Assessment of hydropower resources in Tanzania. A review article

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Abstract. The hydropower resources have become an attractive means of generating electricity to the off-grid network, especially in rural areas. This article assesses the small, mini and large hydropower resources and identified to reach 5.3 GW for electricity generation in Tanzania. The technology development discussed comprises of hydro turbine manufacturers, classification and turbine selection. The barriers presented include the presence of sediment in the hydropower reservoirs, financial viability, policy and regulatory issues related to hydropower development. This reviewed article serves the investors and policymakers to understand the status of hydropower resources in Tanzania.

1 Introduction

The renewable energy sources are exploited more globally due to the rapid increase of energy consumption and reduction of serious pollution to the environment [1]. Renewable energy sources used to generate energy include hydropower, solar, geothermal, wind, bioenergy and oceanic energy sources. Hydropower resources can give more sustainable, reliable and nonpolluting alternative to fossil fuels [2]. Hydropower leads other renewable energy sources to produce the global electricity [3] and is providing about 16.6% from 23.7% of the world’s renewable energy sources to produce the global electricity. Although other renewable energy sources contributed to global electricity include wind by 3.7%, bioenergy by 2.0%, solar PV by 1.2%, geothermal, concentrating solar thermal power and ocean by 0.4% [4].

1.1 Energy sources of Tanzania

The energy balance of Tanzania includes the use of charcoal and firewood, petroleum products, coal and renewable energy sources. The charcoal and firewood are dominating the total national energy consumption by 85%, followed by petroleum products for only 9.3%, electricity by 4.5%, coal and renewable energies by 1.2% [5]. The reliable and cheap energy sources contribute the significant role in the social economic development. Tanzania has increased the access to electricity with 36.4% in urban areas and 11% in rural areas up to 2014 [5]. Excluding large hydropower plants, only 4.9% of electricity generated from sisal and sugar factories, solar and small hydropower plants [6]. Two past decades, hydropower plants contribute about 80% of electricity supplies before the commercialization of natural gas in the year 2004 [7]. The total capacity of hydropower plants was 561.84 MW from six power stations [8]. This installed capacity is equivalent to 12% of 4.7 GW identified hydropower resources. But, the available hydropower resource is estimated to be greater than 38 GW [5].

The status of electricity generation by either hydropower resource, natural gas, oil or coal, peat and oil shale from 1971 to 2015 in Tanzania were shown in Figure 1. The natural gas indicated to have the high magnitude to produce the electricity after hydropower due to the five gas power plants installed with the total capacity of 495.44 MW. But, the two off-grid gas power plants indicated to have the capacity of 25.25 MW and eleven off-grid diesel-fired engines power plants have the capacity of 28.682 MW. These power plants with different energy sources make the maximum electricity generation of about 1.1 GW [7]. Nevertheless, hydropower and other sources of renewable energy have become an attractive means of generating electricity where the grid is not feasible [9]. But, the major hydropower reservoirs experienced severe drought in the period from the year 2003 through 2005 [8]. Also, the energy policy and power master plan for the year 2012 and 2016 indicated to rely on the following four energy sources for electricity generation [5,7].

− To harness the hydropower resources from 561.84 MW to about 4765 MW.
− To increase the capacity of generating electricity by using natural gas from 495.44 MW to 3507 MW up to the
year 2031. The total estimated gas initially in place ranges from 8 TCF in 2005 to 55.08 TCF in 2015.

– To use coal to generate electricity up to 3800 MW. The coal reserve is estimated at 1.9 billion tonnes of which 25% is proven.

– To use the renewable energy sources include biomass, solar and wind to install up to 260 MW in the short term planning. The average solar insolation distribution is about 200 W/m² and wind speed ranges from 5 to 9 m/s.

This article aims to develop the database of hydropower resources, technology development and barriers issues. Therefore, the article examines the developed and undeveloped hydropower resources for the purpose of understanding the past and future trend of hydropower resources contribution to the national energy balance.

