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## Article

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## Research Paper

## Rwanda peat deposits: An alternative to energy sources

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## ABSTRACT

In this era, energy and environmental sustainability is a priority in most African countries developmental agenda. The need for energy equity and security in Rwanda is a priority and thus this paper illustrate the current peat resources and their energy potential which can be mined to meet country vast energy requirements. Six hundred (600) peat samples were collected from eighteen peat bogs and all samples were subjected to proximate analyses respecting the procedures outlined by the Bureau of Indian Standard and American Society for Testing and Materials. The high moisture content (average 70.88%) is typical of peats (70%–90%). The total sulfur percentage values (average 0.49%) are generally medium for all samples. The gross calorific values of peat samples ranged from 2560 to 5350 Kcal/kg, with an average value of 3976 Kcal/kg. These values are moderately very high because typical dry peat has calorific values of 2000 Kcal/kg. Mashya displays the lowest value (19%) while the highest ash content (80%) is found in Kageyo. The average ash content in all studied location is 38%. The moisture content in all locations is slightly high ranging from 53% to 85%. Most of the peat deposits in Rwanda may be converted into energy based on the calorific value of all samples. Akanyaru, Mukindo, Gishoma, Mashya, Kaguhu, Mukindo and Nyirabirande are the most promising sites for peat mining.

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## 1. Introduction

Peat is low rank coal, which is made of plant remains as evidenced by the presence of biomarkers detected through chemical, geological, and petrographic studies (Del Rio et al., 1992). It is sedimentary deposit formed principally from plants and rarely from inorganic substances. It is, thus, an aggregate of macerals or pre-macerals and minerals that when subjected to certain processes, can be converted to coal. According to Cohen et al. (1987) it is difficult to place a precise boundary between what might be a precursor of carbonaceous shale and what might be a precursor of a coal. However, it is agreed that the precursor of a good coal should consist of at least 70% dry weight of organic material (Del Rio et al., 1992). The peat has attracted coal geologists due to their distribution, low ash content, low sulfur content and significant thickness (Staub et al., 1991; Dehmer, 1992). It is used as source of energy mostly in Europe (e.g., Finland, Sweden, etc.) and Russia (Schora and Punwani, 1980).

The use of gas and oil during 20th has shadowed the use of peat (Andriese, 1988) but the high demand for electricity

has stimulated the construction of peat-fired power plant. In developing worlds where energy is scarce, they scale it up to meet their objectives to achieve the development. In Sub-Saharan Africa, energy accessibility and affordability (Equity) is a priority in their agenda while European countries need energy security (IEA, 2014; Ituze et al., 2017). Rwanda is most densely populated in Africa with about 10.5 million inhabitants and it is projected that in 2032, the Rwandan population will be 15.4 million (MINECOFIN, 2014). Inefficient and expensive electrical energy supply hinders the development of the country and therefore the government has a target to decrease wood's consumption from 86.3% to 50% of national energy consumption in 2020 (Rwanda, 2012). As the demand for energy is growing, the researchers attempted to evaluate the contribution of peat deposits for energy production to meet country vast energy requirements.

## 2. Peat reserves in Rwanda

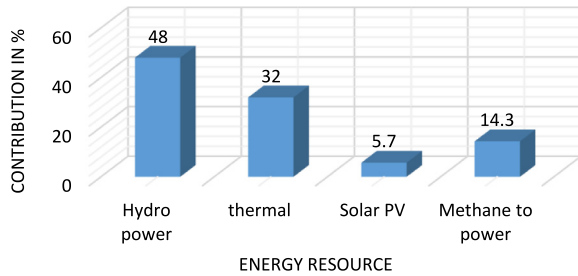
The quantitative assessment of peat deposits in Rwanda is approximately 155 million tons of peat on dry basis across the country (Vitikka and Lahtinen, 2013; Ekono, 1992) and these deposits could be converted into energy (Hakizimana et al., 2016). The major peat deposits are presented on Table 1.

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**Table 1**  
Peat reserves in Rwanda (EDCL, 2014).

