Chapter–5

Plan for MBFS technology transfer

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5.1 Introduction

Development of Multifunctional Biomass Fuelled Stove has been discussed in Chapter 4. The stove is able to perform multifunctional activities and have several beneficial features viz., (i) air pre-heating, (ii) waste heat recovery, (iii) lighter design and (iv) better heat transfer to the pot. These features have also been presented in the Chapter 4. There are several forced draft improved cook stove available in the market and performance results of these stoves are available for making comparative analysis of this new technology (i.e. MBFS). Such analysis is essentially a pre-requisite for any attempt to transfer technology. Keeping in view of the above a comprehensive comparative analysis of 63 nos. of stoves are made to understand the standing of the MBFS.

Technology transfer, which is now becoming domain of technology developer, refers to the process by which viable technologies are attempted to commercialize through some distinct steps. It involves the communication between the technology developer and the recipient of the technology [1]. The term “technology” refers to the know-how to manufacture a product applied to a process or to provide a service [2]. In addition to above it also targets to develop the entrepreneurial and technological skills [3]. Examples of transfer of technology especially from a Transnational Corporation (TNC) to a developing country through International Investment Agreement (IIA) have resulted in creation of job, flow of capital and increase in innovation capacity [4]. Thus, being a developing economy, India is also an aspirant for technology development and transfer so as to generate opportunities for different stakeholders [5].

Adoption of a technology for commercialization needs assessment of its economic viability both in terms of demand and cost. The present chapter analyzes the current demand scenario of Multifunctional biomass fuelled stove in relation to Indian context for economically deprived regions by a detailed economic analysis. The economic analysis have been carried out at two stages viz., (i) operational cost of Multifunctional biomass fuelled stove and (ii) estimation of production cost under a generalized scenario of rural Indian context. Details of methodology and outcomes are discussed below.

5.2 Comparative performance assessment

Comparative analysis of various commercially available stoves along with the newly developed Multifunctional biomass fuelled stove (MBFS) will provide a detailed overview of its merits and demerits. The performance results of MBFS according to both BIS and WBT are considered for the analysis and are provided below.

5.2.1 Comparison with Bureau of Indian Standards certified cook stove models

The biomass cook stove test protocol as approved by Bureau of Indian Standards (BIS) is a test standard performed only for single pot stove operation. The newly developed MBFS, discussed earlier in Chapter 4, could be used for both single and multiple pot operations. The performance of MBFS with single pot operation as reported in previous chapter (37.62%, 4.5 kW) is used for comparative analysis.

BIS test results of twenty six different forced draft biomass cook stoves developed in India are considered for the comparative analysis with the MBFS as listed in Table 5.1 [6-7]. The stoves considered for the present study belong to two categories based on their uses and size i.e. (i) Domestic stoves (Output power ≤ 3kW) (Fig. 5.1) and (ii) Commercial stoves (Output power > 3kW) (Fig. 5.2). MBFS is compared with both the types of stoves as discussed below.

Table 5.1: BIS approved forced draft models [6-8]

Domestic stoves (Power ≤ 3 kW)			**Commercial stoves (Power > 3 kW)**		
Sl. No.	**Stove Type**	**Power (kW)**	**Sl. No.**	**Stove Type**	**Power (kW)**
S1	TERI SPT-0610	1.08	S12	IMPMETAL-TERI-SPFC-1114	3.36
S2	TERI SPT 0314 stove	1.46	S13	Eco Chulha 2.5	3.37
S3	PMTS	1.5	S14	XXXL Plus stove	3.78
S4	Oorja K3 Dlx	1.51	S15	IMPMETAL-TERI-SPFM-0414N	4.25
S5	Biolite homestove	1.68	S16	TERI SPFM-0414E	4.26
S6	Atom	1.79	S17	TERI PMU 0414D	4.36
S7	XXL Echo Chulha stove	1.98	S18	Supernova-SGDCM	4.62
S8	OJAS	1.99	S19	Ojas-M06	5.43
S9	TERI-SPF 0414S	2.24	S20	Smart 9/15	8.36

Domestic stoves (Power ≤ 3 kW)			**Commercial stoves (Power > 3 kW)**		
Sl. No.	**Stove Type**	**Power (kW)**	**Sl. No.**	**Stove Type**	**Power (kW)**
S10	Surya FDD	2.49	S21	Eco-Chulha 5.0	8.36
S11	IMPMUD Stove TERI SPF 0143	3.06	S22	TERI SPFB-0514C	9.05
			S23	IMPMETAL TERI SPFB_0514b	9.11
			S24	Eco-Chulha 10.0	9.47
			S25	Navshakti Continuous Cook Stove: NSCF10	11.46
			S26	Navshakti Cookstoves: NSTF10	12.2