2Hydropower resources assessment

The percentage of undeveloped hydropower potential is the highest in Africa [11]. Panos et al. [12] indicated Sub-saharan Africa remains behind than the rest of the world with a total requirement to access the electricity increases from 31% of the population in 2010 to more than 80% in 2050. The exploitation extent of hydropower resources is only 7.15% in Africa, 37.40% in Oceania, 40.79% in Asia, 44.77% in the Americas and 63.33% in Europe [13]. However, this review article discussed only the hydropower resources available in Tanzania that can either operated or potential identified from different locations. The operated hydropower plants are either large, mini or small hydropower plants.

2.1 Operated large hydropower plant

The capacity of the installed large hydropower reached to 561.84 MW in Tanzania [8]. Table 1 presents the operated six large hydropower plants with the capacity and number of turbine unit, year completed, river allocation and region. The large hydropower allocated to two main rivers of Tanzania includes Rufiji river at the central part of Tanzania toward south-east to the Indian Ocean and Pangani river from Mt. Kilimanjaro to Tanga-Indian Ocean.

| S/N | Hydropower plant          | Capacity (MW) | Year completed | River                          | Region            |
|-----|---------------------------|---------------|----------------|-------------------------------|-------------------|
| 1   | Kihansi station           | 3 × 60        | 2000           | Rufiji river                  | Morogoro          |
| 2   | Pangani station           | 2 × 34        | 1994           | Pangani river                 | Tanga             |
| 3   | Mtera Station             | 2 × 40        | 1979           | Rufiji river                  | Dodoma            |
| 4   | Kidatu station            | 4 × 50        | 1976           |                               | Morogoro          |
| 5   | Nyumba ya Mungu station   | 2 × 4         | 1967           | Mt. Kilimanjaro streams and Kikuletwa river | Kilimanjaro |
| 6   | Hale station              | 21            | 1964           | Pangani river                 | Tanga             |

Fig. 1. Electricity generation by different fuel sources in Tanzania from 1971 to 2015 [10].
2.2 Operated mini and small hydropower plant

The operated mini and small hydropower plants distributed all over the country of Tanzania to the river channels. The mini and small hydropower plants are most installed by the Tanzania Electric Supply Corporation (TANESCO), religious mission or private sectors [14]. Table 2 presents a list of the identified hydropower sites either operated or abandoned due to economic unviable. The repetitive hydropower sites were removed and the one with large capacity remains. The idea is to collect all hydropower sites to have a single database. Table 3 presents the list of under construction/to be constructed hydropower sites and Table 4 presents the list of existing/reconnaissance/pre-feasibility/feasibility studies for hydropower sites. Hydropower potential sites were collected from different sources as indicated in the summary tables. The hydropower sites collected were either connected to the grid in urban services or off-grid to the rural areas.

2.3 Small hydropower resources

The small-scale hydropower potential accounts for about 300–500 MW, of which only around 24 MW has been economically developed so far [21]. Figure 2 presents the 141 hydropower sites. The hydropower sites were georeferenced and digitized under ArcGIS software. About 56 new hydropower sites found and studies ranged from reconnaissance to pre-feasibility. Hydropower sites identified have the total capacity of 300 MW [15]. Also, Kabaka and Gwangombe [22] identified a total of eighty-five (85) small hydropower sites countrywide with a total of 187 MW under TANESCO. The work conducted by using the topographical map reading of the standard 1:50 000 sheets. Furthermore, another study also collected 75 potential hydropower sites with either 77.76 MW off-grid capacities or 408.12 MW connected to the main grid [23]. It based on the desk works and only 11 sites visited for validating the methodology. The latitude and longitude locations of 75 sites overlaid to the map of 141 sites. The map also presented the sites of six operated large hydropower plants in Tanzania.

