Journal of Energy Research and Reviews

3(4): 1-14, 2019; Article no.JENRR.53111
ISSN: 2581-8368

A Comprehensive Review on Status of Solar PV Growth in Uganda

Reuben Gad Mugagga[1*] and Hope Baxter Nqcube Chamdimba[1]

[1]Department of Energy Technology, School of Engineering and Technology, Kenyatta University, Nairobi, Kenya.

Authors' contributions

This work was carried out in partnership with both authors. Author RGM prepared the first draft. Author HBNC performed the manuscript analysis and further editing. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JENRR/2019/v3i430113
Editor(s):
(1) Dr. Hermes Jose Loschi, Faculty of Electrical and Computing Engineering (FEEC), School of Electrical and Computer Engineering, The States University the Campinas (UNICAMP), Brazil.
Reviewers:
(1) J. G. L. S. Jayawardena, University of Sri Jayewardenepura, Sri Lanka.
(2) Raheel Muzzammel, University of Lahore, Pakistan.
Complete Peer review History: http://www.sdiarticle4.com/review-history/53111

Review Article

Received 20 September 2019
Accepted 27 November 2019
Published 19 December 2019

ABSTRACT

Uganda is faced with a challenge of huge energy deficit just like many other developing countries in Africa. Currently, only 26.7% of the total population has access to electricity. Energy being the life – blood of any growing economy, subsequent endeavors and strategies need to be put in place in order to expand the use of renewable energies for socio-economic development and environmental sustainability. Uganda being endowed with plenty of solar energy resource, its role in achieving national ambitions of Sustainable Energy for All (SE4All) cannot be underestimated. This paper therefore reviews the growth of Solar Photovoltaics (PV) in Uganda that was birthed in the 1980's and continues to mature steadily today contributing 4.24%(50MW) to the national grid with several un documented off – grid systems. This progress has been realized under different market segments inclusive of the pico and macro solar home systems, Institutional PV, mini-grids, telecommunications and street lighting. Notwithstanding the prevalent challenges, there are numerous existing opportunities for solar PV development consisting of the financial, environmental, Institutional and the socio-economic factors. With more government and different stakeholder engagement however, this growth in the country could be accelerated further as the costs of the technology continue to plummet.

**Corresponding author: E-mail: gadrobben@gmail.com;*

Keywords: Solar PV; Uganda; challenges; opportunities; renewable energy.

1. INTRODUCTION

With over 1.28 billion people in Africa, 600 million people still live without access to electricity even though the electrification rates have increased by 43% [1]. Provision of electricity will necessitate a combined effort of investment in both renewable off grid and on-grid solutions [2] to speed the electrification process as the grid extension to some of the rural areas that are most populated doesn't seem feasible.

Though the early manufacturers of Solar Photovoltaics (PV) where faced with the challenge of very long payback times simply because the energy requirement in production was more than the total energy that a given panel could generate in its lifetime, the payback periods have fallen to less than 3 years due to advancements in technology and 80% cheaper [3,4]. Economies of scale for solar PV have also led to mass production by countries like China which has precipitously reduced the cost per watt to almost $0.8 per watt [5].

The assumption of solar PV shall play a critical role in averting numerous climate change implications through the alignment of government policies with the Clean Development Mechanisms (CDMs) and the Kyoto Protocol as the demand for energy heightens [6–8]. Provision of cleaner and modern energies to suit the everyday need of the vast populations of the developing world will increase the socio-economic welfare of households and livelihoods while promoting better environmental standards [9,10]. Involvement of all stakeholders will compound to this effect so as to actualize the different international, regional and national energy policies by providing the necessary legislation and supporting environments for the development of these alternative sources of energy to boost power production [11].

Essentially, countries like Uganda have adopted this technology as a measure to meet the energy demand of the rapidly growing population in a social, economic and environmentally sustainable manner in order to attain 80% access to the National grid by 2040 [10]. This is mainly because access to reliable, sustainable and affordable energy has a direct correlation with the quality of lives and livelihoods [12]. The scalability can therefore have direct benefits to children as well as women more so in rural communities.

1.1 Overview of the Solar PV Status in Uganda

The installed generation capacity in Uganda has continued to grow steadily from 872 MW in 2012 to 1179MW in 2019 [13] mainly due to continuous investment in the vast energy sources for power generation [14]. In the past, the power sector of Uganda was predominantly comprised of hydropower. However, hydropower generation is becoming vulnerable to climate change in many countries including Uganda owing to the fluctuation of water levels in Lake Victoria [15], which necessitates for diversification of energy sources. The need for ensuring national energy security has led other renewables to be adopted in the energy mix which is in line with the mission of the Renewable Energy Policy (REP) of Uganda [16].

The country lies on the equator and receives average daily solar irradiation levels (Fig. 1) though not consistent all year round with close to 5 - 7 peak sunshine hours daily (when the average irradiation is 1000W/m^2). However, this irradiation varies from place to place while being dependent on the weather patterns. It also has a solar power potential of about 200MW [15].

The Solar PV industry in Uganda started in the early 1980 primarily with donor funds for vaccine refrigeration and lighting [18] but has since grown and contributes 4.24% (50MW) of the total installed capacity [13]. This is attributed to the provision of alternative energy to the rural and remote communities that are mainly not served by the grid and have less expectations of grid extensions [11,19]. It is expected that in the foreseeable future increased off-grid applications will include, charging systems, water pumping, phone charging, Television, radio, photocopy and income generating activities [20]. Currently the country has over 30 solar companies that supply Solar PV technologies to Government as well as public institutions including education and health.

