Adoption of Eco cook stoves as a Way of Improving Energy Efficiency

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Abstract

Cooking is one of the household activities with high energy requirements, especially for communities living off the grid in sub-Saharan Africa. Traditionally, open stoves have been used for cooking and these are energy inefficient and have potential to release harmful pollutants to the environment. The adoption of eco-friendly cook stoves is therefore of importance in order to conserve energy and also improve energy efficiency. The consideration of design

parameters such as heat transfer, combustion and thermal efficiency as well as the material of construction is therefore of utmost importance.

Keywords: Cook stoves, energy conversation, energy efficiency, sustainable development

1. Introduction

In Africa, above two billion people use cow dung, firewood and charcoal as sources of cooking energy (Smith et al., 2004; Sambandam et al., 2014). Most of this cooking is done in open fires resulting in low fuel efficiency and release of emissions to the environment (Okpu, 2015). This has negative impacts such as human mortality, morbidity, air pollution, deforestation and climate change (Smith et al., 2004; Sambandam et al., 2014). Utilization of biomass as a source of fuel also results in various negative impacts especially on time, strain and risk to children and women during harversting. Figure 1 shows an open traditional fire that is used as a source for cooking energy in the Sub Sahara Africa.

Figure 1: Open fires used for cooking in most Sub Sahara Africa, examples of Uganda (left), Tanzania (right) (Adkins et al., 2010)

There is therefore need to use eco- friendly biomass cook stoves that are cost effective and have low risks so as to minimise the negative impacts on humans and the environment (Ruiz et al., 2011). Adoption of cooking stoves that are environmentally friendly is needful for mitigation of negative impacts associated with cooking with open fires. An example of good usage of eco- friendly scheme is the Biomass Energy Strategy (BEST) that was adopted in Rwanda to promote the usage of charcoal and other related renewable energy fuels. With the BEST intervention, at least 80% of efficient charcoal usage was targeted (Adkins et al., 2010). In addition to reducing deforestation, the adoption of eco cook stoves promotes energy conservation and efficiency (Timko and Kozak, 2016). The investment in eco cook stoves results in reduced indoor air pollution as well empowerment of women and children. In order to well integrate the use of eco- friendly cook stoves, the value chain, activities and experiences of stakeholders involved as well as policies and regulations governing the usage of cook stoves need to be well understood (Blodgett, 2011).

2. Value chain for improved cook stoves

The value chain for improved cook stoves includes the designs, manufacturing, retail and distribution of cook stoves (Adkins et al., 2010; Blodgett, 2011). The roles, activities and effectiveness gaps of the involved stakeholders are detailed in Figure 2.

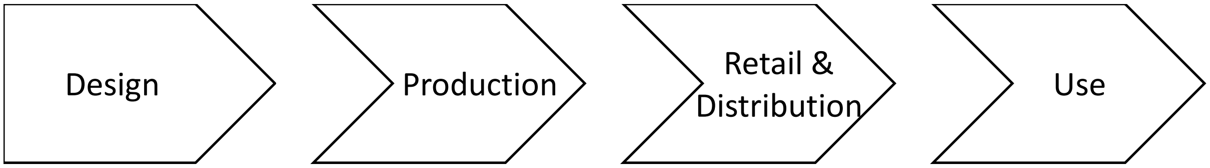

Figure 2: Improved cook stoves value chain (Blodgett, 2011)

The various stages that are involved in the design, development and testing of eco cook stoves include: technology development, laboratory emissions testing, testing in the rural energy lab as well as pilot testing in the village. The schematic representation of these stages for eco cook stoves commercialization is given in Figure 3.

