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Review Article

Current Overview of Renewable Energy Resources in Rwanda

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Abstract: This paper reviews the energy sector in Rwanda with an accent on Renewable Energy. In Rwanda, energy sector plays a vital role in supporting socio-economic evolution and has a close connection to the growth of other economic sectors. The country has both renewable and non-renewable energy sources. Energy policies of the country give special attention to the use of modern, clean and energy efficient technologies. Most of Electricity in Rwanda comes from renewable sources: The total currently installed electricity capacity is 160 MW (March 2015), of which approximately more than 60% comes from hydrological resources along with other indigenous sources and less than 40% comes from diesel-powered generators. The current on-grid access to electricity is estimated at 23% of households and off-grid is 1.5%. Rwanda has envisaged increasing electric power supply by maximizing use of various indigenous energy resources and reach its ambitious target of 563 MW (domestic generation + imports) with electricity access of 70%(on-grid and off-grid) by the end of 2018. However, several challenges laying behind the development in the electric energy sector and utilization of renewable energy resources should be addressed. Challenges to be tackled and measures to be taken to achieve this goal have been presented in this study.

Keywords: Renewable Energy, Electricity Generation, Electricity Access, Challenges

1. Introduction

There is an urgent need to change from existing fossil fuel based energy systems to one based on renewable resources to decrease reliance on depleting reserves of fossil fuels [1]. There are many reasons to decrease reliance on depleting reserves of fossil fuels. Among the main reasons, one is the increasing carbon dioxide (CO_2) emissions which pollute the atmosphere and the other is the increasing consumption of non-renewable energy sources (coal, oil and natural gas) [2, 3]. The limited reserves of non-renewable sources and their effects on the climate change are the main factors which influence higher interests for renewable energy [4]. In addition, renewable energy technologies have established themselves commercially and are cost effective for on-grid applications [5, 6]. For that reason, most of policy makers who are concerned with the development of the national grid system focus on those sustainable resources that produce power, heat or mechanical energy by converting them either to electricity or to motive power [7].

Electrical energy generated from those resources, is the backbone of socio-economic development of any country [8]. It is associated with provision of many services to people which directly enhances their quality of life both in rural and urban areas [9]. However, according to the World Bank Group for Energy Sector, the access to electricity remains a serious problem in many countries of Africa [10]; where an approximation of 620 million people do not have access to electricity and almost 730 million people use hazardous and inefficient forms of cooking. Meanwhile, those who do have access to modern energy face very high prices for a supply that is both insufficient and unreliable. Overall, the energy sector of sub-Saharan Africa is not yet able to meet the needs and aspirations of its citizens [11].

In spite of small access to electricity, Africa is a very beautiful place plenty of good potentiality of renewable energy resources such as solar energy, geothermal energy, hydro and wind energy [12]. As pointed out by World Bank Group in 2014 in series notes for the energy and extractives global practice, Rwanda has an appreciated experience with electrification [13]. That experience is an interesting case of how access to electricity can be quickly scaled up despite deficits in infrastructure and institutional capacity. The magnitude and pace of the successes achieved under the country's Electricity Access Rollout Program (EARP) surpassed even the ambitious targets set by the government. Begun by the national government in 2009, Electricity Access Rollout Program (EARP) was designed to increase access to electricity from 6 to 16 percent of the population over a five-year period. In 2012, the Rwandan electricity utility, the Energy, Water, and Sanitation Authority (EWSA) met the 16 percent target, while the new target under the Economic Development and Poverty Reduction Strategy for 2013–18 (EDPRS 2) is 70 percent of households to access electricity by 2018 [14].

This paper is structured as follows: After this introductory section, energy profile of Rwanda is presented in Section 2. Non-Renewable energy sources in Rwanda are summarized in Section 3, and Renewable energy sources in Rwanda are then summarized in Section 4. Section 5 of the paper presents the challenges and measures within the electricity sector in Rwanda. Finally, there come the major conclusions in the conclusion section.

