Salient Features of Biomass Briquetting in Nepal

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ABSTRACT

Biomass briquette has been looked upon as a potential alternative to fuelwood as well as fossil fuel, whose supply is far from being reliable. The aim of this paper is to assess the potential and prospects of briquettes from residues of agricultural and forest/medicinal plants, which are presently used inefficiently as a source of energy. The scope is to assess the briquetting technology at manufacturing level, assess the performance of the biomass briquetting systems and briquette burning devices in Nepal, analyze selected properties of briquettes, compare briquettes with selected energy forms, and assess the potential of raw materials available for briquetting. From the study, it is evident that the potential of residues generated from agricultural and forest/medicinal plants is significant. However, there is a need to further assess their availability, method of collection and storage, chemical composition, calorific value and other characteristics, environmental implications of their utilization, and other factors. Appropriate machinery has to be developed or acquired for wider application of briquetting technology. Furthermore, there is a need for support from related organizations/institutions for developing and promoting this technology.

1. INTRODUCTION

Biomass is a prominent source of energy in both the domestic and industrial sectors of Nepal. Traditional energy sources such as fuelwood and agricultural residues account for nearly 82% of the total energy consumption [1]. The domestic sector alone consumes 80% of biomass energy while it meets 1.7% of the energy needs of the commercial sector.

Firewood has been the main biomass fuel in Nepal. Agro-residues and herb/wood processing residues can be used as raw materials for briquetting. These solid materials have not been utilized to their fullest capacity. Their effective and efficient use in natural form has been limited due to their very low bulky density, difficulty in handling, and the excessive amount of smoke they generate. An option to improve the handling and fuel characteristics of these biomass fuels is to densify them; the only practiced form of densification in Nepal is briquetting.

Biomass briquettes can be used as a substitute for fuelwood, shortage of which is becoming a matter of great concern in Nepal.

This paper highlights the following aspects of briquettes as assessed by the Royal Nepal Academy of Science and Technology (RONAST):

- Capability related with briquetting technology,
- Production capability under selected scenarios,
- Highlights of selected properties of briquettes made from rice husk,
- Comparative assessment with respect to selected energy forms, and
- Potential of available raw materials for briquetting.

2. TECHNOLOGICAL CAPABILITY

Biomass briquetting based on heated-die screw press is not a new technology in Nepal. The technology was introduced in the country in the early 1980s but has been facing many problems since then. Within the framework of a regional project, RONAST worked on the identification of inherent problems associated with the technology. The aim was to promote the briquetting technology by adopting a sustainable approach. Requirements for this were identified to be development of the technical capability of the machine manufacturers as well as that of the briquette producers for solving the major problems associated with briquetting, e.g., the short life of the screw of the machine and the high cost of production. Another need is to develop capability to efficiently develop, fabricate and disseminate briquette-burning devices.

Technically the categories of components needed to be prepared for developing the biomass briquetting system are:

- Cast iron components, which require to be fabricated in a foundry,
- Electric motor and its accessories, which are available in the local market,
- Screw housing system and other components whose fabrication can be carried out by local workshops,
- Installation, operation and maintenance of briquetting system, and
- Development and dissemination of devices to efficiently burn the briquettes.

In response to the above needs, the Faculty of Technology, RONAST helped enhance the capability of local manufacturers by providing them required orientation, working drawings of improved briquetting system, and assisted the manufacturers not only in the fabrication but also in the repair and maintenance of the system. Briquetting machines, as shown in Photograph 1, have been fabricated in Nepal with the assistance of RONAST. The screws used for briquetting and the end-product-briquettes produced in RONAST are shown in Photographs 2 and 3, respectively.

2.1 Screw Production

Initially the cost of screw production was very high and the time taken to fabricate a screw was also long. With several interactions with the local workshops and careful observation of the manufacturing process, this project has succeeded in achieving a reduction in the manufacturing cost of the mild steel screw by up to 40%. The screw can be made of different materials; depending upon the material used, the cost varies from NRs. 2732 to NRs. 4500 (US$ 1 = NRs. 77). The mild steel screw is most commonly used screw by the industries. Each screw can be reused after repair for 15 to 20 times.

