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A review of improved Cookstove technologies and programs

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Abstract

Many Cookstove programs have been implemented in many countries around the world. The objectives of these programs have been to reduce fuel use and hence reduce deforestation, and improve the health conditions of users by reducing environmental emissions. Other objectives include improving the social life of people in developing countries and reducing global climate change. The success of improved Cookstove programs has been reported as mixed. While some of the programs have achieved their target objectives, many of them have failed. This paper reviews the literature of improved Cookstove programs around the world. It starts with a review of some selected Cookstove technologies, classified by the types of fuel they burn and whether they are fixed or portable. This is followed by a review of different Cookstove programs, with the objective of finding the factors that determine their success, the form they should take, and the role played by the stakeholders. It is found that the success of the programs depends on the factors such as: compatibility of technical parameters of stoves with social expectations, consistency with local needs and culture, attitude of the users who are often afraid adopting new technology, and the stove cost. Also programs that use a "bottom-up" strategy, where users and local artisans play participatory roles in establishing a self-sustaining industry ensure success of the program.

Keywords: Improved Cookstove technologies; Rural energy demand; Sustainable fuelwood supply; Developing country's energy

1. Introduction

Almost 2.7 billion people in the world today rely on traditional biomass such as fuelwood, charcoal or crop residues for cooking, agro-processing and heating; and over 1.4 billion people lack access to electricity [1]. About 2.5 billion of this 2.7 billionare in developing countries [2]. In rural areas of developing countries, traditional biomass fuels account for over 90% of household energy consumption [2]. Fuelwood, charcoal, agricultural residues and animal dung produce high emissions of carbon monoxide, hydrocarbons and particulate matter [3]. According to the World Health Organization (WHO), exposure to these emissions causes approximately 1.6 million premature deaths every year [4].

The traditional three-stone fires used in many households in rural areas of developing countries are inefficient at transforming the wood into heat to cook food and are thus a major source of household air pollution. In rural areas women and girls spend many hours a week gathering fuel wood and to do that they are not available either for school or for earning money [5].

Stoves with improved efficiency have been introduced in developing countries since 1970. The objectives have been to reduce deforestation, save cooking time, reduce health impacts through a reduction in environmental emissions, save money, and improve cooking satisfaction. With the realization of the great potential benefits of improved stoves, several stove programs have been introduced in Africa, Asia and Latin America to disseminate Improved Cookstove (ICS) to

households. The diversity and complexity of these stove programs is enormous. Some of the programs have been successful and have achieved their set objectives [6]. However, satisfying the cooking needs of the users, taking into consideration their cooking behaviour and preferences, while improving overall efficiency, still remains a challenge that has resulted in the failure of many.

This paper provides an overview of the ICS programs and technologies around the world. By doing this, we are trying to find out the parameters that have contributed to the success or failure of a variety of Cookstoves. The paper looks only at the household technologies, and not commercial or industrial applications.

2. Problems with traditional Cookstoves

Traditional Cookstoves can range from three-stone open fires to substantial brick-and mortar models. These open fires are fairly inefficient at converting energy into heat for cooking and the amount of biomass fuel needed each year for basic cooking can be up to 2 t per family [7]. In addition, collecting this fuel sometimes can take an hour a day on average [5].

The rising consumption of firewood plays a crucial part of the increase in deforestation and the amount of time spent predominantly by women and children searching for firewood. This traditional energy source, which even the poorest of the poor can procure, is almost exhausted. Despite the scarcity of resources, firewood is burned very inefficiently in open fire places.

The traditional Cookstoves cause indoor air pollution and health problems, and contribute to global warming. The demand for local biomass energy may exceed the natural re-growth of local resources and causes deforestation from which environmental problems can result. There is evidence that biomass fuels burned in traditional ways contribute to a buildup of greenhouse gases (GHGs) [8], as well as other climate forces, including black carbon (BC), in the atmosphere [9].

Notwithstanding this knowledge, biomass continues to be the main fuel for cooking in developing countries. Fig. 1 shows the percentage of people in developing countries that use biomass fuel for cooking. From Fig. 1, it can be seen that a majority of the people (more than 80%) in rural areas of the developing world rely mainly on biomass for cooking.

Two major approaches that can be used to improve energy security in developing countries, especially in the rural areas, are promoting more efficient and sustainable use of traditional biomass; and encouraging people to switch to modern cooking fuels and technologies. For many households, switching from traditional biomass to modern and clean biomass may not be feasible in the short term because of high capital costs coupled with high poverty levels [10]. Therefore, improving the way biomass is supplied and used for cooking is an important way of improving the sustainability of its supply and use in developing countries, while, at the same time, dealing with the energy security problems in those countries.

3. Improved Cookstoves (ICS)

ICS are cooking stoves that use biomass (charcoal, wood, paper or vegetable matter) and are designed to maximise thermal and fuel efficiency, operate safely and minimise emissions harmful to human health [11]. Evidence suggests that widespread deployment of Cookstoves technology with improvements in energy and combustion efficiencies could potentially help mitigate adverse human health, energy, and environmental consequences [12]. Replacing traditional Cookstoves with improved or advanced biomass Cookstoves is straightforward, but not readily acceptable by the households. Many of the past biomass Cookstove programs have failed due to the lack of proper

understanding of the needs of the people who use this technology [13]. The cooking needs of developing countries are not simply less smoke or fuel-efficiency; they are diverse and sometimes broader than the benefits defined by clean Cookstoves programs implementers [14]. For example, a study in Bangladesh suggests that women in rural Bangladesh do not perceive indoor air pollution as a significant health hazard, and thus prioritize other basic developmental needs (such as the provision of good primary and secondary schools, provision of sanitary latrines and free consultation to a medical doctor) over ICS, and overwhelmingly rely on free traditional Cookstove technology [15]. Bangladeshi rural households also place high importance on the stove cost. Therefore, it has been recommended that the design and dissemination methods of ICS should include features that are valued more highly by users, even when those features are not directly related to the health and environmental impacts of Cookstoves. No program can achieve its goals unless people adopt it, then continue to use it in the long term [16].

3.1. Available improved Cookstove technology in the world

The key feature of any ICS over traditional stoves is the use of insulating material such as clay or mud to conserve the heat and make the Cookstove more efficient. Different classification systems can be used for the Cookstove technologies on the market. Cookstove technology can be classified based on the material used in making the stove and whether it is fixed or portable. It can also be based on whether the stove is equipped with chimneys and if it has grates in the fire box to increase fuel combustion. The design of stoves that are in use varies, based on the location and the type of fuel available e.g. some stoves are specially designed to burn one fuel; others burn a range of fuels. Several Cookstove technologies used in different countries are discussed below.

