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Promotion of Carbon Footprint Development Mechanism: A Case Study of Osu Night Market

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Abstract

Energy, one of the fundamentals for economic growth is also one of the fundamental sources of pollutions, through its by-products, as gases emissions; namely particulate matter ($PM_{2.5}$ and PM_{10}). OSU night market on Lokko street, is an old popular market at Klottey Korle constitution of Accra. OSU is a suburb of Accra in which the market is situated. In this market activities normally starts at 3 pm and climax around 9 pm and ends completely around 2 am. During this period mainly, foods are sold to people from all corner of Ghana. Most travellers, mostly drivers and official from government establishment troop there to buy food for the evening. The delicacy or tasty nature of the food attracts people to the market. Food cooked and sold in the market are mainly, kenkey, rice, kelewele, fried yam, fufu, and porridge. Fish and meat like pork are also smoked and sold in the market to go with some of the food sold. It is the cooking and smoking with inefficient cookstove and smoking ovens in the market that causes the air pollution during trading activities. Firstly, a survey cookstoves, smoking oven and positions for taking air pollution measurement were marked. Air pollution levels were measured before and after interventions, and levels of carbon footprint recorded. New clean cookstoves and fish smoking oven with efficiency of 60% and fuel reduction of 66.66% were installed together with huge chimneys to direct the smoke away into the atmosphere. From our findings there was a rise in particulate matter from 820 ug/m^3 to 8024 ug/m^3 before the installation of the clean cookstoves and then decline from 8024 ug/m^3 to 35 ug/m^3 after the installation of the clean cookstoves. After the intervention the average PM2.5 reduced from 1821.625 ug/m3 to 494.75 ug/m^3 and that of Carbon monoxide reduced from 12.96 ppm to 2.575 ppm.

Keywords: ***Institutional cookstoves; Water boiling test; Fuel efficiency; Power and forced air***

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Introduction

The origin of carbon footprint can be mark out as a subdivision of ecological footprint proposed by Wackernagel and Rees in 1996. Ecological footprint refers to the biologically productive land and sea area needed to sustain a given human population expressed as global hectares. In reference to this concept, carbon footprint refers to the land area required to assimilate the entire CO_2 produced by the activities of mankind during its lifetime. The use of carbon footprint became well known, even though in a revised form when the issues of global warming took dominance in the world environmental agenda [1]. Carbon footprint is factually defined as the total emissions caused by an individual, event, organization, or product [2]. Carbon footprint consists of numerous greenhouse gasses, to symbolize the total emissions in a single number these gasses are converted into an equivalent quantity of CO_2. Carbon footprints are measured in tones of CO_2 equivalent or CO_2e. Greenhouse gasses emissions are directly caused by the burning of fossil fuel for electricity, heating, transportation and indirectly caused by the whole lifecycle of a product. Carbon footprints are useful for a number of purposes; including offsetting of emissions, public reporting of greenhouse gas emissions, setting of target to aid in the reduction of emissions, carbon footprint assessment also helps to identify which activities is a key contributing factor to a footprint, carbon footprint analysis are performed in order to measure changes in greenhouse gasses emissions over a period of time, and to monitor the effectiveness of reduction activities. Different types of footprint have different methods and boundaries. Carbon footprint can be categorised into different types including organisational, individuals, products, services, and events. To estimate such activities, the principles are the same; thus, both the direct and indirect emissions for a defined scope of activity are quantified. Carbon footprint assessment is usually performed by the use of devices such as indoor air quality meter, indoor air quality monitor, air capture hoods, portable emission monitoring systems, and laboratory emission monitoring systems. Cooking with traditional cook-stoves which usually requires biomass tends to contribute massively to carbon footprint aside the activities of automobiles (transportation) and electricity. Since cooking is usually carried out in an enclosed environment, it directly or indirectly obstructs the quality of air in the atmosphere. UNFCCC Clean Development Mechanism (CDM). The United Nations Framework Convention on Climate Change (UNFCCC) established the Clean Development Mechanism (CDM) to allow emission-reduction projects in developing countries to earn Certified Emission Reduction (CER) credits, each equivalent to one tonne of carbon dioxide. The CDM has methodologies to produce CERs that are approved by regulators like the European Commission and can also be used for compliance with commitments made under the Kyoto Protocol, an international agreement that set binding targets for 37 developed nations to reduce their GHG emissions. CDM projects can additionally certify their sustainable development benefits to the Gold Standard, thus creating Gold Standard CERs. In Ghana, Fuel wood and charcoal forms approximately about 75% of the fuel source used in our cook stoves [3]. The quest for charcoal and fuel wood for traditional cook-stoves tends to impose massive hassle on the forest reserves in the country. Studies have shown that rate of wood consumption from the forest far exceeds the growth rate of the forests [4].

