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Chapter 11

Use of Renewable Energy for Electrification of Rural Community to Stop Migration of Youth from Rural Area to Urban: A Case Study of Tanzania

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Additional information is available at the end of the chapter

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Abstract

Rural electrification is the key in developing countries to encourage youth and skilled personnel to stay in rural for production activities. Lack of grid network in Tanzania currently discourages youth and skilled personnel to live in rural areas. Tanzania has diverse renewable energy which needs to be developed for electricity generation. Most of these sources are found in rural areas but they are not developed and grid network are not extended because of low population density. The government has put in place policy which encourages small power producers to develop renewable energy resources. Energy produced would be sold to the community directly or to the government owned company for grid integration. This paper discussed three major renewable energy sources such as wind, solar and hydro power. Electrifying rural areas will encourage youth to reside in their communities and engaging themselves in production activities like farming and livestock keeping. Also communication among communities and networks between rural - urban would be improved. Establishment of small industries would lead more farm products and earn more money. Therefore, the strong links between rural - urban communities would be strengthened; hence youth migration would be stopped naturally.

Keywords: wind, solar, hydropower for rural electrification

1. Introduction

Tanzania is one among the few countries blessed with diverse primary source of energy, some developed and most of them undeveloped. The primary sources of energy available in Tanzania include hydropower (big, mini, micro, and pico), geothermal, solar, wind, biomass, coal,

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natural gas, and biogas. The primary energy used in the country is as follows: biomass (90%); petroleum products (8%); electricity (1.5%), and the remaining (0.5%) contributed by coal and other renewable energy sources [1]. However, more than 80% of energy obtained from biomass is consumed in rural areas, hence contributing to deforestation as well as damaging rural people's health since they inhale smoke from wood when preparing food for the family. Electricity network did not cover the rural area because extending the grid to rural areas is not financially and economically feasible. This situation forced youth people to migrate from the rural areas to urban areas where there is reliable electricity for various income generating and social activities.

2. Renewable energy in Tanzania

Tanzania has plenty of renewable energy sources of which few of them are developed for electricity generation. Currently, a large-scale hydropower resource has been developed for electricity generation, while the small hydropower, which has good potential and is particularly feasible in rural areas, is not developed for electricity generation.

Furthermore, biomass resources are mostly exploited in unsustainable ways resulting in cutting of trees, hence causing the environmental degradation. The country has great potential of organic waste generated from the agricultural sector and remains unexploited.

Tanzania has enough solar insolation which is suitable for off-grid and grid as well. The solar insolation is high in the central part of the country. Currently, the solar energy resources are utilized in small scale particularly for roof-mounted panels for powering domestic appliances such as lighting and mobile phone charging.

Furthermore, wind energy resource assessment in the country indicates its viability; therefore, the plan for developing wind farm is in progress.

This chapter will discuss the availability of renewable energy and the calculation/formula for estimating available energy contained in the energy source.

2.1. Wind energy

2.1.1. Introduction

Wind is a widely distributed energy source, between 30°N and 30°S. Earth is unevenly heated by the Sun resulting in the poles receiving less energy from the Sun than the Equator does, also dry land heats up more quickly than the seas do. This difference in heating gives power to a global atmospheric convection system reaching from the Earth's surface to the stratosphere which acts as a virtual ceiling. Heated air at the Equator rises and is replaced by cooler air coming from the south and the north [2]. That is, cool winds blow toward the Equator. Tanzania is situated near the Equator; it is affected by the air movement as well as benefits from this prevailing condition.

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The availability of wind varies for different regions and locations. It has been noted that there is a period in a year that the wind speeds are higher, and some period, the 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 [3].

Thus, when embarking to the project, not only the mean wind speed but also the wind speed frequency distribution, commonly described by a Weibull distribution, has to be taken into account in order to estimate accurately the amount of electricity that would be generated [4]. 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 the conventional power plant and adjusting their output to meet these variations [5].

Based on the available information, Tanzania has plentiful wind resources, with much of it located around the Great Lakes, the plains, and the highland plateau regions of the Rift Valley [6].

The wind is the sustainable energy source which does not create emissions and it will never run out since it is constantly replenished by energy from the Sun. Generation of electrical power can be done by wind turbine which converts wind energy to mechanical power to drive an electrical generator. Wind turbines undergo natural evolution from traditional windmills with the several blades to three blades, which rotate around a horizontal hub at the top of a steel tower [7]. Wind passes over the blades exerting a rotating force to turn a shaft which

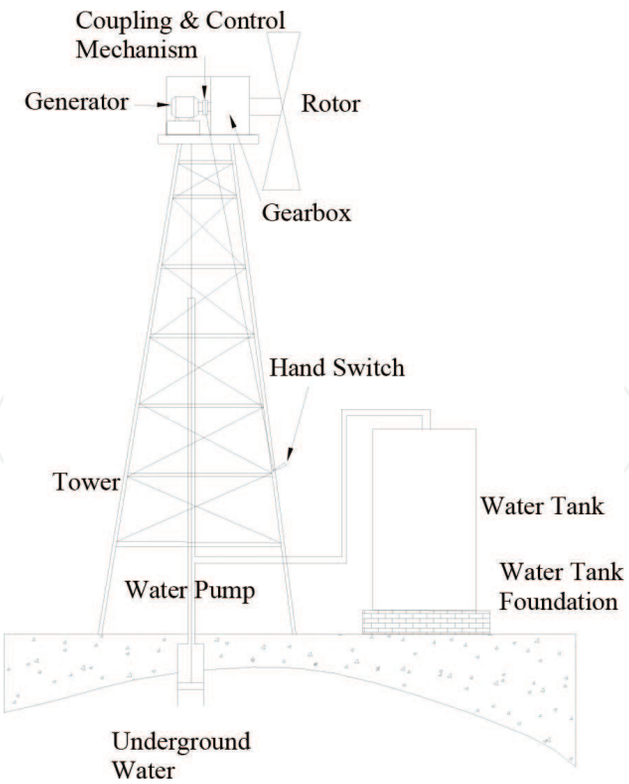


Figure 1. Dual purpose windmill for water pumping and electricity generation.

connects with gearbox enclosed in the nacelle. An electrical generator either induction or synchronous is connected to the gearbox which will amplify speed shaft obtained from the blades (rotor). Most wind turbines start generating electricity at wind speeds of around 3–4 m/s, maximum power would be generated at around 15 m/s and generation stops at the wind speed of 25 m/s by shutting down to prevent storm damage [8] (**Figure 1**).

Wind energy resource in Tanzania would be assessed in the different location of the country as follows: east zone (coastal area), central zone, west zone, southwest zone, southeast zone, northeast zone, and northwest zone (lake zone). Each zone has weather station equipped with measuring wind speed, humidity, temperature, and rainfall. The information collected from individual weather stations have always been submitted to Tanzania Metrological Agency for further processing.

For this study, monthly average wind speed data for 9 years (January 2009–July 2017) measured at the height of 3 m were collected from weather stations located strategically all over the country. The average wind speed shows that in the central zone there is reasonable wind speed which varies from 2.8 to 6.2 m/s; therefore, the place is suitable for the wind farm as well as isolated wind power plant (**Figure 2**). Average wind speed for the east zone found to be ranging from 3.4 to 5.8 m/s but the place is not suitable for the wind farm because of the scarcity of land but can be used for isolated power supply (**Figure 3**). In west zone, wind speed ranges from 2.5 to 4.2 m/s which is suitable for isolated power supply (**Figure 4**). In southwest zone, wind speed ranges from 2.2 to 4.8 m/s which is suitable for isolated power supply