2. SOLAR PV MARKET SEGMENTS

With different innovative financing schemes and tax exemptions, most of the consumers have been tagged from the peri-urban and rural areas

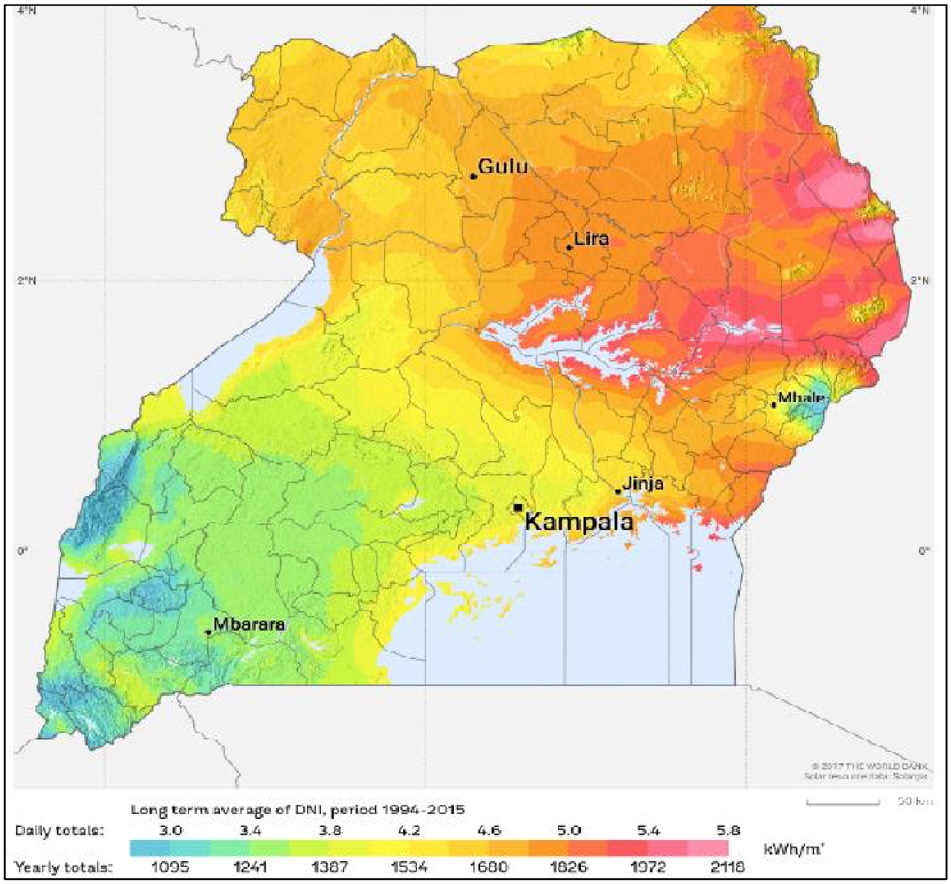

Fig. 1. Solar direct normal irradiation (DNI) map of Uganda
Source: [17]

corresponding to the population with hard to reach grid extensions. And since PV technology is characterized with a wide range of applications, diversification continues to take its course in the different segments discussed herein.

2.1 Pico and Macro Solar Home Systems (SHS)

These systems range from small charging systems (up to 5Wp) to semi portable systems with a small portable module (5 – 10Wp). They comprise of solar lanterns, torches, and lights with minimum wattage and less operation and maintenance costs. There continues to be a wide market of these solar products in Uganda which mainly target rural areas where the majority of the population live [21]. Some of active players in the supply chain in the country are Solar Now, M-Kopa, Barefoot power, Fenix, d.light, village power and Sunking [22]. This growth has been mainly due to the reducing costs of these solar products and the existence of well-established local supply chains [12].

2.2 Solar Home Systems

These systems usually have power ratings of between 10 - 200Wp [23]. The adoption rate of these systems is relatively high in Uganda though the actual statistics were not easy to obtain in literature. However, with the vision to develop off-grid energy access, the Uganda Off-grid Energy Market Accelerator (UOMA) founded in 2017, estimates relate to over 270,000 SHS by the year 2018 [22]. Central and Western regions of the country dominate the access to off-grid power partly due to a government project called the Uganda Photovoltaic Pilot Project for Rural Electrification (UPPPRE) which was rolled out in 1998 with the support from the United Nations Development Programme (UNDP). Despite the many uses of solar power, lighting is the most dominant among the rural households according to [24] corresponding to 21% as eluded by the Uganda household survey of 2017 [25].

2.3 Standalone Institutional PV Systems

The typical systems mainly use a PV, battery, inverter and charge controller and other Balance of the System (BOS) components depending on the capacity of the installation. They usually range from 50Wp – 500Wp and could either be Alternating current (AC) or Direct current (DC) systems. A number of these systems have been adopted partly due to the grid power unreliability as it is characterized by prolonged load shedding and power cuts [26]. In addition, the uptake is mainly through Government agencies in the vie for rural electrification with support from donor agencies and NGO's for different institutions like schools and hospitals as they help in the realization of immediate social, economic and environmental benefits of electricity access [27].

2.4 Solar PV Mini Grids

This market segment is comprised of the use of solar PV systems that are modular for provision of electricity in ranges of 5kW – 1MW (Tab. I). These are considered the more feasible means of rural electrification due to their increased competitiveness and demand. The adoption of solar mini grids is still nascent to the Ugandan market being spearheaded by the Rural Electrification Agency (REA) [22].

2.5 Telecommunication and Street Lighting

The telecommunication industry started using this technology as it had an edge over the old gensets that were vulnerable to the unpredictable global fuel prices. More strategies are being taken up to increase power generation for different Base Transceiver Stations with green power technologies and such initiatives are being spearheaded by MTN (the largest mobile operator in Uganda) with a roll out of seven sites with a Return on Investment being three and a half years [29]. This has in turn reduced generator run times and operating expenditures.