Photo 1 Briquette machine

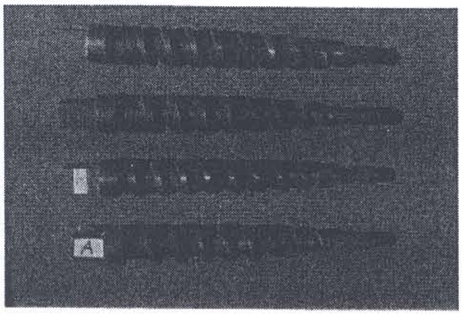

Photo 2 Screws used for briquetting

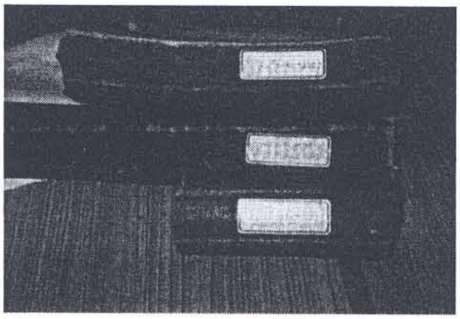

Photo 3 Briquettes

2.2 Briquette Production

Having installed a set of biomass briquetting system within RONAST premises, a series of test productions were conducted. The present paper concentrates only on using rice husk as raw material.

The test results indicate that the required temperature, energy input to heat die, total energy consumption and rate of briquette production varies to certain extent. The maximum production rate observed was 138 kg/hr. Total electricity consumed by the motor and die heater to produce one kilogram of briquette was 0.120 kWh to 0.147 kWh as shown in Table 1.

Table 1 Production, energy consumption and die temperature in rice husk briquetting

Average Die Temperature (^{0}C)	Total Electricity Consumption (kWh/kg)	Production (kg/hr)
309	0.13	106.6
294	0.133	118.6
328	0.141	99.6
301	0.137	101.6
298	0.12	120.0
320	0.126	116.6
352	0.18	98.0

Source: RONAST Laboratory Test

Further test productions were also conducted using rice husk alone to assess the average length and average weight of briquettes produced per minute. The average weight of briquettes produced per minute was about 2 kg, while the average length of briquette produced per minute was nearly 70 cm as shown in Table 2.

Table 2 Results of briquetting using MS screw

Total Time (min)	Production		Total Briquettes Produced (kg/hr)
	Length (cm/min)	Weight (kg/min)	
95	66.1	2.0	117.6
90	67.0	2.0	116.0
195	76.3	2.3	138.0
121	-	1.7	116.5
37	-	2.1	111.3

Source: RONAST Laboratory Test

2.3 Comparative Briquette Production

A comparative test of briquette production was conducted in one of the biomass briquette plants having four Taiwanese-made briquetting machines and four locally-made machines. The test production of biomass briquettes was conducted in three different set-ups: (a) Taiwanese-made machine with mild steel screw/die system, (b) Locally developed machine with mild steel screw/die system, and (c) Taiwanese-made machine fitted with mild steel screw/die system imported from Bangladesh within the framework of the briquetting project of RONAST. The results of the tests are shown in Table 3.

This comparative production test was conducted at a briquetting plant located at Kawasoti,

Table 3 Comparative briquette production results.

Description		Production Rate		Profile Type	Estimated Production Capacity* (kg/hr)
		(cm/min)	(kg/min)		
M1	Taiwanese machine with industry's screw and die	50	1.5	Hexagonal	50 to 75
M2	Taiwanese designed fabricated by the industry with industry's screw and die	43	1.3	Hexagonal	50 to 75
M3	Taiwanese machine with project screw and die (RONAST)	67	1.7	Pentagonal	70 to 100

* This estimation is as per the owner of the Mhayepi Briquette Industry, Nawalparasi.
Source: Field Test

Nawalparasi District. The production rate was found to be 30% to 40% higher in case of machine system fitted with screw provided by the Biomass Briquetting Project of RONAST compared with screw/die normally used in the briquetting plant.