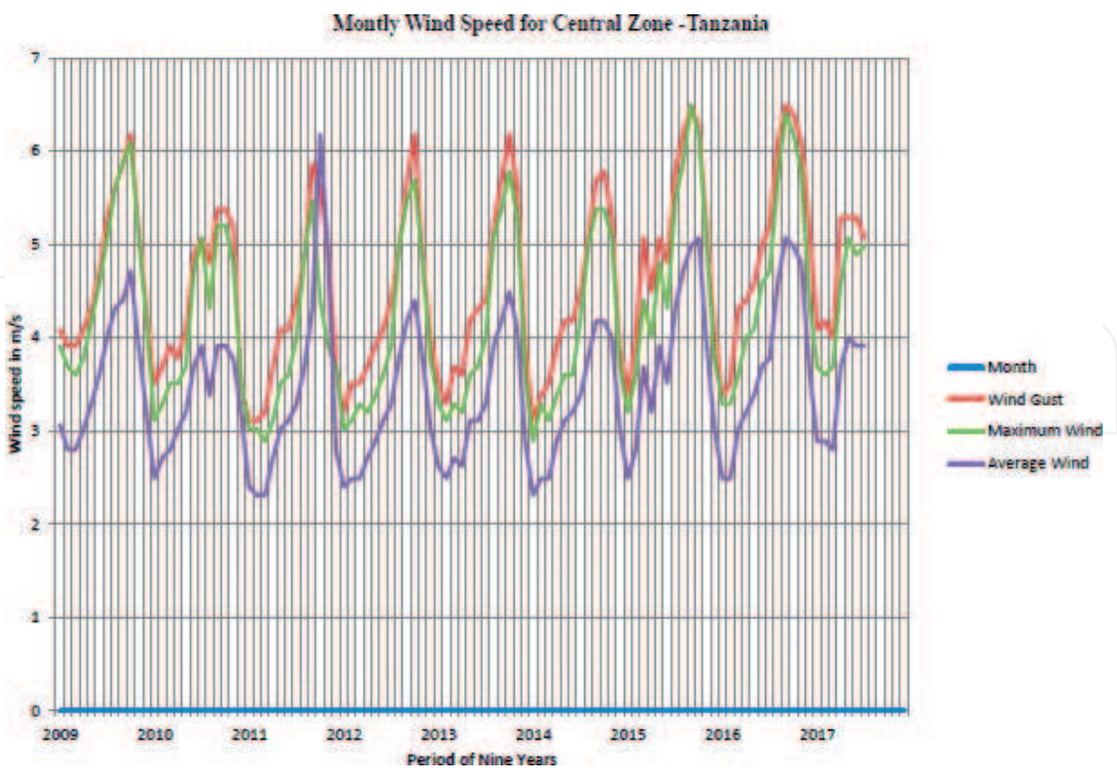


Figure 2. Average wind speed for central zone of Tanzania.

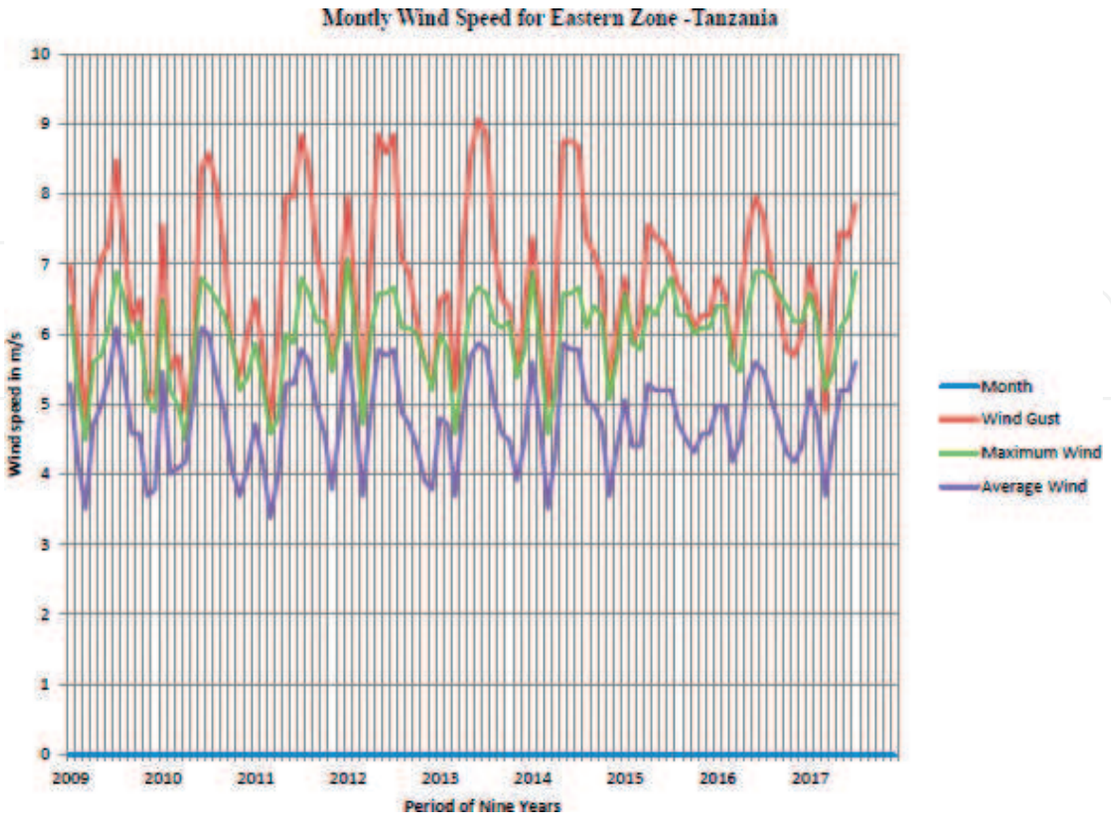


Figure 3. Average wind speed for eastern zone of Tanzania.

(**Figure 5**). In southwest zone, wind speed ranges from 3.8 to 6.7 m/s which is suitable for isolated power supply (**Figure 6**). In northwest zone, wind speed ranges from 2.8 to 4.2 m/s which is suitable for the wind farm and isolated power supply (**Figure 7**). In southwest zone, wind speed ranges from 2.7 to 4.4 m/s which is suitable for isolated power supply (**Figure 8**).

To date, there is no wind farm in Tanzania or even stand-alone systems in Tanzania. Therefore, the country waived taxes such as import, value-added tax to promote renewable energy in the country. Therefore, energy demand for grid connections or stand-alone system would be estimated.

2.1.2. Theory and principles of wind energy conversion

Having the energy demand for grid integration or stand-alone systems, wind energy parameters and equipment would be estimated. Wind turbines can extract kinetic energy from air that passes through the area intercepted by the rotating blades only [9]. For air mass m in kg moving at speed U in m/s, kinetic energy in Joules or Nm available for conversion is:

$$KE = \tfrac{1}{2} \times m \times U^2 \text{ or } KE = \tfrac{1}{2} \times \rho_a \times V \times U^2.$$

where

ρ_a = air density in kg/m^3, V = volume of air in m^3, m = mass in kg/s and can be expressed as:

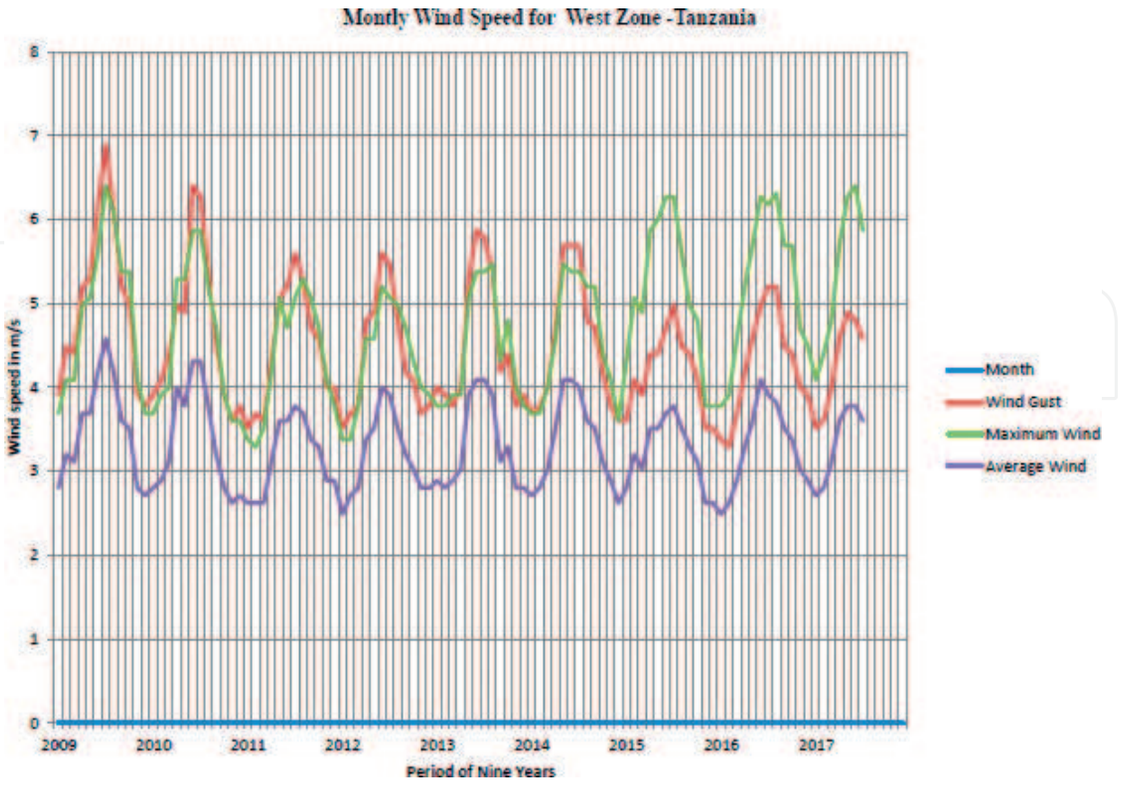


Figure 4. Average wind speed for western zone of Tanzania.

