Delivery Model of Wood Gasifier Stoves in Sri Lanka

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Foreword

Policy Innovation Systems for Clean Energy Security (PISCES) is a Research Programme Consortium (RPC) funded by the United Kingdom's Department for International Development (DFID). It's implemented internationally through five core partners in India, Sri Lanka, Kenya and Tanzania, along with a range of associate institutions and high-level Consortium Advisory Group (CAG). The idea behind the PISCES project is to generate new knowledge on bioenergy that policy makers use to formulate or enhance respective national policies and strategies on bioenergy.

This working paper presents a delivery model for wood gasifier stoves in Sri Lanka. A brief history of the biomass sector is highlighted followed by the product technology development process and its associated benefits. The delivery model shows how the demand and supply channels can be enhanced through the successful promotion of wood gasifier stoves in the country.

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Background

Attributable to being situated near the equator, Sri Lanka is blessed with ample sunshine, reasonable rainfall and fertile soil. These conditions have led to Sri Lanka having a good green cover of biomass. Biomass currently contributes to nearly half of Sri Lanka's primary energy supply. It has been found that 88% of the households in Sri Lanka cook with biomass while 90% of the energy used in a traditional Sri Lankan kitchen is from biomass.

Like many other developing countries, Sri Lanka faces a weak supply chain of biomass based cooking fuel which contributes towards deforestation. In addition, urbanization makes it difficult for households to access biomass. As a consequence, in the 1970s the Ceylon Timber Corporation introduced energy efficient cook stoves that used biomass to replace the conventional 3-stones stoves. Timco stoves were fuelled with timber off cuts generated mainly from the then ongoing, multipurpose Mahaweli Development Scheme . Subsequently, Practical Action (then ITDG- Intermediate Technology Development Group), the Ceylon Electricity Board, Sarvodaya Movement and Integrated Development Association , introduced and promoted energy efficient cook stoves made from clay which were made locally. The penetration of this stove is wide across Sri Lanka.

1. Need For Wood Gasifier Stoves (WGS)

Despite the introduction of improved cook stoves, deforestation and the energy crisis continued. Furthermore, improved living standards of the Sri Lankan population increasingly demands more modern and cleaner forms of energy. Cooking using fuel-wood based stoves result in a significant degree of indoor air pollution. The improved cook stoves do not completely eliminate smoke, carbon and soot deposits on the pots & pans used for cooking. These deposits need to be washed and causes a problem as water is a scare resource in most parts of the country. Additional problems such as the removal of soot from finger nails and discoloring of the walls due to soot bring about the extra consumption of water for cleaning purposes. Moreover, increase in income have led to many households changing to alternate forms of stoves such as kerosene, electric and LPG cookers which symbolize an increased social status of the family. These problems and developments led the National Engineering Research and Development Centre of Sri Lanka (NERDC) to look for alternate solutions to the improved cook stoves.

Using the emerging knowledge and experience on wood gasification, NERDC with its principle researcher Eng. D. M. Punchibanda, introduced a Forced Draft Wood Gasifier Stove in 1999 and patented it in 2002. Subsequently this stove won a National Presidential Award as well as an International Innovation Award from Geneva, Switzerland. It was marketed domestically in the year it was patented.

Instead of burning the fuel-wood with a complete combustion to generate heat directly, a wood gasifier stove, which is also called a Forced Draft Wood Gasifier Stove, follows a two-step process. Initially partial combustion of the fuel produces Carbon Monoxide (CO) gas which is combustible. The second step involves the complete combustion of this gas generating heat. This two stage process leads to a more complete combustion, releasing less smoke and less emission, particularly particulate matter. In order to control the flame and burning, the supply of oxygen from the surrounding air is supplied to the combustion chamber through a small electric air blower (fan). This helps regulate the air supply and thus controls the stove flame.

Since an electrical fan was installed, such a stove could only be used if a household had access to electricity. At that juncture many houses in the rural and remote areas of the country did not have access to electricity. This prevented the majority from using such a stove. Furthermore, consumers feared having an electrical appliance (air blower) within close proximity to the fire in the stove. Due to these reasons, the forced draft WGS did not take off as expected and NERDC was forced to provide the community with an improved option. Additionally NERDC being primarily an engineering research and development organization realized that there were possibilities of adding improved features. As a result, the invention of the Natural Draft WGS was conceived.

