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The Gambia's future electricity supply system: Optimizing power supply for sustainable development

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A B S T R A C T

Access to a modern, reliable electricity in The Gambia is limited and unsecure as it relies on old and undiversified electricity supply system. To diversify this system several options are feasible, including electricity imports from neighboring countries, which is expected to commence by 2020. In this study, an optimization of the national electricity supply system with (EDD-Electricity Dependent Scenario) and without (EID-Electricity Independent Scenario) hydroelectricity imports for 2030 horizon commencing 2015 is presented and analyzed. The results showed that the EDD scenario (desired scenario) will displace about 349 GWh (2020) and 216 GWh (2030) of oil based generation with hydroelectricity imports, which will lead to the avoidance of 142.69 kT on average CO_2 emissions. Also, it can save up to USD $ 23 million and USD $ 0.0206/kWh on average annually of total system cost and unitary electricity production cost compared to the EID scenario.

In addition, the EDD scenario was tested for its sensitivity to delays in commencement of the hydroelectricity imports. The further the delay causes more generation (216 GWh annually) expected from new oil power plants, and this is equivalent to the annual amount of hydroelectricity.

1. Introduction

Energy is a crucial means to growth and development. In the past, as well as the present, societies depended on solid fuels such as wood, animal dung, and other biomass forms to derive useful energy for cooking and heating [1]. However, during the mid-19th century, coal became prominent and effective in the energy supply mix, thereby replacing much of the other solid fuels used in past millennia. After the mid-20th century oil became dominant in the global energy supply mix [2]. During the same period, gaseous fuels (natural gas) use expanded but at a limited pace; in the last two to three decades natural gas displaced some of the liquid fuels. Nowadays, the gaseous and liquid fuels are currently being displaced by modern, renewable energy forms.

This trend in the evolution of energy supply forms from solid to liquid, liquid to gas, and to modern energy sources are mainly influenced by cost and convenience [1]. Modern and reliable electricity is an essential pre-requisite in the transformation and development of any society. Like most developing West African societies, the electricity supply system in The Gambia[1] is unsustainable [3] as it totally relies on a single, undiversified fuel source: imported petroleum. This dependence has led to serious electricity challenges characterizing the electricity system. These challenges include, but not limited, to electricity supply insecurity. As at 2014, there is an insufficient supply of 270 GWh but the demand exceeding 550 GWh. Furthermore, petroleum inputs are sometimes unstable and these inputs are associated with high electricity production costs, averaging USD $ 0.50/kWh [4] compared to the West African regional average of about USD $ 0.32/kWh [5].

Currently, The Gambia's electricity supply system is completely

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[1] The Gambia is one of the smallest mainland countries of African (West Africa). It is surrounded by Senegal on three sides by except for 60 km of Atlantic Ocean front and has a total land area of 11, 235 km^2. It has a population of 1.8 million and 173.6 persons per km^2 [4], according to the World Bank, the country is one of the densely populated countries in West Africa resulting in huge concentrated energy demand.

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Table 1
Existing national power plants installed capacity, production as well as demand [3,4,6,7].

Location	Power Stations & Description		Installed Capacity (MW)	Production (MWh)	Peak demand (MWh)
Greater Banjul Area (GBA)[2]	Kotu	Thermal	41.4	99 977	535 360
	Brikama	Thermal	47.4	162 429	
	Batokunku/Tanji	Wind	1.5	119	
Provincial Towns/Regional Towns	Essau	Thermal	0.8	483.79	24 640
	Farefenni	Thermal	4.5	2721.33	
	Kerewan	Thermal	0.9	544.27	
	Kaur	Thermal	0.66	399.13	
	Bansang	Thermal	1.9	1149.01	
	Basse	Thermal	4.32	2612.48	
Total			**103.65**	**270 435.01**	**560 000**

dependent on oil (Heavy/Light Fuel Oil – H/LFO) based technologies which have been struggling to keep up with demand making the system insecure and unsustainable. The description of this system as at 2014 is presented in Table 1.