The role of street lighting has been assumed by the district local governments with provision of lights in the range of 35 to 250W. The street lighting has enabled night stalls, security as well as socializations like entertainment during night time [23].

Table 1. Solar PV mini grids

Completed minigrids	
Mini grid	**Installed capacity (kW)**
Kayanja	5
Kasese	5
Kyenjojo – Kyamugarura	13.5
Kyenjojo - Kyanyagaramire	13.5
Kitobo Island	230
Kalangala - Bugala Island (PV diesel hybrid)	1600
Luwero - Kabunyala	22.5
Total Installed Capacity	**1889.5**
Tendered minigrids	
15 villages in Rakai and Isingiro Districts	966
25 villages in Lamwo District	936
Total tendered capacity	**1902**
Total Capacity	**3791.5**

Source: [22,28]

Table 2. Grid connected Solar power plants

Solar plant	**Installed capacity MW**	**Year of commission**
Soroti	10	2016
Tororo	10	2017
Xsabo Solar (Kabulasoke)	20	2018
Mayuge	10	2019

Source: [31]

2.6 Grid Connected

These are battery less systems where the DC energy generated by the PV modules is converted directly by the inverters to AC with a frequency that is synchronized with the grid. This obviates the use of batteries that reduces on the overall costs of the system [3]. They typically range from 1 – 50 MWp.

The rapid adoption of the grid connected systems (Table 2) is as a result of government's commitment to adopt supporting policies and regulations [30]. This move birthed the GETFiT policy that begun in 2013 so as to fast track the adoption of small scale RE projects that were at advanced stages with development permits by provision of finances in terms of top up premium payments to suitable private project developers. They, in the long run attain their financial commissions through power generation with costs ranging from 0.5 – 2.0 US cents per kWh. This is actualized through Power Purchase Agreements (PPA) for periods of up to 20 years [16].

3. CHALLENGES TO SOLAR PV GROWTH

3.1 Technical Capacity

Capacity building is the cornerstone of the off-grid energy development as without this capacity, the implementation of the energy strategies, policies and adaptation of technology becomes problematic [32]. The country has few institutions providing these training needs though the number of graduates with the theoretical knowledge of solar PV continues to grow annually. However, they lack the technical experience on how to design, install and maintain the solar systems [28,33]. In addition, the country has low levels of diffusion and uptake of new technology changes so as to suitably fit in the framework that the technical expertise can adopt easily. This has become an outstanding limiting factor in Solar PV development especially in rural areas as most technicians are located in urban areas.

The PV installation permits in the country are still generally grouped under Class Z irrespective of the PV system size which are not followed strictly. This affects quality of work as some installation activities are done by less experienced technicians. However, some countries such as Kenya adopted 3 levels for solar technician training where Technician Levels 1-2 are for the solar standalone while Technician Level 3 is for the grid tie and hybrid systems. Such trainings are pre-requisites before a solar technicians license is issued by the Energy Regulatory Commission [34].

3.2 Technology Awareness

The uptake of solar PV technology is relatively slow because of the level of understanding and perception to the vast population of the country [35]. It is viewed that increasing energy access while tackling climate change and air pollution in a country demands inclusion of all sector players. However, some of the most important players are still in the dark [36]. This spans from the banking sector to the small business developers whose confidence in financing RE projects is vital in the planning and implementation of Solar PV related growth.

Business owners have lacked adequate awareness about the Renewable Energy Technologies (RET) financing opportunities, investor networks, social and environmental factors during the early stages of business idea development. In addition, their struggle to come up with appropriate strategies to reach their target markets has been in vain [37]. It has also been difficult to factor in the business models that are most opportune for different market segments [38,39] which currently comprise of four main distribution models namely; direct sales, the traditional distribution model, the franchise and the savings co-operatives model [37].

Consumer awareness campaigns are still lacking as to the majority of the rural customers, solar technology is bought for trial and its reported that when faults occur, the systems are abandoned because they do not know the right people to consult [40]. Secondly, when the systems did not work for the time they anticipated, it kills their interest and they would rather stick to their conventional energy sources missing out on the potential benefits and opportunities offered by the technology usage [41]. This being mainly caused by the inability of most technology users to distinguish between the counterfeit and good quality products found on the market.

3.3 High Investment Costs

The initial equipment capital costs are high compared conventional energy sources which have been used for quite some time which deems it the most critical deterring factor which negatively affects PV development [19,40]. These solar equipment wholesale prices are hiked by the importers and retailers by adding up to 40% of the original market prices for fixed and mobile systems hence limiting the uptake by small scale consumers in regard to affordability of the solar equipment [37]. This up rise has partly been caused by the Value Added Tax (VAT) exemption which was recently removed by government yet it had helped make RE products competitive [42]. This is aggravated by the risk associated to the theft of panels and SHS that is not backed by any insurance policy [37].

The level of investment on the other side, dictates on the level of profits anticipated. Big projects development is accompanied with more risks such as equity financing. However to reduce the risks associated with the costs of investment, debt financing can be employed [14].

3.4 Unattractive Feed in Tarrifs (FiT)

With considerations of solar PV in the FiT the average cost of energy of the first installed PV plants in the country under the Global Energy Transfer Feed in Tariffs (GETFiT) was still higher at USc 16.4/kWh. Reasons behind such high tarrifs being that the country has a small market size. In addition, there is limited competition and the risk of investing is very high which is attributed to poverty, poor infrastructure and most importantly corruption [43]. Private developers in the country have been limited by the low FiT costs for grid tied solar PV systems [44] as the technology is still steadily picking up with a likelihood of reducing electricity tariffs in the long term [45]. Introducing attractive FiTs will allow for reduced maintenance and running costs and could even give room for ease of PV power increment in terms of modules for existing systems which will ensure less Green House Gases through the relatively long life-spans of above 25 years dependent on the maintenance levels [46].