Name of peat bog	Area (ha)	Quantity of exploitable peat reserves, dry basis (tonnes)	
		Sod peat	Milled peat
Rucyahabi	925	813 973	687 998
Akanyaru North–North part	1321	501 291	68 753
Akanyaru North–Middle part	1994	3 572 375	2 026 147
Akanyaru North–South part	3208	15 740 346	11 517 536
Akanyaru South	2108	7 797 785	6 763 219
Mukindo	959	1 323 573	698 581
Kaguhu	195	69 712	64 942
Gishoma	423	171 880	88 305
Gihitasi	90	12 168	12 168
Mashya	36	89 821	78 191



**Fig. 1.** Main energy resources in Rwanda (RDB, 2019). It is clear that the hydropower energy is the leading energy resources in Rwanda.

### 3. Energy scenario in Rwanda

The main energy resources are Wood, Hydropower, Solar energy, Biogas, wind, biomass, Solar photovoltaic (PV), methane gas, peat, geothermal and petroleum products (Safari, 2010; Ituze et al., 2017). According to RDB (2019) the main energy resources are hydropower; thermal, solar PV, and methane to power (Fig. 1). Rwanda energy sector improvement in the past few years is a result to economic reform, development and clear vision.

Wood consumption has been the main source of energy to Rwandan households for the past decades. For example, wood provided 99% of energy in 2000 and 86.5% in 2010, (Rwanda, 2012). Nyamvuba and Gakuba (2014) indicate that supply and consumer needs analysis revealed that 85% of primary energy used in the country were coming from biomass, either in the form of wood directly used as fuel (57%) or charcoal (23%). Bimenyimana et al. (2018) states that, at present day, wood is still the main source of energy, mainly due to its low cost in comparison to other sources. Consequently, however, this large-scale wood consumption has been associated with deforestation, soil degradation (Rwanda, 2012), and have been found to contribute to global warming.

In addressing the issue associated with energy production, the Government of Rwanda, in its Vision 2020 policy, planned to have diversified energy resources, provided electricity to 75% of the population and wood consumption to have dropped at 50% of energy consumption, by the year 2020. At present day however, the Rwanda Energy Group (REG) re-drafted targets for electricity generation. REG new planning policy targets on generating 586 MW, from the current 220.9 MW, and providing a 100% electricity access to Rwandans, from the current 45.3%, by the year 2024, (REG, 2019a). This include 52% on-grid and 48% off-grid connections, (USAID, 2018). In addition to wood, Rwanda has various potential resources of energy including biogas, hydro, solar, petroleum, methane gas, wind and geothermal, (Nyamvuba and Gakuba, 2014).

**Table 2**

The Von post classification system and Von post degree of humification (H1 to H10) for peat.

Source: Adapted from Andriess (1988).

Symbol	Description
H1	Completely undecomposed peat which, when squeezed, releases almost clear water. Plant remains easily identifiable. No amorphous material observed present
H2	Almost entirely undecomposed peat which, when squeezed, releases clear or yellowish water. Plant remains still easily identifiable. No amorphous material present
H3	Very slightly decomposed peat which, when squeezed, releases muddy brown water, but from which no peat passes between the fingers. Plant remains still identifiable, and no amorphous material present
H4	Slightly decomposed peat which, when squeezed, releases very muddy dark water. No peat is passed between the fingers but the plant remains are slightly pasty and have lost some of their identifiable features
H5	Moderately decomposed peat which, when squeezed, releases very “muddy” water with a very small amount of amorphous granular peat escaping between the fingers. The structure of the plant remains is quite indistinct although it is still possible to recognize certain features. The residue is very pasty
H6	Moderately highly decomposed peat with a very indistinct plant structure. When squeezed, about one-third of the peat escapes between the fingers. The residue is very pasty but shows the plant structure more distinctly than before squeezing
H7	Highly decomposed peat. Contains a lot of amorphous material with very faintly recognizable plant structure. When squeezed, about one-half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty
H8	Very highly decomposed peat with a large quantity of amorphous material and very indistinct plant structure. When squeezed, about two-thirds of the peat escapes between the fingers. A small quantity of pasty water may be released. The plant material remaining in the hand consists of residues such as roots and fibers that resist decomposition
H9	Practically fully decomposed peat in which there is hardly any recognizable plant structure. When squeezed it is a fairly uniform paste
H10	Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers

Hydropower, solar, and methane gas constitutes the main natural resources of energy in Rwanda (USAID, 2018) (Fig. 1). According to Bimenyimana et al. (2018), hydropower and solar resources are the main renewable energy resources, with the largest power proportion originating from hydropower projects across numerous rivers and water falls across the country. Lake Kivu methane gas production currently contributes ~14.3% of energy (Fig. 1), and at full completion, the Kivu Watt project aims to produce over 100 MW of electricity (Contour global, 2019).

Since 2007, the government of Rwanda has put tremendous efforts in Biogas technology to cut down wood consumption, (Landi et al., 2013). Biogas is mainly used in schools, prisons and some rural households, (Sinaruguliye and Hategekimana, 2013).

Currently, Rwanda has not yet discovered any petroleum resources in line with the East African Rift Valley petroleum system. As of 2016, the daily consumption of petroleum products in Rwanda accounted at ~6000 bbl (US liquid barrel) (Munyaneza et al., 2016). Most of the petroleum products in Rwanda are imported from neighboring countries such as Kenya and Tanzania, (Munyaneza et al., 2016).

In addition to the above resources, peat resources are becoming significant contributors to the energy production sector in Rwanda. It accounts for ~155 million tonnes of dry peat, which can be used for electricity generation (Bimenyimana et al., 2018; REG, 2019b). Seventy seven percent (77%) of such deposits occur