2. Technology Development And Dissemination Cycle Adapted For WGS By Nerd Centre

The technology, product development and dissemination cycle of the WGS as adapted by NERDC was not very different to other organizations. Once the product idea was conceived, it was developed into a concept note and in turn to a project proposal for research and development. Following the approval of the Board of Directors, research and development commenced consisting of further improvement and modifications of the product conceived from the Forced Draft WGS.

Once the product was developed to an appropriate stage, prototypes were developed and tests were carried out through a continuous and iterative improvement process. To reach the stage of initial dissemination of the WGS over five rounds of prototypes were developed and tested in-house at the NERDC workshops and laboratories. After technical drawings of each version were developed, prototype samples were taken to the field for field testing and trials. From the field results of the users' feedback, the product was further improved and the technical drawings were finalized with the technology finally ready for dissemination.

In order to attract suitable and interested entrepreneurs to produce and sell the WGS, advertisements were placed in the national newspapers calling for applicants to transfer the technology. Applications were screened based on a criteria developed internally by the NERDC. Operating and maintenance manuals were also developed for the stove product. As part of the technology transfer process, the capacity of the selected applicants was developed through hands-on training. This consisted of one-to-one hands-on training where the entrepreneurs, as future manufacturers of the WGS made their own stoves together with the engineering staff of NERDC. Those who were interested in continuing with the production and sales of the WGS were recommended to obtain manufacturing and sales licenses. NERDC organized a public launch for the WGS and continued with marketing and publicity.

After the technology was transferred, those who were trained initially produced a few WGS on their own and sent the samples to the NERDC. NERDC checked them against the standard specifications and quality and in turn recommended any improvements to be made as necessary. Manufacturers who satisfied NERDC by demonstrating that they could adhere to the product specifications were granted licenses to produce and sell the WGS. Those who were able to produce a high quality product were allowed to make external modifications, i.e., color, appearance etc, subject to meeting the basic model specifications. NERDC issued licenses to produce and sell WGS to 19 persons, present across many parts of Sri Lanka. All of them were small or medium scale entrepreneurs who were already engaged in the production and sale of other goods. These entrepreneurs purchased their raw material and consumables in Colombo or other near-by towns. Over time, some of the producers made slight modifications to the original product in response to customer needs and market conditions.

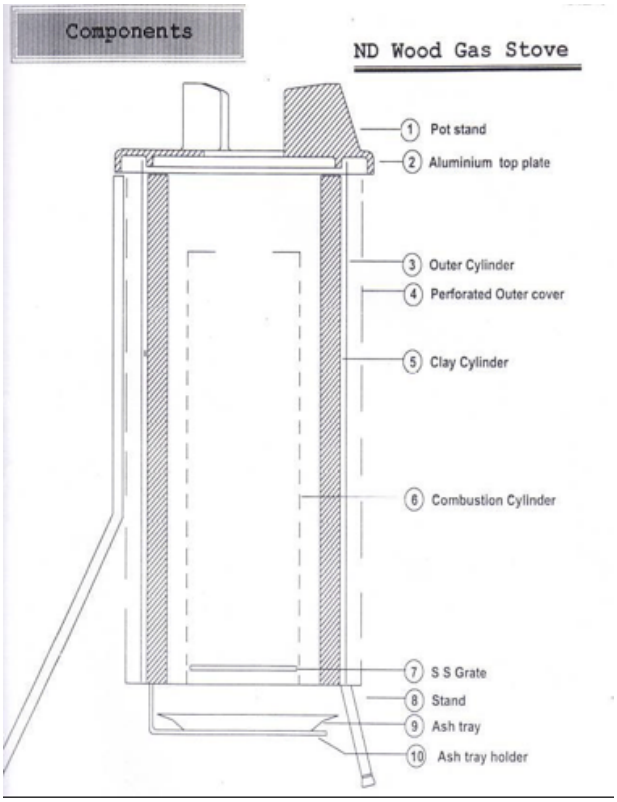
One of the components of the WGS is a cylindrical clay insulator. As most of the WGS producers were engaged in the metal industry and had no exposure to the clay industry, a potter was selected and trained to produce the insulator. In consultation with experts in the ceramics industry, NERDC developed the right texture of clay to produce the required properties of the insulator. The producer of the insulator was

assisted with the design and was provided with the required moulds. All the licensed WGS manufacturers were asked to procure the clay insulator from the specified producer, as it was tailor made and not produced by any other potters in the market.

