JREE: Vol. 3, No. 4, (Fall 2016) 20-26

Journal of Renewable Energy and Environment

Research Article

Journal Homepage: www.jree.ir

Small Hydro-power Plants in Kenya: A Review of Status, Challenges and Future Prospects

John. G. Mbaka[a,*], Mercy. W. Mwaniki[b]

[a]Department of Land and Water Management, University of Embu, Embu, Kenya
[b]Department of Geomatic Engineering and Geospatial Information Sciences, J.K.U.A.T., Nairobi, Kenya

PAPER INFO

Paper history:
Received 03 July 2016
Accepted in revised form 09 May 2017

Keywords:
Electricity
Energy
Small Hydro-Power Plant (SHP)
Kenya

ABSTRACT

Small Hydro-power Plants (SHP) are important sources of electricity in many countries. However, little is known about SHP in Kenya. This paper reviews the status, challenges in implementation of SHP and prospects for future development of SHP in Kenya. The paper shows that SHP has not yet fully utilized the available hydro-power potential. The challenges associated with SHP development should be addressed to realize its full hydro-power generation potential in the future.

1. INTRODUCTION

Globally, about 1.6 billion people do not have access to electricity [1]. In the Sub-Saharan Africa, less than 10% of the rural population has electricity supply, and many social and commercial institutions have limited or no access to electricity [2, 3]. For example, Kenya, with its fast developing industrial development and commerce, is facing a difficult task providing the energy required in the various economic sectors [4, 5]. Moreover, the existing electricity network does not have the capacity to provide power to the entire country, and electricity supply is characterized by high connection costs [6, 7]. Despite the increasing requirements for power, electricity power generation has not been increased at a similar rate. Consequently, lack of adequate power hinder potential local and foreign investments affecting the economic development of the country negatively. Indeed, the energy consumption per capita of Kenya, estimated at 122.1 kWh, is much lower than that of developed areas of the world, such as New York (2,050 kWh) in the USA [3, 8, 9]. To overcome the deficiency in energy requirements, Kenya needs to identify and maximize the development and use of available fossil fuels and Renewable Energy Resources (RERs) [8, 10, 11]. Among the RERs, hydro-power is the major (74%) source of energy and has a fundamental role to play [4, 6]. Hydro-power is particularly important because fossil fuels are responsible for the increased concentration of carbon dioxide in the atmosphere, and are non-renewable [12]. In fact, to avoid negative environmental consequences, it would be increasingly impossible to undertake activities requiring large-scale utilization of fossil energy resources (e.g., coal) [10, 13].

Hydro-power which contribute 17% of world´s electricity power, is the most widely used RER, and its use is predicted to increase by up to 4% by 2020 [14]. Large hydro-power plants are defined as having a power generation capacity of more than 30 MW. On the other hand, Small Hydro-power Plants (SHP) are defined as having a power generation capacity of up to 10 MW. The SHP includes the pico (up to 0.01 MW), micro (up to 0.1 MW) and mini (up to 1 MW) hydro-power plants [15]. The micro and pico SHP are typically used by communities for energy provision in areas without electricity connection, whereas the mini SHP tends to be connected to the grid electricity system [16, 17]. The former can be largely designed and installed using locally available materials and human labour [18].

The SHP system is a proven renewable energy technology for generating electricity with a long historical background [19]. Despite the fact that it is not well documented, SHPs have played a fundamental role in the earlier electrification efforts in the African Continent [20]. The SHPs are particularly ideal for power generation in hilly rural areas, with a high abundance of small permanent streams, where

*Corresponding Author's Email: mbaka.john@embuni.ac.ke (J. G. Mbaka)

electricity supply through the grid system may be unsustainable. When compared with large hydro-power plants, SHPs are advantageous because of short implementation times, low initial financial investment and environmental effects, potential to service the power requirements of populations living in remote areas, community participation in construction, limited need for human resettlement, and capability to generate electricity from small water courses [19, 21, 22]. The SHPs are cheaper than other power supply systems such as solar photo-voltaic, and play an important role in supply of power as stand-alone power generation systems or through the grid electricity system [18]. Additionally, the SHP can be integrated with other energy generation systems such as wind based systems to maximize the utilization of available resources in generating power [18]. The SHP can be of the run-of-river or impoundment types. The former has no water storage and power generation is done by diverting water from the main river channel through a weir (Fig. 1).