In Fig. 5.1, 10 domestic stoves are compared with MBFS for their performance in terms of efficiency, whereas in Fig. 5.2, 16 commercial stoves are compared. As depicted in Fig. 5.1 out of ten domestic cook stoves thermal efficiency of three domestic cook stoves namely Surya FDD (S10, 40.9%), Teri SPT-0610 (S2, 40.81%) and TERI-SPF 0414S (S9, 40.78%) are higher than MBFS (37.62%). The comparison with larger size commercial stoves is depicted in Fig. 5.2 where the efficiency of only three stoves namely Navshakti Cookstoves: NSTF10 (S26, 42.8%), Eco-Chulha 10.0 (S24, 41.15%) and Eco Chulha 2.5 (S13, 39.28%) are higher than MBFS.

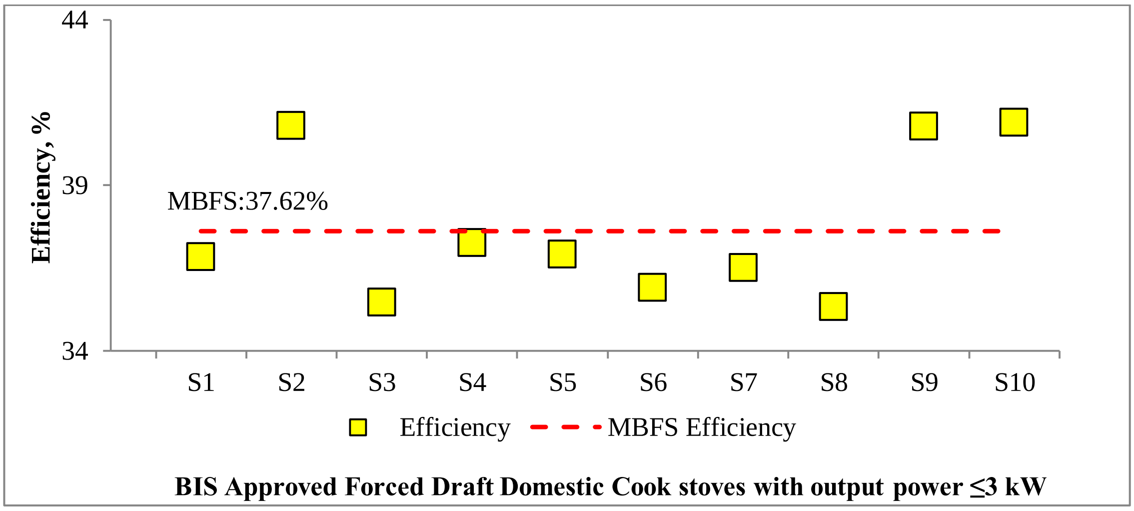

Fig. 5.1: Comparative analysis between Forced Draft Domestic Cook stoves and MBFS [6-7]

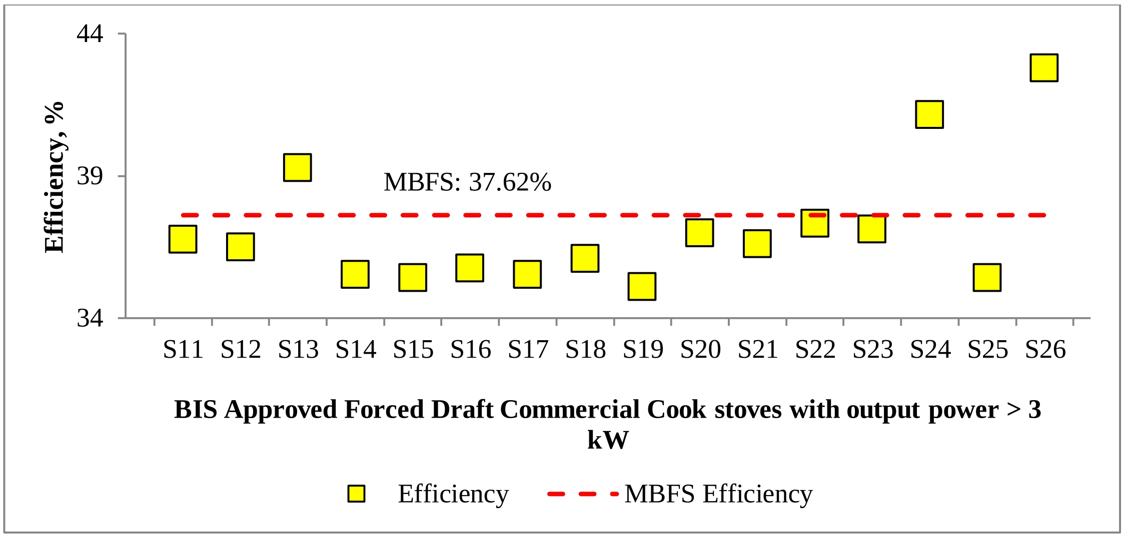

Fig. 5.2: Comparative analysis between Forced Draft Commercial Cook stoves and MBFS [6-7]

