Journal of Energy Research and Reviews

3(4): 1-12, 2019; Article no.JENRR.52563
ISSN: 2581-8368

Successes and Challenges of Improved Biomass Cooking Stoves Adoption along the Product Value Chain in Kilimanjaro Region, Tanzania

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JENRR/2019/v3i430108
Editor(s):
(1) Dr. Bojan Durin, Department of Civil Engineering, University of North, Varaždin, Croatia.
Reviewers:
(1) Emmanuel Attah Ubuoh, Michael Okpara University of Agriculture, Nigeria.
(2) Jacopo Barbieri, Politecnico di Milano, Italy.
Complete Peer review History: http://www.sdiarticle4.com/review-history/52563

Original Research Article

Received 05 September 2019
Accepted 18 November 2019
Published 23 November 2019

ABSTRACT

The aim of this study was to assess the adoption of ICS along the value chain. The existing studies have focused much on measuring adoption based on the user's installation or purchase of the ICS and few have gone to the level of assessing other aspects along the ICS value chain. The argument of this paper is that adoption is a multidimensional concept that goes beyond the initial acquisition of the stove to the sustained use of the same. Using a cross-sectional study design data were collected from 294 households in two Districts of Kilimanjaro regions and were analyzed using both quantitative and qualitative approaches. The findings show that at the lower levels of value chain i.e. promotion and distributions the efforts have been somehow successful since people are aware of ICS benefits and negative effects of using traditional fuels and stoves. In addition, various stove distributors and technicians are in place. On the other hand, the uptake is limited since only 26% of all households had ICS in place of which only 22.1% had functional stoves. The intensity of ICS use is very limited and households have not integrated the stove into household cooking behavior. The study concludes that the stoves program implementers have adopted a disintegrated approach that disconnects various levels of the value chain. The efforts are much concentrated at lowers levels with limited interventions to address challenges limiting uptake, the intensity of use and sustained

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adoption. The study recommends that a holistic and integrated approach that will facilitate ICS adoption along the value chain should be adopted. This approach will facilitate forward and backward communications on challenges facing each level of the value chain.

Keywords: Improved cookstoves; biomass; value chain; adoption; the intensity of use; sustained adoption.

1. INTRODUCTION

The use of biomass in a traditional way is associated with significant negative environmental and health effects with an estimated 4.3 million global deaths directly associated with household air pollution [1]. Therefore, in reducing adverse human health and environmental impacts caused by the burning of traditional biomass improving access to affordable, clean and reliable energy services for cooking is essential for developing countries [2]. Governments around the world are looking to address these problems by scaling up access to cleaner cooking technologies and fuels [1]. It is unfortunate the investment to cleaner cooking solutions like electricity and LPG are out of reach to many consumers in poor countries given its high investment costs [3].

Given the expected continued dominance of biomass as a major source of cooking energy in developing countries, the feasible short and medium-term solution is to move to efficient utilization of biomass through improved and efficient cooking technologies like improved biomass cookstoves (ICS). Despite concerted global efforts to promote improved biomass cookstoves and its apparent multiple benefits less than 30% of biomass users use any form of ICS [4] and sustained use has been a challenge [5]. The adoption of clean cooking technologies including ICS goes beyond initial stove acquisition and requires attention on how to bring the stove adoption to scale [4]. Adoption and its sustenance are affected by various factors that cut across the value chain of ICS. Therefore, the challenge remains on how to implement the stove programs that will achieve sustained use and render tangible health, environmental, and social benefits to the target populations [6].

The argument of this paper is that adoption is a multidimensional concept that cannot be measured by using a single metric on whether the household has a stove in place or not. As explained before, the improved stove adoption should go beyond the household purchase or installation of the product to the user's behavior change in terms of healthy cooking practices and understanding of the economic and social benefits of the stoves that will facilitate sustained use [4,7]. Therefore, the adoption of ICS requires analysis that goes beyond the initial uptake of the stove and considers the adoption dynamics along the product value chain. The product value chain starts from the existing policy environment to designing, promotion, distribution & uptake, the intensity of use and sustained adoption [8]. It is imperative to understand what happens in each node of the product value chain and its key features that will facilitate or hinder long term intended objective of the ICS programs. Failure to understand what happens in each product value chain node will result in a poor understanding of the practical challenges hence impaired adoption and sustained use.