2. Energy Profile of Rwanda

A variety of technologies and natural resources, such as petroleum-based fuels [15], hydro, solar, methane gas, peat, geothermal, biomass, waste, and wind [16]; contribute to the generation of electricity. Likewise, in Rwanda the energy sector scope goes beyond electricity and includes bio-products, such as wood fuel, charcoal, and biogas, as well as petroleum products, such as diesel, kerosene, Liquid Petroleum Gas and natural gas such as methane gas. As shown in Figure 1, of total primary energy consumption in Rwanda, Biomass contributes 85% of primary energy consumed of which wood contributes a percentage of 57%, Charcoal 23%, Crop residues and peat of 5% [17]. Non-Biomass sources contribution is 14% of which Petroleum products equal to 11% and electricity contribution is approximately 4%.

The count of electricity is still small but in the country there are many Private Companies participating in the projects of raising the electricity generation capacity. The most important projects are KivuWatt developing 100 MW from methane gas by ContourGlobal (US), Turkish company "Hakan" developing 120 MW from peat, Symbion Power from USA to develop 50 MW from methane gas, Goldsol II developing 10 MW from Solar (Portugal, South Africa and Rwanda), Ngali Energy developing Micro hydropower project for 45 MW (Rwanda), Gigawatt Global operating 8.5 MW from solar (Israel).

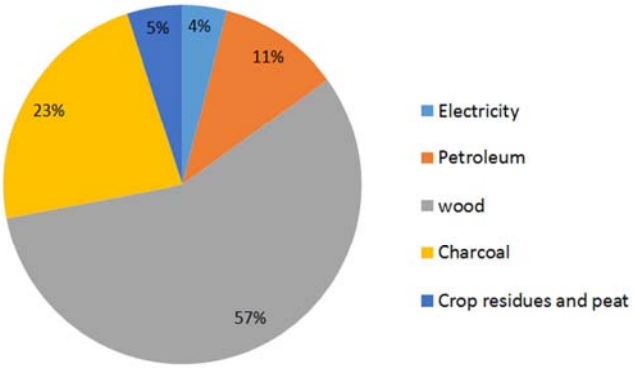

Figure 1. *Main Energy Sources in Rwanda.*

2.1. Current and Targeted Energy Consumption Charts

In fact, as mentioned earlier, the primary source of energy in Rwanda as in many other countries of Africa is biomass [18]. In Rwanda, the available amount of biomass energy resource in form of woods is 4.2 million tonnes = 650 MW and is principally used in cooking.

Considering energy use in Rwanda, the main consumers are households (91%), followed by the transport sector (4%), industry (3%), and public services (2%). As shown in Figure 2, wood use is greater than wood production, so is unsustainable (only 3.3 million tonnes supply) [19].

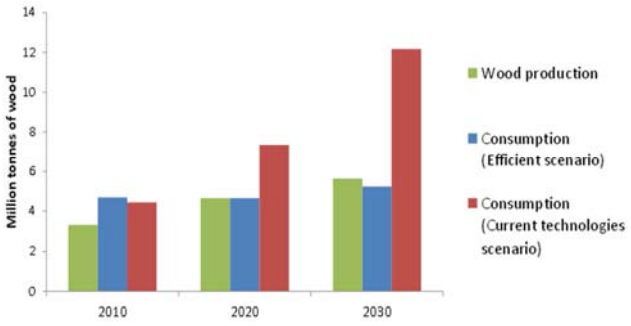

Figure 2. *Wood production and Consumption Chart [19].*

2.2. Electricity Generation, Access and Consumption Charts

The electricity generation and access in Rwanda is still low and are currently estimated at 160 MW and 24.5% respectively. The policy of the government targets the electricity generation capacity of 563 MW by 2017/2018 [20]. Table 1, which can be also accessed at http://www.africa-eu-renewables.org/market-information/rwanda/ governmental-framework/, summarizes current and targeted electricity generation and access where the policy target is to increase the access to 70% by 2017/2018. Public institutions (schools, health facilities, administrative offices) will be connected 100% by 2017/18.