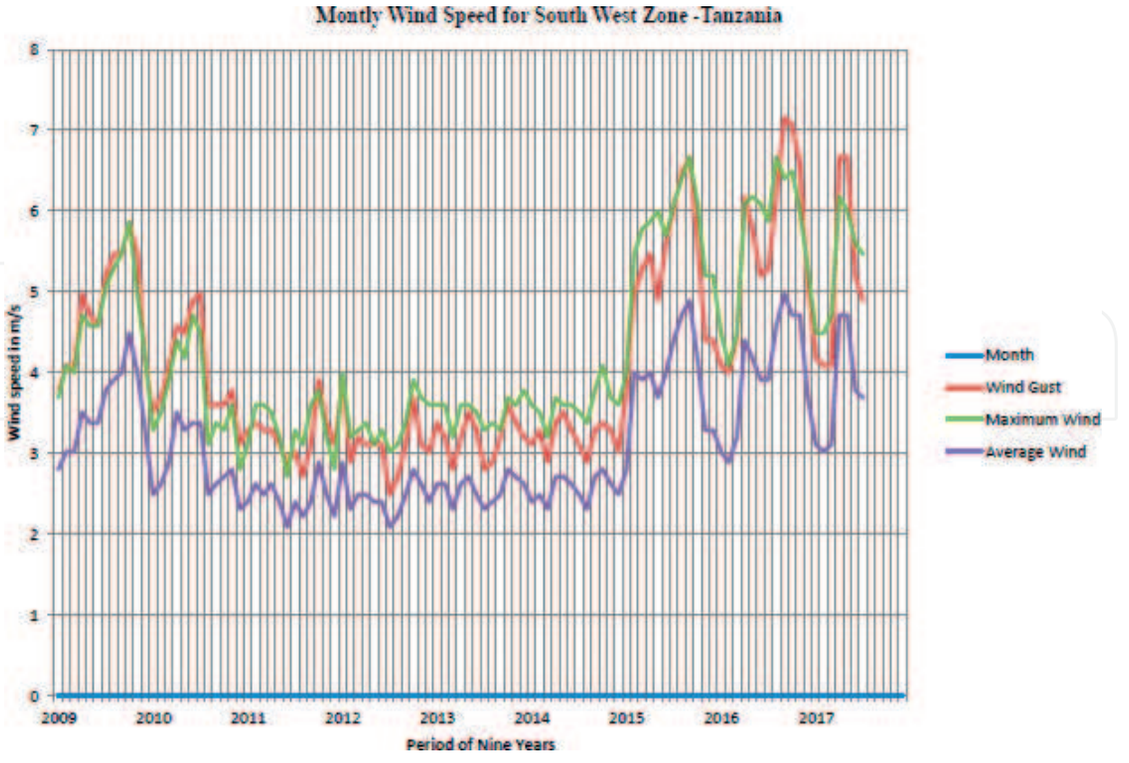


Figure 5. Average wind speed for southwest zone of Tanzania.

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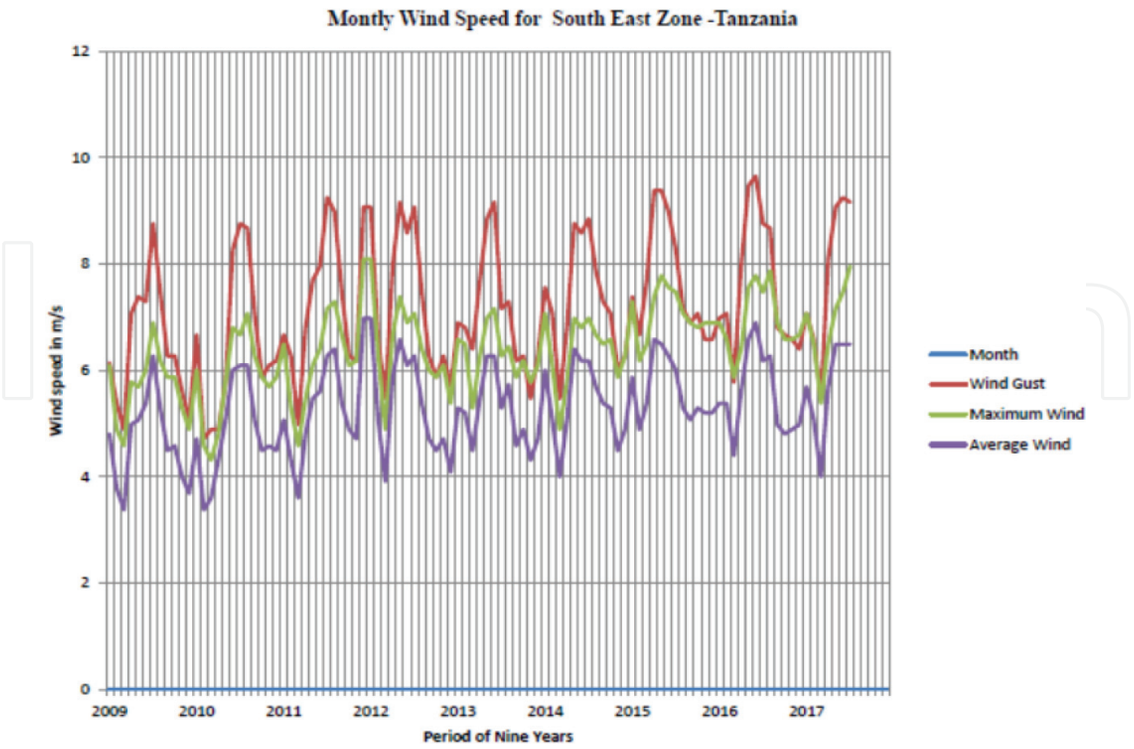


Figure 6. Average wind speed for southeast zone of Tanzania.

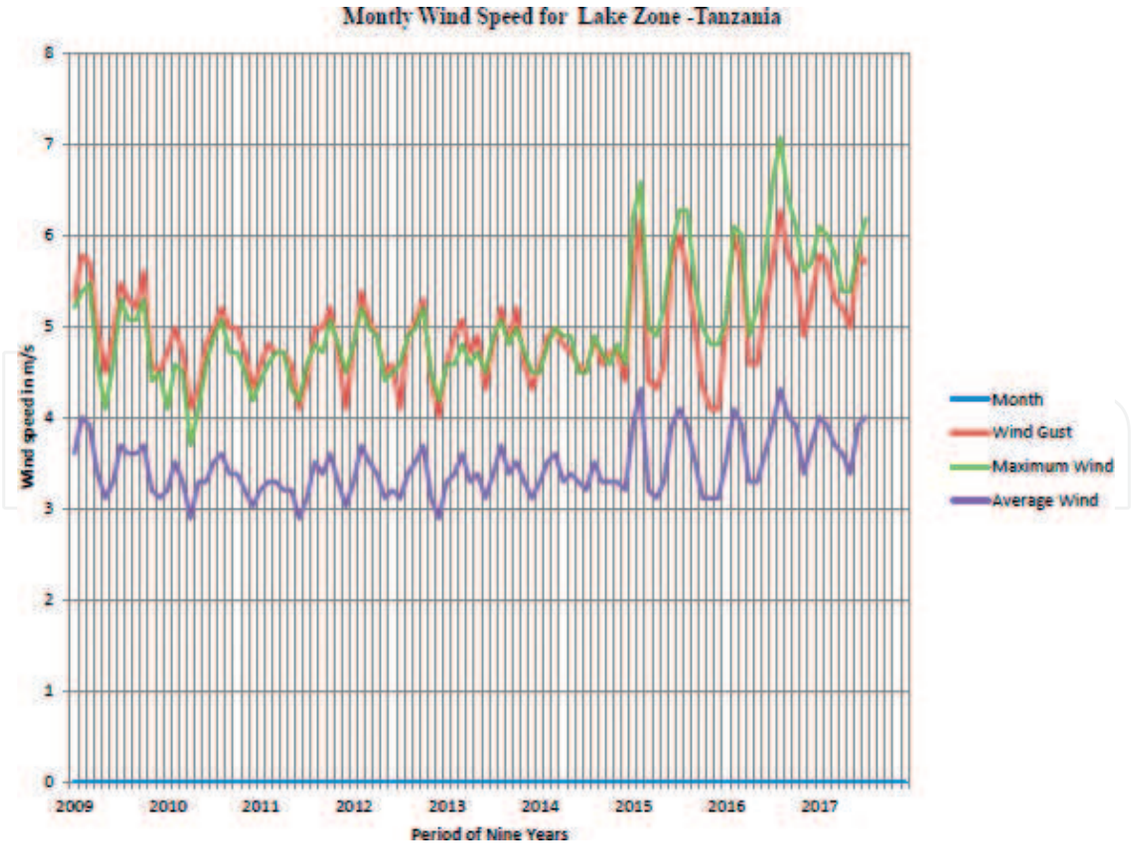


Figure 7. Average wind speed for lake zone (northwest) of Tanzania.