3.1.1. Envirofit international family of rocket stoves

The stoves are made of metal with either a ceramic or a metal chamber. The stove design is based on advanced Computational Fluid Dynamics (CFD) and heat-transfer modelling. They are designed to burn raw biomass (wood) and other derived biomass material such as charcoal. Colorado State University′s Engines and Energy Conversion Lab (EECL) provides Envirofit with state-of-the-art research and development, engineering and rigorous emissions and durability testing [17]. Envirofit boast the world′s most fuel-efficient Cookstoves, producing 80% less smoke and harmful gas emissions, 60% less biomass fuel (wood, crop waste, etc) consumption and up to 40% reduction in cooking cycle time, compared to the traditional three stone open fire. They can have a chamber life of up to 5 years. Envirofit Cookstoves are currently distributed around the world in South America, Central America, Africa, and in Asia. The cost of a basic stove without a chimney is about US$30 and the cost of a more advanced stove (e.g. G3300) about US$95[17]. Fig. 2a shows examples of the Envirofit family of rocket stove.

3.1.2. Ugastoves

Ugastoves are manufactured in a factory in Uganda. There are two major types; improved charcoal stove and a rocket wood stove for household use. They have a ceramic liner encased in a sheet of metal. Ugastoves have different sizes and shapes. The rocket-type wood-burning stove has a metal “pot skirt” permanently fixed to the outer edge of the top of the stove. The Ugastoves are manufactured in several sizes. Fuel efficiency of up to 36% has been reported for charcoal stoves and 58% for the wood rocket types [18]. The stoves have an estimated working life of 3–10 years, depending on the usage level [19]. Fig. 2b shows examples of Uga stove.

3.1.3. Centrafricain improved stove

The Centrafricain is a portable improved stove that can be found in Africa, in Chad and Cameroon.. The stove is made of metal and has a ceramic chamber. The combination of metal and clay allows a longer operational lifespan in comparison with other simple ceramic models [20]. The clay ring

increases the stability, resistance, and efficiency of the stove. Moreover, the Centrafricain stove was designed to accommodate the local round-bottom pots, making it possible to cook according to local traditional practices. The addition of two handles ensures the portability of the stove. The Centrafricain stove burns raw wood. According to observations on site, prices vary between 5000 and 7500 franc CFA (7.62–11.43 €). The stove is found to reduce family fuel expenditure by 25% per cooking purpose [20]. Fig. 2c shows the Centrafricain ICS.

3.1.4. BCSIR 1 pot portable Cookstove with grate

This stove can be found in Bangladesh. It is the improved Cookstove model promoted by the government of Bangladesh (GOB). It features a fuel inlet, a metal grate to increase fuel combustion, and two air inlets at the base. The stove is suitable for burning fuel wood, branches, cow-dung cake, briquettes. It is found to reduce fuel use by 50% [21]. This stove costs around Tk. 150–300 (US$2–4), with the higher prices charged to customers outside the project area [22]. Fig. 2d shows a picture of the BCSIR 1 pot portable Cookstove.

3.1.5. Patsari wood-burning Cookstove

Patsari is a fixed stove developed in Mexico, where approximately one quarter of the population still rely on open fires for cooking and/or heating. The Inter-disciplinary Group for Appropriate Rural Technologies (GIRA), based in the Central Mexican state of Michoacán, used a participatory approach in which input was provided by the actual users. The body of a Patsari stove is made of a mixture of sand and mud and a small amount of cement. The combustion chamber is shaped in the form of a box and also has a chimney. Hot plates on the top surface, over the fire, provide the cooking surface. Compared to the traditional 3-stone open fire stove, the Patsari stove is said to reduce indoor air pollution by about 67%. It cost about US$130 [23]. Fig. 3a shows an example of a Patsari wood-burning Cookstove.

3.1.5.1. BCSIR 2 pot fixed model with chimney

This model can also be found in Bangladesh, and was previously promoted by the GOB. It is a fixed stove that includes a grate for the first pot hole, air inlets, fuel inlet, and an ash outlet under the chimney. It has fuel saving of about 45–50% compared with traditional stoves and efficiency of 22% [25]. This stove costs around Tk. 500 (US$ 7) [22]. Fig. 3b shows an example of BCSIR 2 pot fixed ICS.

3.1.6. ONIL improved cookstove

HELPS International, an international not-for-profit organization, was originally founded to provide medical care for the poor in Central America. Doctors involved in that program, who treated a high number of burn cases related to the use of traditional stoves, initiated an effort to develop energy-efficient improved stoves that would prevent burns and remove smoke to improve health [24]. The ONIL Stove, which was developed for the program, is a fixed ICS. It was developed by Don O'Neal from Texas, USA, a Project Manager for HELPS International, for Central American households. The top of the stove measures about 400 mm across and 900 mm long, which provides adequate space for two pots. The stove is normally mounted on concrete blocks, to raise it to a convenient and safe height for cooking [25]. The stove is made of cast concrete. The combustion chamber has a ceramic lining so as to withstand high temperatures. The space between the concrete and ceramic parts is insulated with ground pumice and ash. A set of covers with graduated holes allows efficient use with different-sized pots. The stove has a chimney made from galvanized steel. The stove has been tested in an independent laboratory and has been found to reduce CO_2 emissions from 408 mg/m^3 to 1.1 mg/m^3 (99%), carbon particles from 10.2 mg/m^{3}to 1 mg/m^3 (90%) and fuel use by 70%. Onil ICSs are distributed by HELPS International to NGOs in Central America, specifically, Guatemala, Honduras, and Mexico at a cost of US$87. Users receive the stove free from the NGO, or by

contributing a token of the market price[25]. Fig. 3c shows an example of Onil ICS. Table 1 gives summary of the Cookstoves technologies.

Across many Cookstove technologies, two common parameters that we found could clearly distinguish between stove types, are the type of fuel used and whether the stove is portable or fixed. The fixed stoves are usually made with mud or cement [26]. These are built up in situ, and can be made very cheaply using local materials. They work by directing hot gases from a fuel-wood fire up to the cooking pot. Portable stoves on the other hand could either be made of ceramic, or metal or a combination of both – ceramic liner within a metal cladding. The two most common fuel types used are raw wood and derived wood material such as charcoal, with only BCSIR 1 from Bangladesh employing cow dung and briquettes. The efficiencies of the stoves are specified using different parameters, thus making direct comparison impossible. The prices range from as low as US$2.00 to as high as US$87.00 (not subsidised).

