in specified isolated systems
- Fees for programmes, publications, seminars, consultancy activities and other services provided by the agency
- Interests or returns on investment.

REA/REF have already supported various off-grid projects in small hydro power projects, biomass cogeneration projects, biomass gasification projects in Mafia and Mkonge Energy project. The supported projects are currently at various stages of implementation. The total expected capacity is 46 MW. A total of 8,400 new connections are expected. REA/REF support fiscal incentives for rural energy projects and programmes and count amongst the National aid initiatives attracting fiscal initiatives. On top of government subsidy to REF, the agency is also allowed to take up to 5% surcharge on each unit of energy generated by commercial electricity producer. REA/REF subsidies also support solar PV Systems. However, the subsidy is limited to 100Wp for domestic use and up to 300Wp for Institutions.

3.3 Electricity act (2008)

The electricity Act of 2008 replaces the electricity ordinance Cap 131 of 1931. The act implements the National Energy Policy of 2003. The act opens up the electricity sector for generation, transmission, distribution and sales to private sector participation. It provides instruments for the regulator (EWURA) and stipulates the roles of Rural Energy Agency (REA) and Rural Energy Fund (REF) and sets the general conditions for cost effective tariffs and least-cost electrification options in particular to rural areas.

In addition, the act recognizes other activities such as:

- The preparation of rural electrification strategies
- Plan to promote access to electricity in rural Tanzania
- Recognize Fair Competition Commission
- Standardized small power purchase agreement for 100kW to 10 MW
- Standardized Power Purchase Tariffs and Fair Competition Tribunal
- Power Sector Master Plan (PSMP) to be updated annually.
- Electricity to be generated from any primary source including renewable energy.

The electricity act of 2008 has opened up windows for renewable energy promotion in particular in rural areas. It is anticipated that more research and development in renewable energy would increase competitiveness of renewable energy technologies.

3.4 Guidelines for sustainable liquid biofuels development (2009)

Advanced technologies available today facilitate production of liquid biofuels and generation of electricity using solid by-product through cogeneration. Using current technologies, economically it is feasible to produce biofuels through the use of agriculture crops which in some cases are also food crops. In this aspect, the government of Tanzania

is aware of potential benefits that could be realized through development of the biofuels industry; these include technology transfer through new bio-energy industries, employment and income generation in industry and agriculture sectors, improved energy security, foreign exchange savings via the reduction of oil import, increased foreign exchange through export of biofuels and reduced emission of pollutants and other harmful particles.

In order to create an avenue for biofuel development, the government has published guidelines for sustainable liquid biofuels development, which include:

- Application and Registration procedures for biofuels investments
- Permit and fees
- Taxation and incentives
- Land Acquisition and use
- Contract farming
- Sustainability of biofuel production
- Farming approaches and seed management
- Efficient utilization of biofuel crops
- Appropriate infrastructure development
- Community engagement
- Processing of biofuels
- Storage and handling of biofuels
- Transportation and distribution
- Quality of biofuels (quality standard)
- Blending (biofuel and mineral fuel)
- Biofuel waste management (use, re-use, recycling and disposal)
- Research and Development (condition to fund or support research and development)

The guidelines will attract more investors to come and invest in the country. It is anticipated that in the near future, biofuels will contribute massively to the energy mix of the country.

Modern energy services require the growing inclusion of renewable energy into the sustainable energy mix of the country. The legal frameworks and policies have already been enacted and are in place. The task ahead is how to implement. However, this task is not easy; it needs concerted efforts, organisation and proper planning which include identifying the leading renewable energy resources in the country. A brief summary of leading renewable energy resources is presented in section 4.

4. Leading renewable energy resources in Tanzania

Although biomass is the main source of energy in Tanzania particularly in the rural area, the country is still relying heavily on imported commercial energy in the form of oil and petroleum products; characteristic of all non-oil producing economies. In this aspect, most planners have simplified their work by directing their attention on fossil-fuel, especially petroleum where data is easily available. Thus, more investigation has been on commercial fuels and less on biomass fuel or other renewable energy sources. However, as the effect of fossil fuel on the environment and climate change is becoming serious than before, the attention is now shifting towards renewable energy resources utilization. As this shift is taking pace, more research and resources must be undertaken and used in developing renewable energy technologies for sustainability of the country. In this sub-section the focus

is on establishing leading renewable energy sources in the country which can be used as input in renewable energy technologies in generation of energy.

Modern biomass comprises a range of products derived from photosynthesis and is in fact chemical solar energy storage in nature. This type of renewable energy represents a renewable storage of carbon in the biosphere. Wind energy is a result of thermal heating of the earth by the sun, having global patterns of a semi continuous nature. Geothermal renewable energy originates from heat stored beneath the surface of the earth. The source of this energy is from the earth's molten interior and the decay of radioactive materials. Solar energy is a result of radiation from the sun. Another form of renewable energy which has great potential in future is industrial waste heat. This form of energy is a result of unused heat streams from industrial processes. Manufacturing and processing industries such as Paper and Textiles are one of the major sources of this kind of renewable energy.

By definition, renewable energy sources should provide a continuous and unlimited supply of energy in particular to rural areas. However, several barriers are hindering promotion and penetration of its use. Barriers such as technical difficulties, the intermittent nature and some of the renewable energy sources, as well as constraints still pose limits to their wide promotion and deployment.

It is the fact that renewable energy sources are almost an unlimited supply of energy if one considers the energy required by mankind compared with the extremely large amount of energy we receive from the sun. For sustainable development, modern energy services require the growing inclusion of renewable energy into the sustainable energy mix of the country.

The technologies used now and in the future for conversion of renewable energy sources to heat; electricity and or fuels are plentiful in the country. These technologies can play part and contribute to the energy mix of the country. Their development will contribute to the gradual lowering of technology prices on the one hand and to improvement in their efficiency on the other hand. In the future, it is anticipated that renewable energy and its different energy conversion technologies will become economically viable, capable of competing with fossil-fuelled technologies in the Tanzanian market. However, this will succeed only if all the barriers will be tackled.

In the country there are several leading renewable energy sources which can be used in generating electricity in particular to rural areas. In the following sub-sections, the leading sources are discussed in detail. The information from these sub-sections was obtained from the assessment conducted from 2006 to 2010[Kusekwa et al., 2007].

