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The potential of a dual purpose improved cookstove for low income earners in Ghana – Improved cooking methods and biochar production

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ABSTRACT

Many cookstove designs and biochar programs have been implemented in many countries around the world. These programs have had varied degrees of success which is generally low. Some were able to achieve all their target objectives, others achieved a fraction of their target objectives whiles others achieved different results from their initial targets. The low success rates have been attributed to disregard for various users' considerations by the past implementers of such designs and programs. This study seeks to determine the factors and features that Ghana cookstove users want to be incorporated in the designs of their cookstove and biochar programs. The study used a nationwide survey of household cooks. It was found that about 99% of the respondents will prefer a smokeless cook stove. The challenges that they will want eliminated from the conventional cooking systems are ranked from the highest to the lowest as: smoke and heat (35.80%), difficulty in use (21.8%), cost of cooking systems (6.8%), faulty parts (3.1%), and fuel availability (2.90%). About 83% of the respondents have no idea of the use of charcoal as a soil amendment tool (biochar), which presents an opportunity to educate the communities about the potential of biochar to improve soil fertility and quality. This paper therefore recommends that future cookstove designers, researchers and biochar programs implementers consider elimination of smoke and heat as well as fuel availability ahead of the other factors considered in the design of cookstoves.

1. Introduction

The role of energy in sustainable development process is vitally gaining more attention and concern in recent times [1]. Ghana is experiencing periodic spikes in fuel prices [2] though world market prices of petroleum products on average are reducing in recent times. The spikes in Ghana are due to removal of subsidies by the government of Ghana. This situation is compelling a lot more Ghanaians to advocate for sustainable and affordable clean cooking fuels. In spite of the seemingly temporary reduction in world market oil prices, growing concern over climate change, depleting fossil energy supplies and the push for energy independence coupled with alternative means of energy production are becoming increasingly viable [3–5]. The common alternative sources of energy production are: nuclear, hydroelectric (small, micro and pico scale systems), photovoltaic, solar thermal, wind, geothermal and biomass energy technologies. Biomass is any potential renewable energy resource obtained from living or recently living organisms [6,7]. 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 emissions compared to fossil fuels, if produced sustainably [8–10]. In developing countries, biomass already supplies the bulk of energy services (e.g. cooking, cooking-oils extraction, food preservation, space heating)albeit in very inefficient forms, particularly as firewood and charcoal for cooking and heating [11]. For example, over 50% [12] and to be precise, 55.3% [13] of cooking fuels come from biomass. First generational biomass renewable technologies have been found to be less effective in helping to bring about sustainable development. First generational biomass energy technologies produce energy and its chemical by-products from food crops such as grains, sugar beet and oil seeds. They are of particular interest to the agricultural sector as they will have significant impact on food security, utilization of cropland and other agricultural resources. The cumulative negative impact of these concerns have increased the interest in technologies that produce energy and its co-products from non-food biomass, particularly biomass originally seen as waste [14].

The use of biochar (a co-product of biomass gasification or pyrolysis)

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as agricultural soil amendment tool is currently gaining considerable interest globally because of its potential to improve soil nutrient retention capacity, water holding capacity, and also to sustainably store carbon, thereby reducing greenhouse gas (GHG) emissions [15–17]. Enhanced nutrient retention and water holding capacity of soils reduce the total fertilizer requirements and environmental deterioration associated with fertilizers.

Biochar is a form of charcoal produced through the thermochemical process of biomass under low oxygen conditions known as pyrolysis. Various types of biomass such as agricultural crop residues, forest residues, wood waste, organic portion of municipal solid waste (MSW) and animal manures have been proposed as feedstocks for biochar production. However, the suitability of each type of biomass as feedstock is dependent on its chemical composition, thermal process and agro-system involved, as well as economic and logistical factors of biochar production and soil application [16,18].

Biochar is a carbon negative technology which can help improve soil nutrient retention capacity, water holding capacity, hence, it is useful in amending soils of Ghana, where the decline in soil fertility due to continuous cultivation and rapid organic mineralization have been identified as major causes of food insecurity and poverty [19]

Stoves with improved efficiency have been introduced in developing countries since 1970 [20].

The objectives were initially to reduce deforestation, save cooking time, reduce health impacts through reduction of smoke and environmental emissions, save money, reduce or eliminate the collection time for cooking fuels and improve cooking satisfaction. Modern improved cook stove programs now try to use biomass gasification which has the potential of producing clean energy and also biochar at a low cost. With the realization of the great potential benefits of improved stoves and biochar technology, several stove and biochar programs have been introduced in Africa, Asia and Latin America to disseminate Improved Cookstove (ICS) and biochar to households.