In under developing and developing countries, biomass fuels are a cheaper source of fuel for cooking and in some circumstances the only hands-on source of fuel for cooking. Particulate matter emissions are associated with a lot of health problems. It is suggested that the dominant proportion of this emission is from cooking with biomass fuels [5]. Cooking with biomass fuels also poses a threat as a great contributing factor to deforestation [6]. About 20 years ago, 32% of the world's population and 45% in the developing world depend mainly on wood fuel [7]; even though technology has advanced over the year, the tradition has not changed much. Most people still rely on wood fuel for cooking and heating. The condition is not different around most parts of the developing world. Globally, an increase in health risk affect the environment negatively, this is as a result of increasing population growth. The Word Health Organisation states that about 3 billion people cook with poorly designed cook-stoves that utilises biomass globally. Nearly 2 million people die as a result of inhaling polluted indoor air caused by the usage of solid biomass fuels. Excess particulate matter in the air has adverse health effects on people. Considering a case study in

1600 cities, the average PM_{10} level was estimated to be 71 $\mu g/m^3$ [8]. Indoor air pollution is associated with numerous diseases including pneumonia in children under age five and Chronic Obstructive Respiratory Disease which causes an annual mortality of approximately 1 million people [9]. A case study in Central America shows that, continuous exposure to smoke from a biomass stove as compared to smoking three packs of cigarettes a day were of no difference in children. The consequences of undeveloped biomass stoves on global warming, human health and deforestation which leads to other environmental degradation like erosion and destruction of habitats of living organisms calls for a worldwide development of improved cook-stoves [10]. Traditional cook-stoves are known to be very polluting and unsustainable. Thus, stove technology could be significantly improved upon to eliminate the negative effects by increasing efficiency through advanced combustion techniques. Nearly about 2-10% of energy is generated and utilised by the traditional cook-stoves, whereas about 82% of the energy produced by traditional cook-stoves is lost to the environment [11]. Studies have shown that incomplete burning of biomass fuel leads to excess emission of particulate matter and greenhouse gasses thus causing change in climate, weather patterns and then accelerates the melting of snow, ice and glaciers, which serves as a source of drinking water and a source of water for irrigation purposes [12]. The implementation of innovatively effective and efficient clean cook-stoves and ovens is a significant means of moderating climate change, as well as saving lives, environment and creating wealth as less fuel to energy ratio is required in cooking with the improved clean cook-stove. It has been observed that there is a significant change in the life of people and the environment which includes an increase in income, employment generation, the acquisition of new skills and knowledge, minimization of deforestation in the forest reserves, protection of water, flora and fauna, massive reduction in emissions and maintenance of biodiversity thus raising the level of environmental awareness. A stove qualifies to be an improved stove if its fuel consumption rate is highly efficient, resulting in less fuel usage, which translates into less cooking cost. Improving combustion efficiency does not significantly causes a stove to utilise less fuel. On the other hand, improving heat transfer efficiency to the cooking pot makes an outsized difference [13]. Improving the combustion efficiency is necessary to reduce smoke and harmful emissions that damage health. Unvented stoves should be used in an open area. When chimneys are not practical the adoption of a hood, or opening windows through the walls or roofing are some of the measures that can be implemented to decline the levels of harmful pollution. The use of a cleaner burning stove can also be helpful in this look but, if possible, all solid biomass stoves should always be fitted with a functional chimney [13]. In Korle Klottey constituency, precisely in Osu, both direct and indirect impact on greenhouse gasses emissions is highly rampant. Osu is situated about 3 kilometres east of the central business district, Osu is a community in central Accra, which is known for its busy fishing, commercial, restaurant and nightlife activity. It is locally known as the West End of Accra. The southern part of Osu is bounded by the Gulf of Guinea whereas the western boundary is the Independence Avenue. The Ring Road separates Osu from the northern district of Labone. The activities of automobiles, heating, electricity generating systems and the whole lifecycle of a product tend to increase carbon footprint in Osu and its environs. The Osu community is equipped with two local markets with moderate pricing, which is the Osu day market and the Osu night market aside the numerous landmarks, restaurants, and expensive dining places. The day market is characterised by selling of items and food stuff whereas the night Market is characterised by vigorous cooking activities. Greenhouse gasses and particulate matter emission rate is escalating due to the extent of cooking, the source of fuel wood and the type of cook-stove used in cooking in the Osu community night market. Poor air quality within the market's atmosphere directly or indirectly causes a lot of health hazard to not just the caterers but also to their customers and people within their immediate surroundings. This poor air quality is as result of the inefficient and ineffective traditional cook-stoves used in cooking. Aside the indoor air pollution which is as a result of incomplete combustion of the biomass used as a source fuel, the smoked fishes prepared tend out to have very sour taste and look very dark after smoking signifying the deposition of polycyclic aromatic hydrocarbon (PAH) compounds on the fishes. This polycyclic aromatic hydrocarbon occurs as a result of the incomplete combustion of organic products and has high tendency of causing cancer in humans. This health related hazards associated with the use of traditional cook-stoves have caught the attention of many stakeholders including the Member of Parliament of Korle Klottey constituency in the person of Honourable Dr. Zenator Rawlings. Over the years efforts have been made to improve upon the use of cook-stoves to eliminate the negative issues associated with the traditional cook-stoves. According to [13,14] their research investigate how to design effective and efficient clean cook-stoves to eliminate excessive greenhouse gasses and particulate matter (smoke) emissions and conserve massive fuel wood usage. Therefore, the motivation of this case study is to reduce carbon footprint in Osu night market by means of replacing traditional cook-stoves with an effective and efficient clean cook-stoves in order to improve upon the lives of the people in Korle Klottey.

