# ENERGY SECTOR AND SOLAR ENERGY POTENTIAL IN TANZANIA

**Esebi A. Nyari[a*], Tatiana Pogrebnaya[a] and Lugano Wilson[b]**
[a]The Nelson Mandela African Institution of Science and Technology, P. O. Box 447, Arusha, Tanzania,
[b]Tanzania Industrial Research and Development Organization (TIRDO), P. O. Box 23235,
Dar-es-Salaam, Tanzania

## Abstract
This paper presents the current energy situation, energy demand, and the potential of solar energy in Tanzania. Tanzania is blessed with abundant resources such hydro, wind, solar, geothermal, natural gas, coal etc. However, today the country energy sector specifically electricity depends mainly in hydro energy resource (36%) and fossil fuel (62%) such as oil and natural gas. Annual energy consumption of the country is approximated to be more than 22 million tonnes of oil equivalent (TOE), where as the rate of electricity demand increase is about 10 – 15 % per annual. Natural gas is one of fast growing sector, and at present the country has eleven proven onshore natural gas deposits. It is expected that more than half of electricity generation will come from natural gas in the near future. Moreover, Tanzania receives between 2800 – 3500 hours of sunshine per year and a global radiation of between 4 to 7 kWh/m$^2$/day. This makes the country to be one of potential area for solar energy applications in both electricity and other thermal applications. However, use of solar energy potential for both thermal and electricity generation are still in development stages.

***Keyword:*** *Energy sector; Energy production–consumption; Energy demand; solar energy; Tanzania*

## 1. Introduction
Energy is one of the crucial inputs in all aspects of development as it supports population growth, urbanization, and industrialization as well as tourism industry (Larsen, 2007; Johari *et al.*, 2011; Bauner *et al.*, 2012). In developing countries like Tanzania, electricity supply is usually low compared to its demand; as such the country is forced to continue expanding its power generation capacity to meet the growing demand, but it has to be in a sustainable and diverse manner (MEM, 2013). Generally, there are two methods of supplying electricity to both rural and urban areas in this country; grid extension and the use of isolated diesel generators. Both options are not sustainable for rural areas since grid connections are costly and isolated diesel generators necessitate continued reliance on expensive diesel fuel (Painuly *et al.*, 2005). For instant, the World Bank estimates that grid extension prices vary from USD 6,340/km in densely populated regions to USD 19,070/km in regions with dispersed population (Kimambo, 2012). Therefore, there is a need to utilize sustainably the available substantial indigenous energy resources such as solar, hydro, biomass, wind, and geothermal in Tanzania, which can reduce the country's dependency on fossil fuels (Damian, 2009; Bauner *et al.*, 2012; Kimambo, 2012; GreenMax-Capital-Advisors, 2013). In this regard, solar energy is perhaps one of the hopeful sources of renewable energy as Tanzania receives abundant sunlight throughout the year. Therefore, this paper presents a review of current energy sector and solar energy potential in Tanzania.

## 2. Geographic Profile of Tanzania
Tanzania is located in Eastern Africa between latitude 1º and 12º South and extending longitude 29º to 41º East (Damian, 2009). It is the largest country in East Africa in terms of size and population. The country covers an area of 945,749 km$^2$ (which includes Zanzibar of approximately 2000 km$^2$), where by about 94% of area is land and the remaining portion is covered by water (Alois, 2009; Damian, 2009; MEM, 2013; Msyani, 2013). Woodlands accounts for 33,500 km$^2$ and arable land suitable for agriculture is concentrated in the central part of the country, covering 44 million hectares (Damian, 2009). The water surface includes three lakes: Lake Victoria in the North, Lake Tanganyika in the West, and Lake Nyasa in the South-West.
On the other side, 2012 Population and Housing Census estimated the population of Tanzania to be 45 million people with about 70% of the national population lives in rural areas. Figure 2.1 shows the Tanzania population trends from 1967 to 2012 censuses. In 2012 census, the growth rate was estimated to be 2.7%, which implies that in the next 26 years the populations will double the current (NBS, 2013). This increase in populations would consequence increase energy consumption of country. On the other hand, Tanzania is sparsely populated with population density of 51 persons per square kilometer with variation across regions (NBS, 2013). Study by MEM (2013) put forward that, given the dispersed nature of rural populations and low densities, electrification would have to be accomplished using a combination of grid extension, mini and micro-grids, or stand-alone systems.

