Chapter 15
Technologies to Support the Technologies

Pramod Khadilkar, H. I. Somasekhar and Monto Mani

1 Narrow Focus of Designing Technologies/Products

The current focus of the design in the areas targeting the rural/informal markets that deal with underprivileged, resource-constrained populations is technology or product-centric [5]. RuTAG centres as the application of Science and Technology has this great responsibility of providing technical solutions to demand driven problems. However, such technology-centric focus also could lead to the myopic scope of the centres [8].

Science/Engineering focus of such centres is crucial, as that is specialized professional knowledge that grass root innovators lack due to lack of formal education. However, there is a lot more to do within science/engineering focus if the final goal of RuTAG outcomes is evaluated at improved well-being of the involved beneficiaries rather than the technical solution to a functional problem. Interestingly engineering design practitioners also agree that technology centeredness is not sufficient in focus areas, where RuTAG caters [12].

This paper presents a case study of biomass cook stove and challenges linked with its dissemination to elaborate the points discussed earlier. Being self-sufficient in meeting the energy needs is crucial for sustenance. Industrially produced fuels like Liquefied Petroleum Gas (LPG) or kerosene need mechanisms to ensure predictable supply. Additionally, these fuel sources need financial budgeting. On the other hand, fuels like firewood, farm produce (like stalks of cotton or chilly crops), sawdust and cow-dung cakes, commonly referred as biomass, are easily available and, in most cases, do not need any additional financial budgeting. Cook stove provides an envelope to generate the heat for cooking and transfer to cooking vessels.

P. Khadilkar (✉) · H. I. Somasekhar · M. Mani
Indian Institute of Science, Bangalore, India
e-mail: pramod.khadilkar@gmail.com

P. Khadilkar
Ajeenkya DY Patil Univeristy, Pune, India

S. K. Saha and M. R. Ravi (eds.), *Rural Technology Development and Delivery*,
Design Science and Innovation, https://doi.org/10.1007/978-981-13-6435-8_15

Cook stoves, thus, play a crucial role in ensuring energy security and thus are an important topic of research and an interesting market attracting global attention and large financial expenditures [4]. Traditional cook stoves, predominantly made using clay and commonly referred to as three stone fires, are inefficient, however, they can run on multiple biomass fuels. Seventy per cent of the Indian population lives in rural areas, and they have reliable and economic supply of biomass [15]. Among the rural population, ninety per cent households use biomass and thus cook stoves. In contrast to these positive effects, indoor pollution due to incomplete combustion in the biomass cook stoves is a crucial negative outcome of the energy self-sufficiency through cook stoves.

Literature present alarming health hazards of the indoor pollution generated by cook stoves [6, 9]. Indoor environment has two aspects, one is linked with smoke and its inhalation and other is blackening of houses. Exposure to smoke is responsible for long-term health problems, which result in morbidity. Women and young girls from poor families that do not own land spend considerable time, up to 20 h a week [3], in collecting the firewood. This time can be utilized for other purposes like to generate additional income, to take rest, to pursue education/hobby or to spend time with family and children. The open fires in traditional cook stoves are also responsible for almost 3000 burn deaths, which occur annually [13]. The monthly expenditures of families on firewood can be as much as one-third of their monthly expenditure. Due to the poverty [14], the amount of money spent by poor is more than non-poor and by average population. This restricts the opportunities to escape from poverty. With the rapid transition of traditional houses into Reinforced Cement Concrete houses retaining the beauty has gained critical importance.

Inefficient burning of fuelwood emits a high amount of green gases that are harmful to the environment. Higher firewood requirement due to incomplete combustion is responsible for the reduced forest cover affecting the local and global climate.

Cook stoves with features like naturally induced or force draft to clear the smoke through a duct pipe, improved efficiency of burning, improved utilization of generated heat are called as Improved Cook Stoves (ICS) [1]. All the possible permutations and combinations of these features entitle a stove for a label of ICS. However, Adoption of these ICS by the affected populations is very low [1, 11]. Dissemination of improved cook stoves is crucial to solving the critical problems that affect the well-being of the majority of Indian population. One such ICS is Astra stove and challenges linked with its dissemination are discussed below.

