Review Article

The Status and Future Prospects of Hydropower for Sustainable Water and Energy Development in Tanzania

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Tanzania is among the countries with the fastest growing economy in Africa and therefore the need for affordable, clean, and most importantly sustainable electrical energy to meet her ever growing demands is pressing. In recent years, the country's electricity needs have been largely dominated by thermal generations despite the fact that Tanzania is gifted with huge hydropower resource potential approximated at 38,000 MW with only a very small portion exploited to date. However, the exploited potential is expected to grow by commissioning of identified large and medium-scale hydropower projects with a total installed capacity of 4,765 MW currently under various stages of implementation. Moreover, the geographical location of Tanzania has several benefits to support development of small hydropower projects essential for appropriate utilization of available water resources as a way of mitigating climate challenges effects. Over the last decade, the country electricity demand along with end-use of energy has witnessed significant increases as economic development spreads towards achieving Vision 2025 goals. Proposed hydropower developments are projected to have enormous benefits in the acceleration of economic growth while contributing to greenhouse gas emissions reduction. In this paper, hydropower, which is one of the domestic options for clean energy development path, its present and future potential status, and water resources are explored based on a comprehensive review of energy sector relevant documents and policies.

1. Introduction

Access to clean, affordable, and reliable energy coupled with its impact on mitigating the drastic effects of climate change due to human activities is one of this era's most serious concerns in the quest for increasing prosperity through sustainable economic growth. Energy access is important to achieving sustainable development goals. The country's strategy is to accomplish electrification rate of more than 75 percent by the year 2033 with the focus on the transport and industrial sectors [1, 2]. Therefore, it can be noted that, in order to sustain the continually growth in an annual electricity demand, the indigenous renewable energy resources ought to be included in the pursuit of sustainable energy alternatives. This gives a determined motivation to investigate the potential of hydropower as a renewable energy source, which is yet to be fully exploited. Current hydropower technologies are able to convert more than 90% of the available energy into electricity as compared to the efficiencies ranges

of 30%–50% for thermal-power plants and other similar technologies [3, 4]. Hydropower continues to remain the most efficient technology for electricity generation with the expectations of further improvements in future [5, 6].

In pursuing her quest to attain a middle-income economy status as envisioned in its Development Vision 2025, Tanzania faces huge tasks of meeting energy needs due to the high expectations in growth to fuel the economy and at the same time minimize environmental challenges [1, 7, 8]. Providing affordable and reliable energy specifically electricity, is characterized as an important function of any country's economic sectors [9, 10]. Past decades have witnessed the actual electricity sector falls short of the required level of reliability, despite abundant hydroenergy potential available in the country. Lack of a reliable energy supply as expounded in URT [11] was recognized as the main binding constraint to economic development. Realizing solutions to meeting electricity demands while minimizing environmental challenges, requires long-term and firm actions for sustainable

economic development. In this paper, hydropower which is one of the domestic options for clean energy development path, its present and future potential status, and the water resources are investigated in detail for Tanzania based on a comprehensive review of energy sector relevant documents and policies.

2. Hydropower: Renewable and Sustainable Energy Resource

Energy renewability relates to the concept of energy being extracted from a resource and replaced with the same amount on a comparable time-scale as that of its extraction. Renewability is a direct response to uncertainties of energy supplies owing to possible interruptions and subsequent depletion of primary sources [15, 16]. Renewables are considered as carbon-neutral and inexhaustible energy resources encompassing varieties of fuel types and usages with minimum secondary wastes productions [17, 18]. Renewables are also described as one of the most efficient and effective solutions to environmental challenges as compared to nonrenewable sources [19–22]. Hydropower is accepted as renewable energy resource and worthy of international support [23, 24]. Hydropower utilizes water for electricity generation without depleting it and therefore helps in contributing to fresh water sustainability for other downstream applications. Hydropower is the only indigenous renewable energy resource in Tanzania whose role in electricity generation is significantly greater than any other renewables [7, 12].