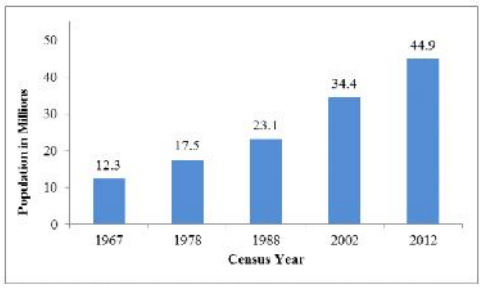


Figure 2.1 Population Trends in Tanzania, 1967 – 2012 Censuses (NBS, 2013)

## 3. Energy Situation in Tanzania

The energy situation in Tanzania is characterized by low per capita consumption of commercial energy sources and a high dependence on non-commercial energies, including biomass fuels in the form of firewood, charcoal, and bio-waste (Maleko, 2005). Biomass-based fuel accounts for more than 90% of primary energy supply and remain is commercial energy sources i.e. petroleum, gas, and electricity (Maleko, 2005; Larsen, 2007; Msyani, 2013). Approximately 80% of all biomass in Tanzania is consumed in rural areas as firewood and only 20% in urban areas mainly used as charcoal (Mwakapugi *et al.*, 2010). As a result of heavy dependence on biomass as the main energy source the rate of deforestation is frightening. In 2009, the rate was estimated to be 412000 hectares per annum and this puts the availability of future biomass sources at risk (Damian, 2009; Pye *et al.*, 2010).

On the other hand, Tanzania imports 100% of the petroleum and the related products. Petroleum is mainly used for transport, and electricity generation (Bauner *et al.*, 2012; Energypedia, 2014). Consequently, price fluctuations on the world market creates a big negative impact on the country's economy (Damian, 2009). According to Pye *et al.* (2010), the consumption of fuels in transport sector increased from 400 kTOE in 2000 to 1000 kTOE in 2007, at the same time road vehicles number is getting higher each year. Kerosene is mostly used in rural areas for lighting devices and costs about USD 0.50 per day (GreenMax-Capital-Advisors, 2013). Currently, oil importation costs about 25% to 35% of the nation's foreign currency income (Msyani, 2013).

In the 1970's local availability of natural gas was confirmed in Tanzania and today the country has eleven proven onshore natural gas deposits namely: Mnazi Bay, Songo Songo, Mkuranga, Kiliwani, Ntorya and Deep Sea eight discoveries; (Chaza, Jodari, Zafarani, Pweza, Mzia, Chewa, Papa 1, and Lavani1) (PSMP, 2013). Among the discoveries, Mnazi Bay and Songo Songo have proven commercially viable quantities of gas and are in operational, with utilization of only about 20% and 100% of their capacity respectively (Larsson *et al.*, 2013). At the moment, the available natural gas is mainly used to generate electricity by the following power plants; Songas Power Plant, Tanesco Power plants, and Wentworth. Whereas Somangafungu (Kilwa), Kinyerezi, Symbion - Ubungo and Tegeta IPTL power plants are expected to take off in the near future. The use of natural gas for cooking and transportation are still in a pilot stage.

Tanzania coal reserves are estimated at about 1,200 million tonnes of which 304 million tones are proven with main coal reserves at Lake Nyasa area (Energypedia, 2014). The Government of Tanzania is strategizing to generate electricity using Mchuchuma coal in collaboration with private sector. The PSMP (2013) update assumed that 3,800MW of new local coal would be developed from presently proven reserves from Mchuchuma, Katewaka, Ngaka, and Kiwira coal fields by 2034.