4. Brief overview on Cookstove programs in the world

In the early 1970s due to the oil crisis, fuelwood energy security and deforestation became a big concern for the world. Institutions such as the World Bank and the UN Food and Agriculture Organisation claimed that food and fuel needs of the rapidly growing populations had resulted in deforestation[27,28]. Cookstove programs were promoted throughout the developing world as a way to significantly improve rural welfare. Major government programs disseminated thousands of new Cookstoves to rural villages. It was thought to be a quick win-win opportunity, with rural citizens benefiting by saving fuelwood, with a vast reduction in deforestation. But the analyses of Cookstove programs in the mid-1980s reported mixed success. According to a World Bank report by Fernando Manibog, "*After years of promotion efforts, large-scale diffusion has not occurred. Fewer than 100,000 stoves have been distributed worldwide, of which 10–20% have fallen into disuse and another 20–30% are used only intermittently*.[27]".

By 1984, there were very few Cookstove programs, distributing only a few thousand Cookstoves. The countries with well-established programs that had distributed or sold up to 5000 improved Cookstoves included Guatemala, southern India, Indonesia, Kenya, Nepal, Papua-New Guinea, Senegal, Somalia, and Sri Lanka, [27,29]. There were also a few programs which distributed or sold a significant number in countries such as Burundi, Malawi, Mali, Niger, and Rwanda. Finally another group of countries where minimal initiatives took place included Bangladesh, Botswana, Fiji, Gambia, Lesotho, Liberia, and a few Central American/Caribbean countries (the yellow colour in Fig. 4).

In 1990 when scientists emphasised the link between Indoor Air Pollution with smoke caused by stoves, the concept of improving Cookstoves became very popular. A technical paper published by the World Bank in 1994 shows a substantial growth. Large government programs were initiated in China, India, Bangladesh, Sri Lanka, Nepal, Africa and in Latin America. Fig. 5 shows the programs on the world map [6].

Currently, Cookstove programs have become a global enterprise. A variety of NGO and international development programs have sprung up in Asia, Africa and South America (Fig. 6). The Chinese government program that started in 1982 and was terminated in 1992, has re-emerged and successfully distributed more than 200,000 Cookstoves to date [24].

The number of households using improved Cookstoves totals roughly 166 million, with 116 million in China, more than 13 million in the rest of East Asia, nearly 22 million in South Asia, about 7 million in Sub-Saharan Africa, and over 8 million in Latin America and the Caribbean [24]. According to the World Bank report, 'Out of every four developing-country households dependent on solid fuels for cooking, only one uses a stove with a chimney or smoke hood' [24].

There are many different programs implemented by different institutions, for example, NGO-led programs, international development agency-sponsored programs, government-led programs or private initiative programs. Some of the Cookstoves programs are described below.

4.1. Cookstoves programs in Africa

One of the longest running Cookstove programs in Africa is Zimbabwe's Tso Tso Stove Program, which was established in early 1980s. 'Tsotso' means 'twigs' in Shona. The fire grate was made from mild steel and had a removable (and replaceable) bottom grid made from wire [31]. Care was taken in designing the stove to ensure it is consistent with local needs and culture. According to Zimbabwe culture, a metal stove indicates a status symbol [32]. According to the 1988 report in Boiling Point[32], the TsoTso Stove was initially manufactured by the informal sector, but that was soon abandoned to mass production, with quality control by the formal manufacturing sector. The price of the TsoTso was comparable to the 'metal grate' pre-existing stove.

The report also mentioned that sales were initially small and amounted to 400 units in the first four months. A sales breakthrough occurred after commercial farmers and mine managers realized substantial cost-savings for their labourers. There are a number of factors which influenced the development of the stove. Firstly and most importantly, as mentioned by the users, is fuelwood savings, Secondly, quality control and thirdly, better aesthetical stove appeal [33].

One technical problem reported in most of the African programs is the design of the stove that failed to fit cooking pots adequately. According to the project reviews, four projects all cited "stove too small to fit all pots" as the most common complaint about stoves. The Tsotso stove was later adopted and further developed with some changes in the design in the Namibian Stove project [34]. Assessment of the Tsotso Stove program by the Energy and Energy Efficiency Bureau of Namibia (R3E) concludes that "the thought that went into the design of the Tsotso is commendable and is "appropriate technology" at its best" [35]. The TsoTso are sold for 110 N$ (16 US$) and are being subsidised with 32 N$ (4.64 US$) by Namibian government.

Fig. 7 shows the Cookstoves programs in Africa [30]. A red circle indicates an NGO-led program, an orange circle represents an international development agency-sponsored program, a green circle represents a government-led program and a purple circle represents a private initiative program. It should be noted that the geographic data is only represented at country-wide level, therefore the specific regional locations of each program are not represented. Fig. 8 shows the percentage of households with ICS in Africa, both in urban and rural areas in 2010.

4.2. Cookstove programs in Asia

Largest program by far is the Chinese National Improved Stove Program, which successfully disseminated 129 million stoves from 1982 to 1992 [30]. The Indian National program is perhaps the second largest ICS program after the Chinese. The Indian National Biomass Cookstove Initiative was launched in 2009 by the Indian government to extend the use of clean energy to all the estimated 160 million households that cook with inefficient Biomass [36]. According to study done by the India Institute of Technology, the programs has the potential to avoid 570,000 premature deaths in poor women and children and over 4% of India's estimated greenhouse emissions if the initiative were to take place in 2010 [37].

In Indonesia, Several organizations have initiated pilot Cookstove programs; however, their target markets and implementation approaches vary widely. Organizations promoting Biomass Cookstoves include Inotek which has so far distributed 4000 stoves to target households in Central and East Java and in West Tengarra districts [38]. Fig. 9 shows the Cookstove programs in Asia as at 2010.

Cheap manufacturing hubs in China have become centralised producers for the world′s Cookstoves. According to Anne Wheldon (Ashden Awards), there are emerging factory-scale productions that can make cheap stoves available more readily on a global basis. A very basic Cookstove is produced by the Shengzhou Stove Manufacturer, with an ex-factory price of US$3.50.

The 1980s Nepali program [39] largely failed because the prefabricated stoves were of poor quality; however, this was changed in the 1990s by retraining the Cookstove artisans, and implementing higher quality control. Fig. 10 shows percentage of households with ICS in rural and urban areas in the Asian countries.

In Bangladesh, early initiatives in research and development of ICS were spearheaded by a state-owned organisation, Bangladesh Council for Scientific and Industrial Research (BCSIR). The BCSIR-led dissemination program involved both government organisations and NGOs. Presently, NGOs, partially supported by donor agencies, are engaged in the dissemination of ICS throughout the country with Grameen Shakti and GTZ in the leading role. Between 1980 and 2001, over 300,000 stoves were distributed. Stoves developed and disseminated in the program may be grouped into three categories: (i) Improved stoves without chimney, (ii) Improved stoves with chimney, and (iii) Improved stoves with waste heat utilization [40]. Other countries in South East Asia that have some kind of improved Cookstove programs include Bhutan, Pakistan, and Sri Lanka.