The concept of sustainability in development is well-defined by World Commission on Environment and Development (WCED) as the “ability to make development sustainable and to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs” [30, 31]. Sustainability is considered as a direct response to deteriorating environmental quality coupled to a growing energy resource demands under depletion threat as a result of populations growth and living standards improvement [15]. Hydropower as is the case for other renewables is recognized as viable option for sustainable developments because of its enormous potential and positive impact on the environment resulting in much lesser health and global climate change risks [18, 32, 33] (Panwar et al., 2014). Hydropower has obvious benefits directly linked not only to electrical energy production but also to water management to support sustainable socioeconomic development and therefore will continue to remain with a unique role to play in the foreseeable future. For example, hydropower dams, reservoirs, and other infrastructures offer exclusive management of fresh water storage and transportation and thus help fight climate change effects to the surrounding communities.

With the obvious population growth in the coming years likely to be shifting from rural to urban areas, the need for sustainable energy solution in Tanzania will be ever more pressing. As hydropower is adaptive and flexible, it is set apart from other renewable and nonrenewable energy resources and therefore the best option for sustainability [5]. Harnessing of hydropower as renewable energy resource

appears to be a promising solution for improving the quality of life in rural areas where access to commercial energies is a challenge [18, 19, 34]. As dealt with by several scholars and summarized in Figure 1, renewable energy touches all aspects of life including but not limited to socioeconomic, political, environmental, and technological, thus an intimate connection to sustainable development [6, 19, 35].

3. Water Sustainability in Tanzania

3.1. Geographical Location and General Climate. Tanzanian is located in Eastern Africa region south of the equator. The country is characterized with a tropical climate and significant regional topographical variation. Large part of Tanzania is categorized as highland with the exceptional of narrow coastal strip. The climate varies from tropical along the coast to temperate in the highlands. The highland temperatures are around 20–23°C throughout the year and are characterized by unimodal and bimodal seasonal rainfall distribution [36, 37]. The primary drivers of seasonal rainfall in Tanzania are categorized as intertropical convergence zone migration, narrow belt of very low pressure, and heavy precipitation forming near the earth equators [38]. The bimodal seasonal rainfall occurs in the coastal belt, the north-eastern highlands, and along Lake Victoria and is comprised of the short rainfall from October–December and the long rains fall from March to June. The unimodal seasonal rainfall regularly occurs from October to November to April in the central, southern, and south-western highlands of the country [38, 39].

3.2. Water Policy and Resource Management. Water is a basic natural resource sustaining life and provides for countless socioeconomic needs for development [40, 41]. Tanzanian water resource management and governance is divided into nine hydrological water basins through Act No. 10 of 1981 [42]. Seven out of these nine basins are transboundary including Lake Victoria basin jointly owned with Kenya and Uganda; Lake Tanganyika basin jointly shared with DR Congo, Zambia, and Burundi; Lake Nyasa Basin jointly owned with Malawi and Mozambique; Lake Rukwa basin jointly owned with Zambia; Ruvuma River Basin jointly owned with Mozambique and Malawi; along with the Central Drainage Basin and Pangani River Basin both jointly owned with Kenya [43–45]. Water resource management at the national level is principally managed by recognized institutions such as policies, acts, and legislations and other interrelated organizations that are judiciously established in accordance with the formal provisions [42, 46].

The primary goal of the National Water Policy (2002) was to formulate a comprehensive framework to ensure sustainable utilization and management of the country's huge water resources potential [47]. The policy intends to ensure that its beneficiaries take full responsibilities in all stages of water resource development. National Water Policy (2002) recognizes important link between Tanzanian water resources, socioeconomic development, and environmental requirements in achieving Vision 2025 goals [47, 48]. The policy further explicates the vital role in which water

FIGURE 1: Renewables for sustainable development [6].

contributes towards various economics activities including energy and transboundary requirements. In view of this, the National Water Policy (2002) demands for an integrated water resource management approach to ensure unbiased sustainable utilization and management of water resources for both socioeconomic development and the environment maintenance [49].

3.3. Water Availability and Flow. When in its natural state, water is considered as an integral part of the environment whose quantity and quality govern in what manner it can be used. Being a water-rich country, Tanzania is endowed with lakes, river, and water basins that originate from the highlands parts of the country as depicted in Figure 2 [50]. These water resources if sustainably exploited and managed would provide a bright future in terms of hydropower generation and also revenue from economic activities such as tourism and irrigation [7, 51]. A third of the country's water resources are located in highland areas with precipitation in excess of 1000 mm whereas the other third of the country is semiarid with rainfall of less than 800 mm [52].