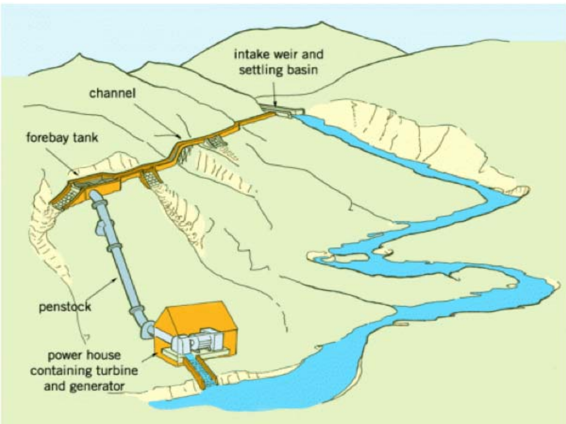

Figure 1. Layout of a small run-of-river hydro-power plant [23]

The run-of-river hydro-power plants are best suited for SHP with small capacities, and for reduction of construction costs and environmental effects, due to the absence of impoundment [24]. The run-of-river SHPs are usually made up of components such as weir and settling tank, channel, forebay tank, penstock pipe, turbine and generator (Figure 1). The sites suitable for SHP installation include areas with slopes and water falls. Thus, most of the sites ideal for SHP are likely to be found in mountainous regions with permanent streams. The site determines the size and type of SHP. This has an influence on the SHP installation cost which typically vary from 1,000 to 20,000 US dollars per kilowatt of electricity [18]. Generally, the capital required for installation of SHP depend on factors such as effective water head, water flow rate and the type of engineering work [1]. The initial investment cost, and effect on the environment, can be greatly reduced by utilizing the already existing impoundments and weirs [1]. The SHP can also be designed to serve several purposes such as power generation and flood control, reducing the period required to recover the investment [1]. Maintenance of SHP is typically less expensive when compared with other electricity generation systems such as diesel generators and their average lifespan can be up to 50 years, with minimum investment on maintenance and replacement [18]. Before investment, it is crucial to determine the amount of power that can be obtained from a site as given in the equation below:

$$P = \eta_O \rho g Q H \qquad (1)$$

where, η_O is the efficiency in energy conversion, ρ is water density, g is acceleration due to gravity, Q is the rate of water flow, and H is the distance from the inlet to the turbine [19]. Information such as water flow rate and the distance between water inlet and turbine is crucial in the design of SHP. It is also crucial to assess the SHP using hydrological and topographical maps including Geographical Information Systems (GIS), before detailed studies can be undertaken [25]. This provide details such as site accessibility, size of watershed and slope, and can be used to gauge whether the project is viable.

Globally, SHPs exist in 148 countries and the findings of the world SHP development report demonstrated that the global potential of SHP is about 173 GW. Additionally, the report showed that more SHP potential might be identified in the Africa and America continents, both of which account for 5% and 13% of global SHP resource hydro-power potential, respectively [26]. The SHP technology is currently being used in African countries such as Rwanda, Kenya and Tanzania [27, 28]. Inclusion of SHP in rural electrification plans in some of these countries and liberalization of the energy sector by allowing independent power producers to generate and sell power to national power utilities, has increased awareness and popularized the SHP [18]. However, the hydro-power potential of SHP in Africa is estimated at 10 GW, and only less than 1% of this power has been exploited [18].

In Kenya, the urban households connected to electricity are 60%, whereas only 10% of rural households have access to electricity from the grid network [26]. Given the fact that Kenyan rural areas have the highest (73%) population density, supply of electricity to these areas, such as through community owned SHP, may help accelerate the economic development and improve living standards. The current review, therefore, was aimed to review the status of SHP in Kenya, challenges that hinder SHP development and prospects for future development.