4.3. Cookstoves programs in Central America and the Caribbean

A country in Central America that has a long history of Cookstove program is Haiti. Improved stoves initiatives in that country started in 1983, when a collaborative project with the Centre de Recherché en Dévelopement International (CRDI), Haitian Government, and World Bank developed the “Recho Mirak” improved charcoal stove. CARE Haiti and the Bureau des Mines et de l’Energie (BME) in the 1990s further promoted the “Mirak” stove, and from 2007 to 2009 a World Bank project produced and sold at a subsidised price over 30,000 “Mirak” stoves.[11]. Following the earthquake of January 12, 2010, thousands of improved household stoves have been distributed in the internally displaced-persons (IDP) camps, and there are many plans for long-term investments in market promotion of improved stoves. UNEP estimate the number of improved Cookstoves in Haiti to be about 50,000 in 2010 [11]. Fig. 11 shows Cookstove programs in Central America and the Caribbean. And Fig. 12 shows the distribution of improved Cookstoves program in Central America and Caribbean.

Another long-running program is the Guatemalan government project, the Social Investment Fund (SIF). The program has cost a total of $12 million and has, to date, distributed approximately 90,000 Cookstoves [30]. Established in 1993, the Fund originally had an eight-year mandate, which, in 2000, was extended for 4 years. The SIF is focused on more than just Cookstoves, but includes a variety of programs to improve the quality of life for poor people in rural Guatemala[30]. Another program is the HELPS International Onil Cookstove program that originated out of the HELPS international humanitarian work in Central America, specifically in Guatemala [24]. Table 2 below gives a summary of the Cookstove programs around the world.

5. Lessons learned from different programs

Most of the programs discussed above focused only on dissemination and hence did neither take into account local culture, social and economic backgrounds of the target areas, nor did they consider costs or availability of biomass fuel. As a result, many projects collapsed soon after donor funding finished. Causes for collapse were usually attributed to:

•poor implementation strategies,

•inappropriate technologies,

•lack of community participation, and

•lack of training.

In most projects, the technical efficiencies were barely achieved in the field. This is said to have resulted in the failure of many early stove programs [10]. Although dissemination had been impressive in India and China, for instance, follow-up surveys suggest that less than one-third of the stoves were still in use by the year 2000. Some reasons given for discontinuing use are that the stoves did not really save energy, did not eliminate smoke, or were broken.

These early failures led to a change in the mistaken expectations of the program planners which had been that huge improvements in efficiency alone would make stoves irresistible and that they would need to do little monitoring, sampling, or statistical work to assess the efficacy of programs [6]. These early failures, in turn, helped stove program implementers find out what determines the success of a stove program.

Following these early failures, answers to the following questions can clarify the lessons learned:

(a) Under what situations are improved biomass stove programs more successful?

(b) What is the most effective process of choosing the best design for a particular program?

(c) What is the role of subsidy in stove programs?

(d) Which benefits does the improved stove need to produce?

Regarding the first question, it is generally accepted that stove programs are more successful in areas where fuelwood is already scarce, and people therefore either spend a lot of money buying wood or they spend a lot of time collecting it [6]. These conditions usually exist in urban or semi-urban centres and it is said to make the programs more cost-effective, as the improved stoves can pay for themselves in fuel savings very rapidly. This was the case in China where the program focused on areas with the greatest need and selected pilot areas with biomass fuel deficits.

Concerning the second question, experience has shown that programs using a “top-down” approach, and relying heavily on donor funding to subsidise the stoves, performed much worse than programs that were participatory from the beginning and in which funding was used to establish a self-sustaining stove industry [6]. In fact, the “top down” approach is reported to have partly contributed to failure of the Indian program which was implemented country-wide, resulting in dispersion of effort and dilution of financial resources. The programs that take into account the users’ need are more successful. An example of that is taking into account the stove design to fit the pot or to fit in the kitchen. The Zimbabwe project also highlights that women also value other characteristics, like how long the stove takes to heat up or the aesthetic and ‘social status’ of owning an improved Cookstove ahead of fuel savings.

Cost is another factor that affects the adoption of improved stoves. Improved fuel stoves are typically about twice as expensive as the local traditional stoves. Although in the long run improved stoves save money, the initial cash outlay required may prevent poorer people from being able to afford the stove. Governments and donors could assist by subsidising stoves for poor families, but, generally, subsidising stoves is risky as a promotion strategy. High subsidies offered by the government, in which about half of the retail price of the stoves was subsidised, has been reported to have caused the failure of the program, the Indian program [41]. This is contrary to the Chinse program where the government contribution was less (about 8%). If subsidies are to be given, the best way is not to directly subsidise the production and dissemination of these stoves but to provide support to designers and manufacturers through training. By providing training to assist in the manufacturing process, production cost can be decreased and at the same time the knowledge acquired can be passed on to the

users which further reduces the chances of failure. This was proven by the program initiated in Kenya, the *jiko* stove program.

The last question concerns the stove itself and the benefits it can provide for its user. Stove programs have shown that superior efficiency is not sufficient to guarantee a widespread dissemination of stoves. Rather, the stove has to be competitive with the traditional stove in a multitude of factors, such as ease of use, safety, time-saving and attractiveness so that the user clearly perceives the benefits it creates.

6. Conclusion

Development of the improved biomass stove programs in the 1970s was to reduce the burden on biomass resources through the provision of reliable and efficient methods of cooking. The quality of Cookstoves persists as a major issue for program success. Several projects that were initially perceived as a success by their funding institution were not self-sustained due to lack of trained people, maintenance and low quality product. The design of the Cookstove did not take into account fuel availability and willingness to pay therefore leading to users" dissatisfaction. Additionally, improved Cookstoves were designed in laboratories to optimise efficiency rather than convenience or cultural cooking practices.

In summary, a successful program should emphasise the following:

•The efficient stove designs should tailored to user requirements and this is a prerequisite for program success. Users need to involve in design and testing process of the stoves.

•Stoves should have proven efficiency before disseminating to the households.

•It need to have the ability to reduce indoor air pollution, and safety.

•Durability is important factor for program success.

•The stoves should be marketed to the households.

Facing fuel wood scarcity or high costs of purchasing wood. These will strengthen a program and reduce the risk of program failure.

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Fig. 1. Distribution of people in the developing world relying on biomass resources as primary fuel for cooking [2].