In Rwanda, households are the main consumers of electricity with 51 percent where the larger portion of electricity is primarily used for lighting. The industrial sector with 42 percent is the second largest consumer of energy, which mainly come from motor-drivers and lighting. The major industrial consumers include companies in the cement,

mining, textile, and agricultural sector (including tea estates). Public sector consumption of electricity (6%) is mainly for powering public buildings, street lighting and water pumping [21].

Table 1. *Current and targeted electricity generation and access in Rwanda.*

Outcome	Indicators	Baseline	Current	Target			
		2013/2014	March 2015	2014/2015	2015/2016	2016/2017	2017/2018
Increase of installed electricity capacity to 563 MW.	MW of Electricity installed capacity	119	160	185	245	427	563
Increased household access to electricity to 70%	% of household on-grid connections	20%	22%	23% 50,000	29,9% 207,971	42.8% 339,099	48% 1,171,200
(48%on-grid and 22% off-grid)	% of household off-grid connections	N/A	N/A	1.5% 24,400	8.6% 185,440	17.3% 212,280	22% 536,800

Since 2008, power supply has increased by 10% to a total of 502,053 MWh as it is shown in figure 3 [21]. In July 2014, the utility had about 450,775 household customers and 170 customers in the industrial category. Total consumption has been growing on an annual basis, following a logarithmic trajectory. Rwanda has a very pronounced peak demand load, which was registered at 87.9 MW on average annually in 2013.

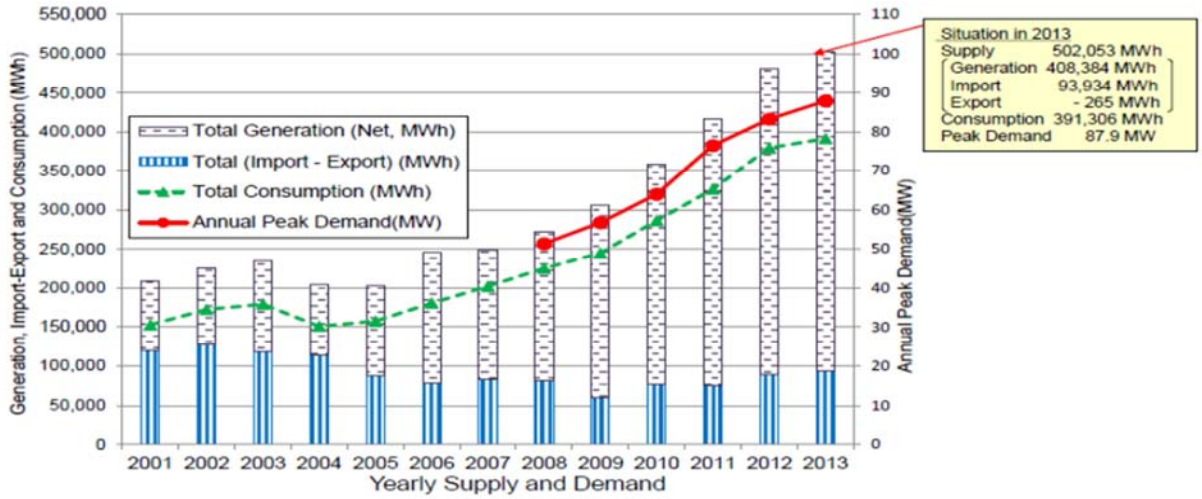

Figure 3. *Energy Demand and Supply Situation (2001-2013) [21].*

3. Non-renewable Energy Sources in Rwanda

Non-renewable energy resources are resources for which there is a limited supply. They do not renew themselves at a sufficient rate for sustainable economic extraction in meaningful human time-frames. These supplies come from the Earth itself and, as it typically takes millions of years to develop, they are finite.

Non- renewable energy in Rwanda includes: Peat (under development), Thermal fuel energy and Methane gas. Table 2, summarizes the plants names and the related total installed capacity from these resources.