4.1 Biomass energy

Energy consumption in the Tanzanian households accounts for more than 88 percent of the total energy, most being biomass. The trend is not expected to fall in the near future but to continue increasing as demand of energy increases. The increase is attributed to low pace of rural electrification caused by high cost of connection material, labour and high cost connection fees charged by the utility company which the majority of the rural poor population cannot afford. In this aspect, only biomass is still serving as the only affordable source of energy. However, utilization of conventional biomass is still high in most rural areas i.e. direct use of firewood, dung or semi processed in the form of charcoal. In this way, there is a need of sensitization to the population to use the available technologies or develop modern technologies which will be of great beneficial to the user.

Thus, new technologies or improving the existing ones have to be undertaken to add value to raw biomass and discourage the user to continue using the conventional methods.

Biomass sources suitable for energy generation in Tanzania covers a wide range of materials from firewood collected in farmlands; natural woods from agricultural and forestry crops grown specifically for energy generation or other purposes; crop residues and cow dung. It includes solid waste, timber processing residues etc. The most significant energy end-user is cooking and heating. During the assessment process, it was established that biomass sources can be divided into four major categories:

- Wood, logging and agricultural residue
- Animal dung
- Solid industrial waste
- Landfill biogas

It was noted that landfill biogas generation is dependent on environmental consideration and waste management practices in particular in the semi-urban and urban areas. The potential for exploitation of this source of renewable energy is high and will continue increasing in the near future because more and more people are migrating to semi-urban or urban areas where they consider opportunities for getting jobs and having good life. The semi-urban areas are now changing into big towns and the cities are growing and becoming bigger and complex. Hence, more wastes are expected to be generated daily.

Biomass is one of the renewable sources capable of making contribution to the future Tanzanian energy supply as well as contributing in job creation and hence poverty alleviation. During assessment process it was established that there are several forms in which biomass can be used for energy generation. Three sources are common i.e. residue, natural resources and energy crops. Residues are divided into three categories. The categories analysed are given in Table 6.

4.1.1 Natural sources

Natural sources include biomass gathered from natural resources such as fallen tree branches, woody weeds, etc.

4.1.2 Energy crops

Energy crops include biofuel as sole or principal product such as trees, grasses, and sugarcane, sorghum and oil crops. In addition, biofuel co-production is also part of energy crop category. Biofuel-co-production is a pre-planned multi-output production including biofuel i.e. sugarcane to produce sugar, ethanol, electricity, timber or tree-fruit production to deliver thinning and harvest waste as biofuel.

Generation of biofuel is expected to increase in the near future. A policy for biofuel has been developed by the government. The government is keen on development and generation of biofuel for the benefit of the country. More local or international investors are expected to participate fully in the production of biofuel and thus enhance the energy mix of the country. Availability of renewable energy sources varies depending on their attractiveness to the end user. Biomass differs markedly from conventional fuels and other renewable sources by having a wide range of competing use such as food, fodder, fibre, agricultural fertilizers, fuels, etc. In many places, some types of biomass are less valuable as resource energy than as source fulfilling other needs.

Primary residues Primary residues materials are usually from forestry, agricultural crops and animal rising. Primary residues can be categorized either as residues arising in concentrated form(dung from stalled livestock, harvested cereal straw, stalk, husk) or residues that must be gathered together (dung from grazing livestock, crop residues which are not harvested such as cotton and maize stalks)	Secondary residues Include material from: <ul style="list-style-type: none">• Processing wood• Food and organic materials in concentrated form such as<ul style="list-style-type: none">• Sawmill bark• Tree chips• sawdust	Tertiary residues Include waste arising after consumption of biomass such as sewage, municipal/city solid waste, landfill gas etc.
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Table 6. Types of Biomass Supply

Potential of biomass sources (non-wood) in the country are given in Tables 7.

S/No	Renewable Energy Sources	Estimated Potential [MW]	Remarks
1	Sawdust	100	More studies are required to establish actual value
2	Sisal Residue	500	Will increase in near future
3	Crop residue	212	Initial estimation. Expected to increase
4	Cattle, Pig dung	-	More studies are required to establish actual value
5	Bagasse	57	Initial estimation. Expected to increase.
	TOTAL	869	

Table 7. Non-Wood Biomass Resource

Estimated average annual production levels of wood fuel and its associates such as tannin residue are shown in Table 8.

S/N O.	Renewable Energy Sources	Estimated Potential [Mw]	Remarks
1	Forest residue	523	Initial estimation. Its value could be high.
2	Wattle residue	15	Initial estimation
	TOTAL	538	

Table 8. Wood Biomass Resource

4.2 Solar energy

Solar radiation is the type of energy which is available at any location on earth. Solar energy in the country was assessed using the following criteria:

- power density or irradiance
- angular distribution
- spectral distribution

The maximum power density of sunlight on earth is approximately 1 kW/m² irrespective of location of the area or country. Solar radiation per unit area during a period of time can be defined as energy density or insolation [Renewable Energy Project Handbook, 2004]. Solar radiation is measured in a horizontal plane; the annual insolation varies by a factor of 3 from roughly 800 kW/m²/year in northern Scandinavia to a maximum of 2,500 kW/m²/year in some desert areas such as: Kalahari etc. Practical applications of solar energy the absolute value yearly insolation is less important than the difference in average monthly insolation values. However, the differences vary greatly from about 25 % close to the equator, to a factor of 10 [Renewable Energy Project Handbook, 2004] in the most northern and southern areas. The average power density of solar radiation is normally 100-300 W/m² and the net plant conversion efficiencies are typically 10 % or less, hence, substantial areas are able to capture and convert significant amount of solar energy for energy generation. Tanzania is well situated near the equator; the country can capture and utilize solar energy in the purpose of rural electrification.

Solar energy presents great development in the country. Investigation conducted by Nzali et al [Nzali et al., 2001] suggested several areas in the country which can contribute to development of solar energy. Table 9 gives the insolation levels values in some areas of the country captured by the study. Solar photovoltaic energy is uniquely useful in rural not served by the National grid to provide basic services such as irrigation, refrigeration, communication and lighting. Solar energy is often more efficient than traditional sources such as kerosene. For lighting, a photovoltaic compact fluorescent light system is more efficient than kerosene lamp; used in rural areas to provide night lighting. Photovoltaic system also avoids the high costs and pollution problem of standard fossil-fuel power plant.