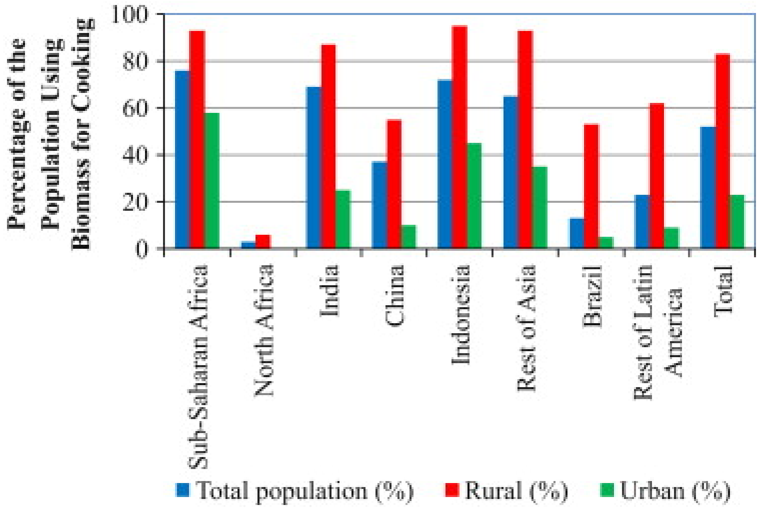

Fig. 2. Examples of portable improved cooking stove. (a) Examples of Envirofit Family of Stove [15], (b) Uga-Charcoal (left) and Rocket (right) ICS manufactured in a factory in Ugand, (c) Centrafricain improved stove (left) and its technical drawing (right) and (d) BCSIR 1 pot portable cookstove.

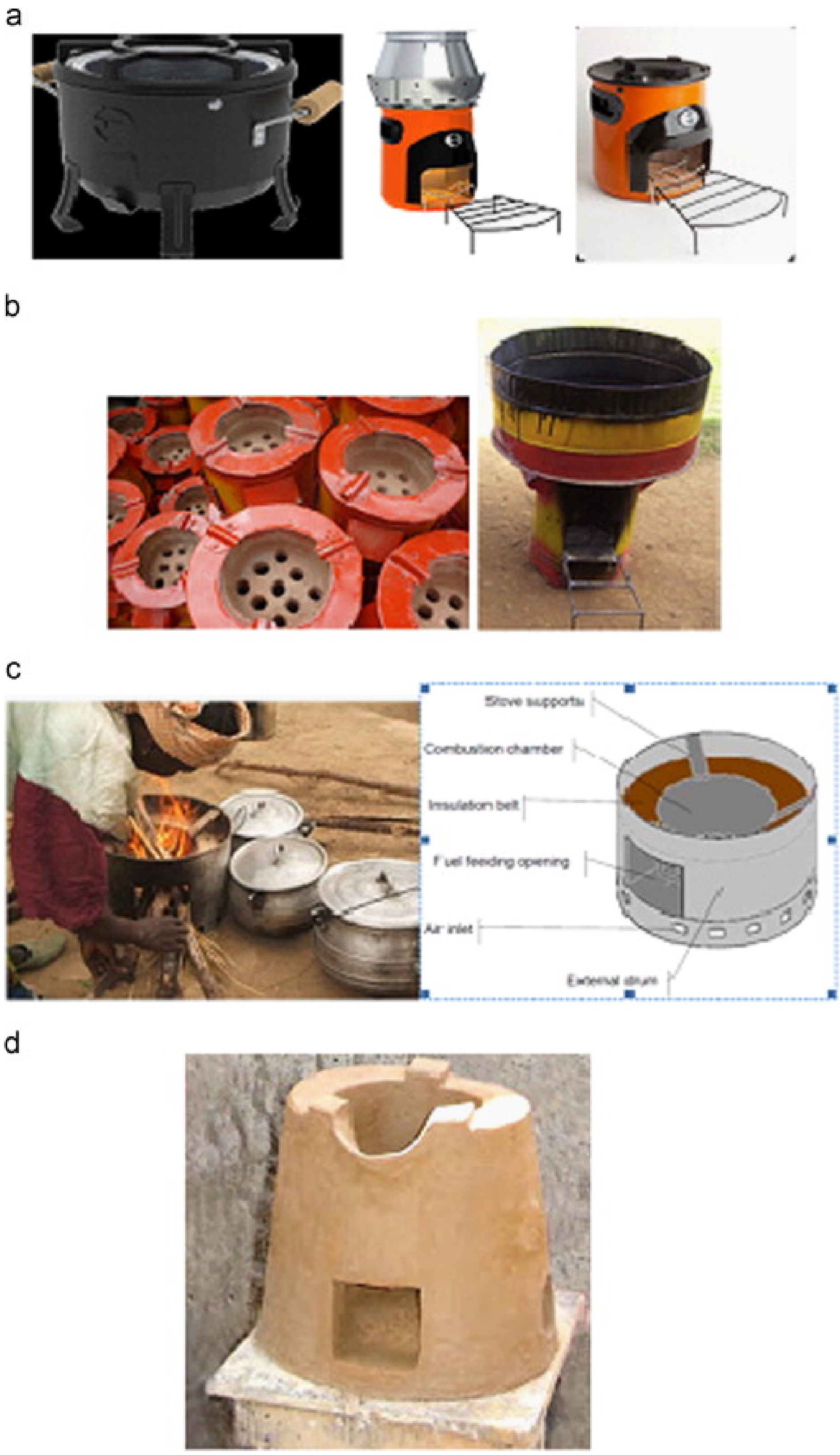

Fig. 3. Examples of fixed ceramic improved cooking stove. (a) Patsari wood-burning cookstove, (b) BCSIR 2 pot fixed model with chimney and (c) ONIL/HELPS improved cookstove.