Table 2. List of operated/existing/abandoned hydropower sites.

| S/N | Hydropower site | Size, kW | Site | Size, kW |
|-----|-----------------|----------|------|----------|
| 1   | Bulongwa        | 180      | 2    | 18       |
| 2   | Ikonda          | 40       | 19   | 400      |
| 3   | Isoko           | 15.5     |      |          |
| 4   | Isoko I         | 7.3      | 20   | 407      |
| 5   | Kaengesa        | 44       | 21   | 200      |
| 6   | Kikuletwa       | 1160     | 22   | 10000    |
| 7   | Kitai           | 45       | 23   | 10000    |
| 8   | Mabarari        | 700      | 24   | 300      |
| 9   | Mbaliiz         | 340      | 25   | 4000     |
| 10  | Ndanda          | 14.4     | 26   | 2000     |
| 11  | Ndolage         | 55       | 27   | 300      |
| 12  | Ngaresero       | 15       |      |          |
| 13  | Nyagao          | 15.8     | 28   | 1000     |
| 14  | Nyangao         | 38.8     | 29   | 2000     |
| 15  | Peramiho        | 34.6     | 30   | 500      |
| 16  | Rungwe          | 21.2     | 31   | 3000     |

Table 3. List of under construction/to be installed hydropower sites.

| S/N | Hydropower site | Size, MW | Site | Size, MW |
|-----|-----------------|----------|------|----------|
| 1   | Ikondo          | 340      |      |          |
| 2   | Kakono          | 53       | 9    | 90       |
| 3   | Kihansi II      | 120      | 10   | 34       |
| 4   | Malagarasi-Igamba III | 44.8 | 11 | 149 | 17 | Kikonge | 300 |
| 5   | Masigira        | 118      | 12   | 157      |
| 6   | Mpanga          | 144      | 13   | 300      |

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2.4 Hydropower resources status

The status of hydropower resources identified in Tanzania is presented in Figure 3 that have been added up to 5.3 GW as the expected to be harnessed with the long-term plan up to 2040. If the total large and small operated/existing/abandoned hydropower in Tanzania is about 624.21 MW, then only 12% have been exploited and contributed to the electricity generation. Noting that the hydropower potential is equal to 38 GW in Tanzania [24] and makes only 14% were taken into the energy master plan for electricity generation. The electrical energy produced by using hydropower resource for year 2015/16 is 1732.75 GWh with plant factor range between 20% and 50% as presented in Figure 4 [24]. With the same plants capacity, the annual energy generation should rise up to 4957 GWh if the plants operated for 8760 hours per year that is equivalent to 35% of annual energy generation with average plant factor of 32.4%.

Table 4. List of existing/reconnaissance/pre-feasibility/feasibility studies for hydropower sites.

| S/N | Hydropower site            | Size, kW | S/N | Hydropower site   | Size, kW | S/N | Hydropower site   | Size, kW |
|-----|---------------------------|----------|-----|------------------|----------|-----|------------------|----------|
| 1   | Mto wa samba              | 1500     | 8   | Mto wa samba     | 1500     |     |                  |          |
| 2   | Hainu                     | 1500     | 9   | Ngono            | 2500     | 15  | Chala            | 130      |
| 3   | Luaita                    | 300      | 10  | Sunda            | 3000     | 16  | Chita            | 400      |
| 4   | Luiche                    | 4000     | 11  | Andoya           | 1000     | 17  | Macheke          | 290      |
| 5   | Lupi                      | 3800     | 12  | Kilifi           | 230      | 18  | Mhangazhi        | 190      |
| 6   | Luwika                    | 1400     | 13  | Lupali I        | 353      | 19  | Salala           | 68       |
| 7   | Malagarasi-Uvinza         | 6400     | 14  | Madope           | 1000     | 20  | Tandala          | 407      |
| 8   | Source: Kassana et al. [15]|         |     |                  |          | 21  | Uliwa            | 407      |
| 9   | Source: Adebayo et al. [20]|         |     |                  |          |     |                  |          |
| 10  | Source: UNIDO-GEF [21]    |         |     |                  |          |     |                  |          |

Total (MW) 30.51

Fig. 2. Potential hydropower resources map of Tanzania.

