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Ranking of Barriers and Strategies for Promoting Bioenergy Technologies in India

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Abstract

There is a large potential for bioenergy technologies (BETs) for meeting the rural energy needs, contributing to improved quality of life and conservation of environment in developing countries such as India. However, the technological development and successful demonstration does not necessarily trigger their large-scale diffusion. This paper aims at identifying and ranking of the barriers to the diffusion of selected BETs and further presents strategies for promoting the BETs by overcoming the barriers. This was achieved by involving different relevant stakeholder groups in ranking of the barriers as well as in developing strategies. The BETs selected are; biogas and improved cook stoves for cooking and biomass gasifier for power generation. The major barriers are different for different BETs. Policy barriers appear to be the key barriers, which have given rise to a host of other related barriers; financial and institutional for example. Therefore, conducive policy initiatives on the part of the government are crucial for overcoming the barriers to the promotion of bioenergy systems in India. High investment cost and lack of guaranteed performances followed by lack of access to information are other key barriers. Thus research and development for cost reduction and enhanced performance is critical. Some generic and technology specific strategies are needed for promoting BETs in India.

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1. Introduction

The focus of the present study is on the development of strategies for the promotion of bioenergy technologies (BETs) in India. Firstly, in India biomass energy dominates rural energy scene by accounting for nearly 80% of the total energy use. Secondly, the efficiency of use of biomass energy is low. Thirdly, biomass energy use in rural areas is characterized by shortages (of fuelwood), low quality of life (due to drudgery in gathering fuelwood and cooking in smoke-filled environment) and environmental degradation (due to loss of trees and forest resource). Fourthly, among the renewable energy technologies, biomass based energy technologies have a large potential to mitigate climate change (about 120 million tonnes of Carbon per year). Finally, bioenergy technologies such as biogas for cooking and biomass gasifiers for rural electrification are commercially available and have a large potential for meeting energy needs as well as to conserve environment [1, 2]. Despite their importance the rate of spread of BETs has been low in India.

India has been promoting several modern BETs over the last two decades. The limited impact of these technologies is due to existence of several barriers that hinder their accelerated adoption. A research study supported by the Swedish International Development Cooperation Agency under the umbrella of the Asian Regional Research Programme in Energy, Environment and Climate made an attempt to identify the most critical barriers to a few selected BETs. The barriers were ranked using the Analytic Hierarchy Process (AHP) by analysing response of different stakeholders regarding their significance based on two criteria: "impact of removal", that is the extent of impact removal of a barrier would have on the sector and "ease of removal", that is the level of efforts that would be required to remove a barrier. The paper presents the key findings of this research activity and in the process has attempted to evaluate the existing policies and institutional mechanisms in the country and propose strategies to promote selected BETs.

2. Description of Selected BETs; Characteristics, Potential and Spread

The BETs selected for barrier and policy analysis include; improved cookstoves and biogas for cooking and biomass gasifiers for decentralized power generation. Improved stoves (nearly 35 million) and biogas plants for cooking (nearly 3.5 million) are the largest renewable energy programs implemented India, with potential to make the largest impact on the quality of rural population as well as on environment. Further, biomass gasifiers have the largest potential to meet rural power needs through decentralized power generation [1].

India also has a large biomass gasifier based power generation program. The rate of spread of these programs is low compared to the estimated potential. Thus, improved cookstoves and biogas for meeting cooking energy needs and biomass gasifiers for meeting rural electricity needs are the BETs selected for analysis of barriers and development of strategies.

2.1. Improved cookstoves

The use of fuelwood for cooking in traditional cookstoves is characterized by low efficiency in the range of 10-14% and emission of smoke in the kitchen, thereby posing a health hazard. Improved cookstoves are fuel-efficient and designed to minimize indoor air pollution. In India, more than 30 models of improved cookstoves are available for family, community and commercial applications. The initial dissemination approaches of the improved cookstoves mainly advocated their use for health and convenience reasons. Subsequently, the environmental imperatives pushed for the accelerated adoption of these stoves.

The improved cookstove programme was initiated in India in 1984-85 with 2000 stoves built during that year, reached a peak dissemination rate of 2.9 million during 1995-96. The aggregate number of improved cookstoves disseminated by 2003, since the launching of the programme in 1985, was around 35.2 million [3] covering 29% of rural households (Table 1). The rate of spread of over two million improved cookstoves annually in the recent past is not significant considering the short life of stoves and the vast potential. At the current rate, nearly four decades are required to cover all the households [2].