3.5 Financing Associated Risk

Uganda has sought financial assistance through loans and grants so as to finance its solar projects from Multilateral Development Banks (MDBs) like World Bank, German Development Bank, African Development Bank [47]. In this vein, it has necessitated the Government acquisition of pre-requisite risk and mitigation reports, feasibility as well as previous project reports [46].

This is fueled by the high loan risk perception as local and international interest rates of up 20% and 11% respectively due to the unfamiliarity of RE projects by the financial institutions [42] while, the involvement of private foreign investors in financing upcoming solar projects has been limited due to their environmental, social, political and economic associated risk [23]. Similarly, for bigger energy projects a risk guarantee is deemed necessary together with a third party international credit agencies like the KfW – a German state owned Development bank [48].

However, the financing of small projects is also hampered by having no recourse on investment and sometimes having small project implementers who are at times perceived to be less knowledgeable and not in position to take up big funding [2].

3.6 Policy and Regulatory Frameworks

Government policies are key in controlling different resources in the best way possible in order to create employment, generate incomes while promoting resource development and diversification of which renewables are part. They are also fundamental in attracting potential project developers and to allow for the long-term sectorial market development. They also focus on development of appropriate regulatory frameworks, developing interlinkages in the energy sector and integration of environmental sustainability in regard to the existent energy initiatives [18].

With the Electricity Act 1999, Energy policy of 2002, the Renewable Energy (RE) policy of 2007 together with other regulatory frameworks like the Electricity Regulatory Authority (ERA) and Ministry of Energy and Mineral Development (MEMD) moving forward to fast track the Private sector participation in power generation came up with the Renewable Energy Feed in Tariff (REFiT) policy in 2007 though it was hindered by limited uptake by project developers as it lacked cost effective tariffs and bankable transaction documentation [43].

Grid enhancement also still stands as a future prospect and shall need to be developed with supporting legislation in the energy act which was not included in the just revised REFiT phase 4 guidelines to guide in the grid connected systems [45]. In Kenya for example, PV plants with more than 500kWp have connected to the grid but the government intends to conduct pilot studies as per the Scaling-Up Renewable Energy Program - SREP plan [49]. This has been existent due to fears of destabilizing the wholesale electricity markets and the expense accrued overtime since they have no adjustments for supply due to increase in demand [14].

In contrary, failure of implementation of set targets within prescribed timelines still remains one of the shortfalls of legislation. The Rural Electrification Strategy and Plan (RESP) formulated in 2001 only had 7,000 out of the anticipated 80,000 systems installed which either showed high ambitiousness or deficiency in institutional capacity. This plan was meant to speed up rural electrification for which grid connectivity was not cost effective yet the formation of District energy committees will help ensure autonomy in energy sector implementation plans [44].

3.7 Product Standardization

There is a dire need for the Uganda National Bureau of Standards (UNBS) to clearly set out regulations on imported PV components [18] in order to avail the market with quality products [50]. This is very essential as poor quality products smuggled into the country through porous borders have damaged the attitude of the consumers.

UNBS should formulate adequate standards in line with the International Electrotechnical Commission (IEC) and foster collaborations with the Lighting global assurance standards considering Rwanda as a benchmark so as to benefit from competitive pricing. On the local scene however, these standards should be enforced routinely by the UNBS that currently collaborates with the Centre for Research in Energy and Energy Efficiency (CREEC) in testing solar products in order to avoid the proliferation of low-quality products in the market [51].

These tests on the other hand could raise the cost of the products but will ensure for adequate technical performance as well as durability and safety of the systems. This is imperative as durability of these technologies needs essential integration of the life cycle impacts at standardization of solar products so as to ensure sustainability in terms of the end of life management [24]. In contrast, setting the standards higher also tends to limit the products affordability which is impractical for the local scene [9], albeit the benefits of setting adequate standards are greater as compared to having poor or low standards.

UNBS will have to increase its technical capacity [37] to allow for requisite verification controls as standardization and product certifications boost consumer confidence. Likewise, the bureau still has the endeavor to study and ascertain the range of all solar PV components available in the country so as to develop a standard framework in order to support the already established technologies and the sector players with emphasis on the small investors with capital constraints.

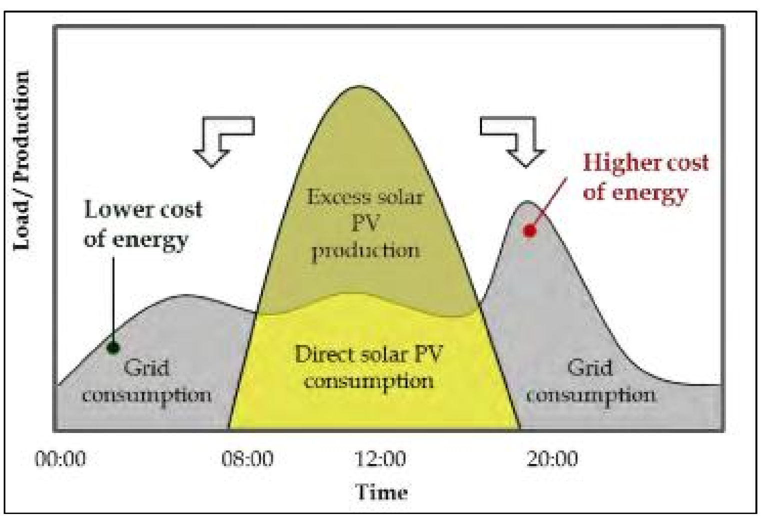

Fig. 2. Net metering principle
Source [52]

3.8 Net Metering

This is an organized arrangement where commercial and individual power producers/ customers generate electricity to feed their loads and are able to sell the excess of their generated power to the grid at a price that is lower than the retail price of electricity which in turn pays up some of the equipment costs [2].