Groundwater is among the vital sources of water in most of areas in Tanzania. Groundwater primarily controlled by geology and climate is variable, an important supplement source of surface water in semiarid water scarce areas of Tanzania accounting for more than 25% of all domestic needs [47, 53, 54]. The rainfall supports and sustains the groundwater level with rivers being the main surface water resource available in Tanzania. The major waterway system provides the vital surface water resources with mean yearly run-off of 83 billion cubic metres and an estimated ground

FIGURE 2: Tanzania's key water ways and lakes [25].

water recharge of 3.7 billion cubic metres. Around fifty per cent of the surface run-off water flows towards Indian Ocean through Pangani, Wami, Ruvu, and Rufiji among other rivers systems with the balance flowing north-ward, into Lake Victoria, west-ward, into Lake Tanganyika, and south-ward, into Lake Nyasa [52, 55].

4. Hydropower in Tanzania

4.1. Hydropower Resource Potential. The history of hydropower generation in Tanzania dates back to the colonial era,

FIGURE 3: Pangani river basin [26].

where most of the operational small hydropower plants were installed through the efforts of missionaries. The installation of small hydropower plants was realized as a result of the natural topographic features which offer the country with plentiful opportunities for hydropower resources. Tanzania has a relatively plentiful hydropower potential as a result of its inland part being at high elevation from sea level and therefore precipitous rivers availability. The total hydropower resource potential is approximated at 38,000 MW equivalent to 190,000 GWh/year [2, 7]. The potential hydropower resources as depicted in Figure 2 are mainly located in the rift valley escarpments in the West, South West, and North East with very little being accounted in the central part of the country due to relatively flat features and dry seasons [56].

4.2. Rufiji and Pangani Basins. Rufiji and Pangani basins gutter water from the “Eastern Arc Mountains” and their neighbouring lowlands and thereafter stream to the Indian Ocean [57, 58]. Pangani river basin is a transboundary shared by Tanzania and neighbouring country Kenya. Tanzanian part of Pangani river basin occupies an estimated 56,300 square kilometres equivalent to 95% of the whole basin [57, 59, 60]. Pangani river basin as depicted in Figure 3 is formed as a series of small streams draining from Mt. Kilimanjaro, Mt. Meru, the Pare and Usambara Mountain ranges and the springs emerging from Kenya. These streams join to create the main Pangani river and flow into the Indian Ocean at the coastal town of Pangani [61–63]. Pangani river basin climate is generally closely related to topography with flatter lowland southwest half of the basin being semiarid, whereas the mountain ranges are cooler and wetter with the high-altitude slopes above Mt. Meru and Mt. Kilimanjaro receiving rainfall of more than 2500 mm annually [62, 64, 65]. Pangani river basin is characterized with two distinct seasons, the first one being rainy season occurring between March and May and the second one being dry season occurring during the rest of the year [65].

Pangani river basin collects an annual rainfall approximated at 34.77×10^9 cubic metres out of which fifty-five percent originates from Mt. Kilimanjaro highlands. The 500-kilometre-long river serves a series of hydropower plants

FIGURE 4: Rufiji basin and its rivers network [27].

namely Nyumba ya Mungu, Hale, and New Pangani falls, which when combined were once contributing approximately 17% of Tanzania's national electricity demands before the introduction of domestically available natural gas fired power plants in the year 2000 [66, 67]. All of the Pangani river hydropower plants are sited downstream of main water users. Nyumba ya Mungu dam receives mean annual flow of roughly 43 m^3 per second with varied outflow of $15\text{--}25 \text{ m}^3$ per second of which 5 to 8 m^3 per second is lost due to evaporation, transpiration, and consumptive usage between the dam and Hale hydropower plant. Groundwater potential in the basin is high in the volcanic and coastal aquifers with 88% of abstraction being used for irrigations purposes [68]. The Pangani river basin is considered as water stressed ascribed by high population growth and climate change among other factors [65, 68, 69].