Materials, Methods and Methodology

The case study was divided into four sections starting with the visit and meeting the market users by the Parliamentarian of the Klottey Korle constituency. The parliamentarian during the campaign for position in parliament was told of a serious health hazard faced by market users. And that was indoor air pollution. In office, she held a series of roundtable discussion with stakeholder users of the market of the air pollution was of an urgent situation. The member of Parliament (MP) looked for individuals and companies who could deliver a comprehensive solution to the problem. A research and development firm called Comeph and associates won the contract to execute the solution. An initial testing stage of air pollution level was first done using it for one week, after the introduction of interventions was done. First one stove was built to show the women how it works and make changes to suit their ergonomics before the rest were built. This comprised of 4 new clean institutional cookstoves with chimneys, 3 fish smoking ovens and three chimneys through the roofs, that went over the first smoking oven. After the installation of the stoves and oven assessment of the market for air pollution was done then to ascertain the final situation and compare results. Consecutively for six days the indoor air pollution meter was fixed at three different positions and then the air quality in the market was analysed for two days at each of the marked positions from 3:00 pm to 12:00 midnight. Randomly the air quality analysed for two days. Seven effective and efficient clean cook-stoves were installed after the air quality test. Out of the seven clean cook-stoves, four cooking stoves were installed whiles the other three are fish smoking cook-stoves. Finally, the air quality test was also conducted after the interventions for four days, three days at the marked positions for fish smoking and lastly the indoor air quality meter was fixed to analyse the air quality at where the four efficient and effective clean cook-stoves were installed. Not all the stoves were replaced due to lack of funding, however there was quiet an impressive difference.