The current status of grid connection as stipulated in the Electricity Act of 1999 under Section 56 outlines that the ERA designates a bulk supplier responsible for transmission, sale and distribution of electricity. However, the 2015 revised Electricity Act draft has no prospects of addressing the role of independent power suppliers in grid power [53]. Utility companies are prone to the fears as the growth of distributed generation could lead to loss of revenues [54].

The final form of the bill and its enactment will require subsidiary regulation and the implementation thereafter will take some time even after the act comes into force [55]. However, efforts are being made by World Bank and the African Development bank to materialize the net metering in the country.

4. OPPORTUNITIES FOR SOLAR PV DEVELOPMENT

The adoption of solar PV globally continued to grow annually from 405 GW in 2017 to 505 GW 2018 [56]. This growth has been stimulated by government subsidies, tax and carbon credits which has resulted to reduced capital costs.

With radiation levels of over 2000kWh/m^2 per year, the country has high prospects of investment in solar projects in response to the relatively high energy yield in favor of increasing the country's energy access to 26% by 2022 [49].

4.1 The Need for Localized Energy Supply

Utility providers have failed to meet and always find it both difficult and expensive to extend grid lines to remote locations. Longer power transmission lines in turn cause power losses in the power distribution currently at 19.1% [55] to which a cost of production has already been affiliated [57]. As such, solar technology serves as a better solution to the above limiting factor with minimal power losses which are more opportune to accelerate rural electrification in conjunction with other renewable energy options [24].

The ability to use energy at the point of generation minimizes the costs that would otherwise have been used in transmissions which has hampered the extension of the grid to remote areas. This endeavor deems unnecessary especially due to the fact that by the time these grid extensions get to these marginalized settlements the unit cost of electricity will be so high for them to afford it yet that of decentralized PV's keeps getting lower [4].

Cognizant of the need for improved power quality and reliability, electricity cost savings, climate benefits and corporate social responsibility, policy makers should encourage the large institutional facilities and industries with supporting regulatory framework and incentives to embrace captive power [55].

4.2 Energy Security and Demand

With less than 5% of the rural population having access to electricity [58] and with a progressive population growth of up to 3.3% per annum [59] it is expected that the industrial and domestic average annual energy demand will supersede the current 7-9% per year [60]. Other uses like powering communal facilities like schools, industrial facilities, street lighting, and communication towers continue to advance to. These commercial and small scale uses postulate the increase of the uptake of the solar technology as over 30,000 solar PV systems have been installed in rural areas already [42]. These PV systems are dominated by Solar Home Systems (SHS) and solar lanterns which are basic for increased rural electrification even with little government intervention hence leading to rural development and social change [61]. Similarly, the urban population has adapted this solution in response to the problem of grid unreliability [9].

This market continues to grow annually majorly in the upper- middle class in partnership with NGOs where different financing models are used. At the end of the day, this has led to an increased productivity whilst providing necessary communal requirements like cold drinks, saloon services, health services, phone charging notwithstanding the need to listen to radio and watch television [44]. A recent study conducted by the Global Off - Grid Lighting Association (GOGLA) revealed improvements in health, time utilization and additional income with percentages of 89%, 86% and 28% respectively through the purchase of SHS [62].

And for the lower class, the solar lantern emerged suitable due to its cost and ease of use as it consists of a small PV module, lantern and battery which is charged during the day under sunlight and used at night for lighting purposes [37]. And being that Solar systems don't require independent wiring systems; they can easily be connected to the already existing connections which in turn alleviates energy security.

4.3 The Presence of Institutional Frameworks

The RE policy of Uganda approved by the GoU in 2007 was birthed in order to reinforce the commitments of the existent Energy policy of 2002 which among others seeks to increase the usage of modern renewable energy from 4 – 61% [63]. Since energy access cannot be accelerated by grid extension alone, the presence of these frameworks is very vital in the promotion of international linkages with inherent support and implementation of energy strategies with clear responsibilities and mandates [50].

The country has a functional Rural Electrification Agency (REA) formed in 2001 as a semi – autonomous agency by the MEMD to fast track rural electrification by providing subsidies to promote rural electrification projects [15] with aims of to achieving 1.28 Million on – grid and 144,000 off - grid connections by 2022 [38].

Supporting set policies provide comprehensive financial and regulatory measures which usually include the FIT systems that set guide lines for future power development plans. With the nascent GETFiT program, the government has been able to increase capacity by 50MW with solar PV technology and with more solar projects still in the pipeline like the 4 MW plant at Busitema University [64]. This regulatory frameworks keep improving by day through the streamline and standardization of critical regulatory aspects for development of REs like financial incentives and the setting of the tariff policies and procedures [58].

With adequate planning and project development, REA shall be able to foresee and implement numerous off – grid PV systems and mini – grids to meet the supply of small distributed power generation facilities compounded SREP financing with the construction solar PV mini – grids as well as the renewable energy component of hybrid systems [63].

4.4 Net Metering

Uganda as of the year ending 2018 had no net metering framework with has withheld a number of private sector investments [55]. However, the inclusion of attractive options such as net metering in the energy policy lures big players into the sector due to the ability to receive credit for the excess of their energy generated on site as prosumers. This is seen as an opportunity to investors to consider investing in big projects if proper Power Purchase Agreements (PPA) are made with attractiveness while ensuring affordable power pricing to the consumers [65].

Once put in place, it will pave way for different private sector players like the residential, industrial, commercial customers to invest in this technology in a free - market based and competitive environment. This will help to meet their energy demands appropriately while improving private investments on solar roof top systems [38,54]. Such developments will also aid in reducing government expenditure for peak load demands as illustrated in Fig. 2. This will be accelerated by the fast tracking of the development of regulations, standards and strategies to set up and assess the proposed ten pilot solar PV net metering systems [49].