4.3 Wind energy

Wind is widely distributed energy source. Between 30°N and 30°S, air is heated at the equator rises and is replaced by cooler air coming from the South and the North. At the earth's surface, this means that cool winds blow towards the equator. Tanzania is situated near the equator; it is affected with the movement of the air movement as well as benefits from this prevailing condition.

The availability of wind varies for different regions and locations. It should be noted that mean wind speed may differ by as much as 25% from year to year. In some areas there are also significant seasonal differences. It has noted that in the country, there is a period when wind speeds are higher and some period wind speeds are low. Due to seasonal variations, the potential of wind for power generation can be significantly higher than the annual mean wind speed would indicate. Thus, not only the mean wind speed but also the wind speed frequency distribution, commonly described by a Weibull distribution have to be taken into account in order to estimate accurately the amount of electricity to be generated. Wind speed varies with height, depending on surface roughness and atmospheric conditions. Daily and hourly variations in the wind speed are also important for scheduling the operation of conventional power plant and adjusting their output to meet these variations.

Station	MONTHS											
	Jan	Feb	Marc	April	May	June	July	August	Sep.	October	Nov.	Dec
Dodoma	6.1	6.0	6.1	5.7	5.6	5.8	5.7	6.0	6.3	6.4	6.5	6.2
D'Salaam	5.2	5.3	4.9	4.0	4.3	4.4	4.4	4.0	4.9	5.1	5.8	5.6
Iringa	6.0	6.1	5.7	5.9	6.2	6.3	6.1	6.6	6.7	7.0	6.7	6.2
Kigoma	4.3	4.5	4.9	4.3	4.4	4.8	4.3	4.9	4.9	4.7	4.1	4.3
Mtwara	4.4	4.6	4.3	4.0	4.4	4.4	4.5	4.6	4.9	4.9	5.2	4.8
Musoma	5.4	5.0	5.4	5.4	5.4	5.0	5.2	5.4	5.4	5.4	5.7	5.4
Same	5.6	5.5	5.6	4.7	3.6	3.8	4.0	4.1	4.6	5.0	5.4	5.6
Songea	4.2	4.3	4.2	3.9	3.9	3.6	3.7	3.9	4.4	4.5	4.5	4.4
Tabora	5.6	5.5	5.8	5.4	5.6	5.5	5.1	5.7	5.6	6.0	5.2	5.4
Zanzibar	5.1	5.2	4.9	4.2	4.4	4.7	4.5	4.8	5.1	5.3	5.0	5.0

Table 9. Mean monthly Daily Insolation totals in kWhm²/day for period of ten years [source A.H. Nzali 2001]

Wind resources can be exploited mainly in areas where wind power density is at least 400 W/m²at 30 metres above the ground. Continuing technical advances has opened up new areas to development, Because of the sensitivity of the potential of the value of the wind speed, the determination of specific sites for wind energy projects depends on accurate meteorological measurements, and sites measurements etc. Even in the best sites, the wind does not blow continuously. Thus, it can never achieve the 100% required for electricity generation. Wind energy potential in Tanzania, wind power densities are given in Table 10.

Wind farms for commercial plants appear promising at Makambako and Kititimo in Singida region as well as Mkumbara, Karatu and Mgagao. Areas along rift valleys, the southern high lands and along Lake Victoria are reported to have some possibilities of potential wind sites.

Over the years, wind energy resources in the country have been used for wind mill to pump water. Less was been done in electricity generation. However with the availability of policy and renewable energy promotion program, emphasize now is toward utilization of wind energy in electricity generation. Number of wind mills available in the country is given in Table 11 and a photo depicting a wind turbine in Itungi village in central Tanzania is shown in Figure 1. The wind turbine is used to generate electricity for water pump.



Fig. 1. Wind Turbine used to Generate Electricity for Water Pumping

4.4 Geothermal energy

Geothermal energy tends to be relatively diffuse in nature that is why it is difficult to tap. Geothermal heat is concentrated in regions associated with the boundaries of tectonic plates in the earth's crust. Eastern rift valley and Western part of rift valley is the area where availability of geothermal sources has been located. It has been established that on average, the temperature of the earth increases by about 3°C for every 100m in depths.

The potential of geothermal is highly dependent on the results of the resources exploration survey, consisting the location and confirmation of geothermal reservoir, with economically exploitable temperature, volume and accessibility. There is some potential of geothermal resource in the country. Currently, the existing potential is being assessed by the government through the Ministry of Energy and Minerals (MEM). A geological survey to establish the potential has been conducted since 2006. The project is assessing the geothermal potential at Songwe west of Mbeya city, Southern Highland. The estimated geothermal potential is about 1,000 MW. Geothermal power is relatively pollution free energy resource which can contribute much to the energy mix of the country if commercially exploited

Wind Power Class	Wind Power Density, [W/m]	Wind Speed [m/s]	Wind Power Density W/s	Wind Speed [m/s]	Wind Power Density, [W/m]	Wind Speed [m/s]
1	100	4.4	160	5.1	200	5.6
2	150	5.1	240	5.9	300	6.4
3	200	5.6	320	5.5	400	7.0
4	250	6.0	400	7.0	500	7.5
5	300	6.4	480	7.4	600	8.0
6	400	7.0	640	8.2	800	8.8
7	1000	9.4	1600	11.0	2000	11.9

Table 10. Wind Power Densities [Source Mmasi et al., 2001]

4.5 Industrial Heat Recovery Power (IHRP)

Industrial heat recovery power represents a poorly known as renewable energy resource in the country, often unused and hence, often wasted resource in energy intensive industries. This resource can provide fuel-free electricity but has been neglected.

Industry heat recovery power use a wide variety of heat resources in applications such as cement, waste incinerators, pulp and paper mills, oil refineries, etc. The industrial applications for waste heat recovery do not require new sitting; the power unit can be installed within the boundaries of existing industrial site. IHRP does not influence the industrial process and does not interfere with the basic objective of production.

IHRP is not well known in the country, however, with the existing three cement industries, one paper mill (Mufindi Paper Mill) and Tipper oil refinery if harnessed they can contribute to the energy mix available in the country.