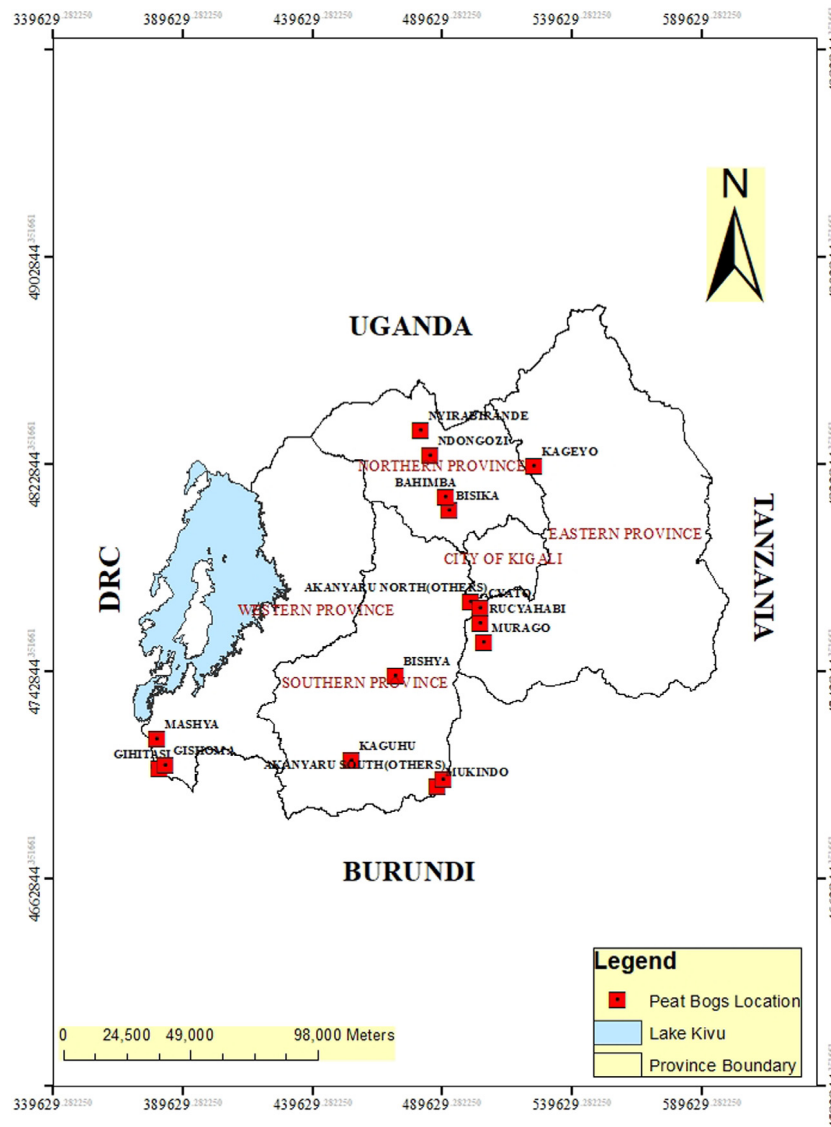


Fig. 2. Rwanda peat deposits distribution map.

proximally near Akanyaru and Nyabarongo rivers and Rwaburoro plains (MININFRA, 2015; REG, 2019b). However, despite the large peat deposit accounted in Rwanda, only two peat to power projects are currently under development. Gishoma 15 MW peat to power project was completed in 2017 and 80 MW Hakan project is under construction since February 2017 (REG, 2019b).

## 4. Materials and methods

### 4.1. Sampling procedures

The systematic grid sampling was used in this study. The sampling process was commenced with determination of the coordinates of all sampling locations and core samples were collected from each drill hole in different locations for each 50 cm interval down to the depth where there is no peat. At each location, the corer was pressed into layers by hand. The six hundred samples collected were placed in tightly closed plastic buckets and labeled prior to being sent to the laboratory for testing. The samples were collected in various peat bogs (Fig. 2). The samples were described on field and classified based on Von Post classification (Table 2).

### 4.2. Methods

The proximate analysis of peat includes the determination of moisture, volatile matter, ash, fixed carbon and calorific value. The first three parameters were determined in laboratory and the fixed carbon was calculated. The samples were crushed to <72-mesh size for chemical analysis. The proximate and sulfur analyses were done following the Bureau of Indian Standard IS:135 (BIS, 2003) and American Society for Testing and Materials (ASTM, 1989) respectively.

## 5. Proximate analysis results and discussion

The average ash content of samples taken from different location are displayed in Table 3 where Mashya display the lowest value (19%) while the highest ash content (80%) is found in Kageyo (Fig. 3). The average ash content in all studied location is 38%. The moisture content in all locations is slightly high ranging from 53% to 85%. Kaguhu and Kageyo display the lowest moisture content (53%) while Akanyaru North is featured with highest value (85%). The ash content of less than 40% in soda peat dried up to 30% moisture content and less than 30% in milled peat dried to

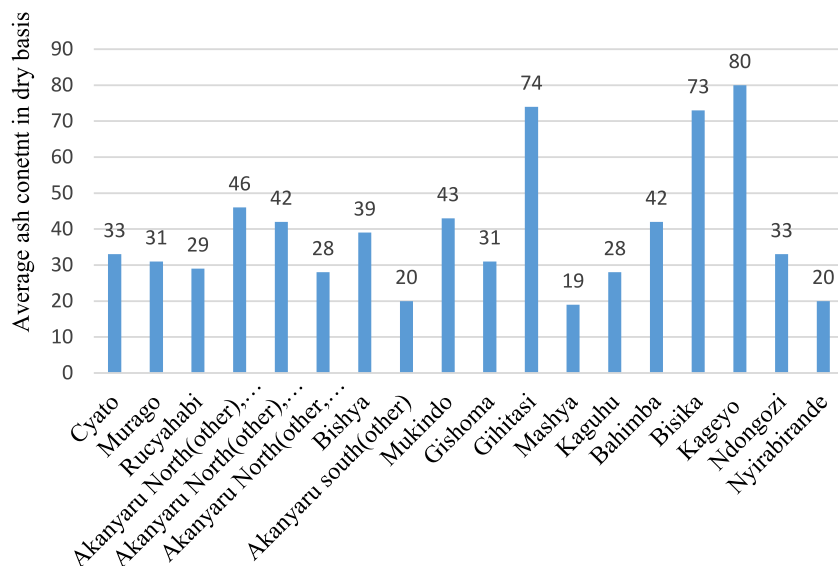


Fig. 3. Average ash content in all sampling locations.