Design of an institutional cook-stove

#stove design

#stove building materials

#engineering drawing of stove

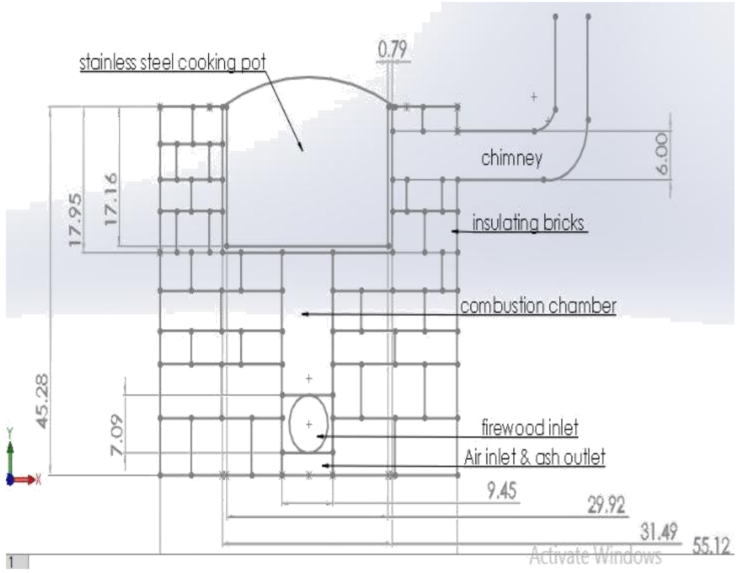

FIG. 1. **Schematic diagram of an institutional clean cook stove**

The pot is a 2 mm thick stainless-steel metal pot, with diameter of 76 cm and a height of 44 cm. It sinks into the institutional cook-stove completely. The gap between the side of the pot and the wall of the institutional cook-stove is 2 cm without skirting. See diagram 1 above. Institutional cook-stove is built of dense normal clay brick with insulating bricks used for the combustion chamber and the wall, where the pot sinks into. Its thermal efficiency under natural draft air flow is 47%. See FIG. 1.

FIG. 2. **Original situation of traditional stoves used**

FIG. 3. **A completed set of institutional cook-stoves. Here we have round and flat bottoms**