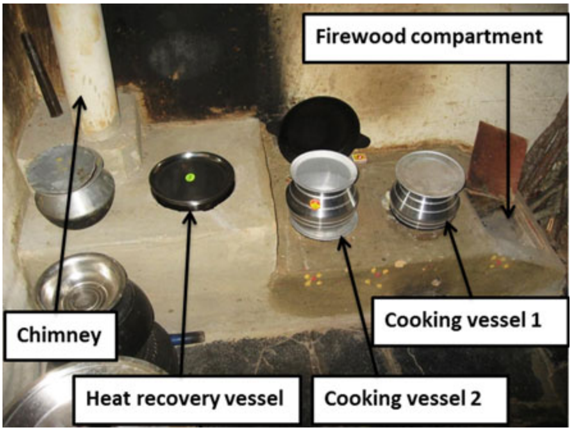
2 Case Study to Demonstrate Astra Ole: A Successful Technical Design[1]

Astra stove is a scientifically designed firewood-based stove, developed by the Centre for Sustainable Technologies (CST), formerly ASTRA (The Centre for Sustainable Technologies was established as ASTRA—Application of Science and Technology for Rural Areas—in 1974) at Indian Institute of Science (IISc), Bangalore. The technology is in use since 1984–1985 and can offer 40 per cent efficiency of cooking in field. In the span of 1984–2003, 15 lakh stoves have been built throughout the Karnataka state using different Karnataka government schemes [7].

Astra stoves are among the best stoves available in the country [10]. This stove is designed scientifically to optimize performance over the practical constraints of resources including cost. The stove has three energy extraction points, with differential heat output reducing from first extraction point till last one. The flue gases are vented out of indoors using natural draft generated in the chimney (Fig. 1 and Table 1).

Dissemination of the Astra stoves through national cook stove dissemination program was government funded. This dissemination covered a continuous geographical region and handled by a central dissemination agency. However, dissemination of the cook stoves in small numbers in distant geographies presented a problem.

Fig. 1 Astra stove structure



[1]The empirical data has been gathered by the authors during the time period of years 2011–2016 at Centre for Sustainable Technologies, Indian Institute of Science, Bangalore, India.

Table 1 Comparison of the traditional stove and Astra stove

Performance parameters	Traditional stove	Astra stove
Efficiency (%)	5–10	35–40
In-door carbon monoxide (CO) (Average for 1 h) Permissible value is 9 ppm max for prolonged exposure [16]	76 ppm	3 ppm
Average cooking Time for the same amount of food cooked—Predominantly in Northern India (includes cooking of Indian bread, curry, dry curry) (Absolute time)	76 min	50 min
Saving in cooking time relative to traditional stove (%)	–	30–40

2.1 Challenges in Manufacturing of the Astra Stove

Astra stove is manufactured in situ at the stove owner's house. The original manufacturing process was masonry construction. The masonry construction involved a skilled meson. Constructing stoves is not economically attractive to a skilled meson over regular vocation. This resulted in scarcity of skilled mesons for stove construction when the number of stoves constructed is not guaranteed, unlike in the government-funded programs where considerably large number was guaranteed. On the other hand, the semi-skilled or unskilled individuals in masonry either could not build technically correct stove or shifted to regular masonry jobs as soon as they acquired the skills. The lead-time and resources consumed in training unskilled mesons were impractical for small dissemination programs. Wrong construction of the stove critically affects the technical performance, aesthetics and life span of the stove. Outside CST, such problems were earlier dealt with simplifying the stove by removing the third energy extraction point. Such easy to construct stoves were made using a mould in pure clay [2]. However, this resulted into considerable efficiency drop of close to 15% and reduced life span of stove due to pure clay construction in relation to masonry stove.

The dissemination of the technically sound product was facing huge challenges due to practical economic forces linked with manufacturing. Mr. H. I. Somasekhar pursued an idea of using another successful and scientific technology for stove construction. Rammed earth technology was used for the construction of the stove without affecting the technical performance of the stove.

Rammed earth construction of the stove using mould. Rammed earth method uses proportions of sand, soil and cement mixed with water. This mix depends on the type of soil available in given region. Mostly in Southern India, the mix is of the ratio of 1 sand: 1.2 soil: 0.12 cement by volume. This mixture is rammed inside a mould. After curing, the structure achieves the desired strength without baking as required in fired bricks. Soil, a freely and easily available natural resource, is the major constituent of the structure. This method is cost effective as it uses 5–8% cement and avoids usage of bricks. Rammed earth technique creates a single monolithic

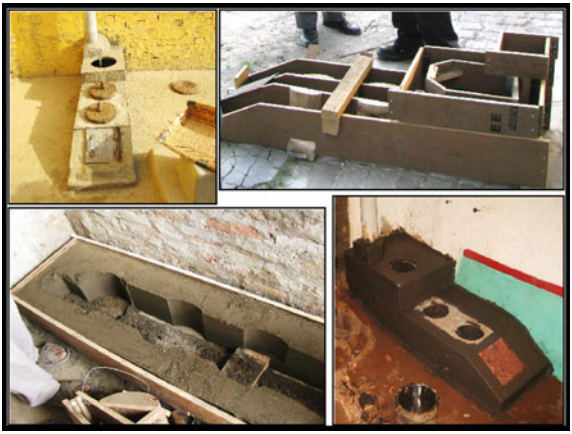


Fig. 2 Manufacturing of the stove using mould

structure. This reduces the problem of breakage due to expansion and contraction of different materials like brick and mortar.