2.2. Biogas for Cooking

Biogas is the product of anaerobic fermentation of organic materials such as animal dung, plant leaves and waste from food processing and households. Biogas can be combusted directly as a source of energy for cooking and lighting or used in internal combustion engines for mechanical or electrical applications. The slurry produced after digestion can be used directly as valuable manure for crop production. Biogas plants in India are largely based on cattle dung with a capacity ranging from 2 to 4 or 6 m^3, for cooking application at family level.

Biogas production is an established technology with a long history of implementation. In the case of family scale biogas program, the cumulative number of biogas plants built since

1982 to 2003 is estimated to be 3.44 million [3] against a potential of 12 to 17 million (Table 1). The annual rate of dissemination has been very slow at an average rate of 2-3% and the cumulative achievements correspond to less than a-third of the estimated potential. The total number of large community and institutional biogas plants installed until 2003 was about 3902. This is a very small achievement compared to the total potential corresponding to a community biogas plant in literally every one of the majority of the 0.5 million villages.

Biogas is an ideal fuel for meeting cooking energy needs in rural areas. Biogas plants when used for cooking lead to substitution of biomass used in traditional cook stoves. The use of biogas also improves the quality of life of women and children by avoiding the drudgery of gathering fuelwood and cooking in smoke filled environment.

2.3. Biomass gasifiers for Power Generation

Biomass, particularly woody biomass, can be converted to a combustible gas for use in internal combustion engines for mechanical or electrical applications. This is done through a two-stage process known as gasification; in the first stage, biomass undergoes partial combustion to generate gas and charcoal, and in the second stage, charcoal reduces the product gas (mainly CO_2 and water vapour) to a combustible producer gas consisting of carbon monoxide and hydrogen (and other gases such as nitrogen). Gasifiers are readily available in India in capacities ranging from 20kW to 500kW. The efficiency of conversion of biomass to electricity with small biomass gasifiers is about 17%. Feedstock for gasification could be wood from dedicated plantations, thin twigs and branches from plantations and forests, logging and milling residues or certain crop residues such as rice husk.

Among the biomass power options, small-scale gasifiers (of 20 to 200 or 500kW) have the potential to meet all the rural electricity needs (of over 100 TWh annually) and also to feed some surplus into the national grid. Degraded land is available for dedicated biomass production for gasifiers. There are manufacturers who can indigenously supply gasifiers of capacities up to 500 kW.

Indigenously developed technology for biomass gasifiers, though readily available from a few manufacturers, is still at the early dissemination stage. Twelve models of gasifiers of different ratings have already been promoted under National Biomass Gasifier Programme

for various applications, namely, thermal, mechanical, electrical and village electrification. The potential for biomass-based power generation is varyingly estimated to be in the range of 28,000 to 47,000 MW. From a total installed capacity of 35 MW of biomass gasifier systems in 2000 [3, 4] for mechanical and electrical applications, it has increased to 53.17 MW as on March 2003 (Table 1). This represents an increase of about 18 MW in three years. Assuming the current rate, then about 1000 years will be required to realize the ultimate potential.

A brief assessment of the three selected BETs, namely, improved (efficient) cookstove, family biogas and community biogas for cooking gas production, and biomass gasifier-based rural electrification, shows that despite their large potential and availability domestically, the rate of spread has been low.

3. Barriers to spread of Bioenergy Technologies

India has implemented a large biomass energy program, which involves promotion of several BETs through several policy, institutional and financial incentives and interventions. In India most of the BETs were implemented with direct capital subsidy support from the MNES. Other policy incentives such as income tax holiday, accelerated depreciation, concessional duty/custom duty free import, soft loans for manufacture and State level policies on wheeling and banking, etc., were also used to facilitate the market development. MNES also supported a large variety of capacity development programmes. Detailed listing of policy, institutional, financial and capacity building measures implemented in India can be seen from www.mnes.com.

Despite a number of supportive policies and incentives, the rate of spread of renewables particularly improved cookstoves, biogas digesters and biomass gasifiers has remained low. The slow rate of spread has been attributed to existence of several barriers, which have been identified in several studies [1, 2, 5 and 6]. Box 1 presents a broad listing of barriers that are likely to prevent large-scale spread of the chosen BETs. The list has been arrived at based on literature survey and discussions with experts. Both generic and technology specific barriers have been included in the list. To improve the spread of BETs it is essential to address the most important of the barriers and develop appropriate measures to overcome them. Identification of the barriers, as listed in Box 1, is however by and large guided by the perceptions of reviewers or researchers. Thus, there is a need to rank (i.e. prioritise) the identified barriers to enable policy makers to focus on the key barriers; also, the

consideration of perspectives of different stakeholders in ranking the barriers or options to address them is necessary.