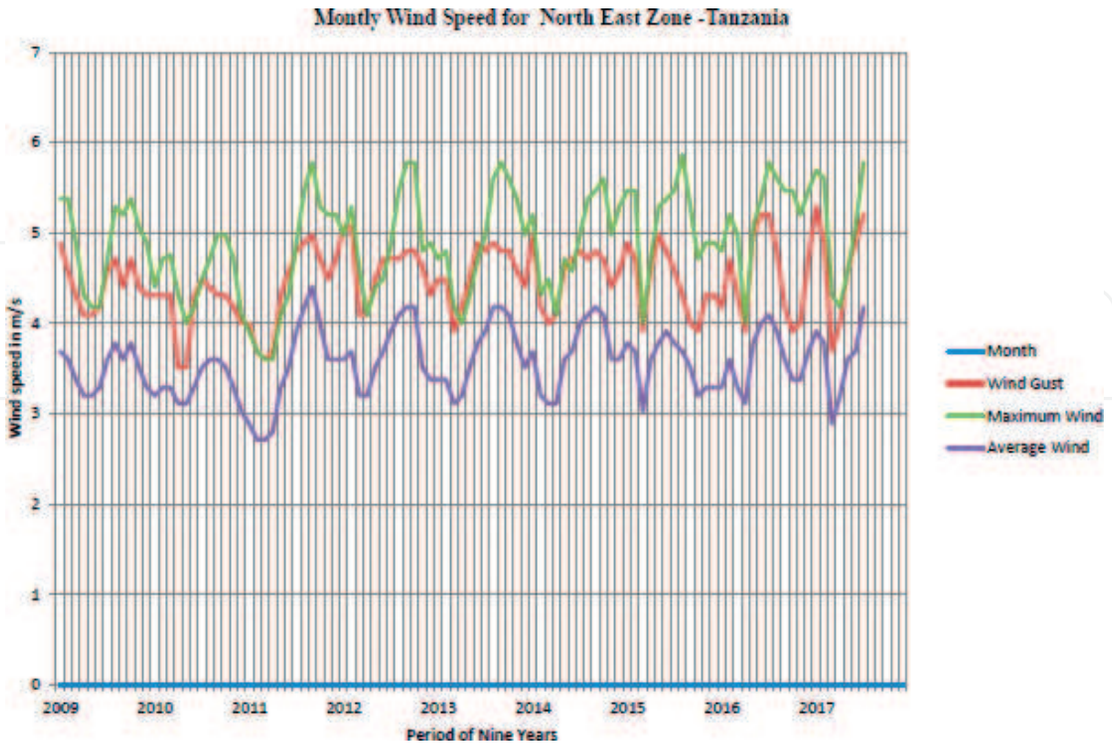


Figure 8. Average wind speed for northeast zone of Tanzania.

$$\mathrm{m} = \rho_{\mathrm{a}} \times \mathrm{A} \times \mathrm{U}$$

Then, available wind power P in watts is:

$$P = \tfrac{1}{2} \times \rho_a \times A \times U^3$$

Power density or power per unit area in W/m^2 of a particular site is:

$$\frac{P}{A} = \tfrac{1}{2} \times \rho_a \times U^3$$

Shaft power that can be obtained from a wind turbine in W is:

$$P = \tfrac{1}{2} \times \rho_a \times A \times U^3 \times C_p \times \eta_t$$

where P = shaft power in watts, A = swept area for the turbine in m^2, U = wind speed in m/s, ρ_a = air density in kg/m^3 (around 1.225 kg/m^3 for 15°C at sea level), η_t = turbine efficiency, and C_p = coefficient of performance that depends on rotor speed and wind speed, i.e., the tip-speed ratio.

Typically, C_p ranges around 0.5 for large electricity-generating wind turbines and 0.35 for water pumping wind turbines. Taking into account generator efficiency η_g, power output from electricity-generating wind turbines is:

$$P = 1/2 \times \rho_a \times A \times U^3 \times C_p \times \eta_t \times \eta_g.$$

2.1.3. Speed extrapolation

Wind speed measurement is usually done by using an anemometer. The anemometer has three cups and vane for capturing wind speed and detects its direction as well. The instrument is normally being installed in a location where wind is free with no influence from nearby object [10]. For the installation of this instrument, economical factor as well as the degree of accuracy is required (as the height increases, the cost of installation increases). Most of the anemometers are installed at the height of 3–10 m; hence, there is a need for speed extrapolation to determine the wind speed at the height of the wind turbine.

Typically, the increase in wind speed with increase in height follows a logarithmic profile that can be reasonably approximated by the wind profile power law, using an exponent of 1/7th, which predicts that wind speed rises proportionally to the seventh root of altitude. Doubling the altitude of a turbine will increase the expected wind speed by 10% and the expected power by 34%. In general, then, wind speed increases with height in some complicated and turbulent way depending on local conditions and topography. Nevertheless, two velocity extrapolation laws exist:

- the 'log law' and
- the 'power law'

These laws can be used to predict the wind speed at the height of power generation from wind speeds measured at a lower height.

2.1.3.1. Log law

The log law, which can be derived theoretically using several different methods, is given by:

$$U_Z = U_{Zr} \times \frac{\ln (Z/Z_o)}{\ln (Z_r/Z_o)}$$

where U_Z = speed at the height of power generation, U_{Zr} = speed at the height of measurement, and Zr and Zo = roughness length.

Roughness lengths range from 0.01 mm for wind flowing over smooth ice or mud to 10 mm over rough pasture to 0.5 m over forests and woodlands.

2.1.3.2. Power law

In power law equation, wind shear is quantified as the exponent n that relates wind speeds at two different heights. Wind shear is possible to be calculated when upper and lower wind speed measurements are available. Wind shear depends on the nature of land surface that is smooth or rough. The areas with trees and buildings will produce more friction and turbulence than smooth surfaces (lakes or open cropland). The greater friction means the wind speed near

the ground is reduced. The approximate increase of speed with height for different surfaces can be calculated from the following equation:

The purely empirical power law is given by:

$$U_Z = U_{Zr} \times \left(\frac{Z}{Zr}\right)^n$$

where

n = exponent determining the wind change,

Zr = reference height,

Zo = roughness coefficient,

U_{zr} = wind speed at the measurement.

But, in practice, wind speed varies with elevation, time of day, season, topography, wind speed, temperature, and other factors. However, increasing more the height of turbine will bring the difficulties about the cost of erecting the tower as well as the cost of foundation. The different values of *n* were indicated in **Table 1** for the different ground natures.

S/N	Type of terrain	n
1.	Smooth sea or sand	0.10
2.	Low grass steppe	0.13
3.	High grass and small bushes	0.19
4.	Woodlands and urban areas	0.32

Table 1. Values of n for different ground covers.

2.2. Solar energy

2.2.1. Introduction

Sunlight is a general term for the electromagnetic radiation emitted by the Sun that can be collected and turned into useful forms of energy, such as heat and electricity, using various technologies. However, the technical feasibility and economical operation of these technologies at a specific location depends on the available solar resource [11].

The Sun rays strike the Earth at the angles ranging from 0° (just above the horizon) to 90° (directly overhead), because the Earth is round and it revolves the Sun and its orbit. The Earth surface will have maximum energy only when the Sun's rays are vertical, as the more Sun's rays are slanted, the long way they travel through the atmosphere, becoming more scattered and diffuse [12]. The Earth revolves around the Sun in an elliptical orbit and is closer to the Sun during part of the year.

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When the Sun is nearer the Earth, the Earth's surface receives a little more solar energy. The Earth has great lines running from west-east namely Equator (0°), Tropic of Cancer (23.5°), north of the Equator (passes through Mexico, the Bahamas, Egypt, Saudi Arabia, and India), and Tropic of Capricorn (23.5°), south of the Equator (passes through Australia, Chile, southern Brazil, and northern South Africa).

Figure 9 shows the energy balance, as the Sun emits solar energy of 173 $\times$ 10^{12} W, at the atmospheric boundary, 30% will be reflected and 70% (121,000 $\times$ 10^{12} W) will reach the Earth. As the Sun comes to Earth, its 30% of energy would be absorbed by the atmosphere and remaining 70% is used in tidal, wind wave, evaporation, fossil fuel, hydro, geothermal, and photosynthesis.

Sunshine is part of the radiation that is supplied by the Sun, especially light, infrared, visible, and ultraviolet light. On Earth, the Sun is filtered through the atmosphere, and it is daylight when the Sun is on the horizon. When the direct sunlight is not limited to the clouds, it has as much sunlight as a mixture of bright light and heat. If it is blocked by clouds or resembles other objects, it is like a diminishing light. Therefore, sunshine is the most important factor for photosynthesis, the process used by plants for converting light energy to chemical energy.