It was declared in the workshop that was conducted in the year 2015 in Peru involving various clean cooking solutions stakeholders around the world that there is no standard agreed indicators and framework of measuring ICS adoption [8]. Therefore, program implementers are using a number of stoves distributed or sold to be an indicator of adoption. This limited indicator is contrary to the general objective of the ICS program that intends to achieve some broad benefits like reduction of the health problems that require user's behavior change and sustained use of the ICS. To maximize the energy-saving and potential health impacts from ICS, the stoves must first be acquired, then used correctly and consistently. Most important, the stoves must come to displace the use of the traditional stove [4]. To solve the challenge raised in Peru on measuring ICS adoption, the workshop participants proposed a practical framework for measuring and evaluating the potential benefits that can be achieved in the adoption of ICS along the product value chain. Therefore, this paper adopted the framework to assess factors for ICS adoption along the product value chain. The existing studies have focused much on measuring adoption based on user's installation or purchase of the ICS and few have gone to the level of assessing sustained adoption and other aspects along the value chain. The findings contribute to the general understanding of the

success and challenges of ICS adoption along the value chain.

2. ICS PRODUCT VALUE CHAIN CONCEPT

Adoption entails the process that goes beyond just accepting the technology at home to include the extent to which the stoves are substituted with traditional stoves and regularly used [9]. However, a review of Tanzania's experience in promoting improved solid fuel cookstoves shows that the focus has been more on increasing production and dissemination of various prototypes of improved cookstoves with fewer efforts to ensure stoves are regularly used. Some studies have shown that some of the disseminated cookstoves are used less frequently and some are completely abandoned [10] hence registering limited success of the stove promotion program. Studies by [11,12,13] argued that for successful outcomes of any intervention that intends to change people's behaviors consideration of both intensive and extensive margins of behavior is important. This implies that, it is not only the mere technology adoption that counts (extensive margin) rather, the focus should also be on the way new technology is used [13]. This necessitated the need to assess product adoption along the value chain.

The study adopted the clean cooking alliance practical framework for measuring and evaluating the potential benefits that can be achieved in the adoption of ICS along the product value chain. The framework highlight key indicators of adoption and appropriate measures from promotion, distribution & uptake, the intensity of use and sustained adoption [8]. According to the framework, promotion implies the sharing of information and the creation of motivation to adopt healthy behaviors in food preparation by generating correct and sustainable demand and the use of ICS. At the individual and community level, it shows actions to inform, motivate, and raise awareness on clean cooking to generate demand and sustain correct and consistent use. Promotion stands as an important stage in the ICS adoption value chain since it will increase the knowledge, awareness and attitude level on clean stoves, which will ultimately create demand for the stoves and motivation for sustained demand and use. Studies have shown that poor uptake of ICS is attributed to low awareness of stoves benefits [14]. The stoves promotion approach needs to be contextualized. The packaging of stoves awareness will depend on the customers' socioeconomic status. For example, focus on respiratory health benefits from improved stoves may be misplaced if users consider health benefits to be of low-value [15,16].

Distribution involves mechanism for stove access (for stoves that meet the needs of users), with continuous availability, access to parts, and repair services. The distribution focuses more on the supply-side that will facilitate access to stoves that meet users' needs. For example, there is a debate on whether ICS distribution programs that offer subsidies will be successful or not in ensuring high stove uptake and usage. Given the low purchasing power of most target ICS consumers, the scholars have different views on the appropriate distribution models that will ensure wide uptake and continued use of the stoves. The failure of the cookstoves program in many African countries was attached to the free or subsidized distribution of the stoves. The studies by [15,16] argued that ICS will be widely distributed if there are subsidies or substantial reductions in production and distribution costs while other scholars discouraged the free distribution of ICS with the argument that people do not appreciate and, consequently, do not use what they receive as a gift [13]. Therefore, it is important to understand the existing landscape of stove access and supportive infrastructure for the same in a study area. As shown in Fig. 1, the study assessed the presence of stove vendors/providers, user's awareness about their vendors/providers, availability of spare parts and repair services and stove finance mechanism present in the study area.