Design of fish smoking cook-stove with a hood

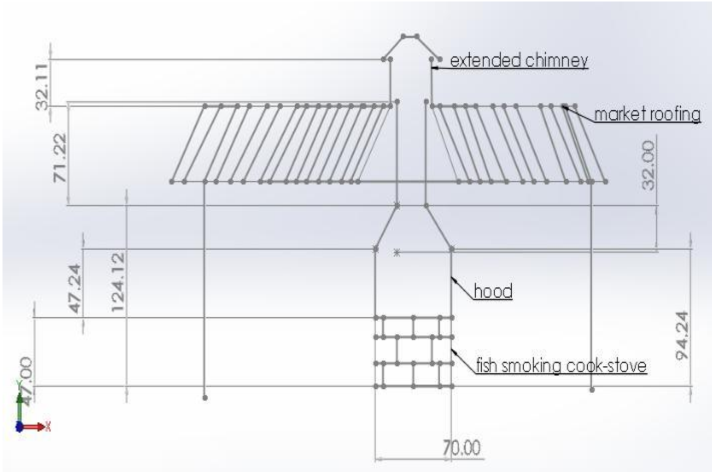

FIG. 4. **Schematic diagram of the OSU night market after intervention**

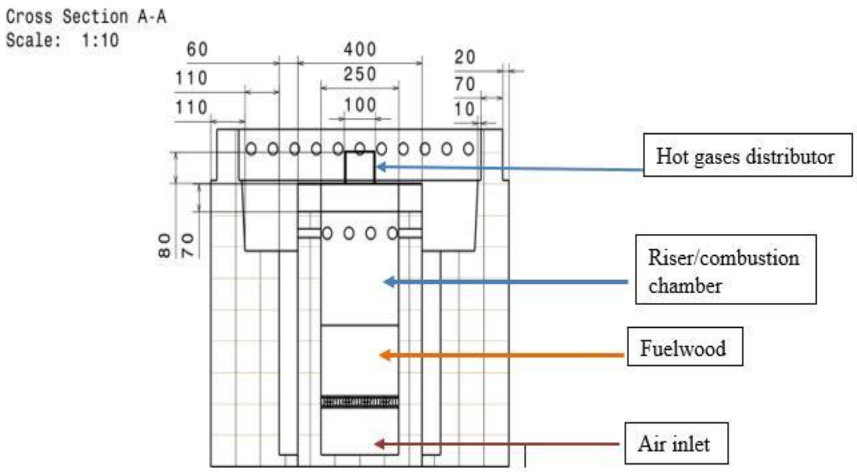

FIG. 5. **Design of the fish smoker**

FIG. 6. **Charcoal fish smoking cook-stove as an approach to replace the old stove made from a car rim closer to it**

FIG. 7. **A paranoma view of osu night market**

Osu night market houses different set of trader and food sellers including fish smokers, banku and kenkey sellers, provision shops, kelewele sellers, etc.

Results and Disscusion

TABLE 1. **Results of the air quality test showing the average particulate matter emission before and after the interventions.**

Date	**Particulate matter $PM_{2.5}$ (µg/m^3) before**	**Date**	**Particulate matter $PM_{2.5}$ (µg/m^3) After**
14.11.18	840	22.11.18	1920
15.11.18	580	23.11.18	99.00
16.11.18	152	28.11.18	135
17.11.18	225	29.11.18	471.00
18.11.18	2731	30.11.18	1338.00
19.11.18	8026	01.12.18	35
Total	12554	Total	3998
Average	2092.33	Average	666.33

From TABLE 1 the total and average particulate matter emitted before and after the installation of the clean cook-stoves for six consecutive days were 12,554 µg/m^3 and 3,998 µg/m^3 respectively was done. Whereas the total and average particulate matter emitted after the installation of the clean cook-stoves for six consecutive days were 3998 µg/m^3. The results showed an average reduction from 31.15% $PM_{2.5}$ even though 4 of the stoves were left to be constructed.

From TABLE 2., below is the total and average carbon monoxide emitted before the installation of the clean cook-stoves for eight consecutive days were 87.77 ppm and 59.1 ppm respectively whereas the total and average carbon monoxide emitted after the installation of the clean cook-stoves for six consecutive days were 10.3 ppm and 2.575 ppm, with average reduction of 67.37%

TABLE 2. **Results of the air quality test showing the average carbon monoxide emission during the first six days before the interventions against the last six days during and after the interventions**.

Date	Carbon monoxide CO (ppm) Before	Date	Carbon monoxide CO (ppm) After
14.11.18	15.7	22.11.18	47.4
15.11.18	13.1	23.11.18	24.20
16.11.18	22	28.11.18	6.0
17.11.18	5.8	29.11.18	15.30
18.11.18	21.4	30.11.18	7.30
19.11.18	9.7	01.12.18	6.30
Total	87.77	Total	59.1
Average	10.03	Average	2.575
European Commission Air Quality Standards: $PM_{2.5}$=25 µg/m^3, CO 10 mg/m^3=0.01 ppm			

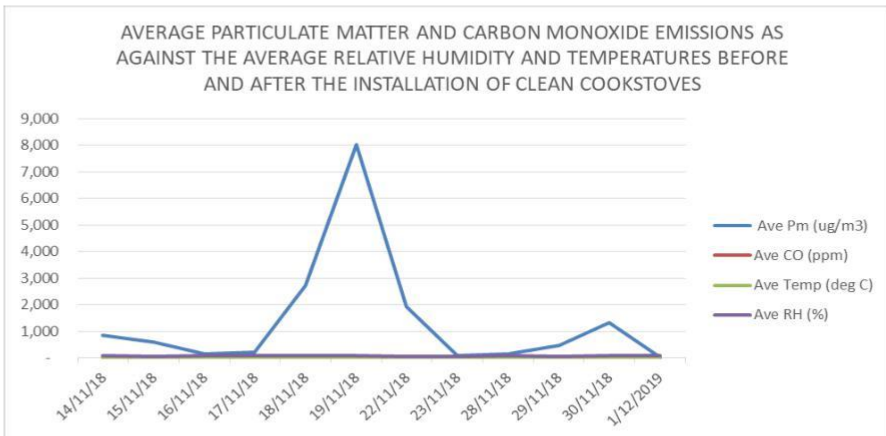

FIG.7. **A graphical representation of the average particulate matter and carbon monoxide emissions as against the relative humidity and temperatures before and after the installation of the clean cook stoves**