The better performance of MBFS compared to 20 BIS certified cook stoves might be due to added features of (i) air pre-heating, (ii) use of pot skirt and (iii) better heat transfer to the pot. The later type of cook stoves also lacks provisions for multiple pot cooking. The analysis is further extended to 37 globally available stoves as tested using WBT in order to incorporate full features of newly developed stove i.e. multiple pot operation.

Emissions

In the present research work the emissions of the developed MBFS were not measured. However it is attempted to determine the emissions through a comparative analysis with the reported data on emissions of various biomass cook stoves. The emission testing of a solid fuelled stove analyses the carbon monoxide (g/MJd) and particulate matter (mg/MJd) within a stove. According to BIS standards the carbon monoxide and particulate matter should be lower than or equal to 5 g/MJd and 150 mg/MJd respectively for forced draft stoves.

A comparison of the emissions of various BIS approved forced draft stoves [6] shows that stoves with power greater than 4.5 kW and operating between efficiencies of 36.1% and 42.8%, releases carbon monoxide and particulate matter within the ranges of 1.03 - 4.63 g/MJd and 68.45 - 123.28 mg/MJd respectively. Thus it is expected that

MBFS will emit similar emissions as both its power and efficiency i.e. 4.5kW and 37.62% respectively lies within similar ranges.

5.2.2 Comparison with WBT tested biomass cook stoves

The corresponding results of MBFS are further compared with 37 different biomass stove available globally as listed in Table 5.2 [8-12]. The comparison is done as per the WBT protocol for efficiency which corresponds to three tests conditions viz. cold start, hot start and simmering. These 37 stoves are categorized depending on output power during cold start, hot start and simmering phases of WBT into (i) lower power stoves (≤ 3 kW) and (ii) high power stoves (>3kW) stoves and is discussed below.

Table 5.2: Stove considered for WBT test results comparison [8-12]

		Power		
Sl. No.	**Stove type**	**Cold Start**	**Hot Start**	**Simmering Test**
S1	Stove-TEC TLUD stove	1.37	1.56	0
S2	Belonio Rice Husk stove	1.69	1.44	0
S3	Oorja stove	1.77	2.56	0
S4	Stove TEC Prototype stove	2.6	3.99	0
S5	Wood Gas fan stove	2.65	2.76	1.4
S6	Berkeley-DARFUR stove	2.66	3.16	2.19
S7	Jiko, Metal stove	2.72	2.92	0
S8	Kenya Uhai stove	3.33	5.07	0
S9	Jiko, Ceramic stove	3.4	3.29	0
S10	Philips Stove HD4008	3.7	3.65	1.92
S11	Mayon Turbo stove 7000	3.74	3.8	0
S12	Kenya Ceramic Jiko stove	3.85	3.59	0
S13	Stove TEC-Greenfire stove	3.91	5.05	0
S14	Wood flame fan stove	4.09	4	2.05
S15	Envirofit G-3300 stove	4.35	4.86	0
S16	Philips stove HD4012	4.58	5.16	0
S17	Sampada Gasifier stove	5.42	5.62	0
S18	Upesi Portable stove	5.44	5.48	4.55
S19	Gyapa Charcaol stove	5.79	6.73	3.17
S20	Mali Charcoal stove	5.85	5.44	2.58
S21	GERES New lao stove	5.86	6.93	0
S22	Modified Rocket box (longer firebox)	5.91	7.78	10.41
S23	Uganda 2-Pot stove	6.57	7.58	2.55
S24	Ghana Wood stove	6.77	6.2	3.29
S25	Rocket Box stove	7.11	5.49	5.33
S26	Three stone fire	7.76	8.24	3.13
S27	Mud/Sawdust stove	7.8	8	2.07
S28	VITA stove	8.12	7.94	2.38
S29	Justa stove	8.2	8.68	4.18
S30	Patsari stove	8.21	8.43	4.25
S31	Ecostove	8.99	9.62	4.53
S32	Ceramic improved stove	9.43	13.64	3.49
S33	San Mateo stove	9.71	12.76	8.71