The Rufiji river basin depicted in Figure 4 is an extensive area of land that includes mountains, savanna woodlands, farmland areas, and extensive wetlands which spreads across the southern part of Tanzania [57, 70, 71]. The Rufiji river basin is the largest of the nine river basins in Tanzania which covers about $178,000 \text{ km}^2$ equivalent to 20% of the total land and is characterized with varied topography rising from sea level in the east to approximately 3,000 metres above sea level in the west [44, 57, 72]. The Great Ruaha river catchment which is part of Rufiji river basin, covers an area of approximately $68,000 \text{ km}^2$, and encompasses the Usungu area, which has a total area of $20,811 \text{ km}^2$ in the southwestern part of the country [52, 72, 73]. The Great Ruaha river catchment got its name from the Great Ruaha river which is among the significant rivers in the basin. The Great Ruaha river originating from the Usungu highlands is the main supplier of water in the Great Ruaha river catchment. The Great Ruaha river flows into the Usungu plains and wetland through to the Ruaha National Park and provides 56% of runoff to Mtera hydropower plant while the remaining balance is from little Ruaha river (18%) and Kisigo River (26%) [73].

The Great Ruaha is a multifaceted basin with mixed multisectoral water applications for sustained irrigation, power generation, and other water-related livelihoods such as fishing and livestock keeping [74, 75]. Primary activities in the basin include irrigation of high-valued crops such as rice and are located in the upstream from the main hydropower plants [76–78]. The Great Ruaha river basin

supports extensively ecological necessities for the Ruaha National Park and it is a significant tributary of the Rufiji river [79, 80]. Economically, the Great Ruaha river basin is one of the utmost important waterways hosting more than fifty percent of the present country's hydropower capacity [73, 78, 81]. Concerns over water availability remains as the topmost challenge at the basin stirred by repeated water shortages at Mtera hydropower plant which is the largest dam in the country considering height, crest length, and concrete volume [7, 82].

4.3. Effects of Climate Change on Hydropower Generations. Climate is an important factor in determination of the amount of water flowing through the water-cycle [83]. Global warming and the corresponding growth in the world annual temperature have weakened the natural way in which the earth normalises its climate, thus affecting water resource availability as a result of seasonal rainfall cycles [84]. The rivers feeding Pangani and the Great Ruaha basins have irregular regimes with the average annual precipitation, evaporation, and surface run-off greatly varying geographically depending on whether it is dry or wet season. Observed rainfall over Tanzania as described in McSweeney et al. [38], MEM [7], and Paavola [85] depicts statistically considerable annual decreasing trends of up to 17% over the past decade. The decreasing trend in rainfalls is further shown to affect June, July, August, and September (JJAS) and March, April, and May (MAM) rainfall seasons with the decrease in annual rainfall observed to be at an average of 2.8 mm per month equivalent to 3.3 percent per decade affecting the most southern part of Tanzania. MAM and JJAS rainfall decreases are recorded at 4.0 mm (3.0%) and 0.8 mm (6.0%) per month per decade, respectively. Notwithstanding efforts to mitigate climate change effects, reduced precipitation and increased evaporation are anticipated to increase in future and therefore water security problems in water-stressed areas of Southern African will be increased [86, 87]. Subsequently, authorized and unlawful water abstractions from rivers and reservoirs is expected to increase limiting water availability for electricity generations.

Climate change in numerous previous dry years was able to negatively impact the country's ability to provide stable electricity based on hydropower sources [86, 88, 89]. According to recent spatiotemporal distribution of rainfall analysis done by Loisulie [88], the extremely dry years from 1979 to 2009 were recorded to be 2000, 2001, 2003, 2005, 2007, and 2009 as well as in 2015. Dry weathers years resulted in draughts causing reduced water supply which in turn caused hydropower plants generation as low as 140 MW from the installed capacity of 561 MW in 2006. Drought and floods are known to bring extreme weather events which undesirably affects hydropower generation and thus increase operational costs, reduce water quantity and quality, and cause destructions to infrastructure [84, 90].

4.4. Hydropower: Deployment Challenges and Benefits. Hydropower is differentiated from other electricity generating sources including some renewables because of its negative and positive effects that it can have on the environment.

Large- and medium-scale hydropower plants development often result in environmental challenges [91] along with socioeconomic conflict, largely in the case of storage-based hydropower plants [92]. Hydropower plants, dams, and reservoirs construction extends well beyond from direct effects on environment to take in forced human and animal populations resettlements, competition for water usage among power generating plants owners and neighbouring communities. and expanding deforestation associated with new infrastructures such as roads [84, 93]. Human populations resettlements from the dam, reservoir, and other infrastructures in the constructions areas is unquestionably the utmost challenging socioeconomic feature of hydropower that might possibly result in ethical issues to ensure that the rights of affected communities are legally respected.