On the other hand, uptake refers to the presence of a stove in a household but not necessarily in use. It is expected that the presence of conducive promotion and distribution efforts will facilitate the household's uptake of the stoves. Therefore, it is important to establish the level of stove uptake by assessing the type of improved stoves owned by households and whether available stoves meet the user's need. The uptake of the stove implies initial adoption that will not facilitate long term realization of multiple benefits of the stoves. The realization of the benefits depends on the household's intensity of use. The intensity of use is the degree to which clean stoves/fuels have displaced traditional stoves for household cooking purposes. Therefore, assessing the displacement of traditional stoves when ICS is introduced in the

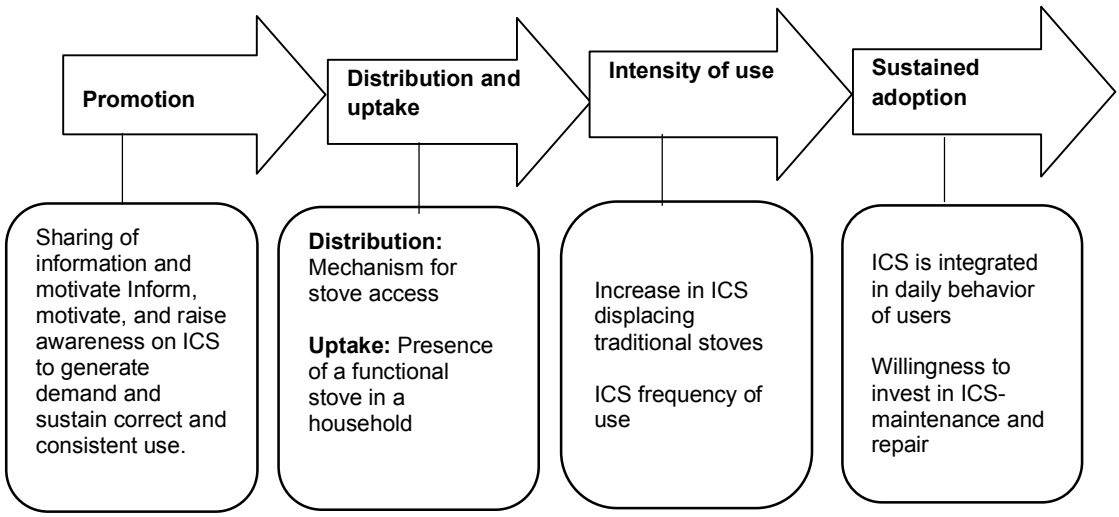

Fig. 1. Improved biomass cookstoves product value chain from promotion to sustained adoption (adopted from a clean cooking alliance, 2015)

household becomes an important measure [17]. The stove-stacking behaviors are very common for households reported to adopt improved cook stove, this involves the behavior in which cooks simultaneously use both traditional and improved cookstoves [6,13,15]. The stacking behavior results in very modest or non-existence of fuel wood saving and also marginal reduction of household air pollution (HAP) and subsequent marginal health benefits [6]. The author further argued that to successfully implement clean fuels and cook stoves, it is necessary to understand all the types of fuel–stove combinations found in the homes and their dynamic use patterns, [2] the connections among household needs, behavior, and culture that shape the extent of the residual use of traditional fires after the introduction of clean fuels and stoves, and [3] the health, environmental, and socioeconomic implications of the actual patterns of stove use [6]. Therefore, it is important to assess if the household considers improved stoves to be the primary stoves and secondary if possible. Therefore, this paper presents the types of cooking stoves owned by households and establish the most common stoves used for household cooking purposes. User's opinions and why the ICS does not replace traditional stoves have also been presented.