Fig. 3. Hydropower resources status in Tanzania.
3 Hydropower technology

3.1 Classification of hydropower development

The hydropower is the rate at which water energy extracted by hydro turbine from falling water at a specific site. The turbine is the type of turbomachine that utilizing water power to convert water pressure and kinetic energies into mechanical rotational energy. Mechanical rotational energy conveyed with the shaft in one end to the turbine and another end to the electric generator for electricity generation [25]. However, the idea of harnessing water energy started many years ago with considered to exist for 22 centuries. It was started by using the potential energy of water freely moving or fallen over the waterwheel that connected with a belt to direct rotational mechanism to different machines include moving millstones for grinding grains, sledge-hammers for extracting ore deposits, running textile and sawmills machines, pumping water for domestic and irrigation uses [26]. The potential energy of water freely moving or fallen over the waterwheel that connected with a belt to direct rotational mechanism to different machines include moving millstones for grinding grains, sledge-hammers for extracting ore deposits, running textile and sawmills machines, pumping water for domestic and irrigation uses [26]. The potential energy of water turns the waterwheel and cause motion to the belt. Water turbine only was emerging from the 1820’s and abruptly substitutes the use of waterwheel [27]. The waterwheel is not flexible during flow rate variation resulted in less efficient compared to water turbine [28].

Both water turbine and waterwheel are simply differentiated by using their definition. Water flow in water turbine admitted to all the vanes or buckets simultaneously and controlled by the governor. Waterwheel consists of a large perimeter of wooden or metal wheel with a number of buckets or blades tangentially outside of the rim [29]. Waterwheel receives the water at the top or one side only [30]. The axle of the wheel mounted horizontal or tilted to vertical. The amount of water is flowing in the number of fixed cups circumferential to wheel arranged more closely without any gap to generate rotational mechanism of the wheel that connected to belts or gears. Table 5 presents the machine type and flow directional for hydropower plants. The details of the head, flow rate and output power were listed in Loots

| S/N | Machine type                  | Direction of flow       |
|-----|-------------------------------|-------------------------|
| 1   | Undershot wheel               | Tangential to wheel     |
| 2   | Breast-shot wheel             |                         |
| 3   | Overshot wheel                | Radial outward          |
| 4   | Fourneyron                    | Radial inward           |
| 5   | Thompson vortex and Francis   |                         |
| 6   | Jonvan                        | Parallel to axis        |
| 7   | Pelton                        | Tangential to buckets   |
| 8   | Mixed turbine (Kaplan etc)    | Ranged from radial to parallel to axis |

Fig. 4. Electricity generation by using hydropower resources with different plant factors [24].
et al. [31]. Furthermore, the hydropower classified by using the plant capacity, head, as well as the means of operation and capacity of water flow to the turbine as shown in Table 6.

### Table 6. Hydropower development classification.

| Type   | Capacity (MW) | Turbine type          | Elevation difference (m) | By operation and type of flow [34]         |
|--------|---------------|-----------------------|--------------------------|-------------------------------------------|
| Pico   | 0.005         | Hydraulic wheel       | 0.2 < H < 4              | Run off river                             |
| Micro  | 0.1           | Archimedes’ screw     | 1 < H < 10               | Reservoir and dam based and;              |
| Mini   | 1             | Kaplan and propeller  | 2 < H < 40               | Pumped storage                            |
| Small  | 1–100         | Francis               | 10 < H < 350             | In-stream technology using existing facilities |
| Medium | 100–500       | Pelton                | 50 < H < 1300            |                                           |
| Large  | >500          | Michel-Banki          | 3 < H < 250              |                                           |
|        |               | Turgo                 | 50 < H < 250             |                                           |