4. Ranking of Barriers

4.1. Approach and Methodology for Ranking of Barriers

A study to identify and rank the barriers to selected BETs was conducted under the Asian Regional Research Programme in Energy, Environment and Climate (ARRPEEC) Phase III. The criteria and methodology adopted to prioritize the barriers as well as measures to over come the barriers are presented in the following section.

4.1.1. Criteria for ranking the barriers

The ranking of barriers has been done using two criteria:
Impact of removal - how much positive impact a barrier removal strategy will have on spread/diffusion/commercialization of the technology. In other words, what level of penetration of a BET can be achieved by removing a barrier?

Ease of removal: how much effort would be needed to overcome the barrier in the form of financial support, incentives, policy changes, capacity building, institutional mechanisms etc; here ease of removal implies that a barrier can be removed with a low level of effort.

4.1.2. Method of data collection

The first step in this process is to assess the relative importance of above two criteria. The relative importance level of these has been measured on a five-point scale (1 to 5) ranging from extremely high to least importance levels. In other words, the two criteria considered are ranked based on their relative importance in ranking a barrier to be removed to promote commercialization of BETs.

4.1.3. Stakeholder Grouping

As explained earlier, different stakeholders may perceive the importance of a barrier differently. To capture this difference, the respondents were grouped into different categories – Entrepreneurs/manufactures/financiers, Policy personnel, Researchers and Users/NGOs – and the analyses of barriers conducted separately for the different groups.

The total number of participants in the barrier-ranking workshop was 59. The distribution of stakeholders who participated in the workshop is as follows;

- *Policy makers*; 12 accounting for 20%
- *Entrepreneurs/ Manufactures/ Financiers*; 20 accounting for 34%
- *Users/NGOs*; 15 accounting for 25%
- *Researchers*; 12 accounting for 20%

4.1.4. Method of Barriers Ranking

The data obtained from the questionnaires were tabulated and the geometric mean scores for the two chosen criteria were estimated for different groups of stakeholders. Based on these scores, prioritization of barriers was made using both impact and ease of removal criteria for different groups using the AHP method [7], which can be used to make decisions in situations involving multiple criteria and multiple alternatives. In this method, first the relative importance of the criteria is determined using a pair-wise comparison matrix obtained from the relative scores for the chosen criteria based on responses of the stakeholder groups. In the second step, the alternatives are evaluated against each criterion.

4.2. Ranking of Barriers to Improved Cookstoves

The ranking of barriers according to different stakeholders and overall priority values based on the two criteria namely; impact of removal and ease of removal for improved cook stoves are presented in Table 2. All other stakeholders, except for the policy personnel, perceive that lack of information on improved designs, cost and performance is the topmost barrier. Policy personnel rank it as the sixth most important barrier whereas others rank it among the two most important barriers. Lack of locally trained persons for building stoves and repair and maintenance gets top rank from researchers, second rank from policy personnel and the other two groups rank it at level four. Policy personnel feel that lack of quality control during construction is the topmost barrier and others seem to consider it as one of the important barriers. Lack of confidence in performance and benefits is one more important barrier, which has been ranked at relatively higher levels by all the stakeholder groups. Entrepreneurs/manufactures/financiers and users/NGOs rank it as the second whereas policy personnel and researchers rank it as the fourth priority barrier.

From the overall perspective, the following barriers seem to be the top barriers in decreasing order of importance – lack of information on improved designs, cost and performance, lack of locally trained persons for building stoves and repair and maintenance,

lack of quality control during construction and lack of confidence in performance and benefits.

4.3. Ranking of Barriers to Biogas Technology

The ranking of barriers according to different stakeholders and overall priority values based on the two criteria namely; impact of removal and ease of removal for improved cook stoves are presented in Table 3.