		Power		
Sl. No.	Stove type	Cold Start	Hot Start	Simmering Test
S34	Centrafricain improved stove	9.72	12.47	3.89
S35	Onil stove	10.82	10.48	4.79
S36	Jinqilin CKQ-801 stove	13.03	10.61	0

Comparative analyses between the 37 different stoves are presented in Fig. 5.3 to Fig. 5.8. Analyses shows that MBFS shows better efficiency than 30 of the above mentioned biomass stoves in every phases of cooking i.e. cold start, hot start and simmering phase. Amongst all the stoves Stove-TEC TLUD stove shows the highest efficiency for both cold start (52.7%) and hot start (53.8%) phases whereas Wood Gas Fan Stove has highest efficiency during simmering phase (46%). MBFS ranks next to Wood Gas Fan Stove during simmering phase in terms of efficiency and its suitability for long duration cooking. During hot start MBFS operates at highest efficiency amongst the high powered stoves.

As discussed earlier the effect of embedded features (waste heat extraction for air preheating and multiple cooking, use of pot skirt and forced draft) appears to reflect through improvement in performance of MBFS compared to majority of improved cook stoves. Further investigation is required to explore the reasons of lower thermal efficiency of MBFS than Uganda 2-pot stove, Wood flame fan stove, Belonio Rice Husk stove, Wood Gas Fan stove and Stove-TEC TLUD stove during WBT tests. The prospect of improving performance using better material and additional waste heat recovery might be some of such options.

Performance is a major aspect influencing choices of stoves however there are several other aspects which also decide the user choice for a cook stove. These aspects are mostly region specific. In context of a typical rural Indian scenario where biomass cook stoves are still a relevant technology, such aspects are analyzed for their consideration for technology transfer as discussed below.

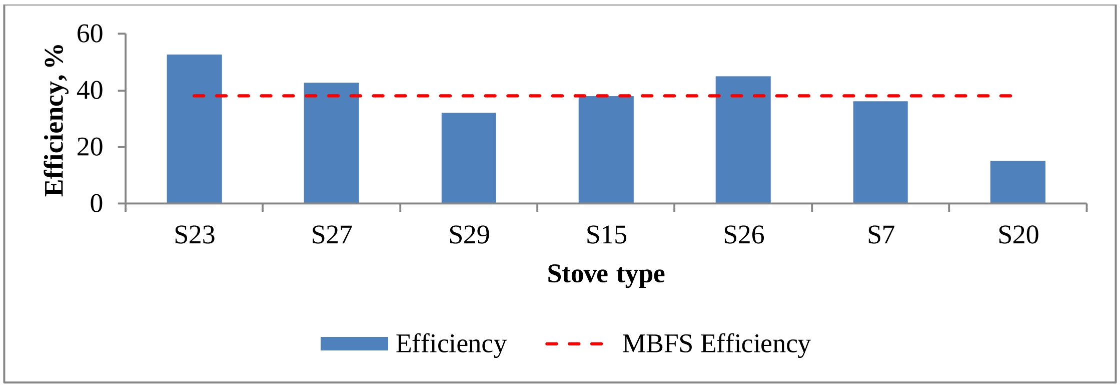

Fig. 5.3: Comparative analysis of WBT cold start results between low power stoves and MBFS [8-12]

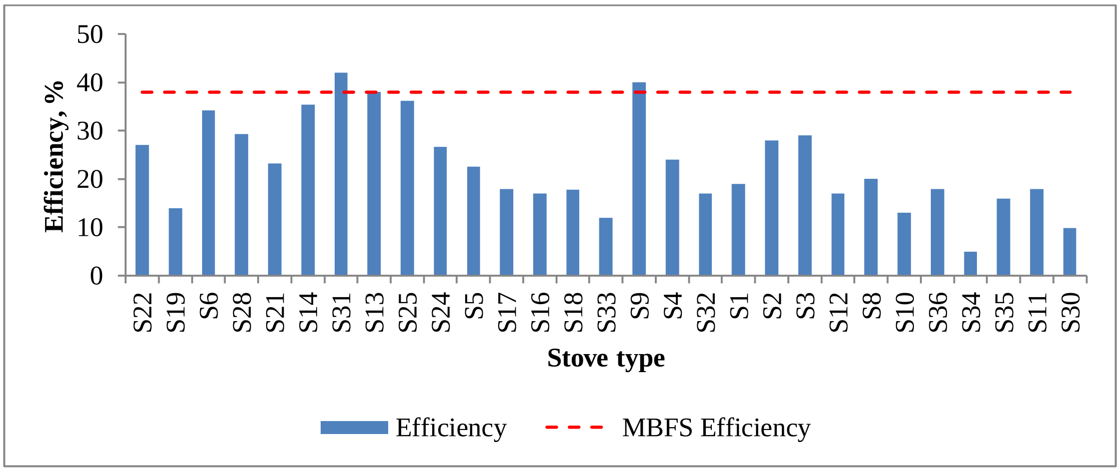

Fig. 5.4: Comparative analysis of WBT cold start results between high power stoves and MBFS [8-12]