The total installed system capacity is about 103 MW (88 MW in the Greater Banjul Area (GBA)) of which only 61 MW are available (55 MW in GBA). The National Water and Electricity Company (NAWEC) is the sole utility company in The Gambia and it is struggling technically to keep up with its routine operations. Only about 60% of installed generation capacity is available, and huge part of this capacity comes from two heavy fuel oil (HFO) thermal power plants in Kotu (41 MW of which 19 MW is on average available) and Brikama (47 MW of which 36 MW is on average available). Aside from Kotu and Brikama, NAWEC also operates six separate plants with 13 MW of installed capacity (7 MW is available) using Light Fuel Oil (LFO) as baseload power stations with very high operational costs [8] [6]. The current grid system is not integrated and works are in progress to implement a single national grid.

Like generation, the transmission and distribution (T&D) system is dramatically underperforming as the loss encountered recently stood at 25% (comprising both technical and non-technical losses[2]) [7]. The Gambia currently has two 33 kV transmission lines with a length of about 125 km conveying electricity from the Kotu and Brikama thermal power plants to 33/11 kV transmission sub-stations and 33/0.4 kV distribution sub-stations. The electricity from these sub-stations are conveyed by 181 km 11 kV lines with various 11/0.4 kV transformer stations at various sites in the GBA and Brikama. Then low voltage lines distribute electricity to three-phase and single-phase consumers at 400 V and 230 V respectively. The high T&D losses can be attributed to limited and inadequacies in the network, overloading of transformation capacity, and high reactive power flows [9].

Given the huge unavailable supply capacity (i.e. gap) of 290 GWh (560 GWh minus 270 GWh) and the reliance on a single imported petroleum fuel, prompted the need to provide the medium to long term optimal expansion of the national electricity supply system to meet current and future demand. A modern, diversified system will be sustainable, reliable and cost-effective. This will allow The Gambian policy makers and planners to facilitate growth and development by addressing the hugely growing electric demand (see section 3 (on demand projections)).

In addition, several renewable (mainly solar photovoltaic (PV), wind, biomass, hydroelectricity) and alternative energy supply sources (mainly natural gas, biomass, coal, hydroelectricity) have potential to close the nation's electricity demand and supply gap based on the policies targets [3] [7] and strategies [10] [9]. According to the national Renewable Readiness Assessment - RRA [9], The Gambia, given its geographical location has excellent potential to generate up to 474 TWh/year (terawatt hours per year) of energy from solar PV, 173 TWh/year from wind (onshore), with biomass estimated at 1.8 TWh/year. The potential for hydropower is quite negligible in the country due to the generally flat terrain. However, there is great potential and possibility to import hydroelectricity from the regional hydropower project under L'Organisation pour la Mise en Valeur de la fleuve Gambie (OMVG[3]). Table 2 summarizes the technical potential of some renewable energy technologies in The Gambia.

Table 2
National renewable energy potential [10,11].

Technical potential of selected renewable energy technologies	
Technologies	**Potentials (TWh/year)**
Photovoltaic (PV)	474
Wind	173
Biomass	1.8
Hydro	Negligible, OMVG imports possible

The challenges coupled with several possible electricity generation options have pushed the Government to implement policies [7] [12] as well as strategies [9] [13] that seek to diversify the current unsustainable electricity supply situation, by using an energy system optimization tool, we sought to evaluate the electricity sector strategies and possibilities. A diversification strategy targets a grid renewable penetration of 10% (2020) and 20% (2030) – excluding electricity trade (i.e. hydroelectricity imports). These penetration rates are increased to 35% (2020) and 48% (2030) with hydroelectricity imports [3].

The hydroelectricity import from the OMVG [14], highly anticipated in 2020, is expected to contribute greatly in diversifying the national electricity supply mix in the medium to long term. Imports can lead to economically bridging the national electricity demand-supply gap. The potential contribution of OMVG hydroelectricity import potential relates to this study which looks at the optimal national electricity supply expansion with and without OMVG hydroelectricity imports for the horizon 2015–2030. Thereby shedding light into the following questions facing the national electricity supply system:

- What are the possible optimal system expansion and generation in both scenarios?

[2] Technical losses include system losses, while non-technical ones are more related to commercial losses.

[3] OMVG is an intergovernmental organisation that is mandated for the exploitation of The Gambia's river basin.