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Smokeless Cook stove an Advancement of the Combustion Technology and Innovative Approach towards Eco-Efficiency and Low Emissions in Rural Areas

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Abstract: *In rural India many women spending several hours a day cooking over an indoor open stove is a normal practice. What these women fail to realize is that there is an invisible killer in their kitchen of burning biomass fuels causes almost 500,000 deaths every year in India alone. A design initiative can use its design expertise to help these women continue with their traditional culture, while empowering them to select a way of cooking that does not endanger their lives. It describes the brief and the open-innovation process used in creating the 'Chulha' (Stove) – a low-smoke stove that prevents sickness and death from indoor air pollution due to cooking activities with biomass fuels in rural low-income communities. Evaluation included a certification of stove's thermal performance, fuel consumption and carbon monoxide emissions. Stoves under testing used bio-organic waste. The firewood used as fuel was free from any potential pollutants. The design brief challenged team has to come up with a low-smoke solution for healthy and safe cooking able to fit the local socio-cultural and infrastructural conditions of rural and semi-urban areas. More specifically, objectives were to design, develop and test a solution, which able to reduce indoor pollution and therefore health-related diseases with respect to local culinary habits and cooking behaviors. With the advancement of the combustion technology and innovative approach towards applying the known principle of cook stove designing. The cook stove technology has gain the boost and now fourfold improvement in the overall thermal efficiency as compare to the traditional tri-stone cook stove. Apart from the type and quality of the fuel used, design of the cook stove chamber is the deciding factor for the associated emission causing by the fuel combustion. . TIDE has put up an effort to train more entrepreneurs. But finding the right candidate for training is a limiting factor to overcome.*
Key Words: *Smokeless Stove, Eco-Efficiency, thermal performance, Low Emissions, Biomass Fuel.*

I. Introduction

The Stove is not only benefits the users but also various stake holders, who are active in the value chain smokeless stoves. The production and distribution of the Chulha stimulates the creation of local entrepreneurial skills and provides low cost, affordable solutions that those who really need them. It became clear from the results of the research that the local design requirements called for a cooking solution able to fulfill the following physical and socio-cultural conditions i.e. adaptability to different biomass fuels from wood to cow dung. A technical assessment of the Chulha (Stove) has been conducted in laboratory to define its eco-efficiency and low emission. Use of different, non-standard cooking vessels and various logistic constraints, results world deaths from indoor air pollution due to burning solid fuels are estimated at 1,917,000 each year. India alone accounts for 25% of such deaths almost 800,000 of the victims are women and children. (Source: WHO 2015)

II. NPIC Program to Improve Cook Stoves

Since the energy crisis of the 1970s, improvement in biomass burning cook stoves to save fuel was considered as an urgent need. Various organizations in the world over started working towards the same. In India, the Department of Non-conventional Energy Sources (DNES), which was created in 1982 initiated demonstration of improved cook-stoves soon after its inception followed by launching of a demonstration project on Improved

Chulha in 1983. The programme objectives were to identify (i) fuel wood conservation; (ii) removal/reduction of smoke from kitchens; (iii) Reduction of deforestation and environmental degradation (iv) Reduction in the drudgery of tasks performed by women and girl-children and their consequent exposure to health hazards; and (v) employment generation in rural areas. In 1992, the DNES was upgraded to Ministry of Non-conventional Energy Sources (MNES) and continued to manage this programme. Later on in 2009 it was renamed as Ministry for New and Renewable Resources (MNRE)).

The **National Programme on Improved Cook stoves** (NPIC) was implemented through involvement of various State Nodal Departments/ Agencies in almost all the States and Union Territories. The technical training support programme was provided by 22 **Technical Back-up Support Units** (TBSUs), set up under the NPIC at different universities, IITs and other institutions of the country. More than 60 fixed and portable models of improved Chulha, with and without chimney, single-pot and multi-pot, suitable for different fuels, cooking habits and local requirements and using different materials of construction were developed and taken up for installation under NPIC.