Despite these challenges, there are hydropower socioeconomic benefits left for the future generation which include access roads, dam, and reservoirs. Dam and reservoirs are often used to collect, store, and manage water needed for economic activities other than electrical energy generation. Hydropower as a sustainable resource can be deployable in a decentralized and modular manner to improve grid stability and to support the utilization of other intermittent renewable energy sources such as wind and solar power [92]. This makes hydropower appropriate energy source for both large-scale and small grids and off-grid solutions, thus perfect for power supply in rural off-grid regions in which connection to the national grid is either excessively expensive or technically difficult to accomplish [84, 94].

5. Hydropower Market and Development in Tanzania

5.1. Energy Consumption and Emissions in Tanzania. Annual greenhouse gas (GHG) emissions as a result of energy consumptions continue to rise at the time the country strives to meet her ever increasing demand for electricity and transport fuels. Tanzanian GHG emissions specifically CO₂ emissions from fossil fuels have grown phenomenally since 1971 to date. CO₂ in Tanzania has been virtually constant for the years 1971–1990 and begun to increase sharply in 2000 to 2015 as depicted in Figure 5. The growth in CO₂ emissions has arisen largely due to the increased burning of coal and oil. The growth of CO₂ emissions as a result of fuel combustion between 1990 and 2015 is equivalent to 595.6% change. The emission for 2015 was estimated at 11.62 million tonnes of CO₂ in which 7 million tonnes of CO₂ and 2.8 million tonnes of CO₂ were generated through various activities in “Electricity and Heat Production” and “Transports” sectors, respectively [12, 13]. Despite this growth, CO₂ emissions and other energy indicators for Tanzania as compared to other countries, for example, Kenya and South Africa, are low in both absolute terms and per capita as depicted in Table 1 [12, 13].

5.2. The Role of Hydropower within Primary Energy Supply. In 2015, hydropower accounted for 0.70% of the country's total primary energy supply which was equivalent to 25,968 kilo tonnes of oil equivalent (kTOE). As can be seen in Table 2, this is against 1.37% for the years 1990 and 2000 in

TABLE 1: Key energy indicators statistics for 2015.

Indicator	Tanzania	Kenya	South Africa
Total energy supply (TPES) (millions of tonnes of oil equivalent)	25.97	25.10	142.03
CO ₂ emissions (millions of tonnes of CO ₂)	11.62	14.14	427.57
CO ₂ /population (tonnes of CO ₂ per capita)	0.22	0.31	7.77
CO ₂ /TPES (tonnes of CO ₂ per tonne of oil equivalent)	0.45	0.56	3.01
Electricity consumption per population (MWh/capita)	0.1	0.17	4.125

Source: [12, 13].

TABLE 2: Key hydroenergy statistics.

	Unit/year	1990	1995	2000	2005	2010	2015
Primary energy supply	kTOE	9733	11022	13462	17243	20663	25968
Hydropower share	kTOE	133	132	184	153	232	181
	%	1.37	1.20	1.37	0.89	1.23	0.70

Source: [12].

FIGURE 5: CO₂ emissions in Tanzania from 1971 to 2015 [12, 13].

which a total of 9733 kTOE and 13,462 kTOE were supplied, respectively. The share of hydropower declined in the years 2001 and 2003 reaching 0.89% in 2005 as a result of a prolonged period of drought as explained in Loisulie [88] and Malley [95].

5.3. The Role of Hydropower within Electricity Generation.

The electricity demand in Tanzania is met through various resources primarily categorized as renewable and non-renewable. Renewable energy resources currently meeting electricity demand in the country include hydro, solar, biomass, wind, and in future geothermal which is still under development stages whereas nonrenewable energy sources are primarily petroleum, coal, and natural gas [2, 7]. Tanzanian hydropower generation for 2015 was estimated at 6,295 GWh or 33.5% of total electricity generation as opposed to 1628 GWh or 95% in 1990 based on International Energy Agency (IEA) data [12]. The roles of hydropower and other resources within electricity generation are depicted in

FIGURE 6: The role of hydropower within electricity generation 1990–2015 [12].

Figure 6. Over the period from 1990 to 2015, hydropower generation has tended to rise and fall irregularly, exhibiting varying water availability due to phases of below or above average rainfall. Nevertheless, the share of hydropower in total electricity generation has increasingly declined over the period from 1990 to 2015 reflecting the higher growth of alternative forms of electricity generating resources. For example, in 1990, there were only two alternative forms of electricity generation, namely, hydropower and oil as opposed to five alternative forms in 2015.