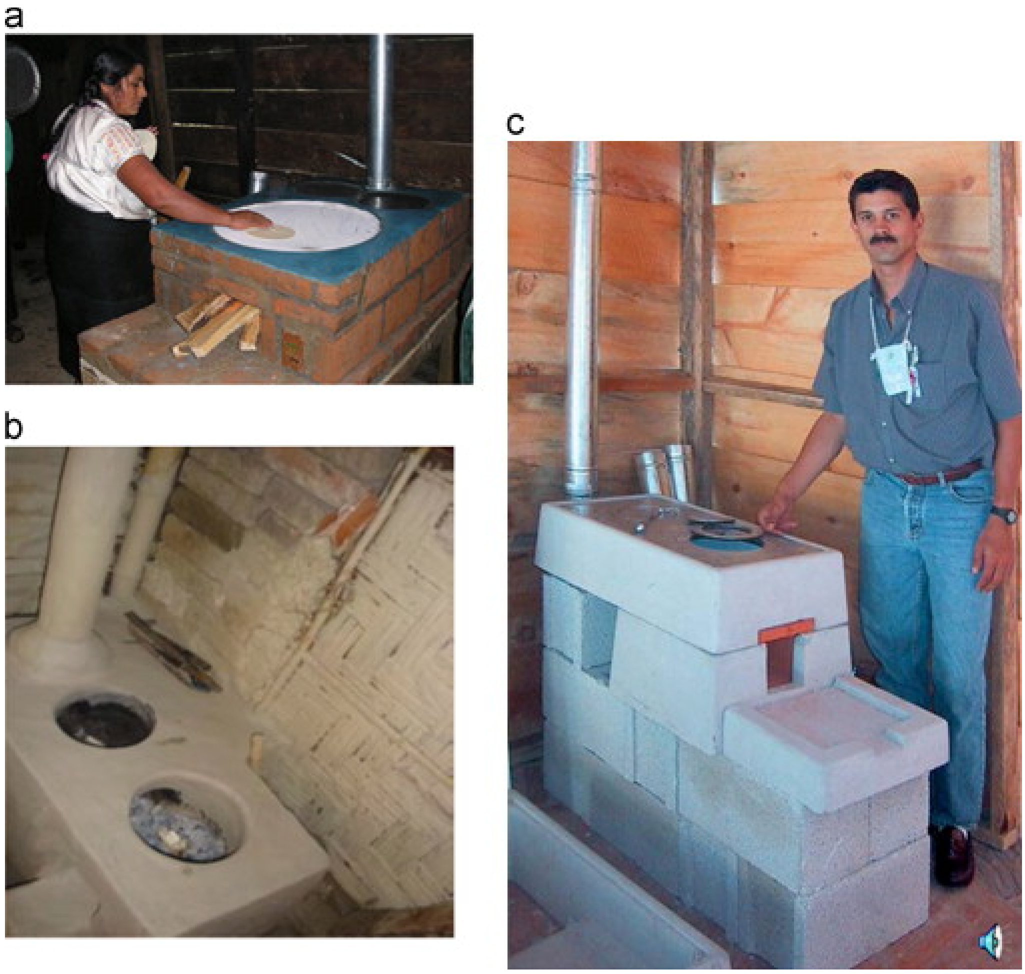

Fig. 4. Improved Cookstove programs in 1984 [30]. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this paper.)

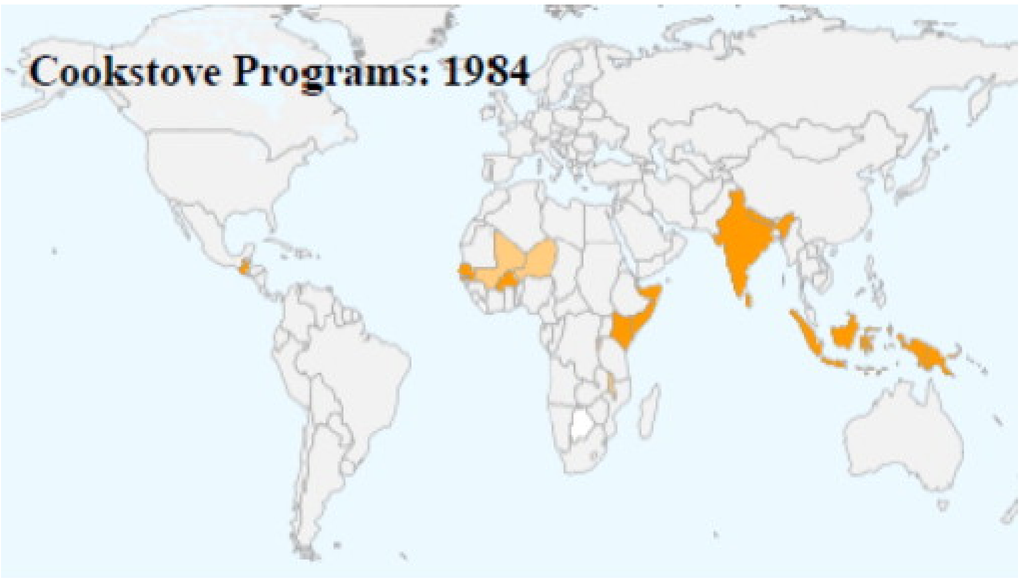

Fig. 5. Improved Cookstove programs s in 1994[31].

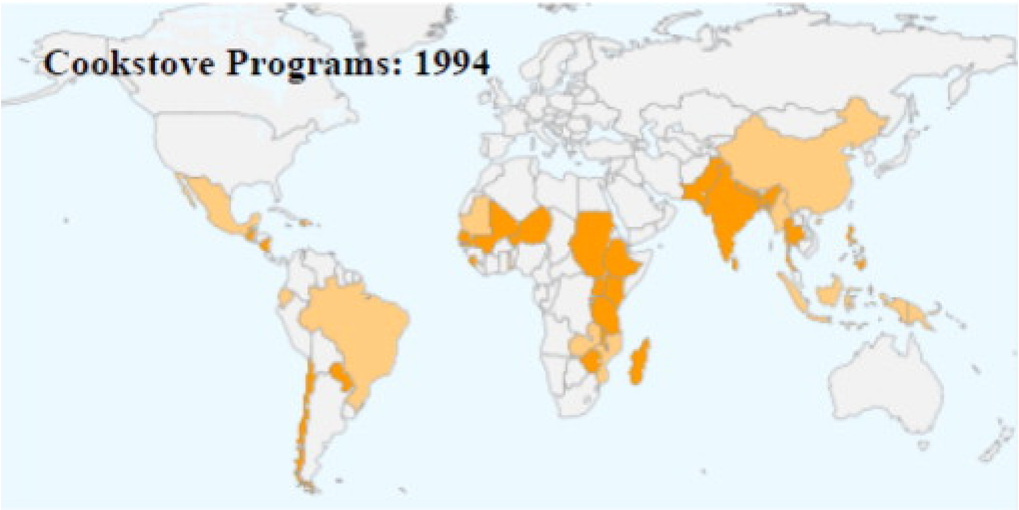

Fig. 6. Improved Cookstove programs s in 2010[30].

Fig. 7. African Cookstoves programs 2010 Source: [30]. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this paper.)

