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Assessment of biomass residue availability and bioenergy yields in Ghana

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ABSTRACT

Biomass is an important renewable energy source that holds large potential as feedstock for the production of different energy carriers in a context of sustainable development, peak oil and climate change. In developing countries, biomass already supplies the bulk of energy services and future use is expected to increase with more efficient applications, such as the production of biogas and liquid biofuels for cooking, transportation and the generation of power. The aim of this study is to establish the amount of Ghana's energy demand that can be satisfied by using the country's crop residues, animal manure, logging residues and municipal waste. The study finds that the technical potential of bioenergy from these sources is 96 PJ in 2700 Mm^3 of biogas or 52 PJ in 2300 ML of cellulosic ethanol. The biogas potential is sufficient to replace more than a quarter of Ghana's present woodfuel use. If instead converted to cellulosic ethanol, the estimated potential is seven times the estimated 336 ML of biofuels needed to achieve the projected 10% biofuels blends at the national level in 2020. Utilizing the calculated potentials involves a large challenge in terms of infrastructure requirements, quantified to hundreds of thousands of small-scale plants.

1. Introduction

Biomass is a renewable energy resource derived from living or recently living organisms (Fernandes and Costa, 2010). Biomass is today a very important energy source and forecasts for energy consumption suggest that it has a pivotal role to play as it can drastically reduce greenhouse gas[1] emissions compared to fossil fuels if produced sustainably (IEA Bioenergy, 2008; IEA, 2012). In developing countries, biomass already supplies the bulk of energy services albeit in very inefficient forms, particularly as firewood and charcoal for cooking and heating. Future use of biomass is expected to entail more efficient applications, such as the production of biogas and liquid fuels for cooking, transportation and the generation of power. Many of the available studies on utilizing biomass for energy have targeted global and/or regional level assessments (e.g. Dasappa, 2011; Smeets et al., 2007) while others have targeted specific countries (see Cai et al., 2008; Kludze et al., 2010). The use of biomass residues, especially, for the production of non-food based biofuels is seen as a positive way to mitigate the effects of climate change (Gustavsson et al., 2007).

In the last few years, several countries with high agricultural potentials have sought to use their agricultural resources for the production of biofuels to limit the local use of fossil fuels and/or for export. Notable economic success stories are from Brazil, United States (US), Malaysia and Indonesia (Lamers et al., 2011). However, there have been criticisms of the use of agricultural land for the production of energy crops because of consequent direct or indirect effects of deforestation and increases in food prices (IEA, 2010). This has encouraged research toward biofuels that are based on lignocellulose in nonedible plant materials, typically in agricultural residues, and on residues and waste from other economic sectors. The bulk of residue-based biofuels (used throughout to refer to biofuels based on agricultural and forestry residues, manure and municipal waste) is expected to be produced from agricultural residues, reducing the negative effects of using cropland to produce biofuels instead of food. Political targets promote this development, particularly in the US and EU, through incentives for domestic production- and consumption targets that encourage production (US Government, 2007; EU, 2009). The EU Commission

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[1] Greenhouse gases are gases that trap heat in the atmosphere. These gases include carbon dioxide and methane.

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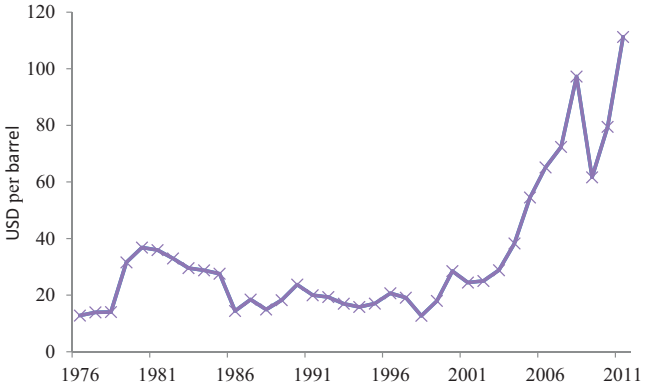

Fig. 1. Historical Brent crude oil prices (nominal prices).
Source: Data from BP (2012).

has published a proposal to limit the use of food-based biofuels to meet its 10% 'renewable energy for transport' target to only 5% with the rest expected to come from non-food based sources (EU, 2012).

Though Ghana is an emerging oil producer, oil reserves will be depleted in the foreseeable future and it is prudent that alternative and more renewable energy sources are identified and made available. According to early estimates, current oil production wells in Ghana could run out by about 2040 (Edjekumhene et al., 2010) but additional discoveries have since been made which could extend this date. Globally, oil reserves are dwindling due to the combination of population growth, urbanization, and increasing per capita energy consumption. As a result, crude oil prices are rising (Fig. 1) with implications for economies that are highly dependent on it. The irregularities in oil supplies and distributions, the challenges of accessing and procuring unconventional oil, and occasional political instabilities in oil producing nations in the developing world have caused general uncertainty regarding global reliability on oil, and have spurred renewed interest in renewable energy (IEA, 2012). Moreover, combustion of fossil fuels contributes to global warming (IPCC, 2007).