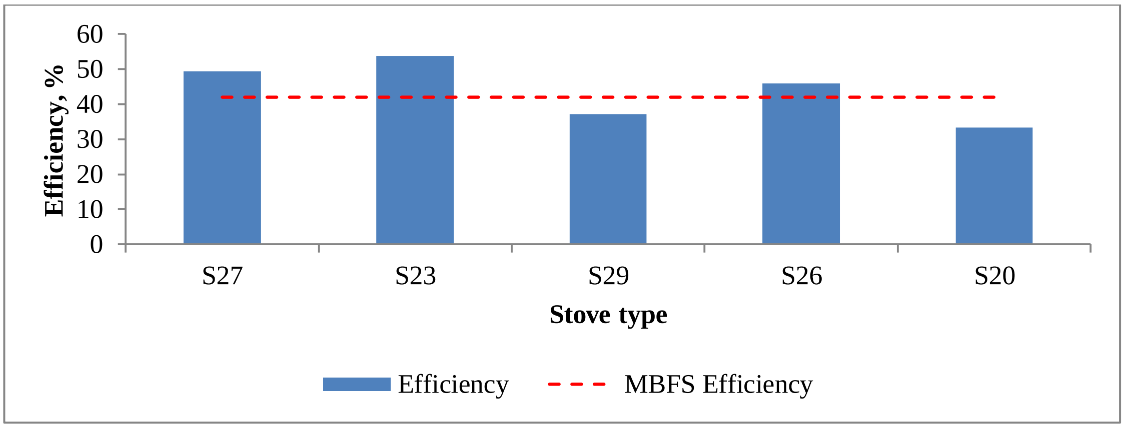

Fig. 5.5: Comparative analysis of WBT hot start results between low power stoves and MBFS [8-12]

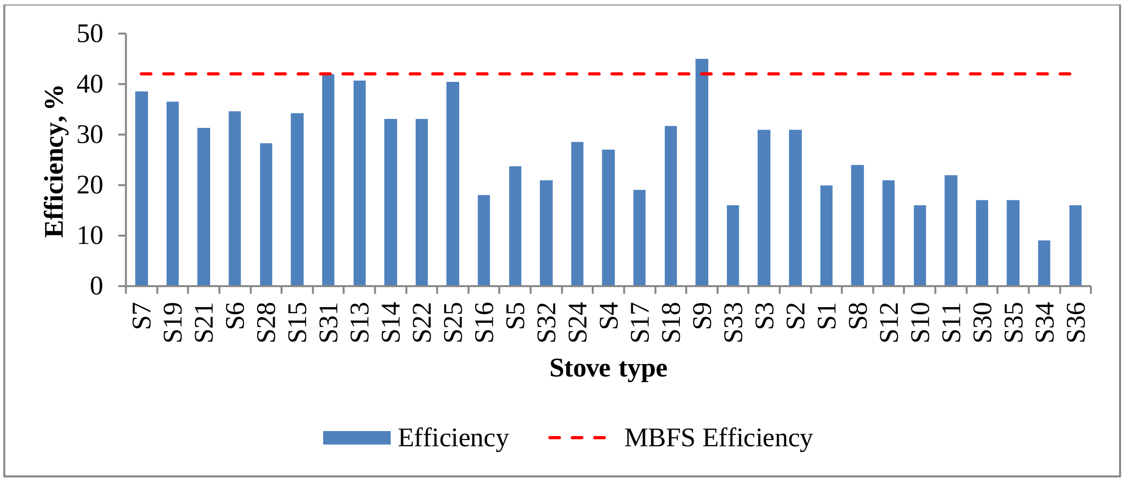

Fig. 5.6: Comparative analysis of WBT hot start results between high power stoves and MBFS [8-12]