Fig.1 Traditional Cook-Stove

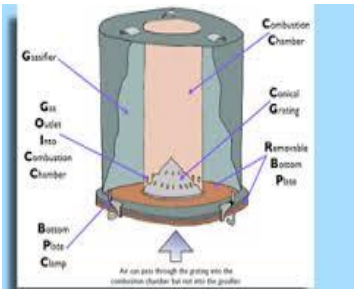

Fig.2 Inner View of Stoves

Fig.3 Traditional way of Cooking

III. Technical Testing

Test conducted upon a few comparative values of Traditional Stoves:–

(a) Time required for boiling 1 liter water-
11.5 minutes, 14 minutes, 22 minutes –

(b) Fuel required for boiling 1 liter water-
225gm, 315gm, 415gm

(c) Heating efficiency
Highest, lower, lowest

(d) Rate of cooling
Lowest, lower, highest

(e) Soot retention-
100mg, 80mg, 20mg

IV. Employment Opportunity

TIDE provides employment to 24 full time staff and some of the staff is engaged in developing the stove enterprises. Further, it has created employment opportunity by training 14 entrepreneurs, who has business employ about 40 skilled and 90 semi-skilled workers for making the stoves. These entrepreneurs also have the opportunity to develop new types of stoves, or improve the existing ones. Benefiting the women workforce, the project helped women self – help groups in increasing income generation in the areas of fish – drying, cashew nut processing and drying of coconuts.

V. Methodology

Based on international standards of emission and combustion, a standard testing protocol and procedure is under development. An international conference, organized by USAID in 1982, has resulted three distinct testing/evaluation techniques under the 1985 VITA protocol. Before launching the cook stove in to the market, cook stove need to go through three distinct test procedures, includes both lab and field test. These are:

The Water Boiling Test (WBT) – This is a laboratory test that simply simulates the cooking process. Here water in the cooking pot is heated to evaluate the thermal efficiency and associated emission generation during the combustion. Other than above, WBT test helps to provide an initial assessment of stove performance, design evaluation during the development, compare the effectiveness as compared to the different designs for performing the same task and ensures to meet the design specifications.

The Controlled Cooking Test (CCT) – This is a field test that analyzes how the new stove performs compared to common or traditional cooking methods. The test helps to compare the amount of fuel used by different stoves to cook a common food.

The Kitchen Performance Test (KPT) – This is a community field test that measures fuel use in homes.

All these tests helps to validate the stove from initial optimization of the technical design in the laboratory under the controlled artificial atmosphere to the final field testing with lot of actual field variables, affecting the cook stove performance. Those who want to secure the carbon credit; they need to go through one more test is called Gold Standard Cook Stove Methodology.

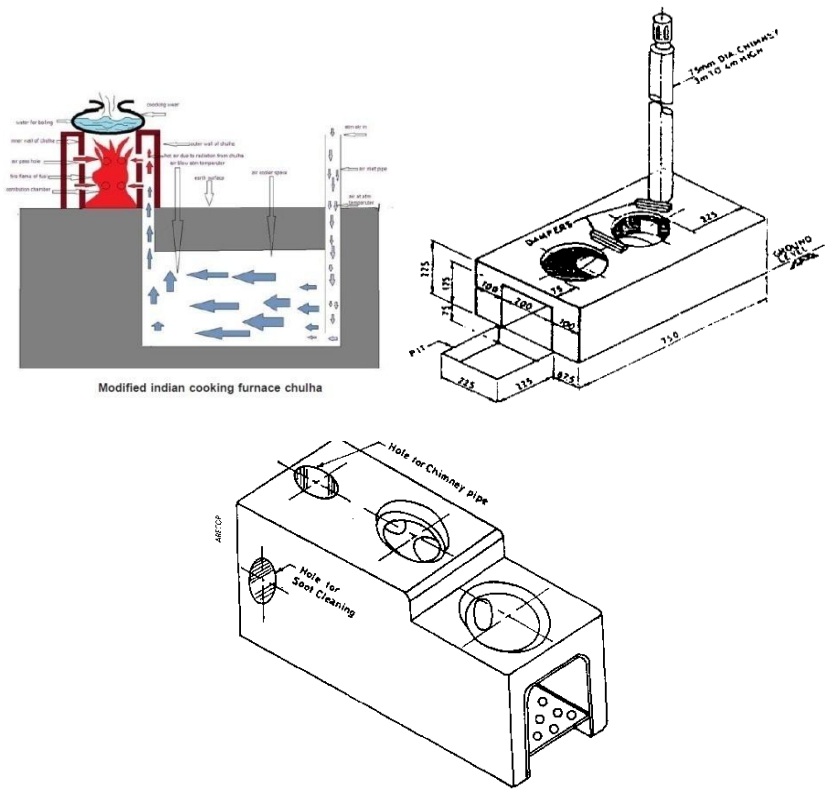

Fig. 4 Modified Design Cook stoves

There are four centers, which have been recognized by the MNRE for the testing and certification of the cook stoves:

1. East zone – IMMT, Bhubaneswar
2. West zone – MPUAT, Udaipur
3. North zone - IIT Delhi
4. South zone - IISc Bangalore

MNRE has been continuously engaged in various new 'improved cook stoves' initiative that aims to facilitate the development on the next-generation of biomass stoves for household cooking and their widespread deployment. Activities undertaken by MNRE under "New Indian Cook-stove Initiative" are given below:

- Organization of Brain-storming consultation on improved cook-stoves.
- Setting up of Core-Group comprising of experts from Institutions, industries, NGOs and other organizations active in the area of improved cook-stoves.

- Project taken up on "A new initiative for improved cook-stoves – preparatory activities for launch" through IIT Delhi and TERI.
- Launch of National Improved Cook-stove Initiative.
- Pilot field testing and evaluation of community size biomass cook-stoves for mid-day meals, hostels and eating joints/ Dhabas.
- Organized meeting of sub-group on revision of modified BIS standards and test protocols.
- Setting up of Steering Committee under the Chairmanship of Member, Planning Commission on National Biomass Cook-stoves Initiative.
- Steering Committee of Planning recommended for Innovative on cook-stoves competition through 'X' Prize Foundation.
- Formulation of Section 25 Company for providing institutional structure to introduce policy interventions.
- Organization of joint national workshop.
- Testing improved cook-stoves at IMMT, Bhubaneswar and MPUAT Udaipur.
- Stoves passed BIS Standard: Vikram cook-stove, Harsha Multi-fuel cook-stove, Oorja Cook-stove, Phillips Cook-stove.
- Excise duty exemption for improved cook-stoves.
- Improved cook-stoves included in Indira Awas Yojana of the Government.
- Supporting up gradation of 3 nos. of improved cook-stoves test centers at IIT Delhi, IIMT Bhubaneswar and MPUAT Udaipur and the fourth is already in operation at IISc, Bangalore.
- Pilot Implementation of various 'Delivery Models' for implementation of family type improved cook-stoves including production and supply of processed fuel are being contemplated.

VI. Testing and User Feedback

Aryan Industries **(www.aaryanindustries.in, Bhopal)** is producing smokeless cook stoves and has tested its cook stoves in rural and semi-urban homes, involving technical experts and stove users. Feedback regarding improvements suggested a few modifications to the initial versions of the stove. Design interventions included technical changes related to the manufacturing process to optimize heat flow within the stoves and improve their thermal efficiency, an easier way of assembling components such as self locking pieces. The introduction of a soot collector and fixing chimneys to the wall then, modified versions were installed in 12 homes for further trial and to evaluate their technical performance.

Fig. 5 Aaryan smokeless Cook-stoves

Fig. 6 MNER approved Chulha

Fig. 7 Cow dung Cakes for Fuel

According to the BIS Standards, 2013. The test results of Aaryan Smokeless Cook-stove have been communicated to MNRE. The average values for the different parameters studied were found as follows:
Power Output: 1.61 kW
Efficiency: 25.61 %
PM: 237.80 mg/ MJd,
CO: 5.21 g/MJd
Body Temperature: 69.33 ºC
Handle Temperature: 42.83 ºC

Since, the CO Emission parameter and body temperature parameters are much higher than the acceptable limits set by BIS for natural draft biomass Cook-stoves, therefore it need some modification in design.