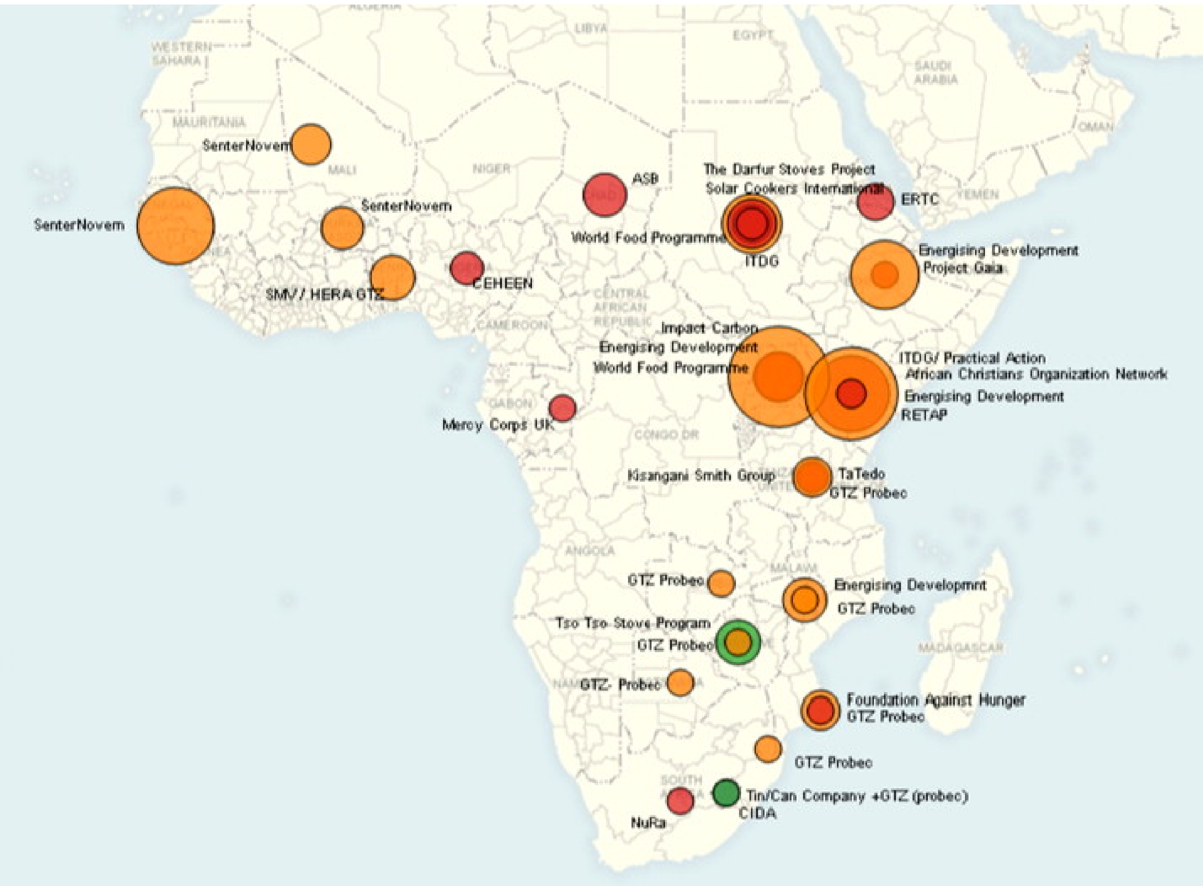

Fig. 8. Percentage of households across Africa with improved Cookstoves [7].

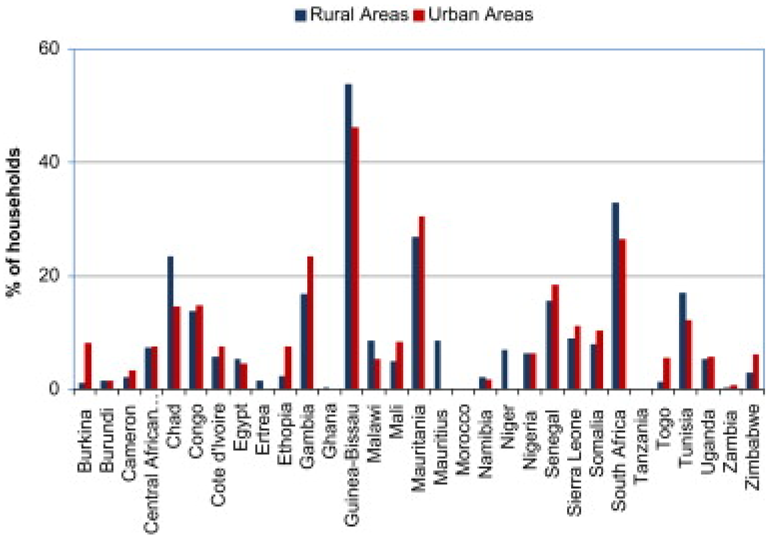

Fig. 9. Asian Cookstoves programs, 2010 Source: [30].

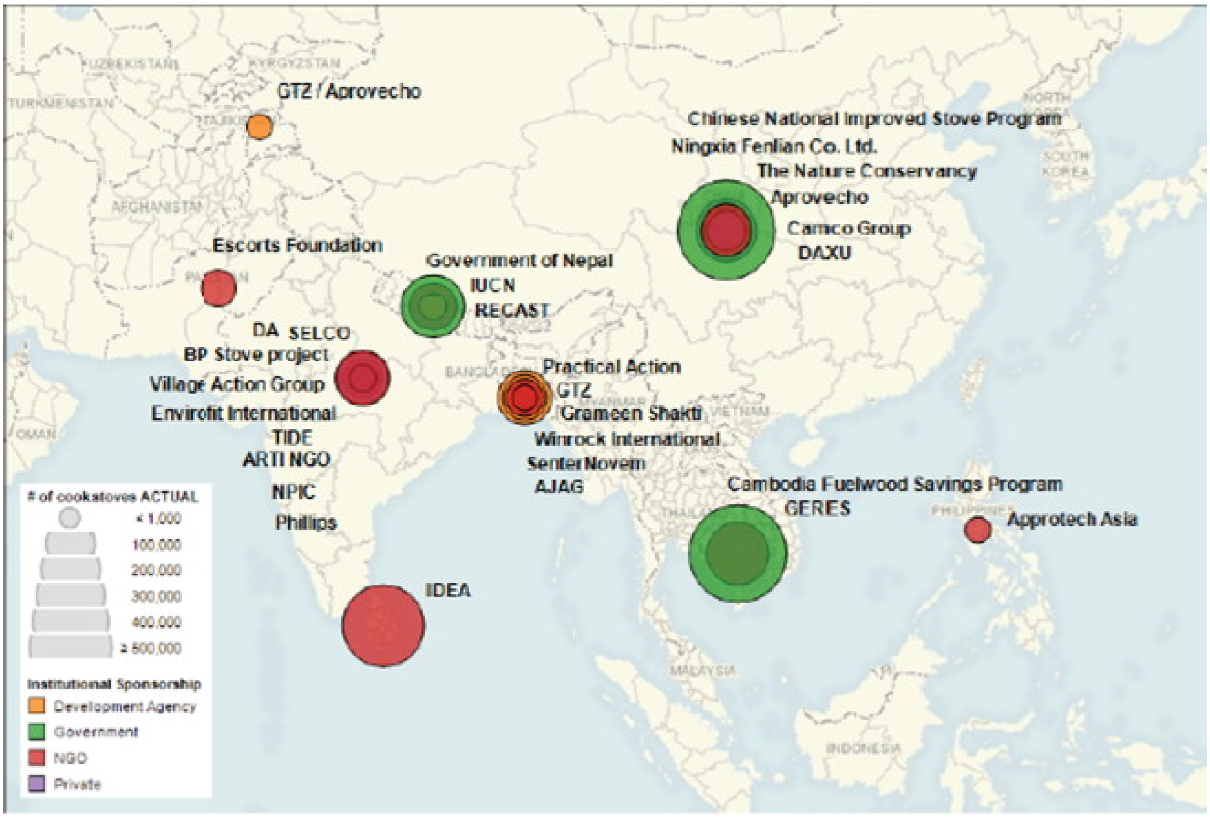

Fig. 10. Distribution of improved Cookstoves in Asia [7].