4.5 Global and National Demand for Carbon Emission Reduction

The downward pressure for carbon emissions goes without say and its inherent that the use of green technology which today accounts to 25% of the global power production will significantly reduce on the level of Green House Gases (GHG) [66]. This has necessitated the adoption of Renewable Energy Systems (RES) both globally and at country level in order to combat the ultimate effects of global warming as 95% of CO_2 emissions are from fossil fuels [67] which currently are Uganda's highest commodity import expenditure.

With adequate underlying policies, the adoption of the Solar PV technology for power generation will foster sustainable industrialization with improved energy efficiency on a large scale [68]. At homestead level, it is expected that there will be great reduction on the rate of respiratory diseases [69] as most of the population residing in the rural areas use kerosene lamps for indoor lighting [70]. This growth shall leverage from the fact that solar PV does not give off GHG and any other pollutants with the considerable technology improvements [4]. The increasing affordability of SHS to small income earners who are the majority of the population shall continue to avert the health and climatic impacts by adopting greener energy hence ascending in the energy pyramid with less pollution levels.

4.6 Financing Mechanisms

East African countries have spearheaded in the take up of SHS due to the interventions of the private sector as well as supportive incentive mechanisms leading to increased sales through the different financing models such as the Pay As You Go (PAYG) [62]. This is the leading business model in Uganda with over 60% market share through which the population is better placed to acquire larger systems through down payments followed by the periodic payments through monthly installments [41].

With the provision of SHS by different companies through hire purchase and remote control to automatically shut down the system once the payments have not been made, an ever-increasing number of consumers will be reached. Different financing models are being developed depending of the targeted population to ease and counter the problem of high initial costs [44].

The success of these financing mechanisms has largely been dependent on the techno – economic status of consumers. This calls for stakeholders prior knowledge about the consumer's energy requirement, income status and ability to maintain these systems so as to ensure sustainability [24].

The nature of the long-term access to finance by the end users will continue to gain dominance as this engages the local financial institutions like banks and mobile phone service providers to monitor the creditability of the consumers/end users [11]. The increased support from the public sector through public finance and direct financing by various organizations (NGO's) will continue to foster increased energy access.

4.7 Short Take Off Times

For long the Government of Uganda (GoU) invested in three geothermal potential areas of Katwe, Kibiro and Buranga since 1993 mainly because geothermal power can deliver large scale, base load power though it's only the Kibiro site that reached advanced stages [38]. However the drilling operations are still prospects yet to be actualized as the government is still seeking technical and financial assistance for surface investigations for that particular site [71].

Evidentially, relatively shorter time periods have been exhibited for the newly installed Solar PV plants due to short take off times as opposed to other renewables. With the Soroti and Tororo Solar projects being operational after 23 months from its tendering [43] and eight months respectively [72]. It is from this background that solar PV (both off/ on - grid) take leverage over geothermal in the selection of priority technologies to be adapted by the Scaling – up Renewable Energy Program (SREP).

4.8 Creation of Employment Opportunities

In the setup, installation and maintenance of solar mini-grids and institutional standalone solar PV systems, a number of jobs are created for the local population [14]. This also contributes to the general standards of living, increased levels of awareness, technical capacity as well as key benefits that can't be measured directly. The Soroti and Tororo solar plants for example provided over 500 contract jobs and about 10 permanent jobs [73]. In addition, a number of sole traders, sales agents and full-time jobs are established within the value chain of the solar industry. This in turn decreases the unemployment gap, provides modern energy and elevates the socio- economic status hence advancing the Sustainable Development Goals (SDGs) including SDG 7 [12].

Additionally, gender equality will be addressed by involvement of women in the distribution of modern energy services by developing their financial skills in establishing and sustenance of their businesses with access to capital from gender specific programmes hence ensuring their participation in decision making towards energy issues as they tend to be hindered by social structures, wrong perception towards work and traditional systems [74,75].

Being that Solar PV offers a longer supply chain from the distribution, installation, sales, operation and maintenance, numerous jobs are being created in the downstream segment which are largely dependent of the social, market -based and the policy based factors [19,76]. This enables greater income prospects by providing better life quality through which SHS have enhanced the income generating capacity of households to $46 per month [62].

5. CONCLUSION AND RECOMMENDATION

Notwithstanding the existent challenges, steady growth is still anticipated mostly in regard to the pico, SHS along with mini-grids provided the financial, environmental, socio-economic as well as the institutional factors are substantially dealt with as examined in this review. The review therefore recommends that the explained concerted efforts are taken into consideration in order to increase the electrification levels though the adoption of solar technology;

- Considerable funds have to be obtained in order to facilitate the increased uptake of the off grid solar to further sector expansion. In regard to investment, the inclusion of more public, non -commercial, equity as well as crowd funding will ensure that more financial opportunities are harnessed so as to bring the off – grid products at hand for the customers.
- Concrete planning by the government that clearly informs of particular areas of electrification and fairly reasonable targets for rural electrification shall spur holistic off – grid solar development.
- With regard to incentives however, solar products import duty exemptions should be revamped to lessen the system costs so as to improve their affordability by coming up with categorized taxation policies and subsidy options so as to support clean energy.
- Moving forward, partnerships between the GoU and the private sector shall continue to thrust sectorial development in terms of technical assistance, credit and in policy development. This co-operation should also be fostered within the intergovernmental agencies in materializing the off- grid strategies for accelerated development.
- The GoU should strengthen the Research and Development (R&D) by taking a holistic view of the sector from supporting vocational and tertiary education as well provision of funds for students and researchers to carry out related studies. This will positively encourage innovations and technological developments that will suit the social needs of the population as well as national development.
- Putting in place carbon emission strategies and inherent policy for power generation will positively align the project development to the global agenda of mitigating the escalating GHGs.
- And with the Government playing center role in the awareness creation, positive attitudes along with strong confidence will be nurtured in the consumers through their knowledge of the benefits available alongside the opportunities not to be missed through the assumption of the technology. This on the other hand will favor women inclusion in energy supply and utilization.
- A sturdy quality framework inclusive of different component standards should be put in place in line with the IEC to appropriate standards so as not to close out the small-scale consumers fiscally.
- For grid automation however, the 2015 Electricity draft revision should be revised to accommodate net metering so as to guarantee grid access. It is imperative for the GoU to identify the policy gaps and the disaccord between different energy sector players to streamline the policy implementation strategies.