It may be observed from Table 3 that differential perceptions in terms of priority of barriers prevail in the case of biogas for cooking. It is surprising to see that there is no unanimity even with respect to one barrier. High initial investment/capital cost is ranked one by researchers, two by entrepreneurs/manufactures/ financiers, three by users/NGOs but gets a low rank of eight from policy personnel. In other words, policy personnel do not agree with the notion that biogas plants are capital intensive. Lack of entrepreneurs for providing services for operation, repair and maintenance gets a low rank of six from entrepreneurs/manufactures/ financiers, two from both policy personnel and researchers and one from users/NGOs. The users who had experience with biogas plants feel that lack of entrepreneurs for support services is the topmost barrier. However, entrepreneurs/manufactures/financiers agree that lack of quality control is the top ranked barrier. Even the users/NGOs seem to agree with them by ranking it as the second most important barrier. Policy personnel and researchers have ranked this barrier as of fourth and fifth priority respectively. The policy personnel perceive that the lack of confidence in technical viability is the topmost barrier but, except for entrepreneurs/manufacturers/ financiers to a certain extent, other groups do not seem to agree with this view. All the stakeholders perceive that lack of information on technologies is also an important barrier by giving reasonable high ranks.

From the overall perspective, the following barriers could be considered as the top priority barriers preventing the commercialization of biogas technology for cooking applications – lack of entrepreneurs for providing services for operation, repair and maintenance, lack of quality control, high initial investment/capital cost for biogas plant and lack of information on technologies.

4.4. Biomass gasifiers for power generation

Table 4 contains the priority values and overall ranking as generated by AHP for different barriers for the commercialization of biomass gasifier for power generation based on the two criteria impact and ease of removal, according to perceptions of different stakeholders.

High initial investment/capital cost has been ranked as the topmost barrier by all the stakeholder groups. However, this unanimity among stakeholder groups seems to be missing in the case of other barriers. For example, difficulty in ensuring continued biomass supply ranks second from the perspectives of entrepreneurs/manufactures/financiers and researchers, however policy personnel and users/NGOs rank this barrier respectively as fourth and third priority respectively. Also, perception regarding this particular barrier is the result of prevailing local conditions and cannot be generalized. For the policy personnel, lack of information and financial support are the second and third most important barriers respectively. The users/NGOs perceive availability of other cheaper alternatives as the second most important barrier whereas the researchers feel this as the third most important barrier. On the other hand entrepreneurs/ manufactures/financiers and policy personnel consider this barrier to be among the least important ones by ranking it at 10 and 12 respectively. Lack of confidence in economic/financial viability is ranked third by the group entrepreneurs/ manufactures/financiers but other groups do not consider this as that important.

This analysis has revealed that there is nothing like a common list of prioritized barriers and different stakeholders have different perceptions about the importance levels of the different barriers. However, the following barriers appear to be regarded as having relatively high priority from the majority of the stakeholder groups - high initial investment/capital cost for gasifiers, difficulty in ensuring continued biomass supply, lack of financial support/incentives and lack of information on technologies.

5. Strategies for promoting BETs

The stakeholder prioritization of barriers to the spread of BETs has clearly indicated the need for evolving both the micro (local) and macro (national/regional) level strategies to overcome the barriers. Some of the barriers have emerged mainly due to local inadequacies whereas few other barriers are the result of lack of supportive policies/regulations and infrastructure at the national levels. Considering this, the approach adopted for assessment of strategies to overcome the barriers and to promote BETs is two pronged. First, the

stakeholders' perceptions have been used to arrive mainly at the strategies needed at the local level to remove barriers and their expectations with respect to national level initiatives. Second, literature has been used to corroborate the stakeholder perceptions and to build on the macro strategies identified by the stakeholders.

5.1. Strategies to promote BETs; Based on Perspectives of Stakeholders

The stakeholders were provided with a list of measures for removing the barriers and requested to rank them based on the perceived importance. Also, provisions were made to include and rank any other measure not included in the list, which was considered to be relevant by the respondent. These rankings were obtained from the same stakeholders who had identified and ranked the barriers and based on a numerical score given to each measure depending on its importance. The overall ranking of a policy measure was obtained from the mathematical average of individual responses for each of the three selected technologies.

5.1.1. Improved cook stoves

The three most important measures to overcome the barriers as prioritised by the stakeholders for improved cookstoves are presented in Table 5. The most important measure to overcome the barrier lack of local trained persons for building stoves and repair and maintenance was identified to be training programs to create a pool of skilled personnel. Similarly, the suggested most important measure for lack of information on improved designs, cost and performance was widespread demonstration of stoves; for lack of quality control during construction it was develop quality consciousness among entrepreneurs; and for "lack of confidence in performance and benefits it was demonstration of stoves.