Table 2. *Installed capacity from non-renewable resources in Rwanda.*

1. Thermal/diesel power plants			2. Thermal /methane gas power plants	
No	Plant name	Installed capacity (MW)	Plant name	Installed capacity (MW)
1	Jacana 1	7.8	KP1	5
2	KESZ TPP	11	Kibuye Gas methane	25
3	Jacana 2	20.5		
	Total 1	38.8	Total 2	30

4. Renewable Energy Sources in Rwanda

4.1. Solar Energy

Rwanda is well benefited with solar energy, even during the months of the rainy seasons there is daily and sufficient sunshine as indicated on Figure 4, the average daily global solar irradiation on the tilted surface has been estimated to be 5.2 kWh per m^2 per day from Photovoltaic Geography Information System (PVGIS) [12]. The long term monthly average daily global irradiation range from 4.8 kWh/ (m^2 day)

(location Burera, month of May) of to 5.8 kWh/ (m^2 day) (location Nyanza, month of July). This indicates a good potential for solar energy development and it resulted in the 8.5 MW plant at Agahozo-Shalom Youth Village, in the Rwamagana District, Eastern Province of Rwanda which is the first utility scale solar farm in Sub-Saharan Africa outside of South Africa. The plant is 20 hectares (49 acres) of land and uses 28,360 photovoltaic panels and produces 6% of total electrical supply of the country. The project was built with U.S., Israeli, Dutch, Norwegian, Finnish and UK funding and expertise [22]. Total number of solar power plants and total capacity are shown in Table 3.

Table 3. *Total number of solar power plants and total capacity.*

No	Plant name	Installed capacity (MW)
1	Jali	0.25
2	Ndera	0.16
3	Gigawatt /Rwamagana	8.5
	Total 4	8.91

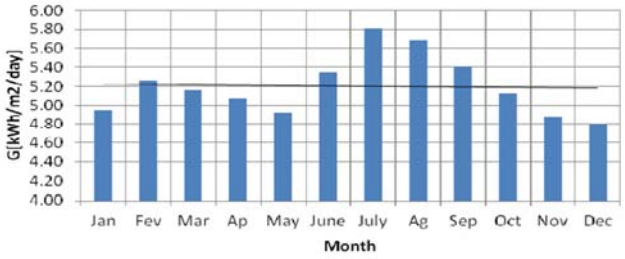

Figure 4. *Monthly average daily global solar irradiance in Rwanda [12].*

4.2. Geothermal Energy

In Rwanda, potential exists for between 170–320 MW of geothermal power generation, due to the country's proximity to the geothermal resource of the Great Rift Valley [23]. Studies have indicated thermal waters with temperatures of up to 150°C. According to surface studies, the most promising geothermal areas in Rwanda are Karisimbi and Kinigi where Government of Rwanda considers a commercially viable geothermal resource for power generation using either binary or condensing steam turbines [24]. According to Rwandan Ministry of Infrastructure, the development of Geothermal Resources has been given the highest priority over Economic Development and Poverty Reduction Strategy phase (EDPRS) second period and among envisaged developments there are: 10 MW from Test Generation site at Kinigi and 10 MW from Test Generation site at Karisimbi with 50 MW of production scale generation at Kinigi/Karisimbi.

4.3. Wind Energy

Being located close to the equator, Rwanda's inherent resource potential for wind energy is low. A rapid wind energy resource assessment was carried out in Rwanda in five locations over the course of 2011. Preliminary indications from the analysis of recorded field measurements of wind speeds and climate data were that most of Rwanda is not highly suitable for wind energy. The Eastern province was identified as the location with the most promising potential, and a simple analysis comparing wind and solar energy feasibility suggested that wind energy could be competitive in this region. Wind energy is currently exploited only in decentralized off-grid applications like windmills or water pumping for agricultural and intuitional needs [25, 26].