NERDC asked for no royalty fees from the licensed manufacturers but charged a very minimal technology transfer fee of LKR 10,000. As support to the producers, at the early stages of WGS promotion, NERDC purchased approximately 50 WGS stoves from each producer as an initial sales boost. The selling price was determined by the individual producers, intermediaries or retailers. NERDC's techno-marketing division assisted in the dissemination of the technology.

3. WGS Product

Carbon Monoxide, in this context is referred to as a 'producer gas'. A special feature of the WGS stove is that fuel is designed to burn from the top to the bottom (described as "top burn") instead of the bottom to top as in the case of most fuel-wood, liquid and gas fuel based stoves. In order for the fuel-wood to interact with oxygen to give a better combustion, the surface area of the fuel-wood has to be increased so that the efficiency of the stove is increased. To do this, the WGS uses small fuel-wood chips, thus the effectiveness of the WGS depends heavily on access to and supply of quality fuel-wood chips of the correct size and type.



The main components of the WGS are the outer cylinder (made out of stainless steel) and the inner cylindrical clay insulator. The insulator should have elevated strength and insulation and therefore is made out of special clay. These two components were designed considering ease of manufacture as well as of use. The stove also contains a rack to rest the pots or pans at the top of the WGS, a dish at the bottom to collect the ash and an opening for air intake at the side. Compared to other commonly used stoves it is narrower in width (diameter) and greater in height. The standard WGS is a single burner stove and approximately 600g of fuel-wood chips burn for approximately 50 minutes.

Figure 1: Wood Gas Stove (Source NERD Centre)

3.1 WGS Stove Price

The price of the WGS gradually increased over time. By 2010, the retail price was within the range of LKR2750 - LKR3750 with the cost of production being an average of LKR1750-LKR3000. Retailers maintained a margin of approximately LKR300–LKR750. None of the manufacturers were found to keep proper accounting records related to the WGS which may be due to their small scale of operation. Additionally, none of the producers were producing quantities to achieve economies of scale and therefore the unit price of production was quite high.

The purchase price of a single burner WGS stands at the highest among the domestic cooking stoves used in Sri Lanka. Most of the stoves available in the retail market are imported from China except for the clay stove produced in-country. Table 1 summarizes the market prices of single burners or the equivalent stoves available in the retail market in Sri Lanka. However, it should be noted that an assessment and comparison of the stoves is of equally great importance. The following data excludes the costs relating to the environment, society, hassle, operations, dependence on imports, drains on foreign exchange, local value addition etc. which are all parts of a life cycle costs. The prices of reputed brands and after sales service support including warranties may be higher than the prices quoted below.

Stove (Single burner or equivalent)	Market Price (LKR)
Clay stove	125
Hot plate (with coil and base)	625
Liquefied Petroleum (LP) gas stove	1,450
Kerosene cooker	2,000
Electric Cooker	2,200
Wood Gassifier Stove	3,750

Table 1: Market prices of single burner or equivalent stoves in Sri Lanka (2010)

Figure 2: A popular clay stove

The stoves are also dependent on fuel availability and price. A full life cycle cost analysis of Sri Lankan stoves is beyond the scope of this study. In order to have a full understanding of the appropriate household stoves in Sri Lanka a price analysis, accessibility, availability of relevant fuels and efficiency of different stoves (thermal, heat transfer and cooking efficiencies) must be carried out.

Typical market prices of common fuels used for domestic cooking in Sri Lanka are given in Table 2 below.

Fuel	Typical price (LKR)
Fuel wood (Rubber fuel wood -including transport to door step)	8 / kg
Electricity (for total cumulative monthly consumption of over 120 kWh)	16/ kWh
LP gas (domestic cylinder of 12.5 kg and excluding transport)	132 / kg
Kerosene (at the petroleum distribution sheds)	51 / litre

Table 2: Market prices of common fuels used for domestic cooking in Sri Lanka (2010)

The average per capita monthly mean income of a Sri Lankan in 2009 was LKR19662. Therefore the cost of a WGS amounts to 19% of the per capita monthly mean income. This figure is significant because most families cannot afford this due to cash flow problems as they need to meet other expenses from a limited monthly income. There is also a question of readiness to purchase these stoves in the case it was economical to purchase. Generally, cooking is considered a women's chore and it is questionable as to whether the said amount will be allocated for cooking purposes in a male dominated society.