It is notable that the electrification levels are still low regardless of the provisions of concerted efforts by the Government, public and private sectors. However, in light of the existent supporting policies, strategies and regulatory framework further revisions shall continue to respond to the inherent policy and plans shortfalls and embedded integration of these in line with the global agendas will prove worthwhile. In view of providing the required demand in a more affordable and environmentally sustainable way, barriers to access of finance through reduction of the associated risk shall continue to foster solar PV development.

Since the demand is the backbone of this development, affordability, reliability, accessibility and more after sale services for the fixed and mobile systems shall foster solar market development more in rural areas forthwith.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. IEA. World Energy Outlook (International Energy Agency; 2018.

2. REN21 Renewables 2018 Global Status Report (REN21 Secretariat, Paris, France; 2018.
[ISBN 978-3-9818911-3-3]
3. IRENA. Renewable Power Generation Costs in 2017 (International Renewable Energy Agency); 2018.
4. IEA. Technology Roadmap: Solar photovoltaic energy. (International Energy Agency); 2014.
5. IRENA. Renewable Power Generation Costs in 2017 (International Renewable Energy Agency, Abu Dhabi.); 2018.
6. Ripple WJ, Wolf C, Newsome TM, Barnard P and Moomaw WR. World Scientists Warning of a Climate Emergency Bioscience. 2019;XX:1–5.
7. SEG Confronting Climate Change: Avoiding the Unmanageable and Managing the Unavoidable. (Scientific Expert Group on Climate Change); 2007.
8. UN-HABITAT. Annual Report 2012 (United Nations Human Settlement Programme,Nairobi, Kenya.); 2013.
9. Fashina A, Mundu M, Akiyode O. The Drivers and Barriers of Renewable Energy Applications and Development in Uganda : A Review Clean Technol. 2018;1:9–39.
10. NPA. Uganda Vision 2040 (National Planning Authority); 2007.
11. IRENA. Off-grid renewable energy solutions to expand electricity access : An opportunity not to be missed. (International Renewable Energy Agency, Abu Dhabi.); 2019.
12. IRENA. Off-grid renewable energy solutions: Global and regional status and trends. IRENA, Abu Dhabi; 2018.
[ISBN 978-92-9260-076-1]
13. Era Electricity Supply Industry Performance - 2018 (Electricity Regulatory Authority); 2019.
14. Couture TD, Cory K, Williams E. A Policymaker ' s Guide to Feed-in Tariff Policy Design (National Renewable Energy Laboratory (NREL)); 2010.
15. ERA. Developments and Investment Opportunities in Renewable Energy Resources (Electricity Regulatory Authority); 2013.
16. MEMD. The Renewable Energy policy for Uganda (Ministry of Energy and Mineral Development; 2007.
17. PVGIS. Uganda Global irradiation and solar electricity potential Optimally-inclined photovoltaic modules; 2017.
18. MEMD. The Energy Policy for Uganda (Ministry of Energy and Mineral Development); 2002.
19. IRENA. Off-Grid Renewable Energy Solutions: Global and regional status and trends. (International Renewable Energy Agency); 2018.
20. MEMD. Uganda Rural -Urban Electrification Survey (Ministry of Energy and Mineral Development); 2014.
21. Bjergegaard R. Rural Electrification of Uganda – a Technological and Least Cost Feasibility Approach (Master Thesis, Sustainable Energy Planning and Management, Aalborg University); 2015.
22. UOMA. Mapping the Ugandan off-grid energy market (Uganda Off-grid Energy Market Accelerator); 2018.
23. REN21 Renewables 2015: Global Status Report. ((Paris: REN21 Secretariat); 2015. [ISBN 978-3-9815934-6-4]
24. Hirmer S, Cruickshank H, The user-value of rural electrification: An analysis and adoption of existing models and theories Renew. Sustain. Energy Rev. 2014;34: 145–54.
25. UNHS. Uganda National Household Survey; 2017.
26. Mbabazi R, Sebitosi B, Santa - Otim J, Okou R. Uganda's energy sector: Challenges and opportunities Electr. Control. 2015;1–5.
27. IRENA. Policies and regulations for renowable energy mini-grids (International Renewable Energy Agency); 2018.
28. Bjergegaard R. Rural Electrification of Uganda: A Technological and Least-cost Feasibility Study. (MSc. Thesis. Aalborg University.); 2015.
29. GPM. *MTN Uganda – Feasibility Study* (Greeen Power Mobile); 2010.
30. IRENA. Policies and Regulations for Renewable Energy Mini-grids (International Renewable Energy Agency, Abu Dhabi; 2018.
[ISBN 978-92-9260-083-9]
31. ERA. Uganda's Grid-Connected Solar Portfolio Increases; 2019.
32. UNEP. Green Economy (United Nations Environment Program); 2010.