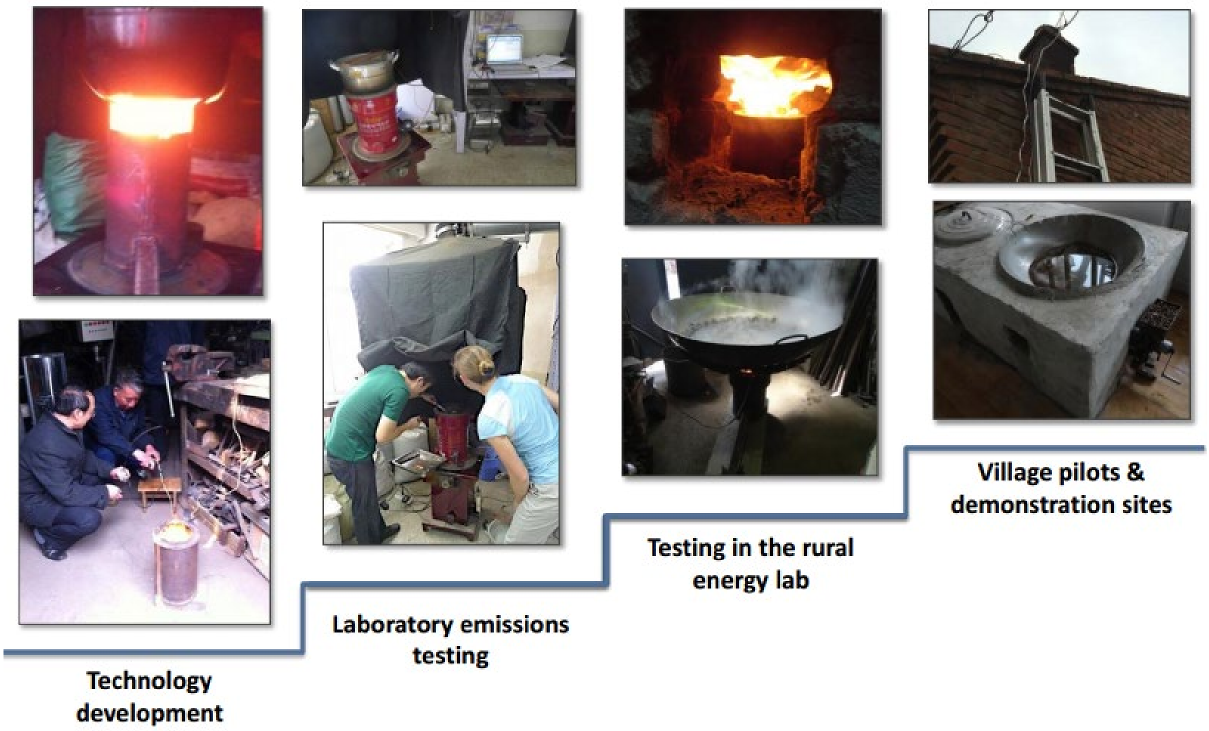

Figure 3: Stages for eco cook stoves commercialization (https://www.epa.gov/sites/production/files/2015-08/documents/baumgartner.pdf)

In this paper, attention is given to the value chain, particularly the stage of design. From the cook stoves observed in sub Saharan Africa, it is apparent that pertinent design considerations have not been taken into account. These design considerations are highlighted in a bid to improve future designs of cook stoves especially in sub Saharan Africa.

3. Design considerations for cook stoves

The design considerations for eco cook stoves include but are not limited to: characteristics of the fuel, optimization of the fuel type, heat and mass transfer, process control as well as materials of construction.

3.1 Combustion and Heat Transfer

The major processes that take place in eco cook stoves are combustion and heat transfer from the cooking stove. Inefficient combustion of biomass results in the emission of harmful substances. Efficiencies of both the combustion and heat transfer have an impact on fuel efficiencies and cooking times. Placing of the cooking vessel closer to the fire enhances the transfer and can also result in quicker cooling of volatiles leaving the fuel bed. The combustion and heat transfer efficiency of cook stoves is affected by the formation of emissions, the combustion chamber density, mixing, geometry as well as the air-to-fuel ratio (Jetter et al. 2012).

3.2 Performance parameters of eco cook stove

Performance parameters of efficient cook stoves are measured through various parameters including the modified combustion efficiency, heat transfer efficiency, overall thermal efficiency, fuel burning rate as well as the water boil test (Dhopte et al., 2015).

3.2.1 Modified combustion efficiency

Modified combustion efficiency (MCE) shows how well the fuel burns in terms of conversion to heat and radiant. Incomplete combustion results in the production of dangerous pollutants as carbon monoxide, carbon dioxide and methane.

3.2.2 Heat transfer efficiency

Heat transfer efficiency (THE) is an indication of the amount of energy delivered for cooking against the total heat released from fuel combustion. Eco cook stoves are therefore designed to minimize the heat loss to the environment.

3.2.3 Overall thermal efficiency

The overall thermal efficiency (OTE) is a combination of both the heat transfer and fuel combustion efficiencies (Dhopte et al., 2015). Equation 1 represents the thermal efficiency calculation.

$$OTE = MCE \ X \ HTE \dots\dots\dots\dots\dots\dots (1)$$

An eco cook stove that is properly designed has a balance of both the heat transfer efficiency and the modified combustion efficiency (Jetter et al., 2012).

3.2.4 Process control devices

Process control devices such as sensors and fan drivers help in the optimal functioning of the eco cook stoves. Process control helps in the reduction of emissions as well as improvement of the heat transfer efficiencies (Biomass Program, 2011). These can be in their simplest forms in order to reduce cost and increase uptake of eco cook stove to the poor of sub Saharan Africa.

3.2.5 Materials of construction

Various types of materials are required for the construction of eco cook stove's combustion chamber, insulation as well as heating probes. Materials must be able to withstand high temperatures, thermal gradients as well as physical stress. The material chosen must be highly durable, cheap and readily available. Due to the factors listed above, metals and ceramics are mostly used in the production of eco cook stoves.

4. Conclusion

Eco cook stoves need to be adopted for usage in the sub Sahara Africa as a means of improving energy efficiency. Proper design considerations, process control and automation as well as usage of the right material of construction need to be taken into account.

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Biographies

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