When viewing the energy ladder, stoves using biomass cooking fuels are generally viewed as inferior products from a monetary sense. This means, as the household income increases, the demand for biomass stoves decreases. The LPG stove performs just as well as the WGS, thus as the household income increases the demand for the LPG stove increases. WGS has the properties of a biomass stove even though it is actually a gas stove and the behavior of the WGS in terms of its economic value has not been clearly studied. It is worth investigating the sensitivity of the WGS to price, household income and social status and to observe where the WGS is viewed on the energy ladder.

3.2 Purchase Locations For WGS Stoves

During the initial stages of the WGS promotion, the stoves were only available at the NERDC and at the Industrial Development Board's show room at Slave Island, Colombo. WGS producers who received production licenses began selling their own products and marketing it themselves. Most of the WGS producers set up low volume and highly customized production facilities which meant the stoves had to be sold in small volumes. This led the producers to adapt a more personal selling approach rather than widely distributing them through intermediaries and sales outlets. Simply one producer sold the WGS in larger volumes through his own and other sales outlets.

A common trait of all the manufacturers was that the WGS was just a single item produced and sold among other products available at their stores. The proportion in volume and value of the WGS compared to their other products appeared to be less than 20% in all cases. The distribution or sales of the WGS was carried out alongside their other products using the contacts and channels already established. Using the same market channels helped them reduce their investment on resources and time. However, the sales of the WGS had to depend on the sales operations of the other products, thus no particular attention was given to the WGS.

One manufacturer adapted a batch production process at his self-owned showroom and at 5 other sales outlets in the country for selling his WGS. He also had his own vehicle fleet and sales & distribution staff. The other producers either had direct sales or sold through the sales outlets owned by others situated closer to their production facilities.

3.3 WGS Stove Promotion

Along with the launching of the product, a public awareness campaign continued through conventional channels, i.e., presentations, exhibitions, radio & TV interviews, newspaper articles etc. These were centrally coordinated by NERDC. NERDC was involved in several public interactions at various events organized by other organizations or themselves which served as an opportunity for the promotion of the WGS. A specific planned intervention was NERDC producing approximately 500 WGS units internally at its private workshops. These WGSs were sold to internal staff who bought them through a repayment scheme of 6 monthly installments. These were priced according to internal costs. Licensees usually sold to the public who generally ordered stoves after promotional activities (TV, paper etc.). After such an event, NERDC generally received over 1,000 enquiries. During the latter stages of promotions, the Science and Technology Centers (Vidatha) were used for promoting the WGS to achieve a wider reach within the country.

While NERDC had a slow but steady centralized approach to promoting WGS, the licensee producers did promotions of their own which complimented each other. They demonstrated the stove locally at their established outlets using the existing links, with a few of them displaying posters and notices in public places. Some institutional staff demonstrated and promoted the WGS, selling it through their staff welfare societies and recovering the price through an installment payment process. The most effective promotional activity proved to be ‘word of mouth’ both positive and negative.

Figure 3: A poster promoting WGS (Spectra)

One producer branded his product, selling it under a brand name. This was the same manufacturer who produced the WGS through a medium scale batch production process facility using his own vehicle fleet, sales staff, show room, sales outlets and sales agents. He developed and added a stand for the stove design which was then patented. The manufacturer additionally packaged the stove in a nice triangular cardboard box with an inbuilt handle of which the design was once again patented. It is estimated that he was producing around 1000 units a month when sales were at their peak. Along with the WGS he also provided complimentary 3 packets of fuel-wood chips weighing 600g to induce sales.

3.4 WGS Stove Financing

Most producers did not undertake commercial loans or financing. The main reasons were that production volumes were small and the contribution of business from the WGS was not very significant compared to their other products. Lack of collaterals (security) which is usually cited by many small to medium scale manufacturers in the country was not cited by any manufacturer as a hindering factor. All the manufacturers already had their production facilities prior to undertaking the production of WGS and therefore they had both the required skills and equipment. Existing workshop facilities were used so that they did not urgently require additional support to purchase capital goods or seed capital. The existing facilities were predominantly self-financed. As the production system adapted was product process the working capital requirements were small.

Commercial loans were seldom undertaken and the rates of interests offered by the banks were the existing commercial rates and not concessionary rates. There was one occasion where a government institution assisted a producer by supplying him with a wood chipper, the cost of which was estimated to be around LKR25000. The producers managed their working capital by receiving credit from their suppliers which ranged from 2-6 weeks. Except for one, the manufacturers purchased the raw materials and consumables from nearby towns and known shops. They extended credit by accepting post-dated cheques. Some of the immediate expenses were met through the finances available for the other products they produced and sold.