The high degree of traditional stoves displacement implies the high chances of sustained adoption. The sustained adoption is the degree to which clean cooking is integrated into the daily behavior of users with no intention of reverting to traditional stove/fuel. if users decide not to use the stove regularly and properly, avoid regular maintenance, or do not update their beliefs about how to use it, the desired human health, climate, socio-economics, and environmental benefits may not be achieved [18,19]. The sustained adoption is reported to be affected by various factors including failure of the stoves to meet user's needs [20].

3. METHODOLOGY

The study was conducted in Hai and Rombo District in the Kilimanjaro region of Tanzania. The selection of two districts was based on the criteria of having improved stove promotion and dissemination interventions. In Rombo District, the selected villages were Shimbikati, Manda Juu, and Mamsera Juu, while Foo, Nkuu Sinde, and Nshara Villages represented Hai District. The cross-sectional study design was employed hence data collection was done only once. The household sampling frames were constructed from the village registers. In events where the hamlets (sub-village) registers were not up-dated the Village Executive Officers (VEO) and Village Chairpersons (VC) were used to provide the information required to construct the sample frames. A simple random sampling technique was applied to select a total of 294 households for interviews. A pre-tested structured questionnaire was used to collect quantitative data from households. During the household interviews, elderly members of the household (husband, spouse and other elder members) were encouraged to be present. This was due to the fact that the study intends to collect the

opinion of the household than individual respondents. The qualitative data were collected through focus group discussions (FGDs) and key informant interviews using a checklist of questions. The qualitative data provided in-depth information that could not be collected through a structured questionnaire. With the recognition that energy needs differ between men and women and within age groups, the study organized separate FGDs for women and men and one combined group for men and women. Descriptive analysis was applied for quantitative data while qualitative data were analysed using content analysis.

4. RESULTS AND DISCUSSIONS

4.1 ICS Promotion Efforts

Efforts to promote improved cookstoves were found to be existing in the study area. The efforts target on increasing consumer's awareness about the improved cook stoves. The consumer's awareness about the social, economic, environmental and health problems associated with the use of traditional three-stone stoves is expected to increase consumer's demand on the product and hence develop the intention to adopt improved cook stoves. In addition, awareness campaign serves to promote the benefits of improved cook stoves. The campaigning efforts such as the promotion of stoves through sensitization, demonstrations, and trials have proved to be important not only for ICS adoption but also in increasing the chances of using stoves regularly [21].

As shown in Table 1, there are various actors working to promote improved cookstoves in the study area but the leading one is Tanzania Traditional Energy Development Organization (TaTEDO). TaTEDO is a famous non-governmental organization that operates in the study area. The organization focuses on developing different designs of ICS, creating awareness on the benefits of ICS and also training local artisans to design locally adapted stoves. Apart from organizations, some individual efforts were also realized, for example, a famous *Dr. Mwasha stove* which is movable and without chimney was designed by an individual and sold at the village at a cheaper price than an improved stove with a chimney. The existence of various promoters and designers of ICS ensures the availability of various designs of ICS hence creating wider choices for consumers. The study by [22] found that the adoption of ICS is higher in households supplied with more than one type of ICS.

The awareness campaigns by various stoves promoters can be considered successful since respondents could list the potential benefits of using ICS. As shown in Table 2, the benefits of improved stoves are well known. The leading benefits cited were a reduction in fuel consumption and cost (58%), making cooking activity easy and less stress (14.2%) and the reduction of indoor air pollution (11.2%). Other studies have found that the stoves that lead to an economic saving in terms of reduction in fuel wood consumption and the cost related to fuel wood purchase have the potential to be adopted by households [23,24]. Therefore, given this evidence by previous studies, it is logical to argue that the current acknowledgment by community members on fuel consumption reduction by ICS to be a good indicator for future ICS adoption.