A mould is necessary for the rammed earth technology for its usage. The mould has three tiers structure similar to that of stove for intuitive assembly and usage. The stove construction sites are generally cramped and badly lit kitchens. The division into three tiers helps in easy maneuverability and transportation between sites (Fig. 2). The mud houses of rural India has various rafter positions, the mould allows the freedom to choose the suitable chimney position to suit it. The mould assembly includes templates for accurate dimensioning. Considering the lack of sufficient light, presence of sand/dust and cramped working area, all the small and loose mould parts (other than fasteners, which could be easily purchased in local hardware shops) are tied to the bigger parts to avoid misplacement. Most importantly, masonry skills are not essential in the new method of construction, thus imparting independence from scarce skilled labour, without any compromise on the crucial dimensions.

Securing specially made loose parts to big parts avoid their misplacement during transportation. Commonly available fasteners are specially used for easy replacement. Modularity of the mould accommodates different stove orientations within the kitchen, based on existing structures for chimney opening and fastening, and Vaastu considerations (see Fig. 3). Simplified mould design avoids angled wood joints, which are difficult to make without special tools, this reduces the skill requirement of the carpenter. Special 1:1 drawings are made to trace the profiles on the plywood, which drastically increases the efficiency of the mould making.

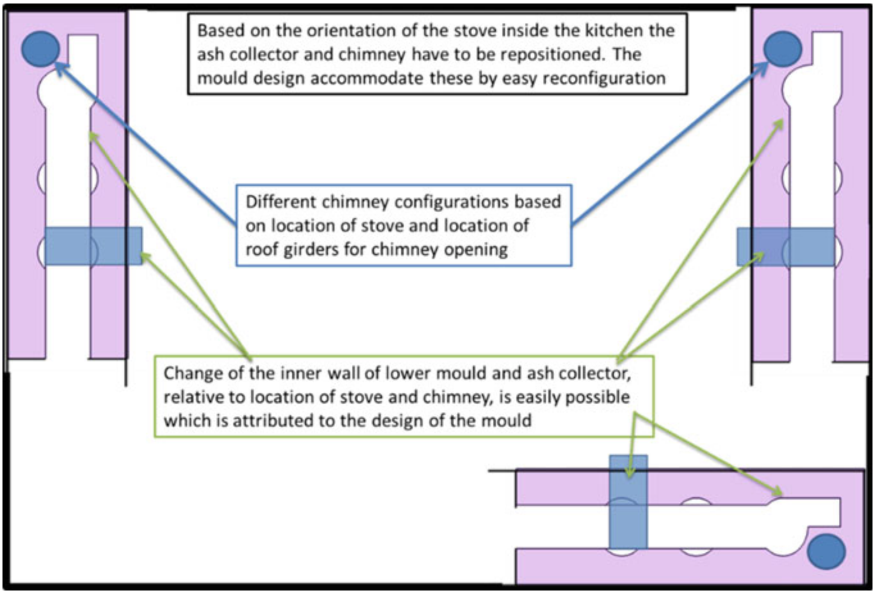


Fig. 3 Flexibility of orientations of Astra Ole using the mould

2.2 *Performance of Stove Manufactured with the New Technology Using Mould*

Technical performance. Set of stoves constructed using masonry method and rammed earth method are tested using water boiling tests at CST and field station at Ungra, Karnataka. The variation in the efficiency is in the range of $\pm$ 2%. Simultaneous efficiency tests using same fuelwood with same specific humidity reduced the effect of environmental conditions on the test results.

Effectiveness of manufacturing (Table 2). It can be measured using many factors as listed.

Effectiveness of dissemination (Table 3). It could be measured on following aspects.