5.1.2. Biogas for cooking

The Table 6 contains the details of ranking of measures to overcome the identified barriers from the stakeholder perspectives. For the spread of biogas technologies, training programs to create a pool of skilled personnel and creating entrepreneurship development programs seem to be the important measures to remove the barrier lack of entrepreneurs for providing services for operation and maintenance. According to the stakeholders, the high initial investment barrier can be tackled through design change to reduce cost and innovative loan schemes whereas effective monitoring and setting up of manufacturers associations were

required to take care of lack of quality control problems. Information campaigns and widespread demonstrations were identified as important measures for overcoming barrier on lack of information.

5.1.3. Biomass gasifiers for power generation

The measures to overcome the barriers as ranked by the stakeholders are given in Table 7. The measures suggested for overcoming barrier on high initial investment were similar to that identified for biogas technology with only an exchange of place between innovative loan scheme and design change. For ensuring smooth supply of biomass, the suggested measures were design modifications to accept different types of biomass and supporting biomass suppliers through incentives. The barrier on lack of financial support was supposed to be tackled through effective government policies/regulations to encourage financing gasifiers and soft interest rates with speedy clearance of loans. The stakeholders felt that confidence in economic/financial viability can be built through transparent feasibility studies, pilot projects and prototype business plans.

It appears that strategies to overcome the prioritized barriers vary with technologies. However, some common strategies have emerged and they are needed to address some important barriers across different BETs such as; investment cost reduction through improved designs, enhanced access to information to end-users of BETs and improving the infrastructure to create access to services such as that of dealers, servicing personnel, quality control staff and raw material supply.

5.2. Generic strategies to promote the three BETs

The broad policy options for overcoming the barriers and promoting BETs based on the national level assessment made by other studies [1, 2, 5, 6 and 8] are reviewed in this section. Even the stakeholders have perceived the need for some of these policy initiatives.

Policy to promote focussed R&D for cost reduction and high performance: There is a need to review the existing R&D policies and projects, and develop programmes to promote coordinated R&D projects for cost reduction and performance enhancement under practical or field conditions with respect to multi-feed biogas systems, biomass gasifiers and high-efficiency cookstoves.

Policy to fund Large-scale demonstration programmes: There is a need for policy to implement large-scale demonstration programmes. However, scaling up of demonstration programmes should not be based on the experience of installation of biogas or biomass gasifier systems in one or two villages. Demonstration programmes are necessary for several BETs such as community biogas (multi-feed), biomass gasifier-based rural electrification in representative locations on a significantly visible and viable scale to:

- generate information on technology's performance;
- create awareness of feasibility and potential benefits;
- generate cost and benefit data;
- develop and test institutional models and mechanisms;
- train entrepreneurs, NGOs, etc; and
- demonstrate the proof of concept.

Rational energy pricing policy: Rational energy pricing policy aimed at full cost recovery is a major policy shift required to promote different BETs, particularly bioenergy for power generation. Appropriate fiscal policies should be formulated to correct price distortion of bioenergy as well as conventional energy options.

Policy to encourage private sector participation: Biomass gasifiers for rural electrification and biomass combustion for power generation can only be promoted through the participation of private sector. Hence, policies to create incentives for private sector participation are necessary. There have already been several policies formulated by the MNES. However, there is a need to evaluate them.

Policy to promote participatory approach: There is a growing realisation of the need to involve communities, particularly the rural ones, in planning, implementation and management of BETs. Institutional development and capacity building are necessary to enable communities and households to participate in bioenergy programmes. The NGOs could play a crucial role in developing village-level institutions. Realising this, MNES has provided some incentives to NGOs. However, this has not made sufficient impact. Capacity building and institutional development programmes among NGOs, rural communities and rural entrepreneurs are required to enable them to effectively participate in BETs implementation.

Periodic assessment and evaluation of technologies, policies and programmes: It is crucial to provide information on various aspects of the technologies to policy makers, manufacturers, entrepreneurs and end-users. In India, there is inadequate learning from the technologies disseminated, programmes implemented or policies adopted. There is an urgent need to generate knowledge and disseminate information on:

- performance of different BET designs in different field situations;
- performance and impact of programmes, financial mechanisms and policies implemented;
- costs of technologies;
- participation of industries, entrepreneurs, NGOs and communities;
- flow of benefits; and
- environmental and socio-economic impacts of the technologies.