Table 1. Actors/ organizations promoting improved cook stoves

Name of the actors/ organization	Frequency	Percentage
TaTEDO	108	77.7
Kilimanjaro native cooperative union (KNCU)	3	2.2
Private designers	28	20.1
Total	139	100

Table 2. Benefits of improved stoves

Benefits	Frequency	Percentages
Reduced fuel consumption and cost	98	58
Reduced indoor air pollution the house roof remain clean	19	11.2
Reduced health problems associated with the use of firewood	10	5.9
Doesn't need constant supervision during cooking	24	14.2
Shorten cooking time	10	5.9
Enjoying tasty food without smoky aroma	8	4.8
Total	169	100.0

The knowledge and awareness about problems associated with the use of traditional stoves and firewood for cooking were well known. As shown in Table 3, mostly cited problems are health-related like coughing, eye itching, headache, flue and burn cases. Also, the uncomfortable cooking environment due to smoke was cited by very few. The findings from qualitative data show that women are considering the smoky cooking environment to be normal to some extent. During female FGD in Nshimbikati Village, women were asked to whether the presence of smoke in the kitchen could stand as a drive to look for an alternative smoke free cooking stove and the answer was as follows;

Cooking in a smoky environment is not something bothering women much… most of us were grown up in the same environment unless you are new to this environment or from urban (Female FGD- Shinmbikati Village)

While women don't consider the smoky cooking environment to be an issue of concern for men it was cited to be a problem limiting time to socialize with the family.

Most of us who we don't own and use improved cookstoves with chimney are not sitting with our wives while cooking or any time the fire is on. You can't enjoy given the smoky environment in the kitchen. This is even exacerbated by the scarcity of fuel where women are using undried firewood (Male FGD- Nshara Village)

The quotation from male household members shows that they prefer a clean cooking environment hence it is expected that since the ICS produces less smoky they stand a better chance for future adoption. A study which was conducted in Rwanda found that the cleanness and low smoke production to be a key facilitator for ICS adoption [25].

4.2 Distribution and Uptake Efforts

The mechanism or landscape for ICS access influences stoves adoption by potential users. This implies that stoves should be locally available and repair and maintenance services should also be guaranteed. To ensure a continuous supply of the various designs of the ICS TaTEDO embarked on a capacity-building where selected interested people especially youth were provided with entrepreneurship and business skills and market development training. This effort ensures the availability of various paraprofessional as shown in Table 4. The local improved stove technicians are found in various villages to provide construction and after sale services.

Table 3. Problems associated with firewood use and collection

Problems associated with the use of firewood	Frequency	Percentage
Headache	37	8.6
Coughing	190	44
Eye itching	183	42.4
Flue & sneezing	10	2.3
Burn accidents	10	2.3
Uncomfortable cooking environment (smoke)	2	0.5
Total	432	100
Problems associated with the firewood collection		
Physical injury to firewood collectors	96	65.7
Sexual and emotional/physical harassments from forestry guards	27	18.5
Headache	16	11.0
Wild animals and snake encounter	12	8.2
Total	146	100.0

Table 4. Presence of various energy technology vendors and technicians

Type of vendor	Frequency	Percent
Improved charcoal stove technicians	14	6.2
Solar units and spare parts dealers	6	2.7
Improved firewood stoves technician	190	84.4
Biogas construction technicians	11	4.9
Solar technician	4	1.8
Total	225	100

The financing approach of the stoves plays a key role in the adoption of ICS. Among the few households reported to have improved stove with chimney only 6.8% paid the full cost of the stove while the rest were subsidized by organizations implementing the program in this case TaTEDO. The subsidies were only for the ICS with a chimney that is a bit expensive. Financing was mentioned as one of the limiting factors for ICS adoption in the study area. Though the improved cookstoves with chimney have broader benefits like reducing indoor air pollution that positively impacts the health of users, unfortunately, the design perceived to be expensive than other models. There is a debate on whether the cost of ICS is a limiting factor for ICS adoption or not. While other studies have cited cost to be the limiting factor [26] others have shown that the option of offering ICS free of charge will not promote the intensity of use. Contrary, a study by [15] in Ethiopia shows that the provision of ICS in subsidizing cost increases the intensity of use.