Table 2 Effectiveness of manufacturing using new construction technology

Factors	Old construction method	New construction method
Dependency on skilled meson	Masonry skills were required	Independent of masonry skills
Cost of manufacturing	Require fired bricks and cement	Freely available soil forms 52% of the total body volume. Only 5–8% cement is required. Actual cost varies depending on local material cost however average saving of 20–25% is recorded in field
Quality and accuracy	Dimensional accuracy is dependent on meson	Dimensional accuracy is inbuilt in the mould. Mould has templates to check accuracy for quality control
Construction time	From 3 to 5 h depending on masonry skill	From 1.5 to 3 h considering the experience of the stove builder in using mould

Table 3 Effectiveness of dissemination using new construction technology

Factors	Old construction method	New construction method
Time to train a stove builder	Close to one week	3–4 days (with the same number of stoves built)
Possibility of on-job training	Low—the construction is mentally challenging for constructor due to multiple simultaneous measurements	High—as the measurements are inbuilt
Cost of training	High due to longer training time, costly material (bricks)	Low
Dependency on the highly skilled trainer	Very high due to the involvement of high tacit knowledge	Low. Newly trained stove constructor can easily train others
Project management	High due to dependency on a few skilled resources and involved material handling	Low due to easily replaceable human resource and usage of locally available material
Dependent on specialized tools	Low	High as dissemination is dependent on mould

3 Conclusion

The new construction technology has revived the dissemination of the core technology, i.e. cook stove through small non-government-funded projects. The new technology improved the quality of construction, finish and life span without compromising on the technical performance of efficiency and ability to vent out the indoor smoke. This technology was not the part of the initial brief for the core technology. However, this technology is crucial for the feasibility of the core technology in the field. Without such manufacturing technology, the dissemination of the cook stove will be impossible for low construction volumes and distant construction locations.

RuTAG programs should consciously identify such supporting technologies as the core scope of the project. This will improve the potential of successful technology dissemination through RuTAG. This extended scope, if included in project planning and budgeting, will result in solutions that can support all life cycle phases of technology to a demand-driven problems. This scope will ensure that the benefits of the core product reach the beneficiaries, which should be the final aim of programs like RuTAG.

Funding The Centre for Sustainable Technologies (CST), Indian Institute of Science funded this study. Ajeenkya DY Patil University provided the financial support for attending and presenting the work at the conference RTDD-2017.

References

1. Barnes DF, Kumar P, Openshaw K (2012) Cleaner hearths. Oxford University Press, New Delhi, India, Better Homes
2. Bhogle S (2003) Rural women as agents of improved woodstove dissemination: a case-study in Huluvangala village, Karnataka, India. Energy Sustain Dev 7:70–75
3. Cordes L (2011) Igniting change: a strategy for universal adoption of clean cookstoves and fuels. Washington, USA
4. Dalberg Global Development Advisors (2013) India Cookstoves and Fuels Market Assessment
5. Donaldson K (2009) The future of design for development: three questions. Inf Technol Int Dev 5:97–100
6. Hanna R, Duflo E, Greenstone M (2012) Up in smoke: the influence of household behaviour on the long-run impact of improved cooking stoves
7. Jagadish K (2004) The development and dissemination of efficient domestic cook stoves and other devices in Karnataka. Curr Sci 87
8. Khadilkar PR (2017) Formulating the design scope for the base of the (economic) pyramid. Des Issues 33:4–17. https://doi.org/10.1162/DESI_a_00436
9. Martin WJ, Glass RI, Balbus JM, Collins FS (2011) A major environmental cause of death. Science (80)334:180–181
10. Ministry of Non-Conventional Energy Sources, Indian Institute of Technology Delhi (1993) Indian improved Cookstoves: A Compendium
11. Mobarak AM, Dwivedi P, Bailis R et al (2012) Low demand for nontraditional cookstove technologies. Proc Natl Acad Sci U S A 109:10815–10820. https://doi.org/10.1073/pnas.1115571109

12. Nieusma D, Riley D (2010) Designs on development: engineering, globalization, and social justice. Eng Stud 2:29–59. https://doi.org/10.1080/19378621003604748
13. Peck MD, Kruger GE, Van Der Merwe AE et al (2008) Burns and fires from non-electric domestic appliances in low and middle income countries: Part I. The scope of the problem. Burns 34:303–311
14. Prahalad CK (2005) The fortune at the bottom of the pyramid. Wharton School Publishing, New Jersey, USA
15. The Registrar General & Census Commissioner 2011 census data. In: Gov. India, Minist. Home Aff. http://www.censusindia.gov.in/2011census/hlo/Houselisting-housing-PCA.html. Accessed 2 Feb 2016
16. Ventilation for Acceptable Indoor Air Quality (2003) American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., USA