### Table 7. List of hydro turbine and manufacturers.

| Hydro turbine                                                                 | Manufacturer capacity (MW) | Source         |
|------------------------------------------------------------------------------|----------------------------|----------------|
| Francis/Kaplan/Pelton/Pump as turbine (PAT)/Cross flow turbine               | <20                        | KBL [35]       |
| Francis plate and Pelton eccentric                                          | 0.5–10                     | STP [36]       |
| Pelton, Francis, Kaplan, Bulb, Pit and S-turbine                           | Not specified              | VOITH [37]     |
| Pelton, Francis and Turgo turbines                                          | <20                        | Gilkes [38]    |
| Pelton <423 MW, Francis <800 MW, Kaplan <200 MW, Bulb <15 MW, Pump/Pump turbine <350 MW | <800                       | ANDRITZ [39]   |
| Pelton, Francis and Kaplan                                                  | <20                        | SIAPRO [40]    |
| Pelton, Francis, Crossflow and Turgo turbines                               | <25                        | AGWV [41]      |
| Propeller-Pico (200 W–15 kW), Cross flow (200 W–250 kW), Pelton (10–250 kW) | <500                       | NHE [42]       |
| Cross flow turbine T series (T1...T15)                                      | 0.005–0.25                 | MHU [43]       |

### 3.2 Turbine manufacturers

A lot of turbine manufacturers are available globally and linked with online access. Table 7 presents only some manufacturers of hydropower components include turbine, generators, transformer, valves, steel penstock, gate, motor, steel pole and relevant structures. The local developers can visit the local technical school, vocational education and training authorities and universities to find the possibility of manufacturing the hydro turbine components. A Salala hydropower plant of 68 kW installed by using the cross-flow turbine with attached components was manufactured at the College of Engineering and Technology, University of Dar es Salaam, Tanzania [21].

### 3.3 Turbine selection

The net available head (H) and flow rate (Q) are the main factors to consider during turbine selection as presented in Figure 5. Different types of turbine include Francis, Kaplan, Propeller, Pelton, Turgo, Pump as Turbine and Crossflow turbines were discussed in [44]. The net head is the gross head minus head losses. Head losses calculated as in [32]. Other factors should be considered include specific speed, efficiency and flow variation. Williamson et al. [45] suggested using the multi-criteria analysis and weighted
values assigned to various aspects presented in Table 8. Also, the electrical components should be sizeable based on the mechanical rotational energy from turbine [46].

4 Barriers of hydropower development

The hydropower development barrier is the circumstance or obstacle to the project that prevents more production from generating the profit. The sediment and agriculture activities indicated to be the main barriers to hydropower development in Tanzania. The accumulation of sediment in a reservoir is a serious challenge that threatens the sustainability of the hydropower plants [50]. The accumulated sediment reduces the storage capacity of the reservoir [51]. The sustainable sediment management strategies for reservoirs should balance sediment inflow and discharge at the same time to maximize the storage volume [52]. The high sediment concentration together with the high percentage of quartz contents in water that conveyed to turbine causes severe damage to a runner and blades [53].

Pangani and Rufiji basins consist of Pangani and Rufiji rivers of which all large hydropower of Tanzania located, are strongly affected by agricultural activities. The agricultural activities upstream of the river reduce the amount of water and loose the in situ land caused the sediment to flow into the reservoir during the wet season. Table 9 presents the agriculture activities practised in the existing hydropower plants in Tanzania. The general concerns related to barriers to hydropower development are presented in Table 10.

5 Policy and regulations towards hydropower development

The appropriate policy and regulations can provide the platform for the sustainable renewable technologies in the urban and rural areas [63]. Energy policy interventions in Tanzania include the Energy Policy of year 2015, Electricity Act of year 2008, Energy and Water Utilities Authority (EWURA) Act of year 2001 and 2006, Rural Energy Act 2005, Standardized Power Purchase Agreement & Tariffs <10MW of year 2008 and other programmes and strategies established to improve the energy recovery and supply to the communities [67]. The establishment of Energy Policy ensures the government to review for standardized power purchase agreement and
Table 10. Barriers and factors hindering the hydropower development.