The study found that the cost of constructing ICS with chimney was reported to range between Tanzanian Shillings (TZS) 120,000 to 150, 000 TZS (52- 65 USD). The cost includes materials and minimal labour charges. During focus group discussions in various villages, it was revealed that there is no financial institution that offers loans to support the purchase or construction of improved cook stoves. Further, it was reported that the individuals who are members of the Saving and Credit Cooperative Society (SACCOS) and Village Community Banking (VICOBA) had a chance to take a personal loan and pay for the stove construction. Despite this opportunity, it was noted that taking a loan for the stove construction was not given priority given the most other pressing needs in most households.

The ICS uptake is achieved once the household makes a decision to buy or install the stove in the households. In this paper, uptake is presented based on two key aspects. One, if the household is having an ICS in place and the second if the households have a functional stove. Given the promotion and distribution efforts in place, the study found that only 26.2% of all households have adopted various types of improved cookstoves (Fig. 3). As shown in Fig. 4, the uptake in terms of a household having functional stoves stands at 22.1%. This is due to the fact that some stoves are placed in the households but they are having various defaults hence no longer working. This is worth considering them as non-adopters since the household will not be using the stove for cooking purposes hence leading to failure to meet the general aim of the stove programs.

4.3 The intensity of Use and Sustained Adoption

In assessing the intensity of use, the paper focuses on the extent to which the household replaces the traditional stove with ICS and also if the household makes an ICS a primary stove for cooking. As shown in Table 5, among all households with improved stove only 39% make ICS be their primary cooking stove. The rest reported ICS to be either secondary or completely not used at all. The reasons for not using ICS full time were many but can be grouped into social, technical and cultural factors. For example, women reported maintaining traditional stoves for various purposes like to use when they want to roast maize, meat or prepares the local brew. Again the technical aspects were more on the designing of the stove where women complain about the stove design especially the one with a chimney to be limited to a specific cooking pan size hence not allowing the cooking of a large amount of food. The same reasons for maintaining traditional stoves and less frequent use of ICS were reported by [27,28]. In addition, it was revealed that once women want to cook for the large family they always go for the traditional stove which is flexible. Generally, women believe the traditional stove to be fast in cooking hence being appropriate once they want to prepare food in a hurry or under pressure [29]. Other studies have reported limited use of the ICS after the acquisition, for example, a study by [30] in Uganda, reported that ICS famous known as Top-Lit Updraft Cook stove to be used only for 7% of all cooking events while traditional stoves count up to 90% of all cooking activities.

The intensity of the use of ICS was also affected by the technical default of stoves. Among the 15.5% of stoves reported to be no longer function, 28% of them were completely broken while the rest were having various technical related challenges (Fig. 5). For example, some stoves reported not able to emit the smoke out through the chimney while others were not transferring heat to the cooking pan after lighting. The technical and design-related problems were attributed among other factors use of some incompetent technicians within the village. It was

also found that the households having the nonfunctional stoves have lost hope to go for maintenance services. The existence of nonfunctional stoves affects the reputation of the stoves to the community hence increasing the likelihood of non-adoption. The study by [21] argued that the reputation of the new cookstoves among community members stands as a key predictor for ICS adoption.

During focus group discussion it was observed that the users were complaining of poor post-sale follow up from technicians after stove construction.