The Aaryan Smokeless Cook-stoves were presented in several places for demonstration and received immense appreciation in-

- Vigyan Mela 2012 Indore,
- Bhopal Vigyan Mela, 2013
- Bhopal Vigyan Mela, 2014 (Best pavilion award by Ministry of Energy Govt. of M.P.
- Savishkar iFAST 2015, MANIT Bhopal MP India.
- Search and Research Youth Conclave-2015, Growing India International Conference on
- Indian Research Scenario, April 11th & 12th, 2015 TTTI Bhopal M.P.
- Tapti Vigyan Mela, 2015 Burhanpur M.P. India.
- Mandla Vigyan Mela, 2015 Mandla M.P. India.

VIII. Initiatives Taken

TIDE established in 1993 is a non-profit organization that aims at applying appropriate technology to rural situations. It does not innovate, but adapts products developed by research institutions to fit the user requirements and local conditions. The organization based in Bangalore, and works through a network at grass root entrepreneurs. These entrepreneurs and university graduates are trained by TIDE.
In southern India, an estimated eight million people work in small and tiny businesses. This includes food processing and preparation, textiles, Ayurvedic medicines and brick-making to name a few. These businesses run with small turnovers and for achieving a healthy bottom-line overheads are kept at a minimum. So when it comes to choosing a heat source for various manufacturing process, it is the low cost wood and other forms of biomass. Fuel efficiency is not given much consideration. However, there is an adverse impact on the environment. To mitigate these environmental concerns, **Technology Informatics Design Endeavour** (TIDE) developed a range of energy efficient stoves for the grass – root businesses to improve their operations using less wood. An improved stove works more efficiently by better heat transfer and combustion of the fuel. The manufacturing site for the stoves is always close to the location where it would be used and as far as possible they use locally available material. TIDE works with small town fabricators for different components of the stove. Quality control is an area where TIDE lays a lot of emphasis. To sustain the popularity of any product is an area that cannot be neglected. Towards this, they collaborate with leading institutes. The Central Power Research Institute tests the efficiency of the product, while The Centre for Sustainable Technologies at the Indian Institute of Sciences collaborates in the development process, carrying out field tests and in data collection. According to an assessment carried by TIDE in 2006 the stoves has saved 39 million per year in fuel costs. The TIDE fuel efficient stove also benefits the environment enormously by saving on biomass. For assessing the biomass savings, TIDE has developed an accounting methodology. This is based on test done by the Central Power Research Institute.

IX. Requirement of Cook-stoves At Targeted Market Are in Four Segments

Mid Day Meal Manufacturer: Stove that can cook more than 40,000 meals per day in a centralized kitchen. This stove is provided with a briquette fuelled steam boiler and stem-kettles that save up to 70% of fuel bills when replaced with LPG.
Micro Entrepreneurs: Stove for making fried snacks is an automated powdered biomass stove (Surya stove) having temperature controlling facility. As a result fuel feed can be controlled on the basis of the heat requirement of the food being cooked (or fried). This stove saves up to 50% of fuel when replaced with diesel fired stove.
Company and College Hostel Canteen: Stove for cooking meals for 1000 people. For such institutions Aryan Industries suggested steam boiler as well as biomass briquette fired Earth stoves (model ES10) and leaves it to the client to decide on the option depending on their financial ability. These options, when replaced with LPG help save up to 70% in fuel bills.
Restaurants and Road Side Dhabas: Vikram Stoves come in two models-ES2 and ES3 and save up to 70% of fuel when replaced with LPG. These models come with briquette fired with DC powered blower.

X. Cost Analysis of Running One Community Cook Stove

In fact, whatever cook stove model is used, each has the potential to save almost 50% of fuel cost. The numbers of LPG cylinders is almost to the tune of 750 LPG cylinders a year. The new models of Cook stoves have a strong body to withstand heavy work load of community kitchens.

Table- 1

Cost Analysis for 500 People		
Average consumption of Briquettes in Smokeless Cook Stoves	150	Kg/day
Total Expenditure on Briquette per month (considering Briquette cost @Rs. 8 per kg)	36000	Rs/month
LPG consumption (for same heat value)	112	No./month
Total Expenditure on LPG Cylinder per month (considering LPG cost @Rs. 450 per cylinder	50400	Rs./month
Net Savings	**14400**	**Rs./month**

VII. Future Scope of Work

The stoves should be equipped with well designed combustion chamber volume resulting in high combustion and heat transfer efficiencies. The stoves should be designed to burn the fuel totally with high temperature with optimized air-to-fuel ratio. The area of contact between the hot gases and the heated vessel volume should be maximized in order to increase the heat transfer process. An efficient insulation minimizes the heat loss and reduces the risk of burning from direct contact. An optimally designed chimney to vent the flue gases is designed to reduce heat losses to the atmosphere. The chimneys take smoke away from the users.

