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Case study

Potential for peat-to-power usage in Rwanda and associated implications

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ABSTRACT

The persistent low-level access to modern energy in Rwanda is attributed to lack of investment in the energy sector. Accordingly, the investment in energy resources use is analyzed for electricity supply security. During a study period that spanned the years of 2013–2045, scenarios involving population and average GDP growth rates are used for the analysis of future electricity demand and supply. The introduction to the national grid of electricity from peat-fired plants helps phase out oil thermal power, thus the removal of electricity utility price subsidies. The supply of electricity security margin is also observed to be between 32% and 51%. In general, peat-to-power technology is cost competitive compared to the electricity utility price in Rwanda and the region.

1. Introduction

Due to its role in the development of the national economy, energy is a key strategic sector in Rwanda. The provision of an adequate energy infrastructure is essential for households, industries, and the delivery of high quality services from health facilities, schools, and administrative offices. Rwanda's vision[2] emphasizes the need for economic growth through private investments and economic transformation; all of which requires a reliable and affordable energy supply [38]. The energy sector in Rwanda is dominated by electric power, petroleum, and biomass sub-sectors. Non-commercial traditional biomass in the form of wood, charcoal, and residues accounts for up to 57%, 23%, and 6% of the country's total energy balance, respectively. In contrast, hydroelectricity accounts for up to 3% and petroleum products account for up to 11% of all utilized energy supplies [16].

The final energy demand can also be viewed in terms of household, transportation, industry, and public sector energy consumption. Information on the sectoral final energy consumption pattern in Rwanda is not available from previous studies. However, the only information available in Rwanda Land Use and Development Master Plan report regarding the share of sectoral total energy consumption allocates 90% to households, 5% to transportation, 3% to industry, and 2% to public services [44]. The per capita electricity consumption per year is also very low in the region at 30 kWh compared to neighboring countries including Uganda (66 kWh), Tanzania (85 kWh) and Kenya (140 kWh) [78]. The access to electricity is still a problem to about 15% of enterprises in Rwanda [60]. The transportation sector is the primary consumer of imported petroleum products, especially gasoline and diesel. About 75% of all imported petroleum products is consumed within the transport sector, and the remaining 25% is used for electricity generation [56].

Although the national installed energy capacity has increased dramatically over the last two decades, from 25 MW in 1994 to 112 MW in 2012, it has mainly been comprised of 46% oil thermal power, and 53% from hydropower. There are also 2% from natural gas (methane) thermal power, and 0.2% of solar power [17]. Considering the average annual hydropower generation in the region, Rwanda combined with Burundi and the Eastern region of the

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[2] Rwanda vision (2000–2020) was launched in 2000.

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Democratic Republic of the Congo (DRC), they produce only 3% of the total hydropower in the region [13]. In contrast, Ethiopia, Sudan, Tanzania, Uganda, Egypt, and Kenya produce 46%, 16%, 12%, 12%, 8%, and 4%, respectively [13]. The high cost of fuel consumption for thermal power requires the government subsidies to keep electricity retail tariffs in the range of $0.12–$0.18 USD, comparatively to the region [17].

Although the electricity access rate has more than tripled from 5% in 2005 to 18% in 2014, the average rate of electrification is still very low as compared to values of 40% and 31% for Africa and Sub-Saharan Africa, respectively [17]. The electricity is transmitted and distributed using high-voltage cables of 110-kV and 70-kV capacities facilitate the total electricity network length of 370 km, where 253 km is of 110-kV capacity and 96 km is of 70-kV capacity [15]. Three major challenges can be identified in the Rwandan electricity sub-sector; (1) electricity demands being nearly equal to the available capacity (which hardly allows for any security reserve margin), (2) costly expenses associated with oil thermal plants, and (3) insufficient investment finances [16].

The objective of this study is the formulation of a medium- to long-term Rwandan electricity system corresponding to demand forecast, utilizing all potential resources available in the country including peat-to-power technology being optimally utilized as a compliment to natural gas and renewable energy resources.