| Barriers                              | Description                                                                                                                                                                                                 | Source                                                                 |
|---------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Policy and regulations                | Common understanding of public and private sector actors to fit together and form an intact mechanism includes:                                                                                         | Kabaka and Gwang’ombe [22]; Ahlborg and Hammar [61]; Rickerson, et al. [62] |
|                                       | – To formulate electrification plan to utilize the available resources                                                                                                                                                                            |                                                                        |
|                                       | – To facilitate the transfer of knowledge and skills                                                                                                                                                                                                     |                                                                        |
|                                       | – To make commercially viable for remote and rural electrification projects                                                                                                                                                                           |                                                                        |
|                                       | – Confusion to identify the small hydropower definitions with policymakers against large hydropower                                                                                                                                                       |                                                                        |
| Financial viability                   | – High investment risk with too slow the rate of return                                                                                                                                                                                                   |                                                                        |
|                                       | – Number of potential investors are not managing to secure funding, i.e. many of the banks are not familiar with the hydropower business                                                                                                                                         |                                                                        |
| Market characteristics                | – Not manage to pay the initial connection costs and monthly bills                                                                                                                                                                                        |                                                                        |
|                                       | – Long transmission and distribution distances because of sparse population as well low load centres                                                                                                                                                     |                                                                        |
|                                       | – A large proportion of electricity used for household (lighting, heating, cooking) and social welfare services (education, healthcare, water supply)                                                                                                                 |                                                                        |
|                                       | – Limited used in grain milling, preserving agricultural crops, irrigation, industrial production, entertainment and rarely ICT                                                                                                                                 |                                                                        |
| Unreliable fuel supply and demand     | – Drastic seasonal changes in the flow of water resources                                                                                                                                                                                                | Javadi et al. [63]; Kaunda et al. [64]; Adebayo et al. [20]            |
|                                       | – Low population density area and poverty to the existing hydropower site                                                                                                                                                                               |                                                                        |
| Construction of large dams and        | – Lacking plan, design and limited human capacity and low level of government to finance the projects                                                                                                                                                   |                                                                        |
| maintenance                            | – Inability to accumulate enough amounts of water during the wet season                                                                                                                                                                                  |                                                                        |
|                                       | – Difficult to purchase fuel and replacement parts                                                                                                                                                                                                     |                                                                        |
|                                       | – Inappropriately low electricity tariffs                                                                                                                                                                                                                |                                                                        |
| Poverty and theft                     | Customers are the billed-debt accumulation and refuse or delay to pay                                                                                                                                                                                     |                                                                        |
| Technology                             | Technology is pushed without explicitly taking into consideration the market demand resulted in either:                                                                                             | Mondal et al. [65]; Kaunda et al. [66]                                 |
|                                       | – Projects are abandoned after the pilot period or                                                                                                                                                                                                      |                                                                        |
|                                       | – Technologies remain in place but stop functioning                                                                                                                                                                                                     |                                                                        |
| Knowledge and skills                  | – Lack of awareness of renewable energy i.e. hydropower in public, industry, utility and financial institutions                                                                                                                                        |                                                                        |
|                                       | – Limited empirical knowledge on costs and benefits of the range of technologies available                                                                                                                                                              |                                                                        |
| Involvement of relevant stakeholders  | – Lack of involvement of local entrepreneurs, end users and local investors                                                                                                                                                                              |                                                                        |
|                                       | – Lack of well set up of local management, local manufacturing facilities, operation and maintenance                                                                                                                                                   |                                                                        |
6 Tariff system for hydropower plants

Renewable energy feed-in tariff (REFIT) is an incentive plan to provide a set of payment for electricity generated from investors include small-scale and large-scale developers. The establishment of REFIT observed as very complex task and requires the involvement in the technology innovations, market development and policy improvement [70]. It also involves the issues of geographical location, infrastructure, technical, institutional and economic assessment [71]. The term tariff refers to the rates and charges for selling and buying the electricity [72]. The feed-in tariff (FIT) is a policy mechanism to guarantee the price of electricity generation [73].

6.1 Status of tariff rating from 2008 to 2015

Tanzania has a tariff price for both grid-connected and isolated mini-grids SPP. Figure 6 presents the tariff price of main grid SPP purchases with wet and dry season adjustment as well as the isolated mini-grid as collected from [67]. It also presented the percentage increase in the tariff price from 2009 to 2015. The tariff price of isolated mini grid SPP indicated to increase from 2008 to 2013. The main grid SPP in both wet and dry seasons indicated the gradual increase from 2008 to 2015. The off-grid and main-grid tariff price indicated to increase from 2011 to 2012 up to 27% and 26% respectively and the coming year dropped to a significant percentage. It indicated the percentage decrease of 3.23% for main-grid SPP and increased by 2.35% for isolated mini-grid SPP in 2015. The tariff price of mini-hydro SPP competes very well with diesel generators to the rural electrification plan [71]. The reality, there is increased of the tariff, but yet not sufficient for cost recovery, as well as low creditworthiness, discourages financial sector and private investor [6].