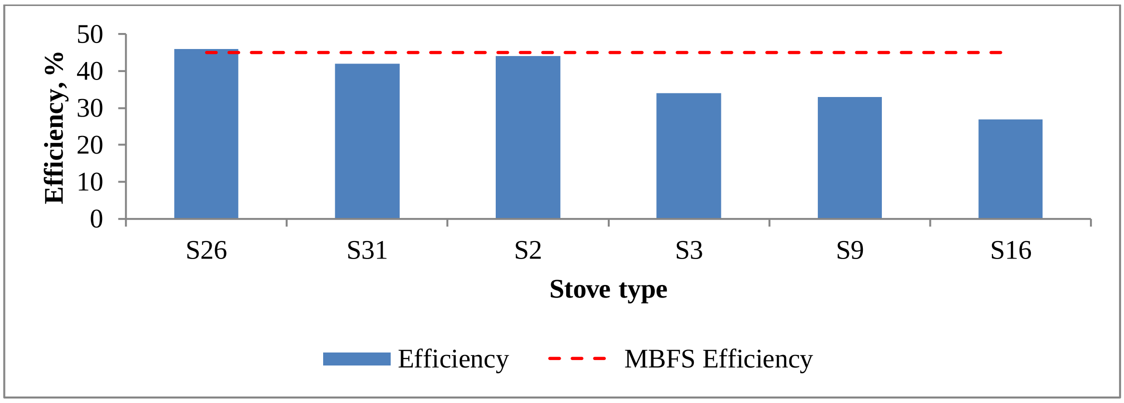

Fig. 5.7: Comparative analysis of WBT simmering phase results between domestic stoves and MBFS [8-12]

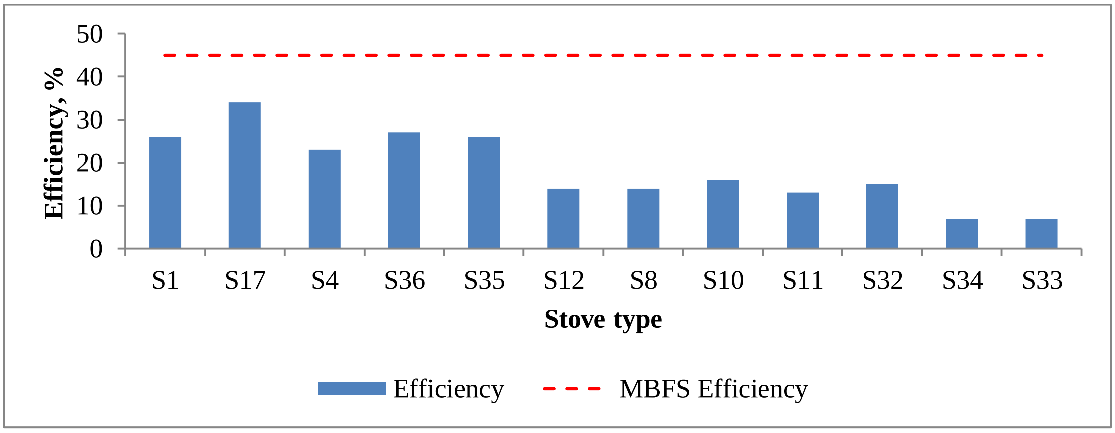

Fig. 5.8: Comparative analysis of WBT simmering phase results between high power stoves and MBFS [8-12]

5.3 Indian cooking energy scenario

In India wood and LPG are two commonly used sources for cooking [13]. With recent attempts to promote cleaner cooking fuel i.e. LPG the Govt. of India has promoted various schemes which resulted in total domestic LPG users to 274 million [14]. One such program is the Pradhan Mantri Ujjwala Yojana which was implemented on 1st May, 2016 which targets to provide additional 50 million LPG connections to BPL families within 3 years [15]. The increase in LPG connections has increased its consumption to 24.9 million tons of LPG in 2018-19 which is 53% higher than 5 years ago [16]. However the cost of LPG has not shown much reduction in India and varies within ₹600 to ₹750 since 2015.

The Government of India also plans to completely replace biomass from urban cooking with high penetration of Piped Natural Gas (PNG), LPG and electricity by the end of year 2047. Similarly the penetration of LPG in rural India is expected to grow to 42%, whereas PNG penetration will be even lower till year 2047. The penetration of biomass which is about 85% in the year 2012 is however expected to be reduced to approximately 20% in the year 2047. Plans are also there to divert the LPG connections of urban areas to rural India once PNG penetration is high [17].

Even though LPG will continue to influence the cooking energy demands of both urban and rural households, however use of traditional cook stoves will continue to prevail due to user’s preference. The abilities to serve multiple functions and to own at affordable price are two important factors for such preference in spite of having limitation such as lower efficiency and high indoor air pollution of traditional stoves. The rural Indian population mostly uses traditional stoves for cooking, space heating, drying and preparing fodder. Use of both LPG and traditional stoves is also common among majority of population.

Despite higher penetration of LPG stove the need for requirement of multifunctional biomass stove will remain for reasonable period of time in rural India context. Therefore the technology developed through present work i.e. MBFS will be relevant to fulfill such requirement ensuring desired features of energy conservation and has the potential to be commercialized. In order to assess the viability of the manufacturing MBFS a detailed economic analysis is done and is discussed below.