The country's electricity sector is run by a vertically integrated state owned public utility enterprise referred to as Tanzania Electric Supply Company Limited (TANESCO) which carries out generation, transmission, distribution and supply. Today electricity in country is produced by TANESCO, Independent Power Producers (IPP), Emergency Power Producers (EPP) and Small Power Producers (SPP) as shown in
Figure 3.1.

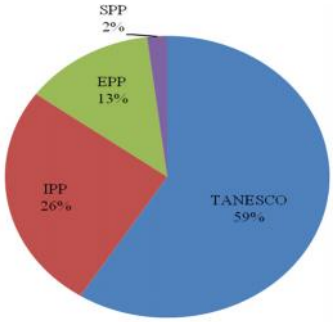

Figure 3.1 Electricity Producer Share (MEM, 2013)

Prior to 2004, electricity generation in Tanzania depended almost entirely on traditional hydro sources. But at present, generation compose 35% hydro and 62% fossil fuels, which is oil and natural gas (GED, 2013). **Error! Reference source not found.** indicates fuel mix in electricity generation in Tanzania from year 2002 to 2012.

Table 3.1 Fuel mix in electricity generation (GWh)

| **Fuel Type** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Coal | 105 | 73 | 86 | 41 | 24 | 36 | 19 | 0 | 0 | 0 | 0 |
| Oil | 1 | 37 | 881 | 587 | 686 | 484 | 326 | 110 | 197 | 833 | 1166 |
| Natural gas | 0 | 0 | 360 | 1149 | 1301 | 1138 | 1392 | 1986 | 2351 | 2580 | 2940 |
| Biofuels/waste | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 25 | 19 |
| Hydro | 2720 | 2549 | 2011 | 1778 | 1436 | 2524 | 2649 | 2640 | 2621 | 1806 | 1657 |
| solar PV | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 |
| **Total production** | **2826** | **2659** | **3338** | **3555** | **3447** | **4182** | **4386** | **4736** | **5187** | **5244** | **5795** |

Source: IEA (2014)

As of May 2014, Tanzania's total installed generation capacity was 1,583 MW composed of hydro 561 MW, natural gas power plants of 527 MW and liquid fuel power plants of 495 MW (MEM, 2014). In addition, the 20 townships in other regions served by TANESCO are reliant on isolated diesel (18) and natural gas (2) generators (MEM, 2013). The country also imports 10 MW from Uganda to serve the Kagera region in the West, 5 MW from Zambia to serve Mbeya and Sumbawanga in the Southwest and 1 MW from Kenya to serve Mara region (Larsen, 2007; MEM, 2014).

Meanwhile, access to electricity is limited to millions of Tanzanians mainly due to the lower connection to grid (Maleko, 2005; Pye *et al.*, 2010). It is estimated that about 21 to 24% of the country's population mainly urban based (50%) has access to electricity (GreenMax-Capital-Advisors, 2013; MEM, 2014). According to recent figures published by the Tanzania Power System Master Plan, the three regions with high access to electricity are Dar es Salaam (39%), Kilimanjaro (21%), and Arusha (17%) while regions with low access are Lindi, Mtwara, Manyara, Mwanza, Shinyanga and Rukwa both with 3% of all households in the regions having a grid connection (PSMP, 2013). Rural electrification coverage is low with fewer than 7% of the rural population having access to electricity (GreenMax-Capital-Advisors, 2013; MEM, 2013). Apart from having thousands of villages and millions of rural households living without grid connection, institutions such as schools, health centers and nursing homes also lack modern energy in Tanzania (Bauner *et al.*, 2012). Several studies anticipate that grid coverage for rural population is likely not to be accomplished in the near future, due to high cost of grid extension, and dispersed nature of rural populations (MEM, 2013; PSMP, 2013).