2. A review of previous study

Few studies have explored the energy potential in Rwanda. Safari [7] presented a review of existing energy resources and applications in Rwanda, while Gupta and Sood [19] analyzed energy sources in Rwanda and proposed alternative solutions that addressed the lack of fossil fuels. The potential of wind energy is still under investigation; therefore, Safari and Gasore [6] recommend that prior to any decision being made on wind harvesting in Rwanda, further investigation into the details and systematic analysis of speed patterns should be performed. Pigaht and Robert [35] studied the development of micro-hydropower projects as a source of on-grid and off-grid electricity via private sector participation in Rwanda. In general, the potential electricity generated from peat-to-power technology as a facet of energy security has been poorly addressed by previous literature; as it accounts less than 0.1% of world energy supply [52].

3. Peat resources in Rwanda

Rwanda is reported to have peat resources that could be converted into energy. A master plan incorporating peat-derived energy, prepared by Ekono [14] indicates potential peat reserves that amount to 155 Mtons of dry peat, distributed over an area of about 50,000 ha and equivalent to 500 MW electrical powers during 30 years. Vitikka and Lahtinen [1] report the same amount of quantity after performing the peat master plan update study (see Fig. 1 and Table 1).

Peat is generally considered to be the first developmental stage in the coalification process, in which there is a gradual increase in the carbon content of fossil organic material and a concomitant reduction in oxygen [31]. It is also treated as a sub-category within brown coal and defined as a combustible soft, porous or compressed fossil sedimentary deposit of vegetal origin; which is easily cut, light to dark brown in color, and holds a high water content (up to 90% in the raw state) [26]. It therefore shares many similarities with coal, it is used to generate electricity, and it has applications in industrial, residential and other sectors like coal [63].

Peat has played a major role in Finland, Sweden, Indonesia, Ireland, Russia, and various areas of the former Soviet Union [64]. In Ireland for example, peat has been used for electricity generation since 1950s, and it is estimated at 10% of the total installed capacity [30]. The large-scale use of peat as an energy source has yet to be established in Rwanda. The Peat Energy Company (PEC) is an industrial scale company operating in the southwestern region of Rwanda, and it produces 13,000 ton per year with wet peat to be supplied to the Rwanda Cement Company (CIMERWA) in the region [4]. The PEC initiated mechanical peat production in 2008; however, it is still vulnerable to its limited capacity to sustain large-scale peat production that could handle up to 50 MW of power [50]. Therefore, more investors are also needed in peat mining for use in electricity generation.

4. Methodology and data input

4.1. Energy modeling tools

The Model for Energy Supply System Alternatives and their General Environmental Impacts (MESSAGE) is employed in this study as an optimization model of electricity generation in Rwanda. MESSAGE is designed to formulate and evaluate alternative energy supply strategies consonant with user-defined constraints (such as limits on new investment, fuel availability and trade, environmental regulations, and market penetration rates for new technologies), with objective function to minimize the total energy system cost, as subject to a set of pre-specified constraints [23]. It also aims to determine the feasible least-cost solution for energy supplies or technologies that satisfy future energy demands.[3] Electricity is non-storable energy form; therefore, the electricity generation and consumption are considered together because the generation has to follow the required variable demand hour by hour. In this analysis, we perform the modeling of the hourly load curve of Rwanda future electricity demand using the Model for Analysis of Energy Demand (MAED). The data resulted from MAED serves as final demand input to MESSAGE.

Chateau and Lapillonne [3] originally developed the general approach to the MAED methodology and the International Atomic Energy Agency (IAEA) improved it in an attempt to establish required parameters to be specified as input data and equations used for calculating the energy demand of certain sectors [24] [22]. MAED has advantages of evaluating future energy demand based on medium- to long-term scenarios of socio-economic, technological and demographic development. It is also built with detailed considerations of technologies that allow for modeling of the impact of distinct and well-defined technologies on the long-term development of energy consumption [46]. MAED relates systematically to the specific energy demand for producing various goods and services identified in the model, to the corresponding social, economic and technological factors that affect this demand.[4] Energy demand is disaggregated into a large number of end-use categories; each one corresponding to a given service or to the production of a certain good.

4.1.1. Descriptions of scenarios

The year 2012 represents the base year, whereas the year 2013 represents the starting year in the optimization model process. MESSAGE recommends a base year followed by the model years each separated by one space and the interval between the model years can vary but it should be constant or increasing [23]. Accordingly, the study period of future electricity supply

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[3] See Ref. [30] for more detailed description of the models internal workings.

[4] See MAED details at http://www-pub.iaea.org/MTCD/publications/PDF/CMS-18_web.pdf.