Region	Number of Wind Mills
Singida	36
Dodoma	25
Iringa	16
Shinyanga	6
Tabora	4
Arusha	4
Kilimanjaro	1
Mara	8

Table 11. Number of Wind mills in Tanzania (Source: Renewable Energy in East Africa – 2009)

4.6 Mini-hydropower sources

Out of estimated 315 MW small hydro potential in Tanzania less than 8 MW have been exploited by installing two power plants. The Ministry of Energy and Minerals (MEM) through REA has been funding studies for small hydro power plants. Dar es Salaam Institute of Technology (DIT) has participated in conducting these studies covering several villages, district, and regions with potential of small hydro power plant development. The villages, district and regions visited include Ruvuma, Rukwa, Iringa, Kagera, Morogoro,

Mbeya, Kigoma and Njoloma. Identified potential river sites for small hydro power generation are given in Table 12. Assessments of actual power available from the established sites are still being worked out. However, the established sites have the potential of generating enough electricity to spur rural electrification in the identified areas. Water falls from the identified area is shown in Figures 2 and 3.



Fig. 2. Water fall at Madaba in South-Western Tanzania



Fig. 3. Water falls for mini-hydro power at Chita-Kilombero

Renewable energy exploitation in the country is still at an initial stage with a limited number of project developers, promoter’s finance providers; services contribute less than 1% of the energy balance. Biomass within the renewable energy section accounts for more than 89% of the cooking resource in rural Tanzania, but the budget allocated by the Government for renewable energy services including biomass is limited to less than 1% of the annual energy development budget of the Ministry of energy and Minerals (MEM). Nevertheless, renewable energy applications in the country have a good potential for powering development goals considering their local availability potential, the limited energy per capital consumption and ever-hiking prices of imported fossil-fuel. Renewable energy will be a catalyst of rural development in the near future. It will play a major role in generation of electricity to spur quick rural electrification. However this, will be accomplished if the existing technologies are improved and new affordable technologies are developed. The following technologies are result of the assessment process conducted in the country from 2006 to 2010 by the author. Some of the technologies are old but need improvement to increase their efficiencies. New technologies need testing and commissioning.

S/No	Site	River	Load Centre	Head[m]	Discharge [m³/sec]	Capacity [kW]
1	Sunda Falls	Ruvuma	Tunduru	13.5	26	2x3,000
2	Kiboigizi	Kitanga	Karagwe	90	3.8	3,200
3	Kenge	Ngono	Bukoba	10	24	2,400
4	Luamfi	Luamfi	Namanyere	40	9	1,200
5	Mkuti	Mkumti	Kigoma Rural	23	3.3	650
6	Nakatuta	Ruvuma	Songea	67.8	50.3	1,500
7	Mtambo	Mtambo	Mpanda	17	13.5	2,000
8	Lumeme	Lumeme	Mbinga	301.2	1.31	4,200
9	Ngongi	Ngongi	Ruvuma	270.7	1.09	3,100
10	Luwika	Luwika	Mbamba bay	359.5	1.5	5,800
11	Mngaka	Mngaka	Paradiso	15	7.64	900
12	Songwe	Songwe	Idunda	75	1.5	720
13	Mngaka	Mngaka	lipumba	25	4.424	870
14	Kiwira	Kiwira	Ibililo	20	10	1,350
15	Prison	kiwira	Natural Bridge	30	12	3,000
16	Kitewaka	Kitewaka	Ludewa Township	50	9.884	4,200
17	litumba	Ruhuhu	Litumbaku Hamba	8	59	4,000
18	Mtitalala Falla	Lukose	Kitonga	70	10	5,000
19	Kawa	Kawa	Kasanga/Ngorotwa	65	0.3	130
20	Ijangala	Ijangala	Tandala	80	6	500

Table 12. Identified Potential River sites [Source REA-March 2010]

5. Renewable energy technologies (existing and new) in Tanzania

Renewable energy technologies deployment in the country is at initial stages of development, although it is not well quantified and well documented. The energy policy focuses on renewable deployment on biomass, solar, micro, mini and small hydro power plants and wind since it was felt that technologies for this energy sources could be disseminated in short term. Geothermal, with existing potential of about 1,000 MW exploitation is considered a long term option since the cost of its development is comparably high.

The use of energy sources such as solar, biogas and LPG especially in the household sector is still low. However, awareness is growing and it is anticipated that in near future its use will increase. It is estimated that about 1.2 MWp of photovoltaic power has been installed in the past three years for various power applications of which more than 35 percent of total installed capacity is from solar home systems (SHSs). The average sales of equipment relating to SHSs between 2000 and 2005 were about 500-600 PV systems per annum. The trend of sales in recent years is growing fast.

5.1 Biogas technology

Recent studies show that, more than 6,000 domestic biogas plants have been built countrywide for domestic and commercial applications. However, as these new technologies get rolled out to more remote areas, especially biogas they invariably encounter more isolated local cultures. For example in predominantly Muslim households it is difficult to convince the community to use pig dung to generate energy. Studies have revealed that pig dung is more efficient fuel than cow dung.

Hundred of tones of livestock dung across the country generated by cattle went unused every year, adding to that for example, The National Ranching Company Ltd (NARCO), has 10 ranches with about 33,000 animal units and proximity to around 55 Villages with a total population of around 156,900 individuals, who are also engaged in the livestock industry. With new innovations in more effective way bio-mass and bio-fuels, the hundreds of tones of cow-dung left over on the grazing land is a resource which could make a difference in the livelihood of the communities close to the ranches as a source of energy and fuel.

The use of bio-gas will reduce deforestation which contributes to global warming, leads to reduction in rains thus leading to low crops and vegetation growth and eventually reduction in crop and livestock production.

Biogas is a cheap [source of energy] when compared to other sources because it uses organic matter such as vegetables and animal waste. Bio gas turned into electricity will improve the quality of life for communities within and around the ranches. Biogas project helps to reduce waste, bacteria and waste odour and clean up the environment. Bio gas based electricity could be linked with solar powered electricity as a hybrid system in order to promote decentralized power systems and consequently enhance energy security.

Dar es Salaam Institute of Technology (DIT) has developed a portable biogas plant made from plastic containers which can be used by rural households. The scheme is shown in Figure 4 and is cheap and affordable. Besides DIT, Small Industries Development

Organisation (SIDO), GAMARTEC, VETA, and private enterprises are researching and developing biogas plants for domestic and institution applications.