The composition of energy resources for electricity generation has changed significantly after natural gas began to claim its market share. As it can be seen in Figure 6, the influence of natural gas into the total electricity generation became apparent after the year 2000s and its share increased

sharply to date compensating the decline in hydropower generations. Thermal-power generations using natural gas has recently been the largest generator of electricity in Tanzania, commanding for approximately 44% of total generation in 2015 [12]. A similar situation is also observed for oil products share into electricity generation. Observations show that imported oil had a significant contribution of around 22% to the total electricity generation in 2015 as opposed to approximately 10% in 2000, and then introduction of natural gas into the market instigated this contribution to gradually decrease to around 4% in 2010. The statistics indicate that since 2000, utilization of fossil fuels specifically natural gas for electricity generation has increased considerably in Tanzania.

5.4. GHG Emissions Reduction: The Future Roles of Hydropower. Hydropower potential in the country has previously been affected by the decrease in an overall annual rainfall accompanied with intensified and prolonged dry and wet spells weather events, making the predictability of seasonal weather patterns more challenging [88, 96]. Kichonge et al. [28] have planned using Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) which is bottom-up modeling approach to two scenarios both for future resource supply mix. Modeling period was between 2010 and 2040 of which supply projections have previously named as dry-weather and business as usual (BAU) scenarios, respectively. Dry-weather scenario, introduced for the purpose of investigating possible energy resources supply mix under extreme weather conditions, revealed that, with less availability of hydropower at least 20% of the existing total potential, the electricity generations swing heavily to thermal-power plants technologies. In dry-weather scenario, higher shares of electricity generation came from coal and natural gas power plants. The enormity at which hydropower has in the generation of electricity is huge and needs special attention for planners and policy makers [28].

The shift to fossil fuels power plant technologies goes in line with the increase in the expenditure for primary energy supply. Moreover, less availability of hydropower reveals huge impact in the environment including the increase of GHG emissions. Demonstration over the immense potential of renewable energy sources in reduction of GHG emissions levels over the entire modeling period between BAU and dry-weather scenarios is depicted in Figure 7. The role of hydropower to the total share in electricity generation is expected to decrease due to first increases in the total energy demand while the current potential remains fixed and second firm measures being not taken to fully exploit existing potential as proposed in a number of studies.

5.5. Installed Hydropower Generation Capacity. The largest hydropower plant in Tanzania is Kidatu with a capacity of 204 MW, which is somehow mid-sized under international standards. The second largest hydropower plant is named as Kihansi with installed capacity of 180 MW. Both these hydropower plants are located in the Rufiji river basin [1, 7]. The total installed hydropower capacity is 561.843 MW of which 82.7% have been installed in Rufiji basin. Majority

FIGURE 7: CO₂ emissions projections scenarios [28].

of Tanzanian hydropower plants are now more than 50 years old as depicted in Table 3 [2]. In order for these hydropower plants to continue to offer services as planned will require refurbishment. Hydropower plants refurbishment will require significant expenditure on infrastructure, including the replacement and repair of vital parts.

5.6. Hydropower Development Projects in Tanzania. Hydropower remains as important renewable energy option for Tanzania due to its useful characteristics rarely found in other sources of energy such as being clean and less impactful on the environment, as well as being a cheap and domestically available [28, 97, 98]. Hydropower development has become a focal point of consideration in recent years to satisfy the energy demand and achieve the country's sustainable socioeconomic development goals as proposed in its Vision 2025 [48]. Hydropower is considered as a link to a shift into more sustainable energy sources and therefore identified as environmentally friendly feasible option pending that the transition to a more sustainable energy producing technology is realized [99, 100].

Based on the facts described, Tanzania, in her quest to meet its Vision 2025 which emphasizes the need for socioeconomic growth supported by a reliable and affordable energy supply as important feature for the development process [48], has identified and proposed twenty-three hydropower projects with nearly 4,765 GW capacity as future power development options [2, 14]. Some of these options are currently in planning phase or in different implementation stages, the largest being Steigler's Gorge located in Rufiji river basin [2, 14]. The Steigler's Gorge hydropower project is still in its initial stages of implementation and is expected to have an installed capacity of 1,048 MW in phase I and 1,048 MW in phase II. The driving motives behind the Steigler's Gorge and other projects aim at sustaining the projected increase in electricity demand while keeping environment clean for future generations [1, 8].