5.4 Economic analysis

The economic analysis of project helps in analyzing the economic feasibility of the project and investigates future cash flows, prior to implementation. Generally, economic analysis is carried out to resemble the implementation phase with detail view of all the costs incurred and revenue generated. There are several standard methods used for economic analysis [18]. In the present study the Net Present Value (NPV) is used to perform economic analysis of MBFS as a product. The production of MBFS is conceptualized as a typical rural enterprise with a provision of engagement of 4 semi-skilled and 11 unskilled workers which would result in annual production of 7300 units of cook stove. The production rate in turn affects the results of the economic analyses. Therefore, the application of the outcomes of the present economic analysis will be limited to similar situation. The size of the MBFS production plant appears appropriate considering the prevailing population pattern in the study area.

The NPV method considers the fact that whatever investments are made in the project, the value diminishes with time [18] as per some discount rate as below.

$$NPV = \sum_{i=1}^{x} \frac{CF_{i,net}}{(1+r)^{i}} \qquad 5.1$$

where *NPV* is the Net Present value, x is the duration of the project (year), $CF_{i,net}$ is the net cash flow during i^{th} year of project period and r is the discount rate. As stated earlier a small manufacturing unit is considered with project duration period of 10 years.

5.4.1 Cost components

The cost to be incurred in the project is divided into four different categories *i.e.*, initial cost, insurance cost, periodical cost for infrastructure and operational cost [18]. The initial cost is the initial procurements for starting the manufacturing unit. Insurance cost includes the cost involved in paying insurance for the fixed assets. Periodical cost includes the cost which is involved in paying the periodical dues (rent, license fee, loan and tax). Finally, the operational cost is the cost of operating the manufacturing unit. The cost components along with relevant assumptions made are provided in Table 5.3.

Table 5.3: Cost components and assumptions

Sl. No.	Categories	Components	Assumptions	Ref.
1	Initial cost	1A. Machineries cost		
		1B. Other tools		
		1C. Electrical cost		
		1D. Safety equipment		
		1E. Permits and license fees		
2	Insurance cost		5% of (1A+1C)	[18]
3	Periodical cost	3A. Building rent	₹129.12 /m^2	
		3B. License fee renewal		
		3C. Loan	Loan amount: ₹50,00,000 Interest rate @18% Debt period: 10years	
		3D. Corporate tax	@25%	[19]
4	Operation cost	4A. Labor cost		
		4B. Maintenance cost	Buildings @3% pa of 3A, Mechanical Equipment (1A+1D) @ 3.5% pa, Electrical equipment (Electrical instruments + 1C) @2.2% pa	[18]
		4C. Raw material cost		
		4D. Loss of raw material	@0.05% of 4C	
		4E. Packaging cost	@1% of 4C	
		4F. Machine operating cost		
		4G. Electrical bill		
5	Other assumptions	Inflation rate	@3.6%	[20]
		Depreciation rate (1A+1C+1D)	@30%	[21]
		Discount rate	@10, 15, 20 and 25%	

5.4.2 Selling price and revenue generation

Potential selling of MBFS is expected to generate revenue. A modest manufacturing unit with engagement of 4 semi-skilled and 11 unskilled workers is expected to produce 20 stoves per day with estimated maximum production of 7300 units per annum. The selling price is expected to vary due to several market related factors. Expected current selling price of MBFS is considered based on the prevailing market prices of the commercial cook stove presented in Appendix A (Table A.1). Most of the available forced draft stoves with power backup are available in the price range of ₹2200 and ₹2300. Thus, a selling price of ₹2200 per unit is considered for the analysis with yearly increment in price due to inflation (3.6%).

5.5 Analyzing the project viability

The analysis is further extended to check the viability of the project using Net Present Value (NPV) method. The effect of varying discount rates (10%, 15%, 20% and 25%) on NPV during the 10 year project period is investigated as shown in Fig. 5.9.