Fig. 4. A biogas plant using plastic containers (Source DIT R&PGS-2011)

Biogas is a feasible option for the domestic energy needs of Tanzania's rural population and offers the following socio-economic and environmental advantages

- provides a low cost energy sources for cooking and lighting
- improves sanitation in the home, farmyard and surrounding environment
- eliminate respiratory and eye diseases caused by indoor air pollution
- save time for women and children because they don't need to collect firewood
- create rural employment
- reduces greenhouse gas emission
- reduce deforestation
- produces an effluent called bio-slurry which is an excellent organic fertilizer

5.1.1 Improved stove technology

Tanzania has about 35 million hectares of forests; of which about 38 percent of total land areas (13 million hectares) are protected forest reserves and the remaining 62 percent are forests on public land in village areas that are under pressure from human activities including harvesting for energy. Forest and trees in farmlands contribute to wood fuel supply. However, supply of wood fuel is declining rapidly in the country causing scarcity of energy to rural and semi-urban low-income families and environmental degradation in areas where harvesting of wood fuel exceeds the growing stock potential.

Much of the research and development work carried out on biomass technologies to serve the rural areas has been based on improvement of available traditional stoves. This was initially in response to the threat of deforestation but has been focused on the needs of women to reduce fuel collection time and improve the kitchen environment by smoke removal.

There have been many approaches to stoves improvement, some carried out by local institutions, individuals and others as part of wider programmes run by international organisations.

Some of the features considered in improving the stoves include:

- An enclosed fire to retain the heat
- Careful design of pot holder to maximise the heat transfer from the fire to pot
- Baffle to create turbulence and hence improve heat transfer
- Dampers to control and optimise the air flow
- A ceramic insert to minimise the rate of heat loss
- A grate to allow for variety of fuel to be used and ash to be removed
- Metal casing to give strength and durability
- Multi pot system to maximise heat use and allow several pots to be heated simultaneously

Designs of stoves depend on the form of biomass providing energy. Improving a stove design is a complex procedure which needs a broad understanding of many issues. Involving users in the design is essential for a thorough understanding of the user's needs and requirements of the stove. The stove is not merely an appliance of heating food, but in rural context is often acts as a social focus; a means of lighting and space heating. Tar from the fire can help to protect a thatched roof, and the smoke can keep out insects and other pests. Hence, cooking habits need to be considered as well as the lifestyle of the users.

Fuels with improved designs of stoves include firewood, charcoal and sawdust. Based on the assessment conducted, it has been established that there are difference between stoves used in rural, urban and institutions or commercial ventures. Use of firewood is predominant in the rural areas and as one travels into the urban areas there is a shift to charcoal.

It was established during the assessment that stoves in use in rural areas are normally adaptable to using more than one form of biomass such as wood and agricultural wastes. Firewood is used widely in the rural areas. The traditional firewood stoves used in rural areas is normally at no cost to the user and these stoves have a lot of inefficiencies. One stove fits any size of pot and the intensity of fire is controlled by adding or removing fuel from the stove. The fuel i.e. firewood is not bought but collected free of charge from the forest or farms. Urban stoves are normally single fuel devices. Charcoal is a very important fuel for urban areas and is usually purchased rather than collected.

Improved stoves designs in the country to date are usually targeted to urban dwellers. This has been probably been due to the higher income levels of this group of people. Hence, improved charcoal stoves are widely disseminated stoves technology. Improved charcoal stoves are highly efficient stoves that save fuel and money because the heat to be lost is minimized by some insulation included in the design. These stoves can save about 35%-40% charcoal over traditional stoves.

Sawdust stove designs are also finding their way into the market especially in small business enterprises called "*Nyama Choma*" or meat roasting in the urban areas. There are

some few problems that would need to be addressed in order to make the technology popular in the country.

Improved stove technology focuses on improving firewood consumption. In the long run it aims at reducing carbon dioxide emission and indoor air pollution, reducing workload to women and children and conserving forest resources. The overall aim of the project is to improve thermal performance of the woodfuel stoves in rural areas

Other benefits are income generation opportunities especially to village technicians. Stove improvement technology adds value on indigenous technology that uses indigenous fuel resources and material. Improved stove technology project is designed to start with small models that can be replicated in the whole country. The project will relate to construction of the efficient stoves and imparting knowledge on proper management of woodfuels. Amongst of the improved stove is “*Jiko Mbono*” shown in Figure 5. The stove is a Top-Lit-UpDraft (TLUP) gasification stove with natural draft air supply. The stove can use Jatropha seeds directly instead of Jatropha oil.



Fig. 5. Jiko Mbono Underdevelopment (Source DIT R&PGS-2011)

Timber and manufacturing industries in the country generate a lot of sawdust (shown in Figure 6). The sawdust can be used as a renewable source of technology. Sawdust stoves have been developed as can be seen in Figure 7. The stoves are cheap and affordable and can be used in both semi-urban and urban areas. The sawdust stoves are expected to be popular in future.



Fig. 6. Sawdust accumulation at one of Timber Processing Industry in Tanzania

5.2 Solar Technology

Over several past decades, new commercial industries have been established for an assortment of solar energy technologies, demonstrating schemes with wide variations of success. The SHSs system components are usually imported through various private sector initiatives. The common PV applications in the country are household lighting, telecommunication, vaccine refrigeration in rural and semi-urban areas, powering electronic accessories e.g. radios, TVs, computers etc, etc. water pumping, powering schools and health centres and rural dispensaries.

Dar es Salaam Institute of Technology (DIT) has developed a high power solar thermal system based on parabolic concentrator Heliostat. The scheme is cheap to construct and can be used by institutions in the country. The system is capable of concentrating 20 kW per unit Heliostat. The unit can be cascaded to a very high power station. A parabolic concentrator is given in Figure 8

5.3 Wind Technology

Based on Mmasi, Lujara and Mfinanga [Mmasi *et al*, 2001] on wind energy potential in Tanzania, wind resources are expressed in wind power classes ranging from class 1 to class 7, with each class representing a range of mean wind power density or equivalent speed at specified height above the ground. In this aspect, Mtwara, Dar es Salaam, Pwani, Tanga, Kigoma, Kagera, Singida, Dodoma, Tabora, Shinyanga, Morogoro, and part of Southern Arusha are suitable areas for future generation of electricity using wind as the source of energy.



Fig. 7. Sawdust stove in Rural Tanzania



Fig. 8. A Parabolic Concentrator Heliostat (Source DIT-R&PGS-2011)

5.4 Domestic waste technology

Household wastes can also be used as source input in generating a closed system steam known as electrical generator from a local kitchen. Small scale electrical generator capable of utilising wood stove waste heat has been developed by DIT. It is anticipated that the system will find market in the future. Figure 9 shows the 3D concept of the steam-electrical generator.