2. SMALL HYDRO-POWER PLANTS IN KENYA

2.1. Historical and Current State of SHP Development

The SHP has been utilized for more than a century in Kenya. The SHP has historically been used for purposes such as grinding food grains, electricity generation, and commercial uses such as operation of tea factories and small industries. These hydro-power plants have been implemented by the Kenya electricity Generation Company (KenGen), private entities such as tea companies and mission hospitals, individuals and communities (Table 1). Additionally, the Ministry of Environment (MoE) has developed two SHPs. These two hydro-power plants are community owned, are located in the Meru South and Kirinyaga districts, and have combined electricity generation capacity of 17.3 KW [29]. The hydro-power plant Ndula was one of the first SHPs in Kenya. This hydro-power plant, installed in 1925, is located along the Thika River, a tributary of the Tana River, and has a capacity of 2 MW (Table 1). Between 1925 and 1958, more than 14 SHPs were built. After 1958, there was more focus on large hydro-power projects [30]. However, interest to install SHP has been revived since 1990s, due to lack of adequate electricity power supply by the grid-based system, and the increased cost of electricity. For example, several private tea companies have installed SHP to reduce the cost of electricity bills [30]. The Kenya Tea Development Authority (KTDA) plans to install more than 10 SHP, generating more than 25 MW. Indeed, the Imenti tea factory, managed by KTDA and located in the Eastern Province, has a SHP that produces close to 1 MW (Table 1), and supplies 0.6 MW to the grid electricity network. The Tana River Development Authority is installing 7 SHP with a capacity of 3 MW, and the German Agency for Technical Cooperation, in collaboration with the Kenya Industrial Research and Development Institute, has been involved in the determination of SHP potential, identifying 14 sites for installation in Western Kenya. The Green Power non-governmental organization has also been involved in the exploration and installation of 17 SHP in Kenya [26, 31]. In summary, the SHP supply about 15 MW into the grid network and the off-grid capacity is 31 MW [18].

2.1.1. The Hydro-power Potential of SHP in Kenya

The hydro-power potential in Kenya is estimated to be as high as 6,000 MW, out of which 3,000 MW constitutes SHP [32]. Despite the relatively high potential of SHP, only about 30 MW has been installed, and most of the other hydro-power potential has not yet been utilized, compared with other eastern Africa countries such as Rwanda, Uganda and Tanzania (Table 2).

Moreover, field investigations have identified over 50 river sites with potential for development of SHP, with average hydro-power generation capacities between 50 KW and 700 KW, and other sites have not yet been discovered [32].

TABLE 1. The capacity (MW) of SHP installed in different rivers between 1925 and 2009 in Kenya. MW: Megawatts; n.a: not available

SHP	Ownership	River	Year	Capacity
Ndula	KenGen	Thika	1925	2.0
MESCO	KenGen	Maragua	1933	0.38
Selby falls	KenGen	n.a	1952	0.4
Sagana falls	KenGen	Tana	1955	1.5
Gogo falls	Mining company	Migori	1958	2.0
Tana 1 & 2	KenGen	Tana	1932	4.0
Tana 3	KenGen	Tana	1952	2.4
Tana 4	KenGen	Tana	1954	4.0
Tana 5	KenGen	Tana	1955	4.0
Wanjii 1 & 2	KenGen	Maragua	1952	5.4
Wanjii 3 & 4	KenGen	Maragua	1952	2.0
Sosiani	KenGen	Sosiani	1955	0.4
James Finlay 1	Tea company	Kericho	1934	0.3
James Finlay 2	Tea company	Kericho	1934	0.4
James Finlay 3	Tea company	Kericho	1980	0.1
James Finlay 4	Tea company	Kericho	1984	0.3
James Finlay 5	Tea company	Kericho	1999	1.1
Brooke Bond 1	Tea company	n.a	n.a	0.09
Brooke Bond 2	Tea company	n.a	n.a	0.1
Brooke Bond 3	Tea company	n.a	n.a	0.18
Brooke Bond 4	Tea company	n.a	n.a	0.24
Savani	Eastern produce	n.a	1927	0.09
Diguna	Missionary	n.a	1997	0.4
Ten wek	Missionary	n.a	n.a	0.32
Mujwa	Missionary	n.a	n.a	0.01
Tungu-Kabiru	Community	Tungu	2000	0.01
Thima	Community	Mukengeria	2001	0.01
Kathamba	Community	Kathamba	2001	0.001
Imenti	KTDA	Imenti	2009	0.9

Source: [26].

Most of the sites with potential for development of SHP are located in areas that are primarily suitable for stand-alone power generation systems, for off-grid supply of power to local communities and commercial enterprises [32]. These river sites are primarily located in the south-western region of Kenya in the Lake Victoria, Rift-valley, Athi, Tana and Ewaso Ng´iro rivers drainage basins [33]. These areas have high human population density, providing suitable conditions for development of SHP [2].

