



An overview of agricultural biomass for decentralized rural energy in Ghana

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ABSTRACT

Efforts to improve the quality of life in rural areas rely upon the provision of electrical energy services. Globally, the focus is on identifying and maintaining sustainable and environmentally friendly energy resources, by means of the clean development mechanism (CDM). Supplying electricity by extending the grid to rural domains is, in most cases, economically unproductive, taking into account other related factors that pertain, especially in developing countries. Furthermore, an unfolding energy crisis in the sub-Saharan Africa (SSA) region intensifies the need for decentralized bioenergy applications using modern conversion techniques. Biomass energy produced in rural areas provides a sustainable alternative to grid electricity. This paper presents an overview of the potential of agricultural biomass-based resources for decentralized energy in rural areas of Ghana. It emphasizes the strategic importance of biomass energy, especially in areas where it is economically attractive because of the ready availability of resources. Assimilation of past and current research reported in the literature on biomass resources and bioenergy technologies in the country underpins this study. A more detailed evaluation of agricultural biomass-based potential was carried out and 2010 was chosen as the base period for the assessment. The result suggests that Ghana has a suitable potential of bioenergy resources and this holds considerable promise for future energy delivery in the country. The paper concludes with discussion of various promising decentralized bioenergy technologies for the exploitation of resources in Ghana.

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1. Introduction

Biomass for decentralized power generation has been a rapidly growing concept in the power sector. In most developing countries, access to modern energy in rural and remote areas is critically difficult from the economic viewpoint. Direct connections of rural communities to a centralized power system impose serious burdens on developing countries, which are subject to integral constraints. Industrialized countries with mature economies and sophisticated power systems have already taken advantage of electrical power from both centralized and decentralized power supply systems. However, the traditional approach to electrical energy supply is to expand existing transmission and distribution networks so that unconnected communities can gain access [1].

In the light of the energy crisis in developing countries, the only realistic alternative for power production in rural and remote villages is, with few exceptions, a decentralized energy system structure. In off-grid rural and remote villages, decentralized power generation using distributed energy resources (DERs) is considered the most important strategic solution to energy problems. In most countries of sub-Saharan Africa (SSA), the capital cost of investment on large-scale power plant is unaffordable by both central and local government authorities. The global quest to sustain economic development and deliver a better standard of living cannot be disregarded, and energy supply has to be improved if socio-economic and technological transformation is to be secured. Since many developing countries are characterized by a series of rural settlements, biomass-based decentralized power generation is a workable option.

Hitherto, Ghana has had to import fuel for power generation, but financial and environmental concerns in rural communities now make renewable energy from biomass the best option. Decentralized generation promotes energy efficiency, lower transmission losses and use of renewable sources [2]. Today, biomass occupies fourth position in the global energy supply mix while accounting for 14% of the world's energy consumption [3]. The rapidly growing interest in biomass for energy is based on its availability in almost every part of the world. It is a major source of fuel for poor people in developing countries. The rate of consumption of biomass to supplement the energy needs of people in developing nations is very high compared to the developed world, as illustrated in Table 1, which shows the contribution of biomass to final energy consumption in different regions of the world.

Decentralized energy provision using biomass is a strategy for planning the demand side of the energy management system effectively. Separating out the demand side of the energy

structure in different regions can aid understanding of income opportunities based on the availability of biomass resources [5]. Agricultural production in sub-Saharan Africa, especially in Ghana, is dominated by rural farmers with a low income. The widespread system of farming here is associated with manual and traditional techniques that are highly labor-intensive. Decentralized electrification operating on biomass can offer a better and more reliable supply of electricity and generate income derived from the use of farmers' local resources [6].

At present, Ghana depends on oil imports to provide a large proportion of its domestic energy because of the low capacity of the country's refinery. The spatial distribution of rural settlements and sparse road network in poor condition make the transport of oils to rural areas difficult. As is well-known, deficiency in commercial energy supply such as electricity in a society can exacerbate social asymmetry in living conditions [7]. The application of biomass as a fuel for power, heat and automobile engines has the greatest mitigation potential of all the renewable sources in this respect [8–10]. In many developing countries, rural electrification generators operating on imported fuels have a cataloged history of failure. Therefore, the need to provide a biomass-based energy alternative is paramount.

This article reviews the literature concerning the potential of agricultural biomass in Ghana to provide a decentralized electricity supply and other forms of energy production. Although the article focuses primarily on agricultural biomass resources, other related biomass sources such as municipal solid waste (MSW) and liquid biofuels are also discussed, as they also have the potential to contribute to decentralized rural energy. Decentralized generation of electrical power and some promising biomass conversion technologies are also analyzed.

2. Methods and materials

2.1. The geography of Ghana and the energy access situation

Ghana is a West African country bordering Burkina Faso to the north, Côte d'Ivoire to the west, Togo to the east and the Atlantic Ocean to the south. The total land area of the country is 23,853 ha. The population is estimated to be 24,233,431, amounting to 0.35% of the world's population in September 2010 [11]. In 2007, Ghana recorded a gross domestic product (GDP) of US\$7.2 billion [12]. The industrial sector in Ghana is one of the major drivers of the nation's economy and accounts for approximately 25% of total GDP [13]. The dynamic nature of the industrial sector compared to others within the same sub-region places more energy demands on the nation's power sector. Table 2 shows the general situation of energy access in Africa.

Most households in Ghana, especially in rural settlements, have hitherto relied heavily on the availability of traditional biomass from firewood and wood charcoal for their primary energy supply. It was reported in 2008 that 72% of total energy utilized in Ghana was obtained from firewood and wood charcoal. Crude oil for energy accounted for 22% and hydro occupied just 6%, as indicated in Fig. 1.

Excessive consumption of firewood and charcoal has been a general propensity in the entire region of SSA owing to low access to electricity. A critical look at electricity access in Africa, as presented in Table 2, reveals that about 20 countries in the SSA

Table 1
The contribution of biomass in final energy consumption [4].

Region	Share of biomass in final energy consumption (%)
Africa	60.00
South Asia	56.30
East Asia	25.10
China	23.50
Latin America	18.20
Europe	3.50
North America	2.70
Middle East	0.30

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