The main objective of this study is to determine how to make our improved dual purpose gasifier cookstove sustainable and popular by means of surveys carried out on stakeholders and family houses with traditional cooking methods. The gasifier cookstove will be sustainable if: its feedstock are easily available; its fabrication and distribution are easy; and its handling and operation are simple. The literature review in Section 2 presents a brief description of earlier work done on cookstove and biochar technologies. The Methodology in Section 3 describes the materials and methods used in the execution of this study. The results and discussion in Section 4 of this paper presents the results and interprets the underlining trends and inferences of the results. The conclusion and recommendation in Section 5 summarizes the key findings of the study and gives recommendations for future research projects. Lastly, Section 6 titled references lists all the cited research material used in this paper.

2. Literature review

2.1. The clean energy challenge

Clean energy can be produced in various ways with various resources but the production of clean energy under discussion in this paper is limited to the use of biomass feedstocks to produce heat and light. Clean energy is defined as energy that is produced with little or no pollution. Per this definition of clean energy, the use of traditional or first generation cookstoves for cooking anywhere in the world definitely poses threats and challenges as far as global warming is concerned.

This study finds the need to assess the global clean energy challenge especially in Sub-Saharan Africa and for that matter, Ghana since the large quantities of biomass utilized for cooking are usually inefficiently burnt by the various cooking technologies [21,22]. This issue becomes relatively critical with the establishment of the fact that charcoal supply chain in the sub-region of Africa is predominately informal and associated with unsustainable forest mining [23]. The clean energy challenge that this paper seeks to discuss is limited to cooking fuels. This challenge is categorized into five dimensions namely, supply-demand imbalance, deforestation, land availability, air pollution and health complications. This paper in agreement with Sedighi and Salarian,[22] and others believes that efficient biomass feedstock cookstoves can be used to produce clean energy based on the premise that efficient burning of any fuel leads to considerable reduction in air pollution. In Ethiopia, for example, improved cook stoves have been found to reduce CO2 emissions by 0.45–2.45 t/year for each household compared with traditional three-stone stoves [24].

About eighty (80) percent of the population of the sub-Saharan African continent - which translates to about 800 million people or 160 million households - still uses firewood or charcoal for cooking [16]. Njenga et al., [24] collaborates the assertion that firewood and charcoal are the main sources of cooking energy in Sub-Saharan Africa of which Ghana is part. In the entire developing world, it has been established that about three (3) billion people use solid biomass as their main source of energy for cooking [25]. Almost every year, about four million people, mostly women and children die prematurely through smoke inhalation and respiratory diseases [25,26]. Most studies indicate that households in most developing countries will still depend on solid fuels or biomass energy for decades to come with its attendant health consequences [27].

With its rich endowment in biomass and its low level of technological advancement and industrialization coupled with its relatively low income levels, especially in the large informal sector, it is not surprising at all that the most predominant source of cooking energy in Ghana is biomass since a bigger picture is painted in Sub-Saharan Africa of which Ghana is a subset. A survey conducted by IMANI, Ghana [28] revealed that the main source of cooking fuel of the country is biomass fuel (mostly woodfuel and charcoal) with 38.8% of the population relying on firewood and 59.1% also relying on charcoal. This implies that majority of Ghanaians use firewood and charcoal for cooking however, plant residues such as corn cobs, coconut shells, sugar-cane peels and a host of others which are region specific are also used as cooking fuels [14]. It is ironical that about 70% of the population of Ghana, mostly rural folks, use biomass as their main source of cooking fuel. Sixty-nine percent (69%) of urban households in Ghana uses charcoal as their main source of cooking fuel [29]. About 20.8 million hectares of 23.8 million hectare land mass of Ghana is endowed with biomass resources [30]. On global scale, biomass is the third largest produced primary energy following coal and oil fuels [31]. Apart from woodfuels as already demonstrated by Ghana and other countries all over the world, agricultural residues such as maize cob, rice husk, groundnut shell, straw in general, millet stalk, coconut shells, palm-kernel shells, jatropha residues, moringa, cocoa shells, elephant grass, guinea-corn stalk, sugar cane peels and bagasse may also be used to fuel cookstoves [32,33].

2.2. The biochar technology

The inclusion of biochar technology in this paper was a spontaneous effort to provide some theoretical background to a key component of the title of the paper (Biochar Production). Biochar occurs both naturally and artificially. Most parts of the Brazilian central amazons are naturally endowed with biochar (Terra pretta), [34]. As human life is greatly dependent on food, efforts to sustain crop farming can never be described as wasteful. In the light of the above, it is very important to develop techniques to produce biochar (a product that increases crop yields) to sustain life on earth [34]. In pursuit of this goal among others, a relatively successful vision that has globally emerged for the production of renewable bioenergy, sequestration of carbon in the soil and the enhancement of soil quality, water quality and agricultural productivity is the biochar technology. One of the thermochemical conversion processes for turning biomass into biochar is pyrolysis. Pyrolysis is a simple, robust and scalable technology for transforming diverse biomass source