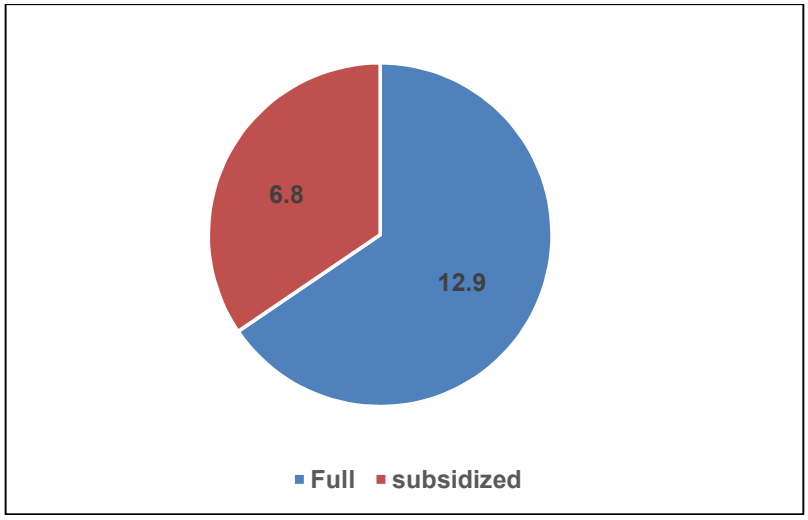

Fig. 2. Payment mode for ICS

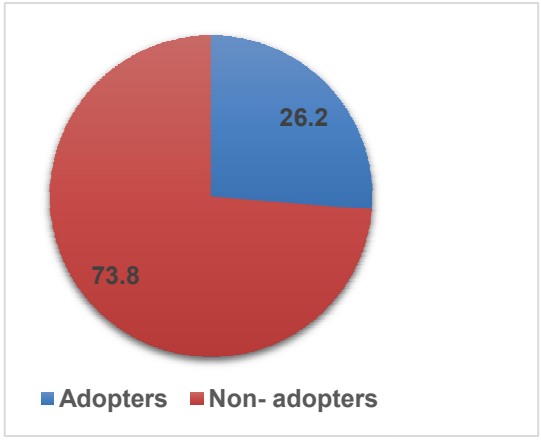

Fig. 3. Adoption of ICS based on the availability of the stoves at household

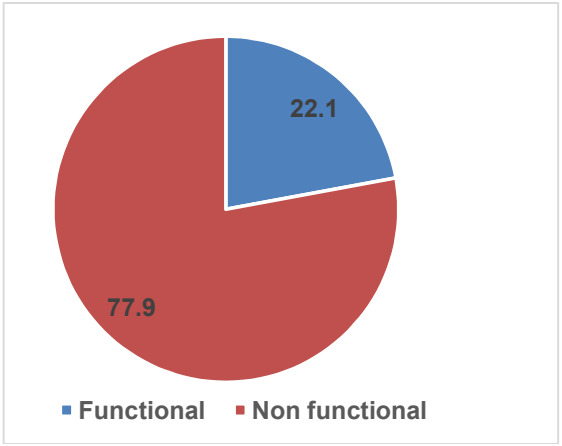

Fig. 4. Adoption based on the functionality of the stoves

Table 5. Frequency of ICS use in the household

Rate of ICS use	Frequency	Percentage
Primary stove	30	39.0
Secondary Partially used - combined with a traditional stove	35	45.5
Stopped/abandoned	12	15.5
Total	77	100.0

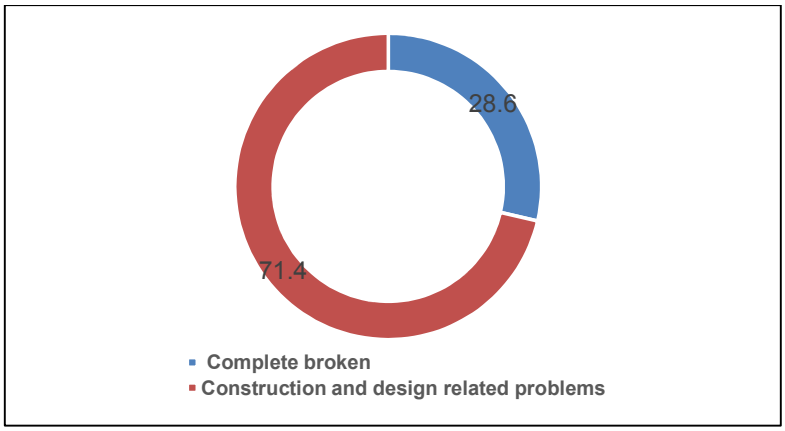

Fig. 5. Key reasons for nonfunctional stoves

Table 6. Future plan to change from the traditional cooking stove

Type of stove	Frequency	Percentage
Improved firewood stove with chimney	82	67
Improved firewood stove without a chimney (locally made)	9	8
Clean stoves	22	18
Sawdust stove	5	4
Not yet decided	4	3
Total	122	100

There are people who installed stoves but hey had never worked, on top of that, no technician is ready to come and help. Once you give them money after installation they don't pay any services after sell. Very few who are willing to visit their customers (FGD participant- Foo village).