The tariff price system changed to isolated mini hydropower plants with a capacity less than 10 MW are based on the United States Producer Price Index [74]. The use of price index provides the platform for each producer to have a different tariff price based on the capacity of power generated as presented in Figure 7. The tariff price is less for higher the capacity to produce and vice versa.

6.2 The principle of tariff design for electricity

The existing of electricity tariff principles were managed to respond the issues related to the economic sustainability and efficiency, equity, transparency, simplicity, stability and consistency. The choice of any tariff setting methodology requires the decision makers to make an informed compromise, reaching a balance between all the principles as discussed in [62]. The setting of electricity tariffs by the EWURA in Tanzania is necessary for the network segments of countries with liberalized electricity energy sectors and for all developers in countries [68].

| Barriers | Description | Source |
|----------|-------------|--------|
|          | Rural electrification sets up is not well linked to the municipal, districts, regional and government |        |
|          | Lack of knowledge and acknowledgement in social, environmental and cumulative impacts toward the implementation of the projects |        |
determination of the electricity tariff is either allowed revenues recovered or define the tariff structure and allocation of allowed costs [75]. The revenues recovered determined by either calculating the cost of service regulation or incentive-based regulation as described in [76]. EWURA estimates the tariff of isolated mini-grid SPP based on the cost-based tariff described in [68]. Also, TANESCO tariff setting based on the avoided costs either isolated mini-grid or main grid systems [69]. The advantageous of using REFiT were presented in Table 11.

Also, the barriers to renewable energy tariff include lacking in the purchase and grid access, involved of the stakeholders in the policies drafting, discovering the renewable energies in the future market and energy efficiency as well as the climate change negotiations [77]. Furthermore, the barriers of renewable energy differ from one form or another include technical, financial, legal and institutional framework. Other details of the renewable energy policies and barriers are described in [78]. It needs also to improve the renewable energy technologies to reduce the initial cost [79].

### 7 Conclusions

Tanzania has the energy policy and energy regulations sufficient to give the conducive environment for renewable energy development, especially hydropower resources. The existing tariff for isolated hydropower is well-distributed with respect to the capacity of electricity generated up to 10 MW. The advantages of having REFiT include the understanding of the technology used to generate the electricity, off-grid or grid-connected, financial, policy, regulations and consumed time. The number of hydropower components was made from worldwide manufacturers and well installed for electricity generation. The hydro turbine is selected on the basis of head and flow rate assessed from potential rivers. Other factors like power demand, civil works, electrical system, maintenance and efficiency are the necessary parameters to consider before developing the hydropower plant. It is still indicated the main barriers include the absence of grid access and lack of financial sectors to the areas of available renewable energy sources. Also, the accumulated of sediment in reservoirs mostly resulted from agricultural activities indicated to affect the hydropower production capacity.

Currently, hydropower plants capacity has reached 624.21 MW and expected to be extended up to 4.7 GW by the year 2040. The total hydropower capacity in operation, under construction and expected to be installed is about 4397.01 MW. In addition to that, the potential hydropower resource under reconnaissance and feasibility studies has reached 925.63 MW. The potential hydropower resource map of the three studies indicated the potential hydropower sites close to each other. There is a high possibility of the single site location found in three studies to present one hydropower site. Although, each feasibility study conducted separately and they do not consider previous studies. Importantly, hydropower plants do not consume water from the river but the challenge still remains to understand the annual flow variation. Therefore, further study should focus on preparing the strategic plan to minimize the barriers and site visiting the potential hydropower sites and update the hydropower database of Tanzania.

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