### 3.1 Energy Consumption and Demand

Tanzania is one of the lowest countries in the world in terms of energy consumption. In 2010, the total energy consumption was estimated to be more than 22 million tonnes of oil equivalent (TOE), equal to almost one billion gigajoule (GJ) or 0.7 TOE per capita (Bauner *et al.*, 2012). According to MEM (2013), most of this energy is used in the residential sector, and the majority of it is biomass and agricultural waste. Other main energy consuming sectors in the country are industry, agriculture, and transport with mining growing in importance.

In terms of electricity, the country has very low levels of electricity consumption per capita – under 100 kWh per person per year (PSMP, 2013). This is far much less than the world average consumption of 2,000 kWh per annum and average consumption in developing countries such as Sub-Saharan African of 552 kWh per annum (MEM, 2013). The annual electricity consumption in Tanzania was estimated to be 5,740.84 GWh in 2012 (Msyani, 2013). Figure 3.2 show the trends of electricity consumption in Tanzania from 2001 to 2011.

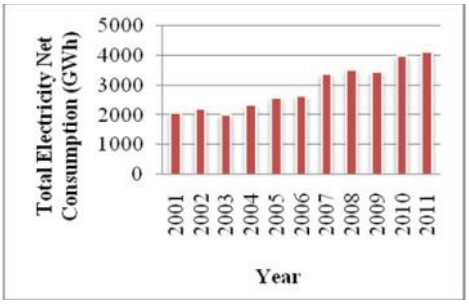


Figure 3.2 Trends of electricity consumption in Tanzania 2001-2011, Source: (EIA, 2014)

In 2012, the final electricity consumption of Tanzania was 4,441GWh, of which the residential sector remained the largest user of electricity (44%), followed by industry sector (25%) this is due to lower industrialization of the county. The commercial and public service sector (23%) was the third largest user of electricity in Tanzania as shown in Figure 3.3. The use of electricity in transport and fishing sector is limited till today (IEA, 2014).

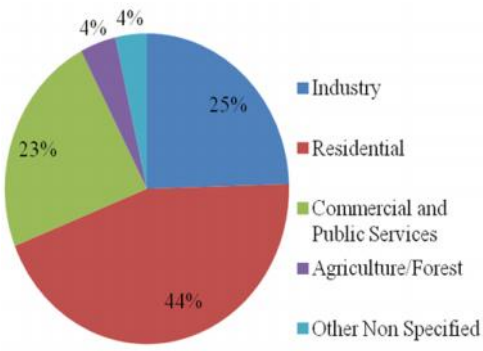


Figure 3.3 Electrictriy consumption by sector in 2012, Source: IEA (2014)

Energy demand has increased in recent years, and this situation is expected to continue in the near future. For instance, electricity demand in the country is rising rapidly (approximately at the rate of 10-15% per annum) mainly due to accelerated productive investments, increasing population, and increasing access (Damian, 2009; Bauner *et al.*, 2012; MEM, 2013; Msyani, 2013). As of the year 2011, peak demand reached 828.99MW for on grid customers (PSMP, 2013). The peak demand is projected to increase rapidly from about 1,000 MW today to about 4,700 MW by 2025 and 7,400 MW by 2035 (MEM, 2013). Moreover, PSMP (2013) predicted that Tanzania will boost electrification status to at least 75% by 2035 while demand from connected customers will increase considerably. According to Msyani (2013), present total number of TANESCO customers is estimated to be 1,032,000 and the plan is to boost customer's base to 1,500,000 by the end of 2015, which involves connection of 250,000 new customers per annum starting year 2013.

### 3.2 Institution and Policy

There are number of institutions governing the energy sector in Tanzania. These include Ministry of Energy and Minerals (MEM), Ministry of Finance (MoF), Rural Energy Agency (REA), Tanzania Electric Supply Company Ltd (TANESCO), Tanzania Petroleum Development Corporation (TPDC), Energy and Water Utilities Regulatory Authority (EWURA), Commission for Science and Technology (COSTECH), Development Partners Group (DPG), Non-Governmental Organizations and Research and Training Institutions.