The quotation shows that the interaction between the users or customers with their technicians to be very minimal that may affect the intensity and sustained adoption. The study by [4] insisted on the continuous engagement between the sellers and customers to allow for the management of challenges along users' learning cycle. After the acquisition of the stoves, users need continuous follow-up and advice to ensure correct use. It was revealed by [14] that knowledge on the correct use of ICS to be limited in the study area that affects the stoves performance and consequently leads to consumers' negative perception about the stove [31]. Prospective customers of any product keep an eye on how the technology is performing for the early adopters hence to make an informed decision. The negative attributes were revealed to influence non-adopters in making the decision to adopt ICS [31]. In the same line, the discussion with a key informant in Foo village confirms the same.

Most of our colleagues who constructed improved stoves with chimney are either not properly working or completely not working, except for a few stoves. It is stressful indeed. If the designers will not improve the stoves the likelihood of many families adopting will be minimal in the future (KI- Foo village).

The sustained adoption reflects more of behavior change within the society where according to the product value chain framework the assessment focus on how the ICS is integrated into the daily behavior of users. It is expected that the household adopted ICS would show no interest to go back to traditional stoves. Specifically, the key indicators are the increasing demand for maintenance and replacement, change of stacking behavior, willingness to pay for the ICS and maintenance and time period of ICS use. As it has been presented before, the stacking behavior is still very common since almost every household has maintained a traditional stove and very few households are using ICS full time. In addition, the existence of nonfunctional stoves in a household with limited interest to repair raise a

concern that the ICS is not a priority technology in the household.

Assessing willingness to change and adopt ICS in the future revealed diverse responses. The results can be grouped into two different options, one is the willingness to change the end-use technology while maintaining the use of biomass and the second is based on changing the fuel type by moving up the energy ladder or using alternative energy sources. The results as shown in Table 6 revealed that 77% falls on the first option where 67% indicated to plan to shift into improved cookstoves with chimney while 8% prefer to shift to improved cookstoves without a chimney. The shift to clean cooking stoves like biogas stove, electrical stoves and others were mentioned by 18% of all households. The results indicate that regardless of biomass access being a problem it is still the most available and affordable source of cooking fuelwood in the study area. The complete switching to more clean and efficient cooking energy in the near future will not be realized. This is well confirmed with the fuel stacking model were studies by [32,33] argued that the households will continue integrating modern fuels and technologies slowly in existing energy patterns.

5. CONCLUSION AND RECOMMENDATIONS

The use of the product value chain framework in assessing the successes and challenges of ICS adoption has been useful to identify the areas that need further investment. Generally, the study concludes that success is registered at lower levels of value chain especially on the promotion and distribution of ICS but with limited success in terms of stoves uptake, intensity, and sustained use. This scenario presents the disintegrated approach adopted by ICS promoters. The disintegrated efforts imply having interventions that focus more on one level of the value chain with limited integration to other levels. The study also concludes that limited success on higher levels of the ICS value chain to be attributed to the failure of stoves to provide expected services to the users. The integration of ICS into users' cooking systems and behavior has been limited given the technical challenges experienced by some adopters. The study recommends that a holistic and integrated approach that will facilitate ICS adoption along the product value chain should be adopted. This approach will facilitate forward and backward communications on challenges facing consumers in each level of the value chain hence facilitate ICS program designers and implementers to offer feasible solutions.

ACKNOWLEDGEMENT

The author acknowledges Research for Poverty Alleviation (REPOA) for financial support to carry out fieldwork. Also, acknowledgment extended to the German Academic Exchange Service (Deutscher Akademischer Austausch Dienst - DAAD) for granting me three years in country Ph.D. scholarship of which this paper is the product of the same

COMPETING INTERESTS

The author declared that no competing interests exist.

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