Table 3

Proximate analysis results of peat samples.

Name of peat bog	In-situ moisture content(% wt)	Average ash content in dry basis	Average volatile matter content	Average fixed content	Average sulfur carbon	Average calorific value
Cyato	64	33	10.70	19.21	0.45	2981
Murago	83	31	46.70	20.81	0.12	2560
Rucyahabi	80	29	55.00	26.40	0.23	3218
Akanyaru North(other), North	68	46	48.13	29.30	0.35	5000.9
Akanyaru North(other), Middle	78	42	40.83	26.00	0.21	5112
Akanyaru North(other), South)	85	28	41	28.10	0.25	4813
Bishya	70	39	68.00	25.70	0.80	3654
Akanyaru South (other)	83	20	60.22	22.62	0.41	3782
Mukindo	65	43	60.00	19.98	1.0	4002
Gishoma	73	31	61.36	22.45	0.25	4756
Gihitasi	73	74	18.50	31.3	0.53	2845
Mashya	86	19	50.10	28.88	0.39	4850
Kaguhu	53	28		21.90	0.65	5350
Bahimba	55	42	40.70	19.21	1.1	3973
Bisika	54	73	63.90	21.00	0.76	3751
Kageyo	53	80	68.20	26.48	0.49	2987
Ndongozi	76	33	72.01	25.28	0.64	3622
Nyirabirande	67	20	68.21	18.22	0.33	4318

40% is suitable for electrical power generation (EDCL, 2014). The volatile matter of peat falls between 60%–70% (Lindström, 1980) while that of Rwanda is ranging from 10%–72%. The quality of peats for fuel production is influenced by humification grade and thus all samples with ash content less than 40% are in humification grade 4 (H4) to H10. As demonstrated by Lasse (2007) the increase in humification grade, positively influence the calorific value of peats.

The high moisture content (average 70.88%) is typical of peats (70%–90%). The total sulfur percentage values (average 0.49%) are generally medium for all samples. The gross calorific values of peat samples ranged from 2560 to 5350 Kcal/kg, with an average value of 3976 Kcal/kg. These values are moderately very high because typical dry peat has calorific values of 2000 Kcal/kg (Fatma and Sadettin, 2015). The peats with calorific value less than 4562 Kcal/Kg are not suitable energy production (Lasse,

2007). Akanyaru peat bogs have the calorific value above 5000 Kcal/Kg and are considered the overall bogs for energy production. The high ash content of Gihitasi; Bisika and Kageyo make them unsuitable for energy production because the ash content in dry basis above 40% affects negatively the calorific value of peats (EDCL, 2014). According to Ituze et al. (2017), the available peat deposits in Rwanda will contribute 20.6% to the energy growth by 2025 (Table 4).

## 6. Conclusion

The peat to power in Rwanda is a matter of urgency to achieve the developmental target and to ensure that all population will have access to the electricity by 2025. Most of the peat deposits in Rwanda can be converted into energy based the calorific value of all samples. Akanyaru, Mukindo, Gishoma, Mashya, Kaguhu,

**Table 4**  
Rwanda energy mix road map projects (Modified after Ituze et al., 2017).

Energy resources	Medium term (2012–2017)	Medium to long term target from 2018 to 2025	Unit
Generation	132–595	595–1450	MW
Hydropower	200	310	MW
Methane	100	350	MW
Peat power	115	300 (20.6%)	MW
Geothermal	160	460	MW
Heavy fossil oil	20	20	MW
Total	595	1450	MW
Average US Dollars (Million)	510	555	\$

Mukindo and Nyirabirande are the promising bogs for peat mining for energy generation. In rural area, the wood is mostly used as sources of power and this has urged the Government of Rwanda and partners to start constructing peat to power plants where the peat are expected to generate 20.6% of all energy resources in Rwanda. This effort to use peat as source of power along with other project, they will promote the development of the Country. To use peat as source of power, it is advisable to develop suitable pollution control as the coal burning contribute to environmental pollution and climate change. The Government is taking initiatives to promote generation of energy from peat including its implications on the environment.

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