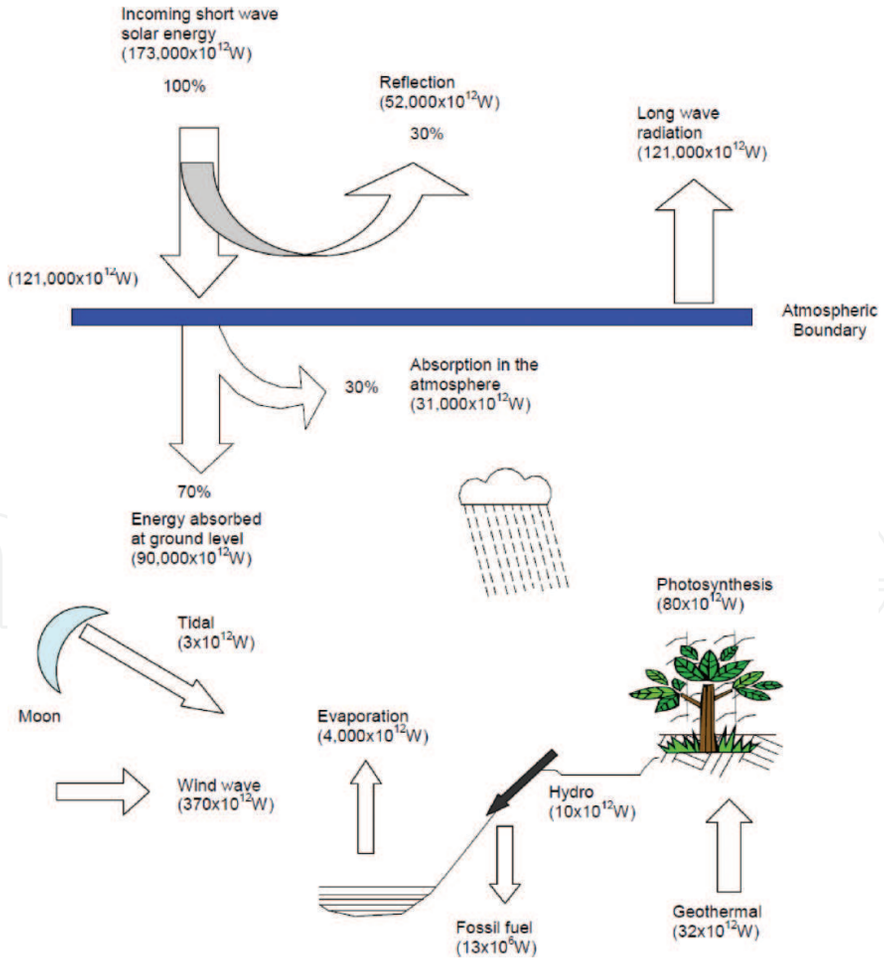


Figure 9. Energy balance.

During photosynthesis, the plant produces carbohydrates and oxygen to form water and carbon dioxide using sunlight as the source of energy [13].

The Sun is overhead at the Tropic of Cancer on June 21 which is the summer in the northern hemisphere and winter in the southern hemisphere. Also, on December 21, the Sun is overhead on the Tropic of Capricorn which is summer in the southern hemisphere and winter in the northern hemisphere. The area bounded by the tropics that are Tropic of Cancer on the north and Tropic of Capricorn on the south experiences tropical climate. The area under tropic climates experiences two seasons in a year that is rainy season and dry season. However, the area in the north of Tropic of Cancer and that at the south of Tropic of Capricorn experiences four seasons in a year that are winter, falls, spring, and summer [14].

The amount of solar radiant energy incident on a surface per unit area and per unit time is called irradiance or insolation. The average extraterrestrial irradiance or flux density at a mean Earth-Sun distance and normal to the solar beam is known as the solar constant, which is 1366.1 W/m^2 according to the most recent estimate [15]. The energy delivered by the Sun is intermittent and changes during the day and with the seasons. Photovoltaic (PV) conversion is the direct conversion of sunlight into electricity [16]. Photovoltaic devices are rugged and simple in design and require very little maintenance, constructed as stand-alone systems to give outputs from microwatts to megawatts and have been used as the power sources for calculators, watches, water pumping, remote buildings, communications, satellites and space vehicles, and even multimegawatt scale power plants. With such a vast array of applications, the demand for photovoltaics is increasing every year [17].

Solar energy exhibits the highest global potential since a number of factors such as latitude, diurnal variation, climate, and geographic variation are largely responsible for determining the intensity of the solar influx that passes through Earth's atmosphere. The average amount of solar energy received at Earth's atmosphere is around 342 W/m^2, of which 30% is scattered or reflected back to space, leaving 70% (239 W/m^2) available for harvesting and capture [18]. The annual effective solar irradiance varies from 60 to 250 W/m^2 worldwide.

Tanzania, an East Africa country, is situated just south of the Equator and is lying in between the area of the Great Lakes such as Lake Victoria, Lake Tanganyika, and Lake Nyasa and the Indian Ocean. It contains a total area of 945,087 km^2 including 59,050 km^2 of inland water. It is bounded on the north by Uganda and Kenya, on the East by the Indian Ocean, on the South by Mozambique and Malawi, on the southwest by Zambia, and on the West by Democratic Republic of Congo, Burundi, and Rwanda. Tanzania has a latitude and longitude reading of 6°00′ south and 35°00′ east.

Table 2 gives the insolation level 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 high costs and pollution problem of standard fossil fuel power plant (**Figure 10**).

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Zone	Solar insolation											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Central	6.1	6.0	6.1	5.7	5.6	5.8	5.7	6.0	6.3	6.4	6.5	6.2
East	5.2	5.3	4.9	4.0	4.3	4.4	4.4	4.0	4.9	5.1	5.8	5.6
Southwest	6.0	6.1	5.7	5.9	6.2	6.3	6.1	6.6	6.7	7.0	6.7	6.2
West	4.3	4.5	4.9	4.3	4.4	4.8	4.3	4.9	4.9	4.7	4.1	4.3
Southeast	4.4	4.6	4.3	4.0	4.4	4.4	4.5	4.6	4.9	4.9	5.2	4.8
Northwest	5.4	5.0	5.4	5.4	5.4	5.0	5.2	5.4	5.4	5.4	5.7	5.4
Northeast	5.6	5.5	5.6	4.7	3.6	3.8	4.0	4.1	4.6	5.0	5.4	5.6

Table 2. Mean monthly solar insolation.

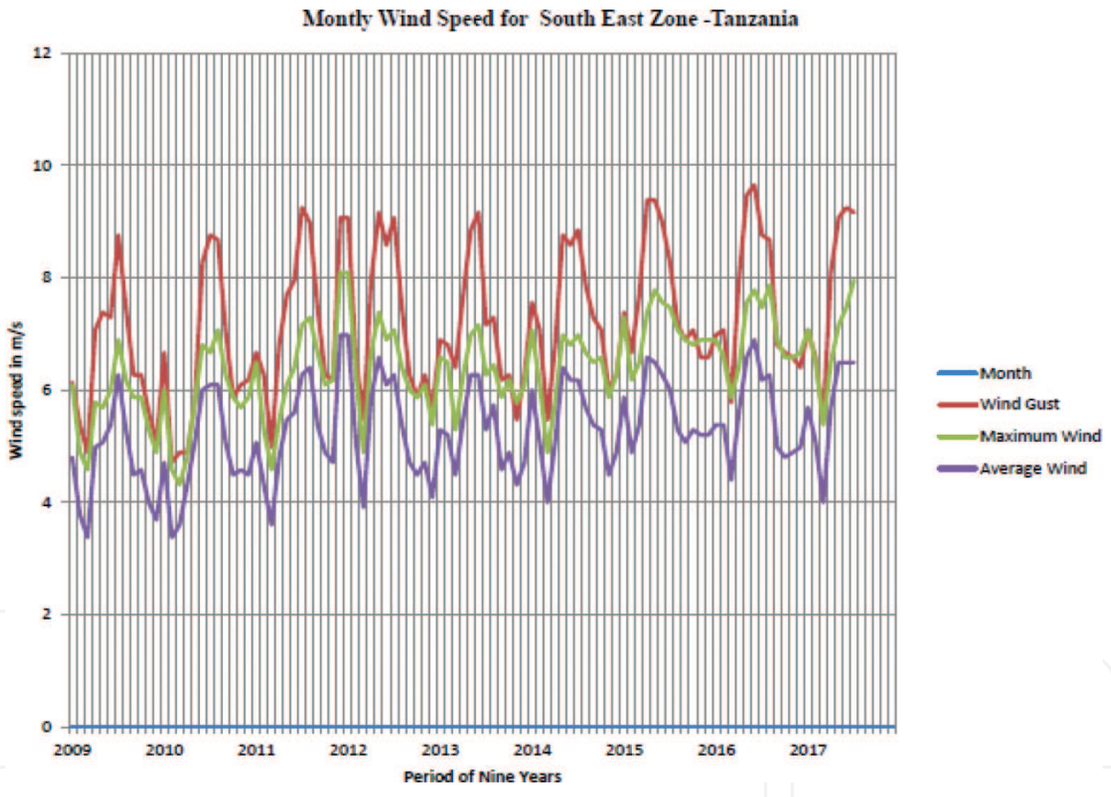


Figure 10. Solar insolation in Tanzania.