4.4. Hydropower

The country has substantial hydroelectric resources which make up the larger part of electricity generation in Rwanda. Apart from the currently implemented big two projects of Nyabarongo 28 MW with funding estimated at USD 80 Million and of Rukarara 1 hydropower project with a capacity of 9.0 MW, the ongoing hydropower project is the regional Rusumo hydropower project with a capacity of 60 MW. The studies are carried out by a Canadian company known as SNC Lavalin under World Bank financing estimated at US$113.30 million to each of the governments of Burundi, Rwanda and Tanzania [27]. The power will be shared equally between the three countries (20 MW Burundi, 20 MW Rwanda and 20 MW Tanzania). The study for high voltage transmission lines will be carried out under the African Development Bank financing estimated at US$ 39 million. It will comprise a backbone transmission interconnection system comprising transmission lines from the hydro power plant to the nearest substation in each of the three countries, and a regional load dispatching centre. Nowadays, Rwanda has approximately 17 on-grid hydropower plants with total installed capacity of 79 MW as shown in Table 4.

Table 4. *Hydropower plants and total on-grid installed capacity.*

No	Plant name	Installed capacity (MW)
1	Ntaruka	11.5
2	Mukungwa 1	12
3	Nyabarongo	28
4	Gisenyi	1.00
5	Gihira	1.8
6	Murunda	0.1
7	Rukarara 1	9.0
8	Rugezi	2.4
9	Keya	2.4
10	Nkora	0.6
11	Cyimbili	0.3
12	Mazimeru	0.5
13	Nshili 1	0.4
14	Musarara	0.4
15	Mukungwa 2	2.5
16	Rukarara 2	2.4
17	Giciye	4
	Total	79.50

5. Challenges and Measures within the Electricity Sector in Rwanda

In Rwanda, the main policy objectives for the electricity sector are to ensure sufficient, reliable, sustainable and more affordable power supply. However, there are a number of challenges that might be overcome first through different measures. The challenges and corresponding measures are the following:

- *High cost of electricity:* Rwanda has a relatively high cost of electricity compared to other countries in the region, and at the same time, extremely low average volumes of consumption. This problem can be solved by realizing a better coordination and an integrated planning over investments and an implementation of 70% energy access and electrification, along with giving more priority to big consumers of electricity.
- *Generation capacity and demand are not aligned:* This challenge is causing lack of maintained efficient tariff. If demand fails to keep pace with increased generation capacity, then the tariff will increase. To address this issue, the cost of generation and losses should be regulated and by diversifying resources and increasing the share of clean power generation in the total generation mix.
- *Insufficient reserve margin:* Current reserve margins are not adequate to maintain quality of supply standards. The strategies to tackle this issue would be to start by estimating the actual peak demand of power consumption and setting out a reserve margin of 15%according to international best practice. For example if the total Demand is 473 MW, then Supply should be 563 MW.
- *High system losses:* A loss in energy between generation and consumption is an inherent feature of electricity networks. Current network distribution losses stand at 23%, which is above average for the region and is a serious issue that requires more attention. Whilst these losses cannot be eradicated completely, they can be materially reduced cost-effectively through better network planning and maintenance.

6. Conclusions

The government of Rwanda plans to provide 70 percent of the population with access to electricity both on-grid and off-grid by the end of second phase of Economic Development and Poverty Reduction Strategy phase (EDPRS 2). The main strategic target is to extend the grid network to allow high users of electricity like industries across the country to connect to the grid. For small users of electricity like households consuming a few kilowatt-hours (kWhs), grid connections are unlikely to make economic sense in the short term and for that reason, off-grid solutions has to be preferred and are being implemented by private investors from all over the world. To keep pace with increased demand for electricity, the government of Rwanda has to ensure increased electricity generation capacity to a level of up to 563 MW by the end of 2017/2018. Using clean and renewable primary sources for power generation and reducing diesel-based generation over time along with grid loss minimization would enable the government to lower the long-term cost of service, to align Generation capacity and demand and to gradually allow maintained efficient tariff.

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Biography

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