#### 3.2.1 Institutional Framework

MEM is responsible for the development of energy and mineral resources and management of the same by formulation of energy policy (GED, 2013). Furthermore, promoting renewable energies is part of the MEM mandate. MoF develop the final budget for all state owned investment projects including those that are financed by foreign loans and grants (Larsson *et al.*, 2013).

To promote and facilitate improved access to modern energy services in rural areas of Mainland Tanzania, the Rural Energy Agency (REA) and a Rural Energy Fund (REF) was established in 2008 by the Rural Energy Act, Cap 131 (Kihwele *et al.*, 2012; GED, 2013; Msyani, 2013). According to Bauner *et al.* (2012), most of the projects implemented by REA in collaboration with MEM are renewable in nature, these include the solar PV, pico and mini hydro, and energy efficiency projects.

TANESCO is the state owned company responsible for generation, transmission, and distribution of electricity. The company operates the grid system in mainland Tanzania, and isolated supply systems in Kagera, Kigoma, Rukwa, Ruvuma, Mtwara and Lindi (Bauner *et al.*, 2012). Due to slow development in the sector and the general global trend in the electricity supply industry, the government lifted the monopoly of TANESCO and allowed the involvement of the private sector known as Independent Power Producers (IPPs) in the electricity industry (Kihwele *et al.*, 2012).
TPDC which participates and engages in the exploration, development, production, and distribution of oil and gas and related services; facilitate a fair trading environment; safeguard the national supply of petroleum products (Larsson *et al.*, 2013). EWURA is an autonomous multi-sectoral regulatory authority established by the Energy and Water Utilities Regulatory Authority Act, Cap 414 of Tanzania regulations. It is responsible for technical and economic regulation of the electricity, petroleum, natural gas, and water sectors in Tanzania (Bauner *et al.*, 2012; Msyani, 2013). The functions of EWURA include among others, licensing, tariff review, monitoring performance and standards with regards to quality, safety, health and environment (Larsson *et al.*, 2013). The Commission for Science and Technology (COSTECH) was established in 1986 and is mandated to be the principal advisory organ of the Government on all matters relating to scientific research and technology development in the country.
The Development Partners Group (DPG) was formally established in 2004. The main development partners in the energy sector are African Development Bank (AfDB), European Union (EU), European Investment Bank (EIB), Millennium Challenge Corporation (MCC), United Nations Development Programme (UNDP), World Bank (WB), Finland, Japan International Cooperation Agency (JICA), Korea - Economic Development Cooperation Program (EDCP), Netherland - Stichting Nederlandse Vrijwilligers (SNV), Norway – Norwegian Agency for Development Co-Operation (NORAD), Sweden - Swedish International Development Cooperation Agency (SIDA), France - French Development Agency (AFD), Germany - Kreditanstalt für Wiederaufbau (KfW) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). A new partner which is not a member of DPG is China (Bauner *et al.*, 2012; Larsson *et al.*, 2013). From these Development Partners, Tanzania has received significant support for the energy sector, including renewable energy and electrification.
Non-governmental organization such as Tanzania Renewable Energy Association (TAREA) formerly known as TASEA (Tanzania Solar Energy Association) was founded in the year 2000. The objective of the association is to promote the sustainable development of renewable energy. TAREA has been realizing its objectives through training, community awareness raising, policy influence, solar industry and end user protection, energy efficiency, research, volunteer programs, and consultancy services (Bauner *et al.*, 2012). TAREA has trained solar PV technicians on behalf of Sida/MEM solar PV project in Tanga, Morogoro, Pwani, Mbeya, Kigoma, Rukwa, Mtwara, Dodoma, Ruvuma, Lindi and Tabora regions. It has also trained Vocational Education and Training Authority Trainers in solar photovoltaic technologies in Dodoma, Mbeya, Mtwara, Ruvuma, Kigoma, Tabora, Singida and Rukwa regions (TAREA, 2009). Other NGOs includes Tanzania Traditional Energy Development and Environment Organisation (TaTEDO), Solar Innovations of Tanzania, AMKA Trust, and CARE-Tanzania few to mention.
There are a number of universities and training institutions that build the human capacities needed for the energy sector. These include, the University of Dar es Salaam, Nelson Mandela African Institution of Science and Technology, Dar es Salaam Institute of Technology, Mbeya Institute of Science and Technology, Arusha Technical College, and Vocational Education Training Authority (VETA). Research Institution includes among others; Tanzania Engineering and Manufacturing Design Organization (TEMDO), Tanzania Industrial Research and Development Organization (TIRDO), and Centre for Agricultural Mechanization and Rural Technology (CAMARTEC).