2.4 Cost of Briquettes Production

The cost of briquettes mainly depends upon the cost of four major parameters: raw material, screw/die, electricity consumption and labor input. Of these, the screw incurs a substantial cost due to the high wear and frequent repair required. The share of raw material cost depends upon the prevailing cost at the location of the manufacturing establishment, whereas the cost of electricity is as per the tariff fixed by the Nepal Electricity Authority (NEA). Also the cost of labor depends to some extent upon the location of the industry and the laborer's skills.

The cost of production was estimated taking into consideration the following parameters: cost of machine, land and shed rent, raw material, screw, die, electricity and labor. Ten percent miscellaneous cost has been added to cover the unforeseen expenses. Wastage during production was assumed to be 5% as shown in Table 4.

The result indicates that of the operating cost, the highest is incurred from the cost of raw material, which is 32.9%. This is followed by cost of screw 22.7%, power consumption 20.8%, labor 10.4% and other costs 13.5%.

Table 5 shows the result of financial analysis for biomass briquette production.

2.5 Uses of Briquettes: Biomass Briquette Stoves

Briquette burning test was conducted in selected stoves. Some of the selected stoves used in the project are as follows:

- Top-fed stove
- Ordinary rice husk stove
- Bottom fed single pot gasifier stove
- Ordinary single pot stove
- Improved stove with water jacket (Photo 4)
- Institutional gasifier stove (IGS-2) (Photo 5)
- Double-tiered insulated stove (Photo 6)

Briquettes were found to burn satisfactorily, like wood in all the stoves. There was no difficulty in firing these stoves. For the same process, few splinters of twigs, paper and kerosene, was used to fire the stoves. The briquettes took slightly more time for firing than wood; however, they burnt for a longer period. As the purpose of improved stove with water jacket is not only for cooking but also for room heating and water heating, obviously the overall performance is better. This stove is suitable for the

Table 4 Data used for financial assessment of briquetting technology

Parameters	Unit	Amount
Cost of completed briquetting machine	NRs.	150,000
Total operation time per day	Hours	14
Total operation days per year	Days	300
Total number of working hours per year	Hours	4,200
Economic life of plant	Years	10
Amount of briquettes produced per hour	kg	95
Raw material used per hour	kg	100
Cost of raw material per kg	NRs.	2
Cost of screw	NRs.	3000
Repairing cost of screw	NRs.	400
Life of original screw	Hours	4
Number of times a screw can be repaired		20
Life of single screw	Hours	84
Economic life of muff	Hours	1,000
Cost of muff	NRs.	5,000
Electricity consumed per kg	kWh	0.18
Rate of electricity per kWh	NRs.	7
Cost per operator	NRs	7,000
Cost per helper	NRs	3,500
Installation cost of plant and machinery	NRs.	60,000
Rent of work space/month	NRs.	6,000
Interest rate	%	10
Wastage of briquettes	%	5

Source: RONAST, Biomass Briquetting Project

Table 5 Result of financial analysis for biomass briquette production

Parameters	Unit	Cost (NRs.)	Percentage of Total Cost Production
Cost of Production			
Power	NRs./kg	1.26	20.8%
Die cost	NRs./kg	0.05	0.9%
Cost of screw	NRs./kg	1.38	22.7%
Labor cost	NRs./kg	0.63	10.4%
Cost of raw material	NRs./kg	2.00	32.9%
Production cost	NRs./kg	5.32	
Total Cost			
Miscellaneous (10% of production cost)	10%	0.53	8.8%
Cost/kg of rent	NRs./kg	0.18	3.0%
Cost of machinery	NRs./kg	0.04	0.6%
Production cost	NRs./kg	5.32	87.7%
Total cost of production	NRs./kg	6.07	100.0%