Bilateral and multilateral institutional and financial support: Bilateral and multilateral institutions and mechanisms could play a critical catalytic role in promoting the BETs. India has strong research and technology base for the BETs, thus technology transfer may not be a key issue for external institutions. However, multilateral mechanisms such as GEF and the emerging CDM and multilateral banks (such as World Bank) could support innovative institutional and financial mechanisms to promote sustainable market development for the BETs. BETs are already attractive project activities under CDM due to their lower cost and direct sustainable development implications.

6. Conclusions and Recommendations

In India among the renewable energy technologies implemented, BETs dominate in terms of spread or reach. India, despite being a pioneer in formulating and implementing innovative policies for promoting BETs, has experienced a slow rate of spread of such technologies. This is due to the existence of barriers to the promotion of BETs. Barriers seem to vary with BETs. Among them, policy related barriers appear to be the major ones, which, in turn, have given rise to a host of other barriers; financial and institutional for example. Therefore, embarking on conducive policy initiatives on the part of the government is crucial for overcoming barriers to the promotion of bioenergy systems in India. Some generic and technology specific strategies are needed. Consideration of the perspectives of stakeholders is necessary in formulating key policy and other initiatives. Investment cost reduction through Research and Development and accessible financial

mechanisms are necessary. Further, institutional mechanisms are necessary to create the infrastructure needed for the spread of the technology, for example; access to trained builders, manufactures and dealers, repair and maintenance services, finance, etc.

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Table 1
Technical Potential and Achievements of Biomass Energy Technologies in India (as on 31 March 2003)

BET	Units	Total Potential (TP)	Achievements	
				% of TP
Biogas	Numbers in million	12	3.44	28
Community Biogas	Number of villages	150,000	3,902	2.6
Improved Stove	Numbers in million	120	35	29
Biomass gasifiers	MW	16,000	53.17	0.3
Cogeneration/ biomass power	MW	3,500	483.93	14

Source: [3]

Box 1
Barriers for the Diffusion of Selected BETs

Biomass Gasifiers	Biogas	Improved Stoves
High initial investment/capital cost for gasifiers	Lack of entrepreneurs for providing services for operation, repair and maintenance	Lack of local trained persons for building stoves and repair and maintenance
Difficulty in ensuring continued biomass supply	Lack of quality control	Lack of information on Improved designs, cost and performance
Lack of financial support/incentives (low interest loans, subsidies, tax and depreciation incentives)	High initial investment/capital cost for biogas plant	Lack of quality control during construction
Lack of confidence in Economic/financial viability	Lack of information on Technologies	Lack of confidence in performance and benefits
Lack of information on Technologies	Lack of confidence in Technical viability	Lack of interest or motivation on the part of user
Lack of confidence in Technical viability	Lack of financial support/incentives (low interest loans, subsidies)	Lack of information on Financial incentives (subsidies)
Lack of information on Government schemes	Lack of confidence in Economic/ financial viability	Availability of other cheaper alternatives (low cost traditional stoves)
Availability of other cheaper alternatives (like grid electricity)	Lack of information on Government schemes	Getting loans is difficult for stoves
Lack of information on Financial incentives	Lack of information on Financial incentives	High initial cost for stoves
Lack of manufactures/entrepreneurs for providing services for operation, repair and maintenance	Multiple agencies and procedural delays	
Lack of quality control	Availability of other cheaper alternatives (like fuelwood, kerosene)	
Multiple agencies and procedural delays		

Table 2
Stakeholders Ranking of Barriers for Commercialization of Improved Stoves

Barriers	Entrepreneurs/ manufactures/ financiers		Policy personnel		Researchers		Users/NGOs	
	Overall Priority Value	Rank	Overall Priority Value	Rank	Overall Priority Value	Rank	Overall Priority Value	Rank
High initial cost for stoves	0.0893	8	0.0891	8	0.1006	7	0.0964	8
Getting loans is difficult for stoves	0.1102	6	0.0886	9	0.0858	9	0.0871	9
Lack of information on Improved designs, cost and performance	0.1318	1	0.1084	6	0.1312	2	0.1248	1
Lack of information on Financial incentives (subsidies)	0.1198	3	0.1099	5	0.0881	8	0.1085	6
Availability of other cheaper alternatives (low cost traditional stoves)	0.0836	9	0.1024	7	0.1049	6	0.1057	7
Lack of local trained persons for building stoves and repair and maintenance	0.1198	4	0.1312	2	0.1412	1	0.1196	4
Lack of quality control during construction	0.1146	5	0.1370	1	0.1220	3	0.1220	3
Lack of confidence in performance and benefits	0.1276	2	0.1167	4	0.1191	4	0.1229	2
Lack of interest or motivation on the part of user	0.1032	7	0.1168	3	0.1070	5	0.1129	5