33. SE4ALL. Progress toward sustainable energy framework 2015 (sustainable energy for All); 2015.
34. MOE(Kenya). National Energy Policy (Ministry of Energy; 2012.
35. Kazoora G, Olweny M, Aste N, Adhikari RS. Energy consumption trends of residential buildings in Uganda: Case study and evaluation of energy savings potential 5th Int. Conf. Clean Electr. Power Renew. Energy Resour. Impact, ICCEP. 2015;695–700.
36. IEA. World Energy Outlook 2018 (International Energy Agency); 2018.
37. Heemskerk L, Eenhoorn G, Namiti B. Market Assessment of Modern Off-Grid Lighting Systems in Uganda (Enclude BV, The Netherlands); 2014.
38. MEMD. Scaling Up Renewable Energy Program Investment Plan (Ministry of Energy and Mineral Development); 2015.
39. IREK. A desk assessment on the overviews of current solar and wind energy projects in Kenya (Innovation And Renewable Electrification In Kenya); 2018.
40. Karekezi S, Kithyoma W. Renewable energy Africa: Prospects and Limits (African Energy Policy Research Network (AFREPREN); 2003.
41. KCIC. Kenya solar PV market assessment (Kenya Climate Innovation Center); 2016.
42. Mokveld K, Eije S von. Final Energy Report Uganda (Netherlands Enterprise Agency; 2018.
43. Meyer R, Eberhard A Gratwick K. Energy for Sustainable Development Uganda's power sector reform: There and back again? Energy Sustain. Dev. 2018;43:75–89.
44. WWF (UNF). Towards Universal Energy Access : Uganda (World Wide Fund, United Nations Foundation.); 2014.
45. ERA. Uganda renewable energy feed-in tariff (refit) guidelines phase 4 (Electricity Regulatory Authority); 2019.
46. UNF. Energy Access Practitioner Network (United Nations Foundation; 2012.
47. Oting W, Avellino K, Mwarania F, Wahab A A, Aime KT. Uganda Solar Energy Utilization : Current Status and Future Trends Int. J. Sci. Res. Publ. 2018;8:317–27.
48. Osok FO. Barriers to the development and deployment of Renewable Energy Technologies in Kenya. (Master Thesis, University of Oslo); 2010.
49. SREP. SREP Investment Plan For Uganda (Uganda's Scaling-Up Renewable Energy Program); 2015.
50. Stephane, de la Rue du Can Pudleiner D, Jones D, Khan A, Energy Efficiency Roadmap for Uganda (Power Africa - Lawrence Berkeley National Laboratory); 2017.
51. CREEC. Solar PV – Centre for Research in Energy and Energy Conservation; 2017.
52. GoK EU. Assessment of a net metering programme in Kenya. (Government of Kenya, European Union); 2014.
53. ERA. The Electricity Act. (Electricity Regulatory Authority); 2015.
54. UNEP. Guide for Energy Efficiency and Renewable Energy Laws (United Nations Environment Programme); 2016.
55. Woods M, Cowman T, Kerigu K. *Uganda: Captive Power* (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH); 2019.
56. REN21. Renewables: Global Status Report. ((Paris: REN21 Secretariat); 2019. [ISBN 978-3-9818911-7-1]
57. Mpagi EM. Assessing the use of power generation technologies in Uganda : A case study of Jinja Municipality (KTH School of Industrial Engineering and Management); 2012.
58. MEMD. Rural Electrification Strategy and PLan 2013 - 2022 (Ministry of Energy and Mineral Development); 2013.
59. UBOS. Statistical Abstract. (Uganda Bureau of Statistics); 2017.
60. Whitley S, Tumushabe G. Mapping current incentives and investment in Uganda's energy sector: Lessons for private climate finance. (Overseas Development Institute, London.); 2014.
61. Jacobson AE. Connective Power: Solar Electrification and Social Change in Kenya (University of California, Berkerley. PhD Dissertation); 2004.
62. GOGLA. Powering Opportunity in East Africa: Proving Off-Grid Solar is a Power Tool for Change (Global Off - Grid Lighting Association); 2019.
63. UN. Intersessional Panel of the United Nations Commission on Science and Technology for Development (CSTD) The United Nations Conference on Trade and Development (United Nations. Geneva, Switzerland 6-8 November 2017);2016.

64. Wafula P. Busitema University to add 4MW of solar power - Daily Monitor Dly. Monit; 2019.
65. IEA, IRENA, UNSD, WB W. Tracking SDG 7: The Energy Progress Report. (Washington DC); 2019.
66. IEA. Global Energy and CO2 Status Report 2018. (International Energy Agency.); 2019.
67. PEEREA. Integration of Energy Efficiency and Renewable Energy Policies (Protocol on Energy Efficiency and Related Environmental Aspects); 2005.
68. UN. The Sustainable Development Goals Report 2018. (United Nations, New York.); 2018.
69. WHO. WHO guidelines for indoor air quality: household fuel combustion (World Health Organization. Geneva, Switzerland); 2014.
70. Walters T, Esterly S, Cox S, Reber T, Rai N. Policies To Spur Energy Access: Volume 1, Engaging The Private Sector In Expanding Access To Electricity (International Institute for Environment and Development); 2015.
71. Zemedkun MT. Overview of Geothermal Resource Exploration and Development In The East African Rift System Exploration for Geothermal Resources (Lake Bogoria and Lake Naivasha, Kenya: UNU-GTP, GDC and KenGen). 2012;1–10.
72. GETFiT (UGANDA). 2017 - Annual Report (GoU and KfW, Multiconsult); 2018.
73. GETFiT (UGANDA) 2019. Annual Report (GoU and KfW, Multiconsult); 2018.
74. World Bank. Tracking SDG7 - Global Tracking Framework; 2018.
75. UNDP. Integrating Energy Access and Employment Creation to Accelerate Progress on the MDGs in Sub-Saharan Africa (United Nations Development Programme); 2012.
76. UNDESA. Electricity and education: The benefits, barrier, and recommendations for achieving the electrification of primary and secondary schools. (United Nations Department of Economic and Social Affairs.); 2014.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/53111