3.5 WGS Stove End-User Concerns

There were several concerns of the end-users. From the perspectives of some end users, one of the major concerns or difficulties encountered was the processing or purchase of correct sized fuel-wood chips. Currently, there are hardly any supply chains of fuel-wood chips suitable for the WGS stove. The fuel-wood available domestically from home gardens or delivered through traditional supply channels did not conform to the specific size required.

Additionally, the insufficient burning time of the WGS stove was also noted. The flame produced by the WGS only lasts for about 50 minutes with 600g of fuel-wood chips. The cooking time period in Sri Lanka generally takes longer than 50 minutes. The stove follows the natural draft principle and therefore there is no possibility to regulate or control the air flow as in the case of conventional stoves. Thus the flame was considered by the cooks as being a hindrance.

Despite improvements, the WGS stove still emitted smoke to a certain extent. Additionally, soot and carbon were deposited on pots and pans. Most cooks wanted to completely eliminate this problem which they expected the WGS could do.

The purchase price of the WGS was also a concern as it was intially considered costly. This concern is justified with the purchase price of a WGS amounting to 19% of the mean per capita monthly income of a Sri Lankan.

Correctly filling the WGS needs some degree of skills and getting used to at the initial stage. Some consumers had not developed these skills. Also, the WGS did not have the facility to add ‘new fuel’ while cooking. Conversely, if the cooking finished before the fuel-wood chips were completely burnt; there was no convenient mechanism

to stop the burning so that the fuel-wood chips and time were saved. In addition to continued smoke and a yellow flame, igniting the WGS was also considered to be difficult - a skill most cooks did not to develop. The WGS is of a standard size for which all the calculations are done and optimizations are made. When cooks want to use pots and pans of different sizes, there was no option for it to be accommodated.

4. Challenges For The WGS Stove

The WGS was not disseminated in large volumes in the country. The number of WGS sold since 2002 is estimated at 30,000 units. At the same time, as explained above the product and its delivery model had various limitations. Finding solutions to the concerns of the end-users was the main challenge the promoters of the WGS had to face. Consumers perceived the stove as a gas stove and expected the stove to have similar or superior features compared to a LPG stove. In reality this was an over expectation of the consumer. Overcoming this perception to advance the WGS is a significant challenge.

Obtaining correct wood chips (quality/moisture content and size in particular) is difficult as the ideal length and diameter of the chips should be around 2.5 cm each. In addition, there exists no effective supply chain. Although the stove efficiency does not depend much on type of fuel-wood being used, i.e., rubber, timber off-cuts, other hard wood etc, its density has an effect. The weight and the energy content of the chips filled in the stove depend on the density, as the volume of the combustion chamber is a constant. Accordingly, higher density types of wood chips have to be used.

As the stoves are produced and packaged by the licensees, it was found that some of them contained wrong or incomplete instructions. In one instance, a manufacturer had promoted his stove stating that a stack of fuel-wood to the length of the height of the stove can be inserted into the stove vertically and combusted. This is erroneous as it is against the working principle of the stove. If this was to be take place, the stove would not have a uniform flame, would emit smoke and ultimately would set on fire. These misconceptions had taken place as a result of the manufacturers not understanding the working principles and science of the stoves.

The inability of consumers to properly use the WGS is a major challenge. This could be linked to the misinformation provided by the manufacturers in the instructions. Another instance of misinformation was, users were asked to soak a piece of cloth in kerosene and wet the wood chips at the top of the stove prior to setting fire of the stove. Once set on fire, the kerosene will burn out quickly allowing the chips to burn well. As this is a top burning stove, the stove will burn efficiently and with less smoke or no smoke. However some users poured kerosene into the stove. The kerosene moves to the bottom of the stove and once fired, the chips at the bottom also would burn. This completely disturbs the operating principle of the stove. This results in obtaining a larger flame and burns off the chips directly without producing producer gas. Therefore the efficiency of the stove decreases while additionally emitting excessive smoke.

To promote the stoves, one of the avenues adapted by the NERDC was to use the network of the Science & Technology Centers of the Ministry of Technology & Research which has over 200 Science & Technology Centres, called Vidatha Centre

which were distributed across the country. Some of these selected centers were provided with stoves for promotion. However, some of the Officers who are supposed to promote the stoves lacked knowledge or skills on how to operate/demonstrate the operations of these stoves. Although there is a detailed operation manual, the instructions do not reach the users or the potential users effectively.