Table 3
Stakeholders Ranking of Barriers for Commercialization of Biogas for Cooking

Barriers	Entrepreneurs/ manufactures/ financiers		Policy personnel		Researchers		Users/NGOs	
	Overall Priority Value	Rank	Overall Priority Value	Rank	Overall Priority Value	Rank	Overall Priority Value	Rank
High initial investment/capital cost for biogas plant	0.0969	2	0.0875	8	0.1121	1	0.0997	3
Lack of financial support/incentives (low interest loans, subsidies)	0.0911	7	0.0938	5	0.0911	7	0.0864	7
Lack of information on Technologies	0.0942	5	0.0993	3	0.0955	3	0.0911	4
Lack of information on Financial incentives	0.0853	9	0.0864	9	0.0861	8	0.0833	9
Lack of information on Government schemes	0.0958	4	0.0849	10	0.0743	11	0.0847	8
Availability of other cheaper alternatives (like fuelwood, kerosene)	0.0789	11	0.0700	11	0.0915	6	0.0888	5
Lack of entrepreneurs for providing services for operation, repair and maintenance	0.0927	6	0.1000	2	0.1087	2	0.1158	1
Lack of quality control	0.1000	1	0.0950	4	0.0921	5	0.1059	2
Lack of confidence in Economic/financial viability	0.0880	8	0.0896	7	0.0926	4	0.0807	10
Lack of confidence in Technical viability	0.0963	3	0.1037	1	0.0746	10	0.0866	6
Multiple agencies and procedural delays	0.0809	10	0.0900	6	0.0813	9	0.0772	11

Table 4
Stakeholders Ranking of Barriers for Commercialization of Biomass Gasifiers for Power Generation

Barriers	Entrepreneurs/ manufactures/ financiers		Policy personnel		Researchers		Users/NGOs	
	Overall Priority Value	Rank	Overall Priority Value	Rank	Overall Priority Value	Rank	Overall Priority Value	Rank
High initial investment/capital cost for gasifiers	0.1111	1	0.1061	1	0.1051	1	0.1002	1
Lack of financial support/ incentives (low interest loans, subsidies, tax and depreciation incentives)	0.0875	4	0.0921	3	0.0893	4	0.0834	7
Lack of information on Technologies	0.0839	5	0.0933	2	0.0854	6	0.0830	8
Lack of information on Financial incentives	0.0789	9	0.0830	7	0.0683	12	0.0684	11
Lack of information on Government schemes	0.0829	7	0.0835	6	0.0707	10	0.0669	12
Availability of other cheaper alternatives (like grid electricity)	0.0762	10	0.0621	12	0.0920	3	0.0907	2
Difficulty in ensuring continued biomass supply	0.0953	2	0.0882	4	0.0962	2	0.0902	3
Lack of manufactures/ entrepreneurs for providing services for operation, repair and maintenance	0.0613	12	0.0787	9	0.0771	9	0.0898	4
Lack of quality control	0.0792	8	0.0692	11	0.0789	8	0.0811	9
Lack of confidence in Economic/financial viability	0.0920	3	0.0827	8	0.0864	5	0.0838	6
Lack of confidence in Technical viability	0.0835	6	0.0877	5	0.0686	11	0.0851	5
Multiple agencies and procedural delays	0.0681	11	0.0733	10	0.0820	7	0.0775	10

