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Techno-economic and environmental analysis of power generation expansion plan of Ghana

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ABSTRACT

This paper examines the current electrical generation expansion plan of Ghana and compares it with proposed expansion pathways with higher penetration of Renewable Energy Technologies. An adaptation of Schwartz's Scenario Methodology was used to develop the scenarios which were then analysed using the Long-range Alternatives Planning (LEAP) model. Each of the scenarios represents policy options for generation expansion in Ghana up to 2040. Energy, economic and environmental analysis of the three alternative scenarios compared to the base scenarios was undertaken. Sensitivity results show that, if the country were to follow the generation expansion path described in the renewable energy scenarios, it could reap economic benefits of 0.5–13.23% depending on the developments in fuel prices and renewable technology capital cost. The analysis further quantifies benefits to be derived from a reduction in Greenhouse gases of the scenarios. Policy implications for the generation system of Ghana based on the results are also discussed.

1. Introduction

Ghana faces serious energy related challenges as the country struggles to meet generation requirement. The electricity supply system of the country is characterised by power outages which have serious implications on the quality of life as well as industrial development. Reliable and affordable electricity generation system is an indispensable commodity in the technological development of any country. Even though the country is unable to meet the current demand, the future demand is projected to be increasing at 10% per annum (Abledu, 2013). This does make the development of a realistic generation expansion plan very essential if the country is to achieve its medium to long term development goals. Inadequate appropriate expansion has resulted in the current situation where the generation capacities can only meet about 65% of the current demand as at March 2014 (Energy Commission Ghana, 2015).

The conventional grid generation in Ghana is by Hydro, with the Akosombo Hydro dam providing almost all the grid power when it was commissioned in 1966 (Aryeetey, 2005). The Akosombo generating plant was originally constructed with a total installed capacity of 588 MW (MW). The capacity was increased to 912 MW in 1972 with an addition of two generating units to the original four (Aryeetey, 2005). The construction of the Akosombo hydro plant was tied to the Volta Aluminium Company (VALCO). The idea was to develop the huge bauxite reserves in the country to make use of the energy from the Akosombo dam (VALCO, 2016). The smelter was subsequently constructed consisting of five portliness capable of producing 200,000 Metric Tons (MT) of primary aluminium annually. The company today, which is now 100% owned by the Government of Ghana, operates at about 20% its rated capacity as a result of insufficient supply of power (Energy Commission Ghana, 2015). An additional hydro dam, the Kpong dam, was constructed near Akuse, 24 km downstream of Akosombo dam. The Kpong hydroelectric plant was commissioned in 1982 with an installed capacity of 160 MW (Aryeetey, 2005). Thermal power generation was introduced to supplement the conventional Hydroelectricity after a drought in 1983 underscored the need to diversify the country's generation system. The introduction of Thermal power generation into the generation mix of the country occurred in 1997 with the construction of a combined cycle power plant with an installed capacity of 330 MW at Aboadze near Sekondi-Takoradi. The Takoradi Thermal Power Station (TAPCO), as it is officially called, was eventually expanded to 550 MW with the addition of two 110 MW combustion turbine plants in 2000. This marked the beginning of a gradual shift to thermal generation in the country. The installed capacity as at March 2014 was 2851 MW which is made up of 1580 MW (55.4%) from the three hydro dams, 1248 MW (43.77%) from Thermal plants and only 2.5 MW (0.09%) from photovoltaic plant (Energy Commission Ghana, 2015). All the plants are operated by

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Fig. 1. Hydroelectric potential of Ghana (Dernedde and Ofosu-Ahenkorah, 2002).

Volta River Authority (VRA) except Bui, which is operated by Bui Power Authority (BPA). VRA and BPA are both government agencies. Sunon-Asogli, and CENIT are private entities which contribute about 11.61% of the installed capacity (Energy Commission Ghana, 2015).

There is a growing interest in power generation systems worldwide because of the growing demand of power and the environmental implications of these power systems. The adverse environmental and societal impacts and fluctuation in the prices of fossil fuels in the world market has necessitated the exploitation of sustainable power generation technologies. Ghana is endowed with a number of renewable energy resources including solar, wind, small and medium hydro and biomass, which can be exploited to help meet the energy needs of the country. There is an excellent solar radiation all year round, and in every part of the country, with an average radiation of 5.5 kWh/m^2. Sites suitable for medium and small hydro power plants have also been identified in various part of the country with a potential of adding over 900 MW to the national grid if fully exploited (Dernedde and Ofosu-Ahenkorah, 2002). The potential sites for the construction of new hydroelectric plants, as well as the existing hydroelectric plants are illustrated in Fig. 1. In addition to the these sites, over seventy micro hydro sites have also been identified with a combined estimated potential of about 4–14 MW when connected to the grid (Kemausuor et al., 2011).

Sites near the coastal parts of the country have also been identified with excellent conditions for wind generation (Gyamfi et al., 2015).

The scenario approach was adopted to examine the possible pathways that future generation system in Ghana could evolve. Scenario approach is a key techniques applied by futurists in various disciplines to develop strategic plans and policies. Several definitions of scenario exist in the literature, however the definition of the Intergovernmental Panel on Climate Change (IPCC) summarises the concept of scenario analysis as applied to the natural sciences (IPCC, 2013) "*A scenario is a coherent, internally consistent and plausible description of a possible future state of the world. It is not a forecast; rather, each scenario is one alternative image of how the future can unfold*". It is deduced from this definition that scenarios are not predictions, and hence do not forecast, but rather present alternatives of possible outcomes. The term scenario as it is applied in strategic planning was pioneered by