5.5 Cogeneration technology

There is few biomass based-co-generation plants in the country. These include sugar processing plants: Tanganyika Planting Company (TPC), Kilombero Sugar Company (KSC), Mtibwa Sugar Estates (MSE) and Kagera Sugar Company, Tanwat (Tanning) and Sao Hill Sawmill have waste that can be used in generating electricity. Table 13 shows electricity generated from cogeneration technology.



Fig. 9. The 3D Concept of the Steam –Electrical Generator Prototype (Source DIT R&PGS-2011)

The highlighted technologies have the potential to contribute to rural energy electrification in the country in the near future. Some of the technologies are still under development. Wind and solar technologies are already in application. These technologies need improvement. Tertiary, higher learning institutions and research centres in the county have the role of improving these technologies.

S/No	Plant Name	Main Resource	Region	Capacity [MW]
1	TANWAT	Biomass	Njoluma	2.7
2	TPC	Biomass (Bagasse)	Kilimanjaro	20
3	Sao Hill	Biomass(Saw Dust)	Iringa	16
4	Ngomeni	Biomass (Sisal Waste)	Tanga	0.5
5	Mwenga	Biomass (Sisal waste)	Tanga	3.36

Table 13. Electricity Generated from Cogeneration Technology (Source: MEM 2011)

With all of the technologies already in place and some underdevelopment, there are still many challenges and barriers that need attention. Some of the barriers are presented in section 6.

6. Barriers to promoting renewable energy technologies in Tanzania

Renewable energy technologies are still perceived as “niche” energy resources by many Tanzanian. Barriers to their enhancement and development are on all levels i.e. cognitive, perceptual, policy attitudes and in the economic sphere. Renewable energy technologies are perceived by many Tanzanian as complementary energy not main, hence, still in the learning curve phase in their developments. They are viewed as relatively new, not sufficiently field proven, somehow expensive to purchase, to install and to maintain. They are often viewed as small, dispersed resources, of unstable output, and incapable of providing sustainable energy for the future. They lack base expertise, information on cost is imprecise and thus there are high impediments to possible capital investment.

The economic barriers are both real and perceived. The real economic barrier is influenced by unfair competition from fossil-fuels or conventional energy sources. Economically, renewable energy technologies project suffers from high up-front capital requirements, high interconnection costs, and lack of financing mechanisms from financial institutions e.g. commercial banks, etc. Financial institutions in Tanzania still perceive investment in development of renewable energy technologies as high economic risk; their entire economic structure is viewed as poor, with long amortization.

The general barriers for development of renewable energy technologies are summarized according to resources as follows:

6.1 Biomass

- Dispersed form of energy,
- Variety of technological solutions
- Competition from higher value applications
- Not sufficiently mature, therefore, risk to investors
- Difficult due to collection in some areas and transportation
- In case of Bioenergy, it is land-intensive
- Low load factors, hence it tends to increase energy system costs
- Minor influence on Tanzanian energy supply
- Not modern enough for mass utilization

6.2 Wind

- Uncompetitive technology in the short and medium run
- Lack of good wind conditions i.e. speed in many part of the country
- Lack of financial resources to finance research and development of wind turbine in the country
- Lack of human resources for servicing and maintenance after installation of the system

6.3 Geothermal

- Drilling technology difficulties
- High up-front investment
- Resource handling problems such as resource depletion, corrosion, etc

- Financing constraints due to high up-front costs
- Competition from fossil fuel power plant

6.4 Solar

- Low energy density in some areas in the country
- Resource available only during daytime
- Sensible to atmospheric and weather fluctuations
- Higher cost of Solar PV
- High capital cost
- Long payback periods
- Grid connection issues
- Storage issues
- High cost of storage solutions
- Hazardous materials in PV systems (battery) etc
- Lack of financial capability to subsidise solar energy projects

6.5 Industrial heat recovery power

1. Lack of awareness of this unused form of renewable energy in manufacturing and processing industries
2. Not included in government energy master plan
3. Unawareness of waste heat potential for power generation in the country
4. Perception as nuisance not convergent with the basic function of manufacturing and processing process of the mills or factory
5. Fear of damage caused to the production process
6. No environmental credits given for waste heat power generation from waste heat by the government
7. Financing constraints because of high up-front costs
8. Lack of interest in using the waste heat potential for generation of electricity
9. Preference for external solutions such as diesel generator applications, etc.

7. Recommended actions to remove barriers to promoting renewable energy technologies

- Development of effective public awareness and promotion programs that depend mainly on market surveys and studies and concentrate on media in particular television programmes and newspapers.
- Allowing systems and spare parts of the developed technologies to be available in shops.
- Establishment of maintenance centres.
- Demonstrating developed technologies can be presented in international trade fairs, engineering conferences, municipals and city councils, big factories etc.
- Establish incentive mechanisms innovators and developers.
- Encourage local manufacturing companies to manufacture the systems.
- Form federation, union or society which bring together representatives of users, companies, financial sources, policy makers and researchers in order to coordinate efforts in using the developed technologies.

- Establish credit mechanism to finance prospective technologies.
- Establish a programme or mechanism to solve the problem of already installed systems. The programme should include some mechanism for informing the user about the systems and their regular duties.
- Setting up coordinating committee for planning and implementing the action plan to acceptable technologies.
- Strengthening the cooperation between the concern ministry, authorities, institutions and organisations involving them in the national action on renewable energy technologies.
- Setting rules and legislation for quality assurance, standardisation and certification for all renewable energy technologies components and systems.
- Development of effective public awareness and promotion programmes such as demonstrating systems, some printed materials (leaflets, brochures etc) training courses, seminars, presentations and workshops for targeted users, small-scale laboratories in schools, technical colleges and universities.