2.2.2. Solar PV system sizing

The electricity generated by solar photovoltaic can be stored or used directly, fed back into grid line or connected directly to customers. Solar PV system includes different components that should be selected according to your system type, site location, and applications. The solar PV system consists of the following components: solar panel, solar charge controller, inverter, battery bank, auxiliary energy sources, and loads (appliances).

2.2.3. Determine power consumption demands

Before embarking to system design, all appliances that need to be supplied by the solar PV system have to be identified.

- Record all power ratings of all appliances to be supplied by the solar PV;
- Estimate average hours need to operate each appliance;
- Calculate the energy need by multiplying appliance ratings with estimated hours of use per day;
- Add the watt-hours of all appliances together to get total watt-hours per day;
- Multiply the total appliance watt-hours per day by 1.3 (the energy lost in the systems such as panel, inverter, charger controller, battery, and wiring systems) to get the total watt-hours per day which must be provided by the solar panels.

2.2.4. Size the PV modules

Solar PV exists in different sizes and ratings. The size of solar PV modules depends on total peak watt-hour needed, the climate of the site location, and panel generation factor. The panel generation factors for different locations in Tanzania are given in **Table 2**. The sizing of PV modules is calculated as follows:

- Calculate the total watt-peak ratings for PV modules by taking total watt-hours needed per day divided by the panel generation factor given in **Table 1** to get the total watt-peak rating for the PV panels needed to operate the appliances;
- Calculate the number of PV panels for the system by dividing watt-peak ratings with the rated output watt-peak of the PV modules available. Increase any fractional part of result to the next highest full number and that will be the number of PV modules required.

2.2.5. Inverter sizing

An inverter is the power converter used to convert direct current power (DC) to alternating current power (AC). The inverter is needed when the available appliances need AC power. The size of the inverter should never be lower than the total watts of appliances. Furthermore, when inverter intended to supply inductive loads particularly electric motors and compressors whose startup current are much higher than the usual running current, then size of the inverter should be 3 times the capacity of those appliances to withstand surge current for short time. The ratings of inverter supplying isolated loads must be 25–30% bigger to handle the total amount of watts used at once.

2.2.6. Battery sizing

The batteries are important energy storage for grid and off-grid use. The type of battery recommended for solar PV system is deep-cycle battery. Deep-cycle batteries are designed to handle deep discharged and rapid recharged or cycle charged and discharged day after day for years. When sizing the batteries, important information needed is how much energy is

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consumed daily. When one is changing from grid power supply to renewable energy (solar) monthly, electric bill can be used to estimate daily energy consumption. Furthermore, in sizing the batteries, the intermitted energy supply from renewable energy has to be taken into consideration by estimating days of autonomy due to clouds or rain. The standard days of autonomy are estimated to be 3–5 days. To find out the size of the battery, calculate total watt-hours per day used by appliances and divide the total watt-hours per day used by 0.85 for battery loss. Then, divide the answer obtained by 0.6 for depth of discharge. Then, divide the answer obtained by the nominal battery voltage, and then, multiply the answer obtained with days of autonomy to get the required ampere-hour capacity of the deep-cycle battery.

2.3. Hydroenergy

2.3.1. Introduction

The geographical areas which are best for exploiting small-scale hydropower are those where there are steep rivers flowing all year round. In those areas, water turbines could be installed without a dam to generate electricity for home or community. A small or microhydroelectric power system can produce enough electricity for a village [19]. Small water turbine will produce power nonstop, as long as running water is available. Microwater current turbines are most suited for places where there is an almost a constant flow of water throughout the year. The underdeveloped and developing countries can use these techniques to provide electricity to remote places where transmission line cannot be connected easily or the cost becomes very high. Tanzania has extensive undeveloped hydroelectric resources mainly located in the southern region [20]. Religious centers (missionaries) and individuals in Tanzania are the first investors of microhydropower generation during the colonial period for mainly supplying power to a specific community or for their own use [21]. Geographically, the hydropower potentials of Tanzania are located in the rift valley escarpments which occur in the west, southwest, and northeast Tanzania. Studies show that 12 out 25 administrative regions of mainland Tanzania are blessed with min-hydropower resources but only three regions (Mbeya, Iringa, and Kilimanjaro) have at least managed to develop them.

Figure 11 shows the location of small hydropower sites which have been identified (green dot on the map) with different plant capacities up to 1 MW. Thus, the government is encouraging private investment in energy generation projects.

Majority of people in rural Tanzania are poverty prone and cannot afford the initial connection costs and the monthly bills. Rural electrification projects through grid extension and grid densification are associated with long transmission and distribution distances because of the sparse population as well as low load centers. In these market conditions, projects need government, multinational development agencies, NGOs, and the private sector to work together in order to design and create opportunities that respond to the needs of the local community.

In order to address these challenges, the government has established the Rural Energy Agency (REA) and the Rural Energy Fund (REF). The ongoing reforms in the power sector (liberalization and privatization) are anticipated to increase the interest of private firms investing in the hydropower generation.

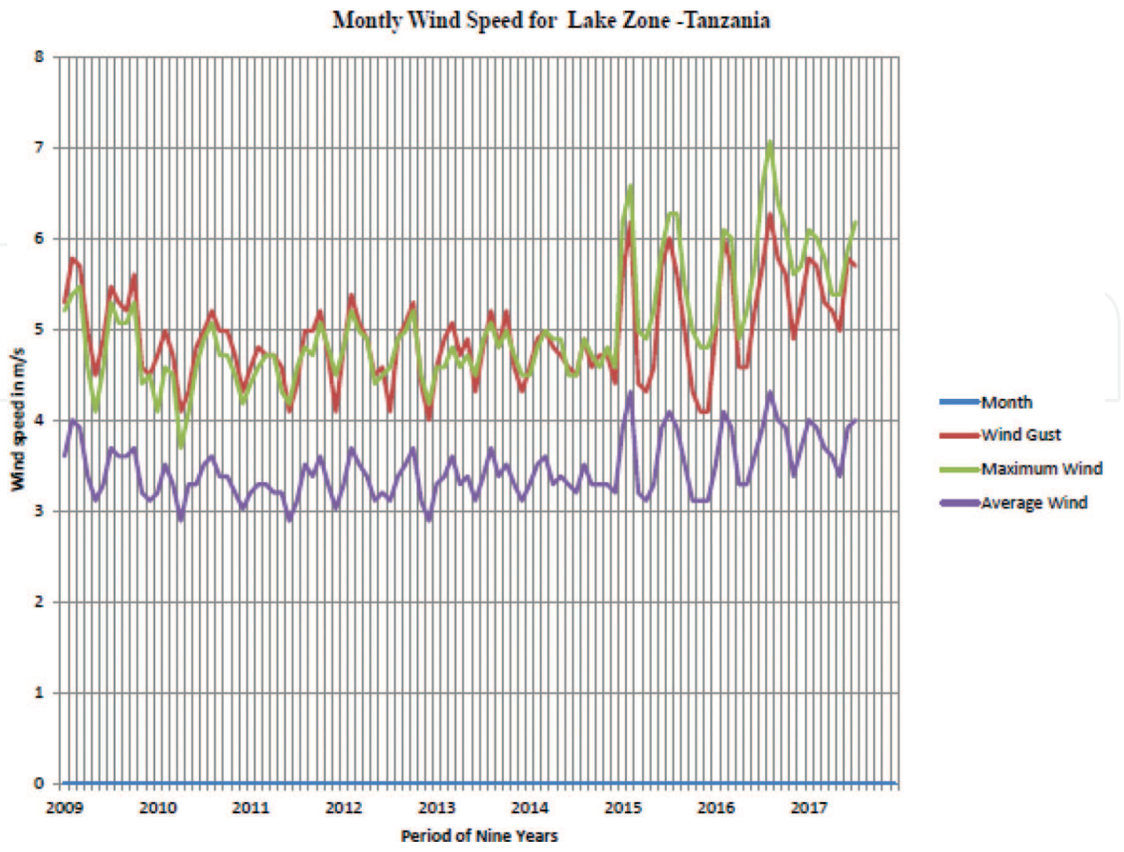


Figure 11. Hydropower potential in Tanzania.

2.3.2. Functionality

Most of the river water starts flowing from higher altitude to low altitude where there are lakes, ponds, or ocean. The river passes in the varying land pattern like steep slope, moderate slope, and nearly flat slope. Current turbines or hydrokinetic turbines are normally installed at the foot of steep slope, so that kinetic energy in water can be converted to mechanical energy for producing electricity. Depending on the nature of the river, that is, when the water flow is seasonal, then, water storage pond is constructed along the river, and when the flow is throughout the year, power-generating systems are directly installed along the flowing water in a river to enable turbine to rotate for producing electricity. Power produced by the moving water depends on water density, water head, and water discharge [22, 23].

2.3.3. Cross-sectional area of natural water steam

$$A_r = \left(\frac{a+b}{2}\right) \times \left(\frac{h_1 + h_2 + h_3 + \ldots h_k}{k}\right)$$

where a = width of top river in meter, b = width of bottom river in meter, and h = height in meter.