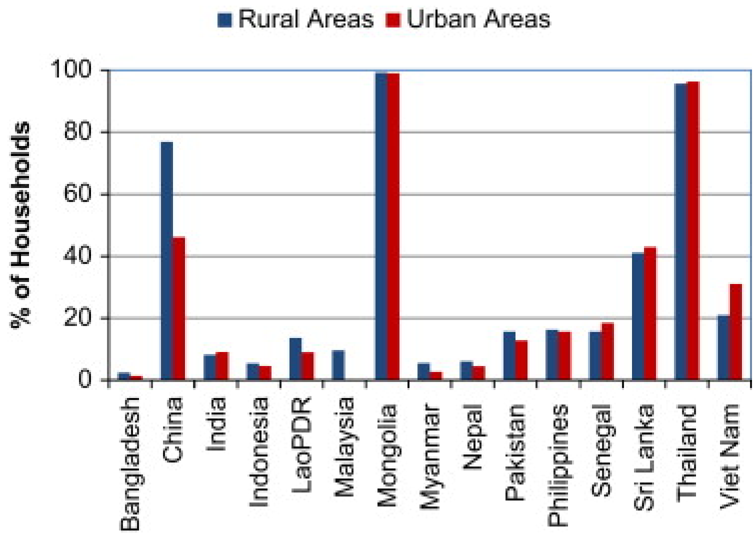

Fig. 11. Cookstoves programs in Central America and the Caribbean, 2010 Source: [30].

Fig. 12. Distribution of improved Cookstoves in Central America and the Caribbean [7].

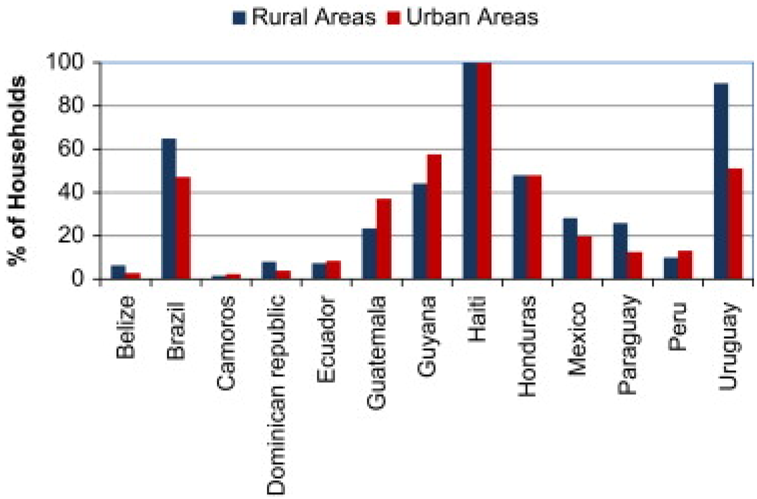

Table 1. Characteristics of selected Cookstove technologies.

ICS name	Type of fuel burn	Efficiency parameters (compared to traditional three stone Cookstove.	Material	Region	Comment	Source
Envirofit int. family of rocket stoves	Wood and derived wood fuels (e.g. charcoal)	80% emissions reduction, 60% fuel saving, 40% reduction in cooking time, lifespan of about 5 years	Metal or metal with ceramic chamber	South America, Central America, Africa, and in Asia	The cost of a Envirofit basic stove without a chimney is about US$30 and the cost of a more advanced one is about three times that.	Envirofit. Winter 2013 envirofit product overview
Ugastoves	Wood and charcoal	36% fuel saving (charcoal stoves) and 58% for the rocket type, estimated working life of 3–5 years	Metal with ceramic chamber	Uganda (Africa)	Ugastoves are widely used in Uganda (US$ 5–11)	Adkins, et al.[18]ECOFYS[19]
Centrafricain improved stove	Wood	Reduce family fuel expenditure by 25%	Metal with ceramic chamber	Chad and Cameroon (Africa)	Prices vary between 5000 and 7500 France (US$11–16)	Vitali [20]
BCSIR 1	Wood, cow dung cake, briquettes	50% reduction in fuel use	Ceramic with metal grates	Bangladesh (Asia)	Cost around Tk. 150-300 (US$ 2-4),	USAID [22]
Patsari wood-burning Cookstove	Wood	Reduce emissions by 67%	Sand and mud with a small amount of cement. It has a metal hot plate on top.	Mexico (Central America)	Production was based on participatory approach with input provided by the actual users. Cost around US$130	Masera, [23]
BCSIR 2	Wood		Ceramic		This stove cost around Tk. 500 (US$ 7)	USAID [22]
ONIL improved Cookstove	Wood	99% reduction in CO emissions, 70% reduction in fuel use	Concrete with ceramic lining insulated with pumice and ash	Guatemala, Honduras and Mexico (Central America)	The stove is sold to the NGO at a cost of US$87. Users then receive the stove free from the NGO, or by contributing a token of the market price	Onil-International[25]

Table 2. Improved cookstove status in Bangladesh.

Name of the project	Dates	Stoves disseminated	Current status/Future plans
BCSIR Phase I and II	1989–1991 and 1999–2001	300,000	Phase III announced to distribute 28,000 stoves in seven districts using the Climate Change Trust Fund
GIZ phase I and II	2004–2011	175,000	Uncertain funding situation beyond 2012. Phase III will train 5000 masons tied to sanitary shops
Grameen Shakti	2006-present	480,000	Monthly sales 25,000
VERC	2000–2011	48,000	
UNDP and UN-Habitat	2011	40,000	Implemented through POs which receive technical assistance from GIZ. Plans to expand to 400,000
Practical Action	2001–2011	7000	Expansion through full time and part time entrepreneurs
Winrock/VERC	2005–2007	580	Entrepreneurs continue to sell beyond end of the project