TABLE 2. The hydro-power potential and installed capacity (MW) of SHP in eastern Africa countries. MW: Megawatts; n.a: not available

Country	Potential	Installed	% installed
Burundi	54	15.8	29.3%
Ethiopia	1500	6.2	0.4%
Kenya	3000	33	1.1%
Madagascar	n.a	22.5	n.a
Malawi	15	5.8	38.7%
Mauritius	9.5	8.7	91.6%
Mozambique	1000	2.1	0.2%
Réunion	n.a	11	n.a
Rwanda	38.2	23.2	60.7%
South Sudan	5	n.a	n.a
Uganda	210	22.4	10.7%
Tanzania	310	25	8.1%
Zambia	n.a	31	n.a
Zimbabwe	120	1.9	1.6%
Total	6261.7	208.6	

Source: [26].

Additionally, many mountainous regions in Kenya have permanent streams running downstream in short steep sections, providing suitable conditions for their use in development of SHP with high hydraulic head. Streams in areas with gentle gradients are generally the most common and are suitable for development of SHP with small hydraulic head. Thus, Kenya has many sites with potential for development of SHP.

2.2. Challenges in Development of SHP

The barriers to development of SHP include lack of detailed information database about potential sites for SHP installation. The local communities or individual entities may lack the necessary technical knowledge on how to carry out feasibility studies, install and manage SHP. This has been suggested to be caused by centralization of SHP administration, where the available knowledge acquired by trained government workers is not available to local communities [34]. Also, local institutions of higher learning may not be adequately providing the infrastructure and training required to fully exploit SHP [35]. The cost of SHP installation, estimated at 3,000 US dollars per kW, may prohibit adoption of SHP by local communities and individual investors, in the absence of external funding [28]. The recurrent drought experienced in Kenya also poses a danger to generation of hydro-power using SHP. For example, the low amount of precipitation in the central region of Kenya has greatly reduced water inflow rate into the Tana River, where most of the country's hydro-power plants are located, reducing hydro-power electricity generation capacity [36]. Global climate change has also caused the snow and glaciers on many mountains to recede fast due to continued rise in temperature, further reducing river flow and electricity generation potential [37]. For example, the severe drought of year 2000 was approximated to have caused over 2 million US dollar losses due to power outages [38]. Installation of SHP is further challenged by deforestation in the watersheds. Clearance of forests reduces river based flow, and increase sedimentation rate of rivers and reservoirs, reducing their capacity to generate electricity. The problem of deforestation is exacerbated by the heavy (70%) reliance on energy resources in form of wood and charcoal [38]. Also, adoption of SHP is hampered if the institutional frameworks and policies do not have clear plans for implementation and funding [39]. Moreover, if a community is connected to the grid electricity system under rural electrification plans, an existing or planned SHP may become less useful. Finally, given that implementation of SHP requires cooperation between different stakeholders such as local authorities, non-governmental organizations and local communities, neglecting involvement of any of the stakeholders may hinder or delay development of SHP.

2.3. Requirements and Opportunities for Future Development of SHP

Availability of documents on plans to extend the grid electricity network to rural areas is important to enable SHP investors assess whether a certain area is viable for SHP development. Integration of SHP with rural electrification plans is necessary in project implementation. Development of local communities capacity to operate and maintain SHP is essential for successful operation of community-managed SHP [28]. Capacity building in practical experience with SHP technologies can be attained through establishment of knowledge networks and training of local technicians, strengthening the capacity of local schools and science institutes to teach and market SHP technologies, transfer of technology from countries endowed with SHP expertise and use of locally available technologies and resources [34, 35]. Technical training is essential and there has been government workers attending short-term training on SHP [30]. The SHP should be made cheaper by ensuring that most of the materials needed for installation such as pen-stock pipes, turbines and generators, are readily available. Also, increasing funding for RERs such as SHP, will go along way in increasing its use in hydro-power generation. Application of research techniques such as models and geographical information systems, which increase the ability to survey large areas more precisely within a short time span, and investigate energy supply systems, will reduce the costs of site identification and analysis in future [25, 40]. Additionally, environmental impact assessment should be carried out before implementation of SHP projects to minimize impacts on the environment [41]. Opportunities exist for development of SHP in Kenya due to availability of adequate water resources (e.g., rivers). The surplus hydro-power potential at existing water supply dams can be used for electricity generation using SHP. For example, it was approximated that integration of SHP into existing water supply dams in Turkey would result in generation of more than 170 GWh of electricity per year, amounting to an economic benefit of over 20 million Euros per year [42]. The recently passed law that encourages communities and private investors to generate and distribute electricity can help in utilization of such water resources in development of SHP in Kenya [27].