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2.3.4. The surface velocity

A floating object, which is largely submerged, is located at the center of the stream flow. The time t (seconds) elapsed to traverse a certain length L (m) is recorded. The surface speed (m/s) would be the quotient of the length L and the time t.

$$V_{rs} = \frac{L}{t}$$

2.3.5. The average flow speed

To estimate the mean velocity, the above value must be multiplied by a correction factor that may vary between 0.60 and 0.85 depending on the watercourse depth and their bottom and riverbank roughness (0.75 is a well-accepted value).

$$V_r = 0.75 \times V_{rs}$$

The flow rate (Q):

$$Q = A_r \times V_r$$

2.3.6. Internal diameter of penstock (Dp)

$$D_p = 2.69 \times \left({n_p}^2 \times Q^2 \times \frac{L_p}{H_g} \right)^{0.1875}$$

where n_p = manning coefficient, L_p = penstock length in meter, and H_g = gross head in meter.

2.3.7. Penstock dimension

Penstocks can be installed under and over the ground, depending on the nature of the ground. The penstock is built in nearly straight lines, with concrete anchor blocks at each bend and with an expansion joint between each set of anchors. The anchor blocks have been provided to resist the thrust and frictional forces caused by the penstock expansion and contraction. The straight section of the penstock lies in steel saddles, made from steel plates to reduce friction forces. For the part of penstock on the ground, it has been provided with supports of different heights depending on the nature of the ground. Spiraled metal sheet-welded steel pipes with flanges on both side have been considered, due to its reasonability in price and availability in different required sizes.

Recommended minimum wall thickness of penstock:

$$t_p = \left(\frac{D_p + 508}{400} \right) + 1.2$$

The vertical weight of penstock and water subjected to support:

$$F = (W_p + W_w) \times L_{ms} \times \cos\theta$$

where W_p = weight of penstock per meter in KN/m, W_w = weight of water per meter KN/m, L_{ms} = length of penstock between midpoints of each span, and θ = angle of pipe with horizontal.

Maximum length between the supports:

$$L_{mms} = 182.61 \times \frac{\left((D_p + 0.0147)^4 - {D_p}^4\right)^{\frac{1}{3}}}{P_w}$$

where P_w is weight of pipe full of water.

2.3.8. Powerhouse

The planned dimension of powerhouse is sufficient for safe operation and maintenance of all equipment included within it. A foundation is required on an adequate bearing soil stratum, with a concrete slab cast to provide a rigid base for the turbine and generator. A channel at the base slab is needed for outflow of water from the system. The powerhouse should be secured to prevent unauthorized access.

2.3.9. Power generated in watts

$$P_t = \rho g h_n Q \eta_t$$

where ρ = water density (1000 kg/m^3), h_n = head, and η_t = turbine efficiency.

2.3.10. Dump load

The load connected to hydropower varies time to time in a day that is peak hours and off-peak. During a day, peak hour's power produced is utilized by the connected load; therefore, the machine frequency would remain within the required limit. Furthermore, during the off-peak, load power consumed by the load is low compared to the power produced by the hydroturbine causing the machine to accelerate, hence the frequency increases. Therefore, to overcome this situation, a dump load in an electrical resistance heater (air or water) is installed to the system to dissipate excess power, so that the machine frequency is kept within the required limit. The size of dump load is usually equal to maximum power generated by the hydroturbine so that it can handle the full generating capacity of the microhydroturbine. Dump loads should be activated by the controller whenever power produced is not consumed by the load or grid (integrated system), to prevent machine accelerations which might result in system damage. Excess energy in the system is diverted to the dump load; it is envisaged most scheme offers excess power at all times.

2.3.11. Metering

In power plant, the quantities such as current, voltage, and frequency need to be monitored by measuring and displayed by the meters (whether analogue or digital). The load connected to

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hydropower needs specific magnitude of voltage and current. Operating load with the low magnitude of voltage and frequency results in efficiency reductions, while operating with higher values results in insulation failure, hence equipment damages. Therefore, several parameters of microhydroelectric system's performance and status are monitored by recording how much electricity is producing or has produced, and how much electricity is being consumed.

3. Government initiative in promoting renewable energy through small power producers

The first power plant was operated by diesel fuel in 1933 followed by 5-MW hydropower plant in 1936. These two power plants were supplied to the big town, leaving the rural area and small town with no electricity. Power generation capacity has been increasing in slow pace until 1959 with installed capacity reaching 17.5 MW. Furthermore, the isolated power plants operated by diesel were constructed in big towns all over the country.

The country has invested by constructing 21-MW Hale hydropower station in 1962, integrated with the existing power plants in north part of the county. For more integration, transmission line was constructed to integrate isolated power supply in the east part of the country. In 1969, there is an 8-MW Nyumba ya Mungu hydropower station on the headwaters of the Pangani River. In 1968, two hydropower plants generating units (50 MW each) to supply 100-MW Kidatu power station were installed. The installed capacity of the hydroelectric power station at Kidatu was doubled and reached 200 MW in 1980 [24].

All this investment in power generation plants was also accompanied by the construction of transmission to integrate the existing power plant as well as decommissioning diesel power plants.

The country has invested in power generation and distribution using state own company. Now, the country has the vision of becoming a middle-income country by 2025, with the electricity consumption of 490 kWh/capital. To support that vision, the Tanzanian government envisages the increase of electricity generation from 1357.69 MW in 2015 to 4915 MW by 2020 and improving electricity connections to 60% of the population from 18% in 2015. On average, the manufacturing sector will grow by over 10% per annum with its share in total exports increasing from 24% in 2014–2015 to 30% in 2020.

In order to meet energy requirement as well as the country's vision of becoming the middle-income country, energy policy was reviewed in order to invite independent power producer as one of the stakeholders in the electricity industry. The small power producers (SPPs) are private companies that develop renewable energy generation projects on a small scale (less than 10 MW). They are licensed to sell electricity either to local communities or to the national grid under a power purchase agreement with Tanzania Electric Supply Company Limited (TANESCO), a government-owned company, or to both TANESCO and the local communities.

4. Strategies of retaining youth in the rural areas

Tanzania has the population of 51.6 million; about 70% of this population lives in the rural area performing agriculture and animal keeping activities. They grow seasonal crops, food crops, fruits as well as cash crops and long-term crops. Most of the seasonal crops are planted during the raining season and harvested in dry season, while few of them practice irrigation agriculture. For the year with low rainfall, farmers get less harvest, hence need to buy food for their family; when rainfall is normal, they get more harvest. Moreover, they grow nonseasonal crops like cassava, cashew nut, banana as well as fruits like oranges, mangoes, and others. During harvesting period, the surplus food crops, fruits, and cash crops would be sold as raw due to the lack of storage facilities and value addition machinery because of lack of electricity. For example, coastal part of Tanzania is famous for the production of oranges. The situation in several markets during the orange harvesting is as seen in **Figure 12**.

Therefore, this lack of electricity in rural areas has caused poverty and also the quality of education is declining time to time as competent educators shifted to urban areas where there are good infrastructures for social life. This fact has discouraged young generation to stay in rural and they tend to migrate to urban leaving their community with no human resource to perform economic activities (farming and livestock keeping).

Therefore, women and youth in rural areas have to be empowered through effective participation in the management of their own social, economic, and environmental objectives by

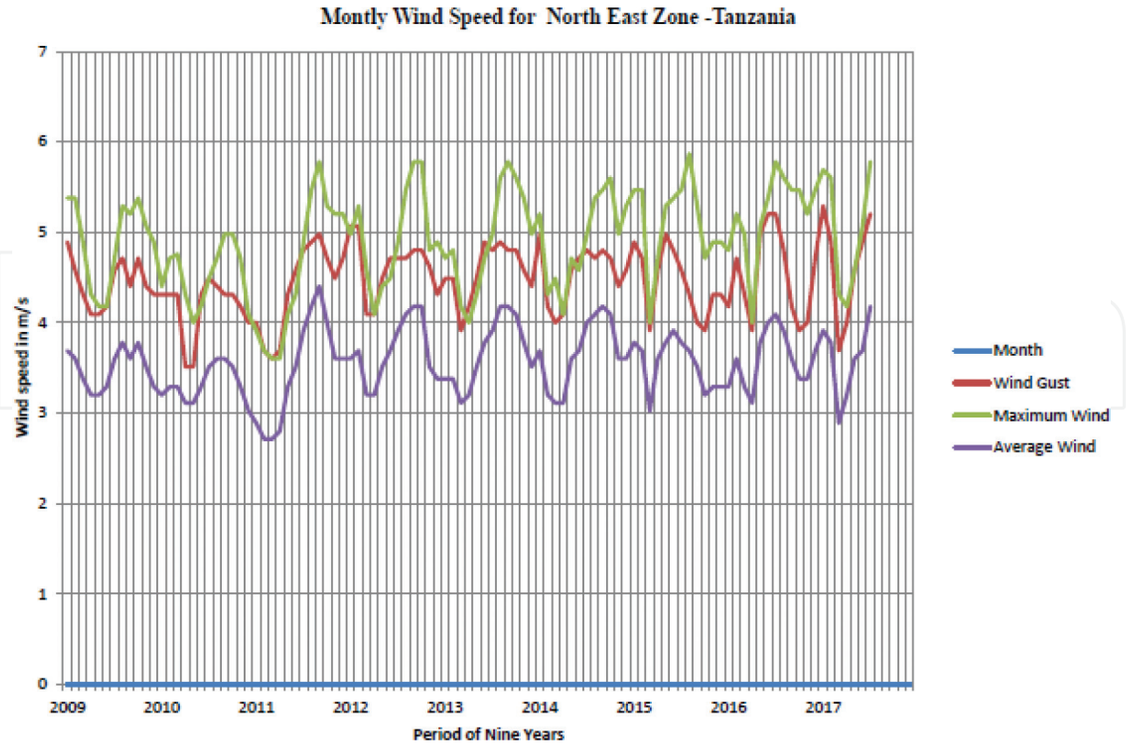


Figure 12. Oranges in the market.