6. Small Hydropower Sector Overview

Small hydropower plants continue to play an important role in rural areas electrification. The projected potential for small

TABLE 3: Installed hydropower generation characteristics in Tanzania.

Plant name	Hale	Nyumba ya Mungu	New Pangani Falls	Kidatu	Mtera	Uwemba	Kihansi	Mwenga Hydro Ltd.
River basin		Pangani				Rufiji		
Generation type	Run-off river	reservoir	Run-off river		Reservoir		Run-off river	
Installation year	1964	1968	1995	1975/1980	1988	1991	1999/2000	2012
Installed capacity (MW)	21	8	68	204	80	0.843	180	4
Plant discharge (m ³)	45	42.5	45	140	96	N/A	23.76	8
Annual generation (GWh)	36.11	21.53	137.2	558.34	166.68	2.3	793.49	17.10
Reservoir active storage (10 ⁶ m ³)	0	600	0.8	125	3.2	N/A	1	-
Turbine type			Francis-Vertical			N/A	Pelton	Francis
Plant factor (%)	20	31	23	31	24	31	50	49

Source: [2, 14].

hydropower generation with capacities of less than 10 MW in Tanzania is estimated at 315 MW [101, 102]. The information gathered for this review shows that the exploited potential is estimated at only 25 MW which is approximately 8% of the total potential with the positive projections to its increase rising. However, a good number of small hydropower potential sites are located in remote rural settings where the national grid does not spread, so most of these sites would be best utilized to supply power to rural areas. The utilization of small hydropower potential could boost electricity access level even higher in rural area as nearly all regions [103, 104]. Map of 75 potential small hydropower sites in Tanzania is depicted in Figure 8 [29]. As seen in Figure 8, most of the promising small hydropower potentials are located in areas close to the main lakes such as Nyasa, Tanganyika, and Victoria. Most of the central and coastal parts of the country have so far not identified with potential small hydropower sites.

Globally, medium- and large-scale hydropower plants have become much riskier for investment attraction as a result of climate challenges among other issues, thus calling for a shift of focus into small hydropower generation [4]. Climate change has negatively impacted ability of large- and medium-scale hydropower plants to provide stable power production in some areas Tanzania inclusive [84, 88, 89]. In such conditions, adaptation measures are necessary such as using small-scale hydropower generation to improve the performance of the reduced flow not suitable for large-scale power plants. The projected challenges as a result of rainfall decrease as seen in McSweeney et al. [38], MEM [7], and Paavola [85] provide a perfect environment for increased development of hydropower resources with the focus on small hydropower plants whose technoeconomic demands can be served by investors with relative less difficulties.

Small hydropower plants are considered as a well functional resource for the sustainable development and therefore suitable solution to all the downsides of large- and medium-scale hydropower projects [105, 106]. Small hydropower technologies are largely “run-off river” and hence do not

• Promising potential small hydro-power site

FIGURE 8: Potential small renewable power sites in Tanzania [29].

require construction of storage facilities and are therefore cost-effective which implies that they have got minimal and ignorable environmental challenges [4, 107, 108]. Moreover, small hydropower plants utilize only part of the available water in rivers, making them less susceptible to fluctuations in the water quantities due to climate changes [4, 109].

7. Conclusion

It is clear that Tanzania, as a lower income country determined to achieve middle-income status, needs, amid other actions, to advance its electricity supply through utilization of locally available resources to meet her ever growing energy demands. Tanzania is a country with huge water resources potential which possesses sufficient and suitable characteristics to develop and maintain sustainable hydropower generation from small to large scale. Continuing exploiting

water resources for hydropower projects will bring on board several significant socioeconomic benefits to the country which might not have been possible with other nonrenewable sources to achieve even the modest environmental goals. The country's unexploited hydropower potential needs to be well thought-out in the future energy mix. However, due to numerous climate challenges sometimes affecting large- and medium-scale hydropower projects, the review explored and determined the key roles in which small hydropower projects can play in electricity generation and conservation of environment specifically mitigation of GHG emissions effects. Generally, the review concludes that, because of the country geographical location and the fact that hydropower potential is the main clean domestic energy resource option, there are substantial benefits to promote its developments to ensure a more sustainable growth pathway in electricity generation.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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