3. DISCUSSION

The hydro-power potential of SHP in Kenya is estimated to be approximately 3,000 MW [32]. However, only about 1% of this hydro-power potential has been utilized (Table 2). This is in contrast with other Eastern Africa countries such as Burundi (29.3%), Malawi (38.7%), Rwanda (60.7%) and Mauritius (91.6%), where a relatively higher percentage of the available SHP potential has been installed (Table 2). Despite the discrepancy between Kenya and other countries, SHP represents one of the most decentralized RERs for providing reliable and affordable electricity to remote areas, with potential positive impacts on livelihoods. For example, use of micro-hydro-plants in Nepal resulted in abandonment of traditional kerosene lamps and reduced usage of firewood. Additionally, the hydro-plants were used to power industries processing agricultural products, reducing the need for traditional water mills [21].

Small hydro-plants have been successfully installed in areas of the world such as Asia and Europe [43]. This could have largely been contributed by the need to reduce the utilization of fossil fuels such as coal, the need for off-grid options for better access by communities living in remote areas, and the challenge caused by topography on development of large-scale hydro-power projects. For example, in Vietnam the installed SHP capacity is 61 MW, with an estimated potential of approximately 1,800 MW. China has achieved a considerable success in SHP development, and possesses 65,000 SHP with a combined capacity of 11,000 MW. The installed SHP capacity represents 35% of the country's hydro-electric capacity [44]. According to Punys and Pelican [45], SHP has been utilized for more than 100 years in most European countries. Turkey has the highest hydro-power potential in Europe, with its 216 TWh/yr technical hydro-power energy [43]. In summary, successful development of SHP in some of these countries can act as model for countries with low SHP development.

Small hydro-plants have been implemented in African countries for a long period of time [20]. However, there is limited information about the outcome of these projects and technical details such as efficiency, in most countries (e.g., Kenya). This lack of information about SHP greatly hinders the ability to learn from past projects. In Thailand, an assessment of the development of a pico hydro-power plant showed that the performance of the overall system, by means of efficiency, was 52% and had an electrical power production capacity of 644 W [46]. In Tanzania, a pico hydro-power plant, operating at 80% efficiency, produced 20 W and provided electric power for mobile phones and lighting [47].

4. CONCLUSION

In conclusion, SHP has contributed to the past electrification efforts in Kenya, and still has a great hydro-power potential if well harnessed. The challenges associated with SHP installation should be addressed in order to increase its utilization in hydro-power generation, and exploitation of the available hydro-power generation opportunities.

5. ACKNOWLEDGMENT

We appreciate the encouragement to write this paper by colleagues at Embu University, Kenya. This study was not funded.

REFERENCES

1. Yüksel, I., "Development of hydro-power: a case study in developing countries", ***Energy Sources, Part B,*** Vol. 2, (2007), 113–121.
2. Parshall, L., Pillai, D., Mohan, S., Sanoh, A. and Modi, V., "National electricity planning in settings with low pre-existing grid coverage: development of a spatial model and case study of Kenya", ***Energy Policy,*** Vol. 37, (2009), 2395-2410.
3. Hancock, K.J., "The expanding horizon of renewable energy in sub-saharan Africa: leading research in social sciences", ***Energy Research and Social Science,*** Vol. 5, (2015), 1–8.
4. Mariita, N.O., "The impact of large- scale renewable energy development on the poor: environmental and socio-economic impact of a geothermal power plant on a poor rural community in Kenya", ***Energy Policy,*** Vol. 30, (2002), 1119–1128.
5. Ulsrud, K., Winther, T., Palit, D. and Rohracher, H., "Village-level solar power in Africa: accelerating access to electricity services through a socio- technical design in Kenya", ***Energy Research and Social Science,*** Vol. 5, (2015), 34–44.
6. Acker, R.H. and Kammen, D.M., "The quiet (energy) revolution", ***Energy Policy,*** Vol. 24, (1996), 81–111.
7. Abdullah, S. and Markandya, A., "Rural electrification programmes in Kenya: policy conclusions from a valuation

study", ***Energy for Sustainable Development,*** Vol. 16, (2012), 103–110.