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establishing their own organizations such as local cooperatives and by applying the bottom-up approach.

Telecommunication in most of the rural areas is affected by the lack of reliable electricity to power microwave telecommunication links. The microwave links need reliable electricity in order to receive and transmit the information; therefore, due to the lack of electricity, the telecommunication providers failed to extend their service to rural areas due to economic viability. The few microwave links found in the rural area are powered by diesel generators which are very expensive.

On the other hand, lack of electricity causes the mobile subscribers to switch off their mobile phone to extend the cycle of recharging their mobile phone. Furthermore, the network is available in specific areas (especially higher elevations), where everybody is going there for communications. Therefore, an electrifying rural area will motivate telecommunication operators to install more microwave towers that will make the availability of network in the rural area as well as strengthen business among the communities in rural and urban areas.

Electrification of rural areas has to be done to stimulate income generation activities and value addition as well. Having the electricity in the rural area will keep busy the rural community by engaging themselves in several income generation activities in their area.

Electrification in the rural area will motivate establishment of small-scale industries for value addition to farm and animal's product. The value addition to milk product industry will motivate rural people to keep more cattle in the modern ways of getting more milk and manure. They will sell their milk to the processing industry where it can be processed for the export to the urban area. The other product is the manure which can be obtained by fermenting cow dung. The gas obtained can be used for heating purposes and the by-product is used as the manure in farms. Furthermore, the small industries like those making tomatoes as source, fabric from tomatoes, processing leather, food processing, and others will stimulate more investment in those sectors. Also, integration of rural areas with neighboring urban areas for the creation of rural off-farm employment can narrow down the migration of youth from rural to urban as well as expand opportunities and also encourage the retention of skilled people, including youth, in rural areas.

5. Conclusion

Renewable energy in Tanzania is not developed to generate electricity; hence, the community in the rural areas depends fully on wood fuel for heating and kerosene for lighting. This lack of electrical energy does not favor young people and skilled personnel to be retained in the rural areas for income generation activities; hence, they migrate to urban area. This situation has resulted in increase in the population in urban area engaging themselves in business, while production of food in rural areas declines due to the shortage of human resource, hence inadequate food in the country. The analyses of three major types of renewable energy that are wind, solar, and hydropower have shown great potential all over the country.

The information collected from Tanzania Metrological Agency shows that in several parts of the country, there is an adequate wind speed to be used for electricity generation, for grid integration, and stand-alone systems. For electricity generation, wind speed needed is 3 m/s and above which has been noticed. Thus, when embarking to the project, not only the mean wind speed but also the wind speed frequency distribution, commonly described by a Weibull distribution, has to be taken into account in order to estimate accurately the amount of electricity to be generated. The location with poor wind speed has blessed with other types of renewable energy; therefore, no location with no source of renewable energy.

Information collected for solar energy shows that there are good solar insolation all over the country of 4.0 and above. The country has two seasons that are rainy season and dry season. Normally, rainy season is between December and May, sometimes several hours of clouds in a day which does not affect solar system. In dry season, June–November, there is enough Sun for charging the systems. The solar insolation in the country is sufficient for grid integration as well as isolated and the roof-mounted solar system.

The information for hydropower in the country is located at the steep rift valley in western zone, northern zone, and west zone, which need to be developed. Most of the hydropotentials are pico, micro, and mini which can work at isolated systems and integrated system when there is grid networking nearby. Majority of people in rural Tanzania is poverty prone and cannot afford the initial connection costs and the monthly bills. Rural electrification projects through grid extension and grid densification are associated with long transmission and distribution distances because of the sparse population as well as low load centers. In these market conditions, projects need government, multinational development agencies, NGOs, and the private sector to work together in order to design and create opportunities that respond to the needs of the local community.

The government has put in place the policy to motivate small power producers (SPP), so that renewable energy power generation would be developed. The SPP would be licensed to sell electricity either to local communities or to the national grid under a power purchase agreement with Tanzania Electric Supply Company limited (TANESCO), a government-owned company, or to both TANESCO and the local communities.

Also, rural livelihoods have to be enhanced through effective participation of rural people and rural communities in the management of their own social, economic, and environmental objectives by empowering people in rural areas, particularly women and youth through organizations such as local cooperatives and by applying the bottom-up approach.

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http://dx.doi.org/10.5772/intechopen.74956

References

[1] https://www.usea.org/sites/default/files/event-/Tanzania%20Power%20Sector.pdf

[2] Kimambo C. Development of integrated water pumping and electricity generating wind system for remote applications. University of Dar Es Salaam; 2007

[3] URT. Sustainable Energy for all Rapid Assessment and Gap Analysis. 2013. http://www.se4all.org/sites/default/files/Tanzania_RAGA_EN_Released.pdf

[4] Mashauri A. A review on the renewable energy resources for rural application in Tanzania. Dar es Salaam, Tanzania: Electrical Engineering Department, Dar es Salaam Institute of Technology; 2011

[5] Melkior UF. Study of electrical power generation from windmill coupled with water pump. University of Dar Es Salaam; 2010

[6] World Bank Wind Resource Mapping in Tanzania Site Identification Report. 2015. http://pubdocs.worldbank.org/en/289831465287638659/Tanzania-Wind-Mapping-Site-Identification-Report-WB-ESMAP-July2015.pdf

[7] http://www.iea.org/publications/freepublications/publication/Wind_2013_Roadmap.pdf

[8] Al-shemmer T. Wind Turbine, 1st ed. 2010; ISBN: 978-87-7681-692-6

[9] Teubner Stuttgart BG. Grid Integration of Wind Energy Conversion Systems. 1996; ISBN: 0-471-97143

[10] Şen Z. Wind Velocity Vertical Extrapolation by Extended Power Law. https://www.hindawi.com/journals/amete/2012/178623

[11] Jäger K. Solar energy fundamentals, technology and systems. Delft University of Technology; 2014. https://courses.edx.org/c4x/DelftX/ET.3034TU/asset/solar_energy_v1.1.pdf

[12] United Republic of Tanzania. Renewable Energy Policies and Practice in Tanzania

[13] http://www.nclark.net/photosynthesis.pdf

[14] Nzali AH. Insolation energy data for Tanzania. In: International Conference on Electrical Engineering and Technology; the University of Dar es Salaam; 2001. pp. EP26-EP32

[15] Al-Tameemi MA, Chukin VV. Global water cycle and solar activity variations. Journal of Atmospheric and Solar - Terrestrial Physics. 2016;**142**:55-59

[16] Hart Hubris, the troubling science, economics, and politics of climate change, Compleat Desktops Publisher (2015). ISBN: 9780994903808

[17] Luqman M, Ahmad SR, Khan S, Ahmad U, Raza A, Akmal F. Estimation of solar energy potential from rooftop of Punjab government servants cooperative housing society Lahore using GIS [article ID:56795]

[18] https://gcep.stanford.edu/pdfs/assessments/solar_assessment.pdf

[19] Zainuddin H, Yahaya MS, Lazi JM, Basar MFM, Ibrahim Z. Design and development of pico-hydro generation system for energy storage using consuming water distributed to houses. International Journal of Electrical and Computer Engineering World Academy of Science, Engineering and Technology. 2009-11-23;**3**:150-155

[20] https://www.esmap.org/sites/esmap.org/files/01-KEF2013-REM_Gratwicke_Rift%20Vallery%20Energy.pdf

[21] https://www.esmap.org/sites/esmap.org/files/TEDAP%20SPPs%2011-18.pdf

[22] Kumar A, Schei T, Ahenkorah A, Caceres Rodriguez R, Devernay JM, Freitas M, Hall D, Killingtveit A, Liu Z. Hydropower. In: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2011

[23] Nasir BA. Design of micro-hydro electric power station. International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249-8958. June 2013;**2**(5)

[24] http://www.ewura.go.tz/wp-content/uploads/2017/01/Power-System-Master-Plan-Dec.-2016.pdf

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