8. Social impact of renewable energy technologies in sustainable development

Renewable energy resources and technologies can serve as one of the key drivers for rural development in the country in a number of ways in:

- Enhancing local micro-economic development in agriculture, manufacturing, and small industries
- Providing vital economic generating activities in the rural areas such as water pumping, battery charging, lighting schools, ICT development, crop drying, milk refrigeration, drug refrigeration, and ice making in semi-urban areas.
- Improving human development such as accessibility to modern education, internet, and improve health services, etc.
- Helping to lower the pace of migration of young people to overcrowded municipalities and cities.
- Preventing social unrest in particular to young people
- Poverty alleviation

Renewable energy technologies for rural and semi-urban electrification is more sustainable; suitable for supplying geographically dispersed villages by means of distributed energy often without relying on a national grid. Grid connection to remote and dispersed villages is expensive and technically difficult; therefore, local mini-grids developed from renewable energy sources can be established and serve the purpose of rural electrification either as stand alone power generating unit for a particular village or interconnected with other village generating unit. In this way:

- Biomass. The majority of the rural population in Tanzania relies on traditional biomass to meet their cooking and heating needs. The challenge is to ensure more efficient and sustainable use of biomass for heat extraction, cooking and generation of electricity instead of using raw biomass.
- Solar PV systems can be widely used in poverty alleviation projects for electrification of remote underdeveloped areas.

- Wind turbine can provide modern, clean, sustainable and economical energy for remote village areas, either via local mini-grids or as stand-alone option.
- Mini-hydro power plants can provide modern, clean and sustainable and economical energy.
- Geothermal energy can provide sustainable continuous energy, independent of weather conditions.

Poverty alleviation objective in the country focuses on rural areas. Hence, development of renewable energy technologies and infrastructure can effectively contribute to poverty alleviation in the coming years.

9. Distribution generation

Dondi *et al* (2002) defined distributed generation as a small source of electrical power generation or storage ranging from less than a kW to tens of MW that is not a part of large central power system and is located close to the consumer (load). Chambers (2001) also defined distributed generation as a relatively small generation units of 80 MW or less. According to Chambers, these units are sited at or near customer sites to meet specific customer needs, to support economic operation of the distribution grid or both. The two definitions assume that distributed generation units are connected to the distribution network. It is clear that the two definitions give or allow a wide range of possible generation schemes. So, the definitions allow the inclusion of larger scale generation units or large wind farms, landfills, etc connected to the transmission grid, others put the focus on small-scale generation units connected to the distribution grid. Nevertheless, all the definitions suggest that at least the small scale generation units connected to the distribution grid are to be considered as part of distribution generation. Moreover, generation units installed close to the customer (load) or at the customer side of the meter are also commonly identified as distributed generation.

Ackerman *et al* (2001) precisely defined distributed generation in terms of connection and location rather than in terms of generation capacity. They defined a distributed generation source as an electrical power generation source connected directly to the distribution network or on the customer side of the meter. The definition is adopted in this chapter even though it is rather broader. The definition does not put limit or technology or capacity of the potential distributed generation application. It suits the Tanzanian condition when referring to renewable resources the country has.

Distribution generation is a latest trend in the generation of electrical power. The distributed energy resource concept allows consumers who are generating electricity for their own needs to send surplus electrical power back into the power grid or share excess electricity via a distributed grid. Distributed generation system can be divided in two segments, as shown in Figure 10. The segments include:

- Combined heat and power
- Renewable energy resources

Combined heat and power (CHP) is the use of a power generator to simultaneously generate both heat and electricity. The method is new in the country, but can be applied at Mufindi Paper Mills (MPM) where the paper machines generate enough back pressure which is useful in electricity generation.

Renewable energy resources (RER) capture their existing flow of energy, from on-going natural processes such as solar, wind, small hydro and biological processes. The two segments are the main component in implementation of distributed generation in the country and can accelerate rural electrification, hence improving accessibility of Tanzanian to modern energy and spur sustainable development.

Distributed generation could serve as a substitute for investment in transmission and distribution capacity or as a bypass for transmission and distribution costs. Distributed generation could result in cost savings in transmission and distribution of about 30% of electricity cost compared to the cost incurred by TANESCO in electrifying rural areas. Distributed generation can substitute for investments in transmission and distribution capacity. It can be used as an alternative to connecting a customer to the grid in a stand alone application. Furthermore, well selected distributed generation from the resources the country has can contribute in reducing national grid losses.

Distributed generation can contribute in the provision of ancillary services. These include services necessary to maintain a sustained and stable operation of the national grid. For instance to stabilize a dropping frequency due to a sudden under capacity such as power plant switching off due to technical problems or excess demand.

Installing distributed generation schemes will allow the exploitation of cheap fuel resources available in the country. For example in the proximity of landfills resources, distributed generated units could burn landfill gases. Also, biomass resources may be envisaged.

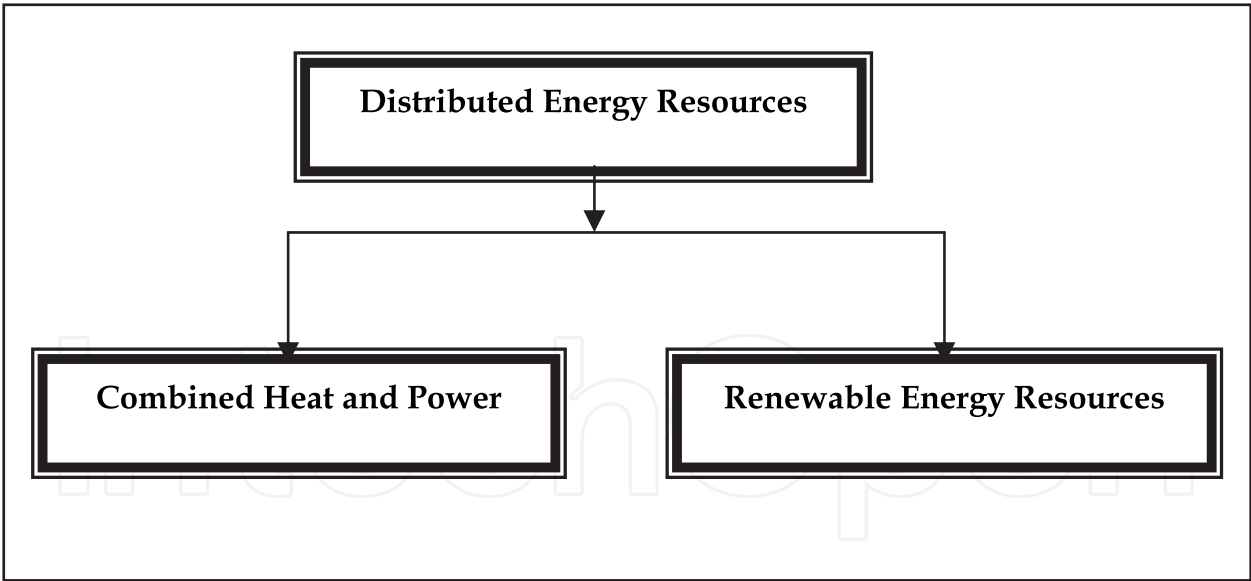


Fig. 10. Split up of Distributed Energy Sources

Increased environmental concern induces an increase interest in distributed generation application worldwide, also in innovations in the appropriate technologies. Nevertheless, the economic as well as technical challenge will be to optimally integrate the distributed generation units in the electricity system available in the country that up to now has been very centralized. The challenges emanating from application of distributed generation in the country is a blessing as more opportunities to engineers and researcher in

investigating new and affordable means of integrating distribution generation in the national grid.