The diurnal profiles in figure 5. Shows an inverse relation between both the particulate matter and carbon monoxide emissions as against the relative humidity and temperatures. Since almost all the readings were talking between the period of 3:00 pm to 12 midnight, representing late afternoons and evenings. From the graph there was a rise in particulate matter from 820 µg/m^3 to

8024 $\mu g/m^3$ before the installation of the clean cookstoves and then decline from 8024 $\mu g/m^3$ to 35$\mu g/m_3$ after the installation of the clean cookstoves. Owing to some environmental factors such as the nature of the market sheds and the measurement schedules there was a decrease in temperatures causing a temperature inversion thus reducing the thermally-induced convection nature of the atmosphere. This phenomenon act as a cap inhibiting the diffusion of particulate matter and carbon monoxide off the market shed and with the structure of the market it tends to also increase the accumulation of particulate matter and carbon monoxide emitted. Even though there is negative correlation between particulate matter and temperature in an open environment, it tends to be positive for particulate matter and the relative humidity according to [15]. Osu night market as our case study exhibited quiet a complex and different dynamics as compared to an open environment in the case of [15] findings. As relative humidity (RH) falls, temperature rises thus reducing the amount of moisture in the atmosphere. Warm air tends to hold a lot of water vapour than cold air. It is realised from the graphs that, where $PM_{2.5}$ increases temperature also increases as RH decreases. This is because of the conductive nature of $PM_{2.5}$ and Black carbons, as do absorbs a lot of heat and moisture due to its nano pores from the upper atmosphere of the market, thus creating phenomenon we see in the graphs or data in the appendix. As moisture and heat is absorbed RH rises and temperature sinks. The $PM_{2.5}$ and black carbon become heavy and settle on the beams and ceiling of the market create a tick black and at time sagging or hanging tar as seen in FIG.6. According to [15] condensation of volatile compounds and the increase of wood burning are the possible cause for the increase in particulate matter concentration at night

Conclusion

The design of the stove is such that any fuel consumption is reduced by 60% and making sure users are not affected by heat and emissions, improving revenue from saved fuel, and reduced labour for in search of fuel wood, LPG. For instance, Dede, a kenkey seller or vendor, saved ten Ghs 10.00 now, from her Ghs15.00 fuel expenditure. Her output has triple within the same period of working time. Customers now have expressed their observation of improve indoor air pollution after the interventions. Even though not all the stoves had been replaced the reduction of emission is significant, indicating an improvement in the carbon foot print. Some of vendors have resorted to a shift system of utilising the new stoves due to its comfortability and fuelwood saving and reduction. Generally, European standard was not reached, but that can be explained by the fact that not all clean stoves have been built yet and also, that, the whole market must be reconstructed to cater for good improve ventilation system.

The approach to promote and implement carbon footprint involves dialoguing with stakeholders in terms of what is needed from their understanding of mental model. This involved the technology of the solution and it is going to affect their health. This done to reduce resistance to change. The use of improved cooking devices has been shown for the results, that it is possible to improve the health of both customers and agro-food processors. Though, not every vendor in the market received the new cooking devices, the indoor air pollution reduced by 31.15% $PM_{2.5}$ and 67.37% carbon monoxide.

Recommendation

It is recommended that the market must be redesign to take into consideration ventilation system, including a place to clean and wash dishes. It is also realized and recommended, that, approach of behavioural science/change/all inclusive, can save lives and protect the environmental health, save money and human health in the process of promoting carbon footprint. It can enhance governance thus, trust, which the fundamental element in getting things done quicker potential through behaviourally-informed interventions in carbon foot print execution thus mitigating climate change.

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