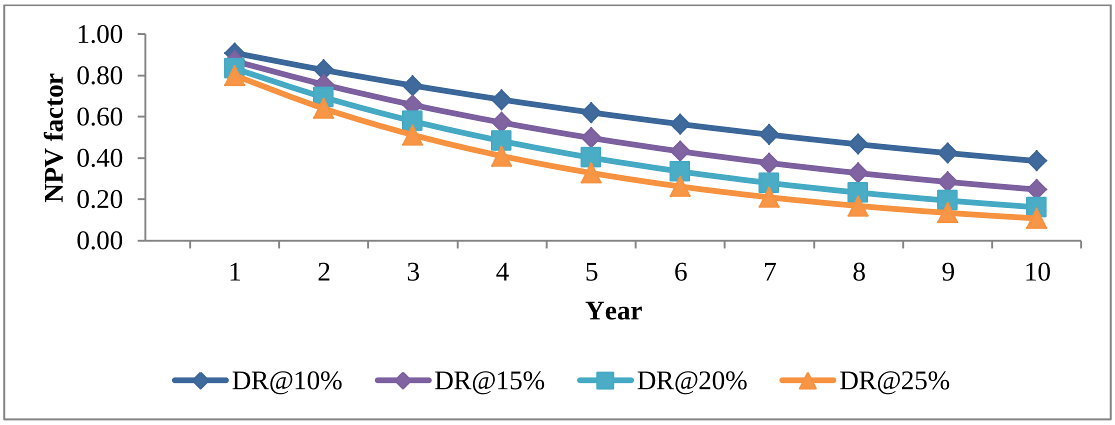

Fig.5.9: Variation of NPV factor with variation in time

It has been observed from Fig. 5.9 that the Net Present Value (NPV) factor decreases with time for all the cases of discount rate. Further, with increasing discount rates NPV reduces. In the beginning, while discount rate increases from 10% to 25%, NPV drops from 0.91 to 0.80. At the end of 10th year the NPV factors are 0.39, 0.25, 0.16 and 0.11 for discount rate of 10%, 15%, 20% and 25%, respectively. Overall, for a 10 years planning, the project appears viable, if selling of products are guaranteed even with higher rate of discount.

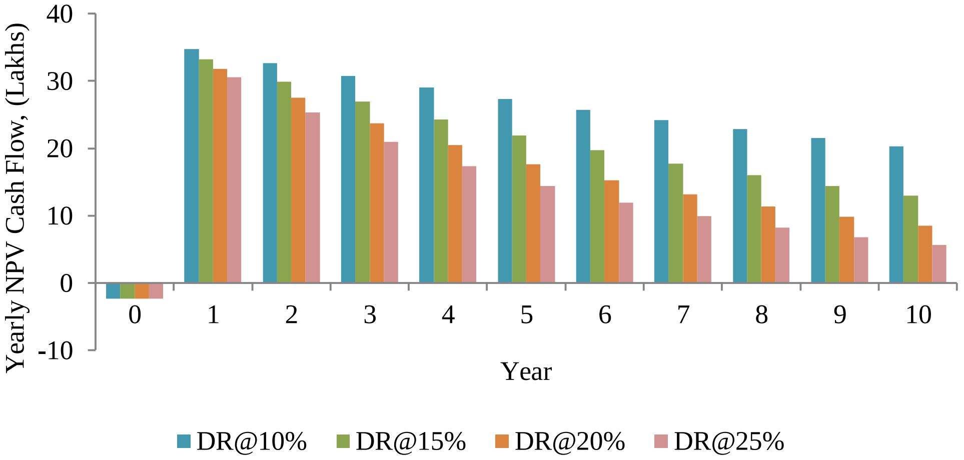

Fig. 5.10: Variation in NPV of Yearly Cash Flow with variation in time

The increase in discount rate reduces the yearly NPV cash flow as seen in Fig.5.10. With a moderate 10% discount rate, the NPV of the annual cash flow varies between ₹ 3.4 million and ₹ 2.0 million during the first 10 year of the project.

5.6 Summary

The present Chapter assesses the prospect for technology transfer of the Multifunctional Biomass Fuelled Stove (MBFS) through a comparative performance and economic analysis. Besides the added advantages due to provision of multi functioning and multi-pot cooking, the thermal efficiency of MBFS is better than majority of stoves considered for making comparative analysis, both BIS tested (26) and WBT tested (37) stoves. The benefits of added features (pot skirt, multiple pot option and waste heat extraction) appear to reflect in performance improvement. Thus, the MBFS is expected to compete with the commercial stoves available in the market. The present study could not assess the emission performance of the stove. However, the provision of innovative air supply is expected to result efficient combustion reducing the risk of emission. Considering the prospect of marketing, an economic analysis is done for a conceptualized rural stove manufacturing enterprises with annual production capacity of about 7000 units. The capacity of the enterprise is considered based on the expected demand in the region. The prevailing rates of economic parameters are used to determine NPV factors as well as NPV of annual cash flow for project duration of 10 years for varying discount rates. The results of the economic parameters may require further verification while implementing the project. However, positive indication of economic feasibility of the project for the assumed rural Indian scenario appears encouraging to transfer MBFS technology for manufacturing enterprises. The technology for development of MBFS is further transferred to Dawnspirit Pvt. Ltd. for commercialization.

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