10. Discussion

A suite of off-grid renewable energy technologies such as solar home systems, biogas cook stove and either mini or small hydropower plants can deliver energy services to rural households most cost effective than national grid, without relying on expensive and polluting fuels. These Renewable Energy Systems are making inroads in some regions worldwide. But assessments on how they perform often neglect local realities.

In conducting the reviews, it has been revealed that cultural attitudes and social expectations can prevent the use of renewable energy technology applications as significantly.

11. Conclusion

The great challenge in Tanzania with regards to provision of modern energy i.e. electricity is found in the rural areas. Rural area development should be the overall priority in the energy access challenge, with the focus on increasing investment from government and private sector as well as assistance from development partners. Greater effort should be made to promote renewable energy technologies and energy resources available in the country.

Tanzania is rich in renewable energy resources; however, due to lack of financial resources, wood fuel and human physical power will continue to be the main source of energy in most rural areas of the country. In order to bring sustainable rural development, it is crucial that long term efforts scaled up to facilitate access to modern energy services in rural areas by employing renewable energy technologies. Rural areas of Tanzania need to use more modern energy services if poverty is to be made history. More modern energy is required to increase and improve production of value added goods and services in rural areas and this can be generated by new and improved renewable energy technologies.

The generation and use of modern energy in the country is a problem of capital and technology, not energy resources. It is a question of whether or not adequate capital and technology would be availed to develop the available renewable energy resources. Hence, the government, development partners and private sector, need to urgently avail the necessary capital to develop and generate own energy from the available renewable energy resources. At the same time, engineers, technologist and private firms corporate in research and development of technologies suitable for the country. The approach will bring positive economic performance and sustainability.

12. Recommendation

It is recommended that for all abundant renewable resources existing in the country and the available renewable energy technologies together will play a major role in the provision of affordable modern energy to rural areas. However, the following issues should be addressed:

- Reduce the initial high cost of implementing renewable energy projects
- Promote relevant research and development in renewable energy technologies

- Disseminate the available renewable energy technologies to the public
- The use of Biogas digesters and sawdust stove should be popularized, by the government. Research centres in the country should be encouraged to design effective digesters as this will help utilize the energy stored in cow dung.
- Energy stored in wind can be tapped and used for pumping water and electricity generation using wind. The government must work in collaboration with experts in this field to built sufficient wind mill to alleviate the energy problem.
- Tanzania has enough coal deposit. The use of coal oven should be highly encouraged as this will solve the energy needs of the rural dwellers.
- Establish energy data bank that will be a model for addressing nation’s energy needs.
- Develop local capacity on use of renewable energy technologies.
- Introduce and application of distributed generation, which could serve as a substitute for investments in transmission and distribution capacity.

13. Indexes

Calorific value conversion factors for wood fuel (firewood) at final user level

1 kg of firewood	=	13.8 MJ
1 kg of charcoal	=	30.8 MJ
1 m³ of solid wood	=	0.725 Tonne
1 m³ of wood	=	10,000GJ
1 kWh	=	3.6 MJ
1 Tonne of fibre of sisal produces 25 tonnes of residue		
1 Tonne of sugar produces 5 tonnes of bagasse		
Energy content of wood fuel (air dry, 20% moisture) = 15GJ/t		
Energy content of Agricultural residue (range due to moisture content) = 10-17GJ/t		
Energy cost: 1 GJ costs U\$ 0.95		
4 kg of Jatropha beans	=	1 litre of biodiesel
10 tonnes of Jatropha beans	=	2,500 litres of biodiesel

14. Abbreviation

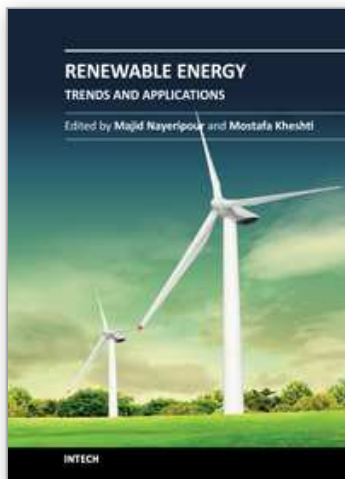
DRC	Democratic Republic of Congo
TANESCO	Tanzania Electricity Supply Company Limited
MW	MegaWatt
EWURA	Energy, Water Utilities Regulatory Authority
NEP	National Energy Policy
RE	Renewable Energy
RT	Renewable Technologies
R&D	Research and Development
REA	Rural Energy Agency
REF	Renewable Energy Fund
PSMP	Power Sector Master Plan
kW	kilowatt
IHRP	Industrial Heat Recovery Power
DIT	Dar es Salaam Institute of Technology
R&PGS	Research and Postgraduate Studies

SHS	Solar Home Systems
NARCO	National Ranching Company Limited
SIDO	Small Industrial Development Organization
VETA	Vocational Education Training Authority
TLUP	Top-Lit Up Draft
TPC	Tanganyika Planting Company
KSCL	Kagera Sugar Company Limited
KSC	Kagera Sugar Company
MSE	Mtibwa Sugar Estate
TANWAT	Tanganyika Wattle Company
ICT	Information and Communication Technology
CHP	Combined Heat and Power
MPM	Mufindi Paper Mills
RER	Renewable Energy Resources
CAMARTEC	Centre for Agricultural Mechanisation and Rural Technology
IT	Information Technology
URT	United Republic of Tanzania
FAO	Food and Agriculture Organization
UNDP	United Nations Development Programme
SIDA	Swedish International Development Agency
TaTEDO	Tanzania Traditional Energy Development and Environment Organization
IPPs	Independent Power Producers
EC	European Commission
IEEE	Institution of Electrical & Electronics Engineers

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University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
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InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

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