At promotional campaigns of the WGS, the demonstrators had a tendency to exaggerate the details of the stove, i.e., that the stove gave a complete blue flame. This led the consumers to have over expectations of the stove. Once they used the stove, it would not perform as expected resulting in clear frustration and disappointment. There exists a possibility that such instances could have led to the stove not being used afterwards. Moreover, despite clear instructions, it has been found that the users do not follow the instructions and operate poorly. Some degree of skill on operation of the stoves is required particularly at the early stages of using.

Out of nearly 20 licensees, only less than 10 of them continue to produce the stoves. Except for one licensee, others have very limited production or distribution capacity. This has led to extremely poor availability of the stoves across the country. Proper channels do not exist for prospective buyers to purchase the WGS as the channels do not extend widely. Due to this, users and prospective users fear that proper after sales services would also be difficult to find. Not limited to purchasing the stoves and after sales services, the availability of right fuel-wood chips at convenient locations is another great problem. There exists difficulty in finding the right type and size of wood chips with reasonable quality, i.e., moisture content, de-skinned etc. As such, lack of supply chains of stoves, after sales services and fuel wood chips stand as major challenges in promoting WGSs in Sri Lanka.

Although the Government and other external factors may influence decision making, price sensitive consumers consider price as one of the major factors in their decision making. As explained, the purchase price of the WGS is the highest among the commonly used stoves at the domestic level and its price is significant compared to the per capita monthly mean income of individuals. Pricing competitively is another challenge faced by the promoters of WGS.

[3] NERDC is a statutory body established under this ministry and therefore has closer relations with the network of Science and Technology Development Centres

5. Recommendations

The WGS has multiple benefits for individual users, local producers of the stove, fuel suppliers and to a country that uses indigenous fuels. Unfortunately the WGS has not had the ability to penetrate many households and as such is not used widely. An extensive awareness and promotional campaign would be necessary to relay the message and motivate people to use the stove. Simultaneously, the product itself would have to be improved according to the concerns of the users.

Supply of fuel-wood chips is identified as the number one concern of the users and utmost emphasis needs to be paid to establish and strengthen the supply chains. Growing energy at homesteads and at plantations, particularly on marginal land can encourage the supply. Use of off-cuts from tree felling and the timber industry can optimize the use of waste. Supply chains have to be extended to its components such as the clay insulators and further importance should be given to after sales services. Mass-scale main streamed supply chains where fuel-wood chips could be bought from many retail shops or super markets have to be established.

Current manufacturers are operating in small and medium scale operations and therefore are not in a position to cater to a larger demand or reduced production and distribution costs through operating near economies of scale. A few companies instead of many should engage in the production and distribution with higher volumes of production and sales while maintaining considerable profit margins. This will help reduce the price and have efficient distribution and after sales services. Mass production may make the WGS closer to the consumers and users and in turn bring them benefits. It is recommended that materials should either be imported or purchased in bulk.

Tax reliefs and other incentives should be offered to manufacturers during the initial stages of introducing the stoves to encourage production. Further suggestions are that the Value Added Tax on principle raw materials could be removed. Lowering the price can lead to higher market penetration. Additionally, financial lending institutions should be encouraged to consider WGSs as a green product and be assisted with the concessionary loan facilities available for such interventions.

For those communities who find it difficult to buy the WGS on a single installment on a cash basis, the Government, other institutions and staff welfare societies could introduce schemes for the purchase of these stoves through an installment payment scheme. Furthermore, micro financing institutions and self-help groups could devise credit schemes for this purpose.

Policy Innovation Systems for Clean Energy Security (PISCES)

PISCES is a six-year research project funded by the Department for International Development of the United Kingdom (UK). Project implementation started in July 2007. Through action research the project is increasing available knowledge and understanding of policy relevant trade-offs between energy, food and water security for livelihoods in relation to bioenergy. PISCES is a Research Programme Consortium whose members include African Centre for Technology Studies (ACTS, lead) Kenya; Practical Action Consulting UK, Eastern Africa, and Sri Lanka; the University of Dar es Salaam, Tanzania; M.S. Swaminathan Research Foundation (MSSRF), India; and the University of Edinburgh, UK. **www.pisces.or.ke**

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