### 3.2.2 Energy Policy and Strategic Framework

The National Energy Policy (2003) 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 (MEM, 2013). In addition, the policy recognizes the contribution of solar PV as well as other renewable energy technologies in increasing access to electricity especially for the rural population (URT, 2003). Recently, Ministry of Energy and Minerals has released a long awaited revised draft National Energy Policy 2014.

## 4. Solar Energy Potential

Tanzania is situated in the so-called “solar belt” world region, with high levels of solar energy resource ranging between 2,800 to 3,500 hours of sunshine per year (i.e. average of 7.5 –9.7 hrs/day) and a global radiation of between 4 to 7 kWh/m$^2$/day (Johanne, 2011; MEM, 2013; Energio-Verda, 2014). Furthermore, the potential of solar energy in country is approximated to be 187 Wm$^{-2}$, with lower degree of exploitation both for solar PV and solar thermal applications (Mwihava, 2010).

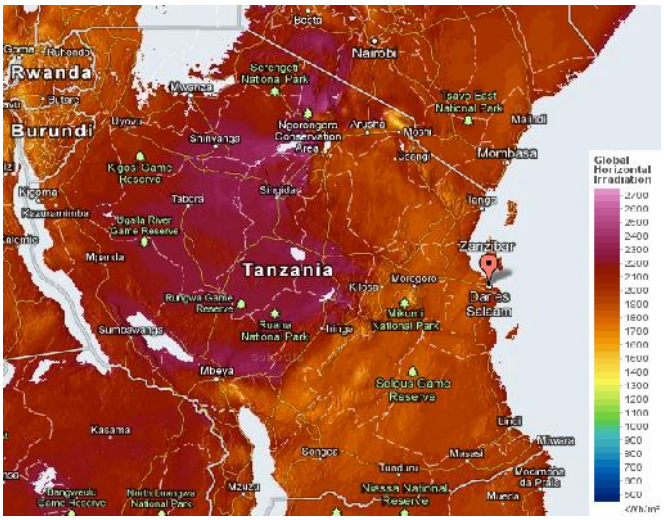


Figure 4.1 Yearly average solar radiation in Tanzania (The KUKU Trust, 2013)

Figure 4.1 shows clearly that solar resources are principally better in the central portions of the country which include; Dodoma, Singida, and Tabora regions. This makes it naturally suitable for the application of solar energy as a viable alternative to conventional energy sources if efficiently harnessed and utilized.

## 5. Conclusions

Power sector in Tanzania is still heavily dependent on non-renewable fuels such as fossil fuels and natural gas. Both of these sources are associated with suspicions in prices, depletion and environmental issues; therefore use of the renewable energy resources as solar can certainly be viable options. Tanzania has a strong potential to build small to large scale solar power due to its location at near equatorial region. The presented review concludes the available country's solar energy potential can be harnessed sustainably for electricity and thermal applications. As such, reduce dependence on biomass and fossil fuel resources which are not environmentally friendly.

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