Bypass duct for efficient draft - It ensures equal heat distribution and right turbulence under the first and second pot, resulting in faster cooking and boiling. - It helps bring down the boiling time by 3 minutes, reaching boiling time in 10-11 minutes: standard stoves boils around 22 minutes while our previous Chulha version (without bypass) between 13-14 minutes.

Soot collector for cleaner air – The soot collector reduces the amount of soot that reaches the chimney and therefore both the risk of pipe obstruction and the time required for chimney maintenance. - Soot can be collected by passing the gases through a zigzag path in the chimney chamber at the stove level. Like any entrepreneurial venture, this also has it challenges. Currently, TIDE and its entrepreneurs are installing 1,300 stoves per year. For taking this project forward.

XI. Results and Discussions

It is expected that these Green Entrepreneurs in the long run will be able to establish the stoves free of charge in the client's premises and establish briquette supply chain for these customers, similar to the existing LPG delivery system prevalent in the country. To make the business more viable for the Green Entrepreneurs, 60% of the carbon offset money is used. In the long run, the firm hopes to create thousands of such entrepreneurs operating self sustaining, It is estimated that with a mere investment of 5 lakh, such an enterprise can be created that can generate an income of 15,000-20,000 per year. A firm near Chandigarh is manufacturing of stoves and delivering more than 3500 Stoves in many parts of the country including Punjab, Haryana, Rajasthan, Bihar, Tamil Nadu, Andhra Pradesh and Maharashtra for diverse clients, including clients making 40,000 meals per day, to small road-side restaurants. There is enormous potential to scale up this technology and use it for a variety of small-scale industries. Literally starting from scratch, the firm lacks the much needed catalyst of capital investment to strengthen its manufacturing infrastructure. Improved stoves also brought hygiene in the kitchen area by reducing smoke and soot in the air. Concentration of carbon monoxide was brought down to 480µg/m³ from 4260 µg/m³ in indoor air. Room temperature of the kitchen was also brought down by at least 8º C. Improved cook stoves also led to employment generation. They provided employment to 80 masons and 12 fabricators, and many people may get employment as the popularity of improved cook stoves increases. The technology is very easy to replicate and costs involved are very low. Due to these factors improved cook stoves have huge potential for replication not only in Andhra Pradesh, where there are about 4000 way side hotels but also all over India, wherever conventional stoves are used for cooking food in way side hotels, Dhabas and individual households.

XII. Conclusions

First of all, we have realized that an understanding of the local physical infrastructural, economic and socio-cultural conditions is imperative before making any technological choices. The challenge is coming up with an accessible, affordable and sustainable solution for local needs to evaluate the best technological solution at a given moment in time, rather than opt for the best available technology. With our Chulha for instance, insights from the targeted users and local stakeholders helped us to understand current barriers to cultural acceptance, as well as constraints on product dissemination. Based on these insights the most feasible and appropriate technological answer is to achieve our objectives. Last but not least, it should be noted that the co-design approach resulted not only in a way of delivering a solution that better fit the context of application, but also enhanced the potential benefits of the stakeholders involved, democratizing the value creation process, and therefore increasing the chance of implementing valuable solutions for all. Indeed, with this approach, users and stakeholders worked together in a participatory process where they all put their own interests on the table. Key, in this regard, was to go beyond listening intensively to local communities to acquiring their true engagement, where users were even empowered in the decision making process. From the very start of the experience, adopting a process in which designers and researchers operate in a multidisciplinary team, where an open dialogue with NGOs and various local stakeholders bringing knowledge from the field, is essential in envisioning an effective human-centered solution. The value co-creation process undertaken during this journey of understanding and learning has resulted in a stove that makes indoor cooking healthier, cleaner and faster when compared with traditional indoor open cooking fires. The Chulha also claims to be, simple to use and easy to maintain.

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