Table 5
Important measures for removal of barriers for Improved Stoves

Barriers	Measures	Rank
High initial cost for stoves	Increased contributions from government through subsidies	2
	Loan schemes to support initial cost	3
	Design change to reduce the cost	1
Getting loans is difficult for stoves	Government policies/regulations to encourage financial institutions to support stoves	1
	Low interest rates and speedy clearance of loans	2
	Micro-credit facility	3
Lack of information on - Improved designs, cost and performance - Financial incentives (subsidies)	Information campaigns through media, seminars, workshops, pamphlets, brochures, etc.	2
	Creation of information on all aspects of improved stoves	3
	Widespread demonstration of stoves	1
Availability of other cheaper alternatives (low cost traditional stoves)	Awareness on potential for fuel wood saving	2
	Awareness on health and pollution related benefits	1
	Improve quality of stoves	3
Lack of local trained persons for building stoves and repair and maintenance	Creation of entrepreneurship development programmes	2
	Training programs to create a pool of skilled personnel	1
	Low interest loan facilities to start support facilities for stoves	3
Lack of quality control during construction	Develop quality consciousness among entrepreneurs	1
	Effective monitoring mechanism	3
	Stove builders associations to ensure quality control and performance guarantee	2
Lack of confidence in performance and benefits	Demonstration of stoves	1
	Performance guarantee by builders	2
	Enforcement of standard designs	3
Lack of interest or motivation on the part of user	Information on benefits, quality of life and fuelwood saving	1
	Frequent advertisements on visual media (TV)	3
	Campaign on smokeless kitchen	2

Table 6
Important measures for removal of barriers for Biogas

Barriers	Measures	Rank
High initial investment/capital cost for biogas plant	Increased contributions from government through subsidies	3
	Innovative loan schemes to support initial cost	2
	Design change to reduce the cost	1
Lack of financial support/incentives (low interest loans, subsidies)	Government policies/regulations to encourage financial institutions to support biogas plants	2
	Low interest rates and speedy clearance of loans	1
	Micro-credit facilities	3
Lack of information on • Technologies • Financial incentives • Government schemes	Information campaigns through media (TV, news papers, radio), seminars, workshops, pamphlets, brochures, etc.	1
	Creation of information database on all aspects of biogas plant	3
	Widespread demonstration programmes	2
Availability of other cheaper alternatives (like fuelwood, kerosene)	Removal of subsidies if any and market based pricing	3
	Awareness on health and pollution related benefits	1
	Awareness on high fertilizer or compost value of slurry	2
Lack of entrepreneurs for providing services for operation, repair and maintenance	Creation of entrepreneurship development programmes	2
	Training programs to create a pool of skilled personnel	1
	Financial support for entrepreneurs	3
Lack of quality control	Single agency certifications and development of common standards	3
	Effective monitoring mechanism	1
	Manufactures associations to ensure quality control	2
Lack of confidence in - Economic/financial viability - Technical viability	Demonstration of biogas plants	2
	Performance guarantee by builders	1
	Enforcement of standard designs	3
Multiple agencies and procedural delays	Single window clearances	2
	Simplified procedures	1
	Agencies to facilitate approvals and clearances	3

Table 7
Important measures for removal of barriers for Biomass Gasifiers

Barriers	Measures	Rank
High initial investment/capital cost for gasifiers	Increased contributions from government through subsidies	3
	Innovative loan schemes to support initial cost and working capital	1
	Design change to reduce the cost	2
Lack of financial support/incentives (low interest loans, subsidies, tax and depreciation incentives)	Government policies/regulations to encourage financial institutions to support Gasifiers	1
	Soft interest rates and speedy clearance of loans	2
	Tax holidays and fast depreciation benefits for gasifier investments	3
Lack of information on Technologies Financial incentives Government schemes	Information campaigns through media, seminars, workshops, pamphlets, brochures, etc.	1
	Creation of information database on all aspects of gasifiers	3
	Widespread demonstration programmes	2
Availability of other cheaper alternatives (like grid electricity)	Removal of subsidies if any and market based pricing	2
	Campaign on environmental friendliness of the gasifiers	3
	Awareness on reliability and quality of services	1
Difficulty in ensuring continued biomass supply	Design modifications to accept different types of biomass	1
	Support and incentives for biomass producers and suppliers	2
	Long term contracts between producers and buyers	3
Lack of manufactures/ entrepreneurs for providing services for operation, repair and maintenance	Creation of entrepreneurship development programmes	1
	Training programs to create a pool of skilled personnel	2
	Low interest loan facilities to start factories/workshops	3
Lack of quality control	Single agency certifications and development of common standards	2
	Effective monitoring mechanism	1
	Manufactures associations to ensure quality control	3
Lack of confidence in - Economic/financial viability - Technical viability	Transparent feasibility studies, pilot projects, planning guidance, etc.	1
	Prototype business plans to demonstrate the project viability	2
	National standards and codes	3
Multiple agencies and procedural delays	Single window clearances	2
	Simplified procedures	1
	Agencies to facilitate approvals and clearances	3