In view of the above, there is renewed interest in Ghana to further develop capacity in alternatives to fossil energy sources and thus (1) reduce the national carbon footprint, (2) reduce the country's dependence on oil, and (3) pursue political and economic goals through utilizing presently under-utilized and domestically available resources. Present political momentum is indicated by the development of key documents such as the Strategic National Energy Plan (SNEP) of 2006 (Energy Commission, 2006), the draft Bioenergy Policy of 2011 (Energy Commission, 2011a), and the Renewable Energy Law of 2011 (Ministry of Energy, 2012). Based on these documents, bioenergy is expected to contribute significantly to renewable energy supply from Ghana's energy sector. In order to pursue a strategy of increased bioenergy production while avoiding some of the problems associated with direct or indirect effects on food availability and deforestation rates, it makes sense for Ghana to explore its potentials for residue-based biofuels. This could make it possible for residue-based biofuels to contribute toward the proposed targets for all types of biofuels. Energy potentials from agricultural residues, logging residues, agro-industrial residues, municipal solid waste, food industry waste, industrial wastewater and animal waste could be explored for present and future energy needs.

Production of biofuels based on the mentioned residues avoids the problem of competition over land with food production. Residue-based biofuels, however, are not automatically environmentally benign nor do they ensure the development of a sustainable energy supply. To mention a couple of issues, the sustainability of feedstock supply is influenced by biomass production

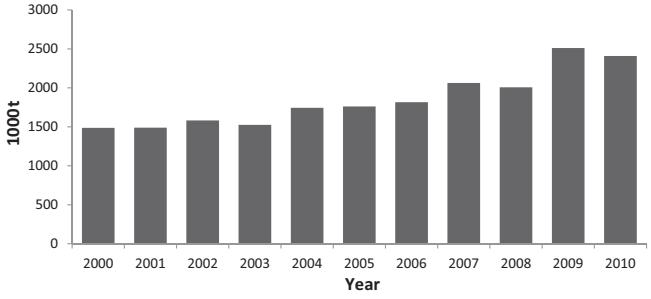

Fig. 2. Petroleum products consumption (Energy Commission, 2011b).

methods, and the transport and conversion of biomass into bioenergy requires additional inputs. Biomass production, transport and conversion are all likely to depend on non-renewable resources. Furthermore, the use of any biomass for fuel production entails a net loss of nutrients from the biomass production site that may cause a systematic deterioration of soil quality. These and similar issues require thorough assessment to avoid the substitution of one set of problems with another set of problems (Gopalakrishnan et al., 2009).

Bioenergy production in Ghana could be more than a means to reach present and short-term energy demands and politically established production targets; bioenergy could be a cornerstone of sustainable development. Therefore, the ability of specific bioenergy projects to sustain themselves over time and through changes in the surrounding environmental, social and economic context should be evaluated before decisions on which projects to develop further are made.

This paper assesses the potentials for bioenergy (biogas and cellulosic ethanol) to meet energy requirements in Ghana using residues and waste as feedstock. Important questions addressed in this paper include: (1) Which resources are available and how much is retrievable? (2) What amount of Ghana's projected energy demand can be satisfied by utilizing the country's crop residues, animal manure, logging residues and municipal solid waste?

2. Present and projected energy consumption and production

At the end of 2010, the energy consumption of Ghana was: 2.4 Mt of petroleum products[2] (equivalent to 111 PJ liquid fuel energy), 6860 GWh of electricity (equivalent to 25 PJ electrical energy) and about 18 Mt of woodfuel (equivalent to 360 PJ of thermal energy, assuming 20 GJ/t of wood) (Energy Commission, 2011b). Even though animal manure is used to some extent in the northern parts of the country, its use is minimal (Arthur et al., 2011). There is currently no commercial production of liquid biofuels in the country. About 200 household and institutional biogas plants were estimated to have been installed at the end of 2009, out of which less than half were functioning (Bensah and Brew-Hammond, 2010).

Petroleum products dominate commercial fuels in Ghana and consumption has been growing over time. In the last decade alone, petroleum consumption increased 60% from 1.5 Mt (69 PJ) in 2000 to 2.4 Mt (111 PJ) in 2010 (Fig. 2). Even though Ghana is producing oil and is likely to benefit from some of the effects of high oil prices, this luxury may be short lived as oil drilling activities in the country are not expected to go beyond the year 2040, even at a low production peak of 250,000 barrels per day (approximately 558 PJ/year)

[2] Petroleum products refer to refined petroleum fuels such as gasoline and diesel. It does not include crude oil used for electricity generation.