8. Capik, M., Yilmaz, A. O. and Cavusoglu, I., "Hydro-power for sustainable energy development in Turkey: the small hydro-power case of the Eastern Black Sea region", Renewable and Sustainable Energy Reviews, Vol. 16, (2012), 6160– 6172.

9. Dusmanescu, D., Andrei, J. and Subic, J., "Scenario for implementation of renewable energy sources in Romania", ***Procedia Economics and Finance,*** Vol. 8, (2014), 300–305.

10. de Groot, R.A.F., van der Veen, V.G. and Sebitosi, A.B., "Comparing solar PV (photo-voltaic) with coal-fired electricity production in the centralized network of South Africa", ***Energy,*** Vol. 55, (2013), 823–837.

11. Kessides, L. N., "Powering Africa's sustainable development: the potential role of nuclear energy", ***Energy Policy,*** Vol. 74, (2014), 557–570.

12. Koch, F., "Hydro-power-the politics of water and energy: introduction and overview", ***Energy Policy,*** Vol. 30, (2002), 1207–1213.

13. Atilgan, B. and Azapagic, A., "Life cycle environmental impacts of electricity from fossil fuels in Turkey", ***Journal of Cleaner Production,*** Vol. 106, (2015), 555–564.

14. Yüksel, I., "Development of hydro-power: a case study in development countries", ***Energy Source Part B,*** Vol. 2, (2007), 113–121.

15. Panić, M., Urošev, M., Pešić, A.M., Brankov, J. and Bjeljac, Z., "Small hydro-power plants in Serbia: hydro-power potential, current state and perspectives", ***Renewable and Sustainable Energy Reviews,*** Vol. 6, (2013), 341–349.

16. Lahimer, A.A., Alghoul, M.A., Yousif, F., Razykov, T.M., Amin, N. and Sopian, K., "Research and development aspects on decentralized electrification options for rural household", ***Renewable and Sustainable Energy Reviews,*** Vol. 24, (2013), 314–324.

17. Gladstone, S., Tersigni, V., Francfort, K. and Haldeman, J.A., "Implementing pico hydro-power sites in rural Rwanda", ***Procedia Engineering,*** Vol. 78, (2014), 279–286.

18. Kaunda, C.S., Kimambo, C.Z. and Nielsen, T.K., "Potential of small-scale hydro-power for electricity generation in Sub-Saharan Africa", ***International Scholarly ResearchNetwork Renewable Energy,*** Vol. 2012, (2012), 1-15.

19. Paish, O., "Small hydro-power: technology and current status", ***Renewable and Sustainable Energy Reviews,*** Vol. 6, (2002), 537–556.

20. Klunne, W.J., "Small hydro-power in Southern Africa - an overview of five countries in the region", ***Journal of Energy in Southern Africa,*** Vol. 24, (2013), 4–25.

21. Gurung, A., Bryceson, I., Joo, J.H. and Oh, S., "Socio-economic impacts of a micro hydro-power plant on rural livelihoods", ***Scientific Research Essays,*** Vol. 6, (2011), 3964–3972.

22. Premalatha, M., Abbasi, T.T. and Abbasi, S.A., "A critical view on the eco-friendliness of small hydroelectric installations", ***Science of the Total Environment,*** Vol. 481, (2014), 638–643.

23. Pallugna, R.C., Cultura, A.B., Gozon, C.M. and Estoperez, N.R., "British Hydro Association. A guideto UK mini-hydro developments", in, http://www.british-hydro.org/mini-hydro, (2005).

24. Larinier, M., "Fish passage experience atsmall-scale hydroelectric power plants inFrance", ***Hydrobiologia,*** Vol. 609, (2008), 97–108.

25. Punys, P., Dumbrauskas, A., Kvaraciejus, A. and Vyciene, G., "Tools for small hydro-power plant resource planning and development: a review of technology and applications", ***Energies,*** Vol. 4, (2011), 1258–1277.

26. Liu, H., Masera, D. and Esser, L., "Worldsmall hydro-power development report", in, www.smallhydroworld.org, (2013).

27. Kirubi, C., Jacobson, A., Kammen, D.M. and Mills, A., "Community-based electric micro-grids can contribute to rural development: evidence from Kenya", ***World Development,*** Vol. 37, (2009), 1208–1221.

28. Ahlborg, H. and Sjöstedt, M., "Small-scale hydro-power in Africa: socio-technical designs for renewable energy in Tanzanian villages", ***Energy Research and Social Science,*** Vol. 5, (2015), 20–33.

29. Karekezi, S., Kimani, J. and Onguru, O., "Global network on energy for sustainable development", in, www.afrepen.org, (2008).

30. Muriithi, J., "Developing small hydro-power infrastructure in Kenya", in, second small hydro-power today conference, China, (2006).

31. Dzelilovic, A., "Small-scale renewable technologies: development and prospects", ***Bulletin of Energy Economics,*** Vol. 32, (2015), 82–90.

32. Kiplagat, J.K., Wang, R.Z. and Li, T.X., "Renewable energy in Kenya: resource potential and status of exploitation", Renewable and Sustainable Energy Reviews, Vol. 15, (2011), 2960–2973.

33. Owiti, E. and Wesley, K., "Small hydro-power development in Kenya", in, the training workshop on small hydro-power technology for developing countries, China, (2011).

34. Jiandong, T., "Some features of china's small hydro-power", ***Hydro Nepal,*** Vol. 4, (2009), 11–14.

35. Colenbrander, S., Lovett, J., Abbo, M. S., Mswigwa, C., M'Passi-Mabiala, B. and Opoku, R., "Renewable energy doctoral programmes in sub-saharan Africa: a preliminary assessment of common capacity deficits and emerging capacity-building strategies", ***Energy Research and Social Science,*** Vol. 5, (2015), 70–77.

36. Bunyasi, M.M., "Vulnerability of hydro-electric energy resources in Kenya due to climate change effects: the case of the Seven Forks project", ***Journal of Agriculture and Environmental Science,*** Vol. 1, (2012), 36–49.

37. Carless, D. and Whitehead, P.G., "The potential impacts of climate change on hydro-power generation in Mid Wales", ***Hydrology Research,*** Vol. 44, (2013), 495–505.

38. Abdullah, S.S.M., "Willingness to pay for renewable energy options in developing countries: the case of Kenya", PhD thesis, University of Bath, (2009).

39. Ahlborg, H., Boräng, F., Jagers, S.C. and Söderholm, P., "Provision of electricity to African households: the importance of democracy and institutional quality", ***Energy Policy,*** Vol. 87, (2015), 125–135.

40. Akinbami, J.K., "Renewable energy resources and technologies in Nigeria: present situation, future prospects and policy framework", ***Mitigation and Adaptation Strategies for Global Change,*** Vol. 6, (2001), 155–181.

41. Hanafi, J. and Riman, A., "Life cycle assessment of a mini hydro-power plant in Indonesia: a case study in the Karani River", ***Procedia CIRP,*** Vol. 29, (2015), 444–449.

42. Kucukali, S., "Municipal water supply dams as a source of small hydro-power in Turkey", ***Renewable Energy,*** Vol. 35, (2010); 2001–2007.

43. Kucukali, S. and Baris, K., "Assessment of small hydro-power development in Turkey: laws, regulations and EU policy perspective", ***Energy Policy,*** Vol. 37, (2009), 3872–3879.

44. Naibo, Z., Shingyi, S. and Zhengli, H.,"Small-scal hydro-power in China", ***Biomass,*** Vol. 20, (1989), 77–102.

45. Punys, P. and Pelikan, B., "Review of small hydro-power in the member states and candidate countries in the context of the

enlarged European Union", **Renewable and Sustainable Energy Reviews,** Vol. 11, (2007), 1321–1360.

46. Chuenchooklin, S., "Development of pico-hydro-power plant for farming village in upstream watershed, Thailand", presented at prosperity and poverty in a globalized world conference, Bonn, (2006).

47. Okamura, T., Kurosaki, R., Itani, J. and Takano, M., "Development and introduction of a pico hydro-power system in Southern Tanzania", ***African Study Monographs,*** Vol. 36, (2015), 117–137.