Source: RONAST, Biomass Briquetting Project hilly regions of the country. Institutional gasifier stove is suitable for institutional purpose; this stove is newly being introduced in the country. In case of double-tiered insulated stove, it is possible to tap energy more efficiently even when there is no flame. This is done by removing the top layer and placing the pot on the bottom layer after the flame dies. The outer wall of this stove is also insulated to improve its performance. Comparatively, this stove showed the highest efficiency, the details of which are given in the next section. Table 6 shows a comparison of the efficiencies of selected stoves using rice husk briquettes as well as fuelwood.

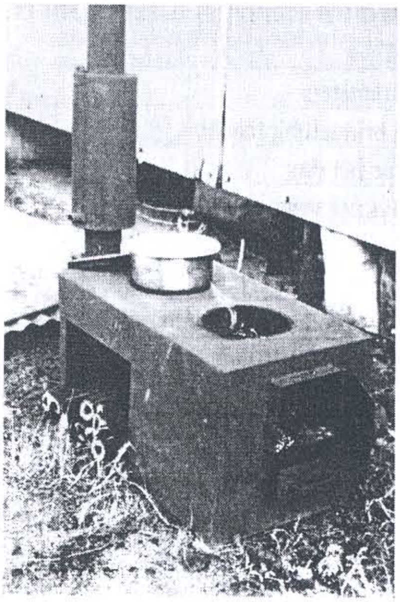

Photo 4 Improved stove with water jacket

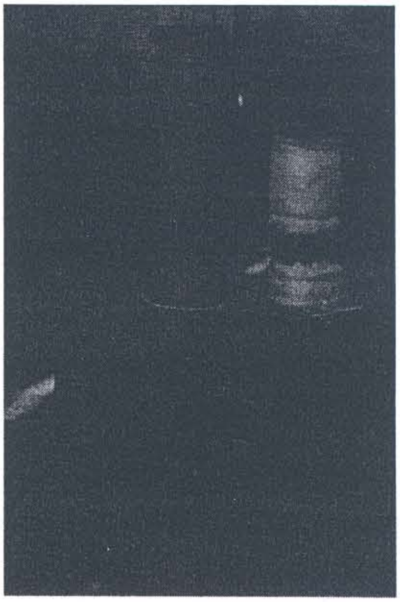

Photo 5 Institutional gasifier stove

Besides large-scale cooking such as in army barracks and boarding schools, rice husk briquettes have been found to have good potential for the following applications:

- Space heating of residences, lodges and restaurants in mountain areas and poultry farms in winter,
- Closed and open-air cooking,
- Water heating using waste chimney heat to produce hot water,
- Tobacco curing,
- Drying of silk cocoons,
- Vegetable and mushroom drying,
- Cardamom drying, and
- Tea processing

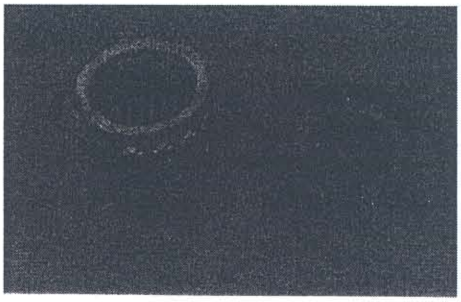

Photo 6 Double-tiered stove

Table 6 Efficiencies of selected stoves using rice husk briquettes and fuelwood.

Type of Stove	Type of Fuel	Efficiency (%)
BGS	Rice husk briquette	11.0
BGS	Fuelwood	9.8
IGS-2	Rice husk briquette	19.0
IGS-2	Fuelwood	17.8
DTS	Rice husk briquette	34.5
DTS	Fuelwood	31.7
Top-fed stove	Rice husk briquette	12.0
Top-fed stove	Fuelwood	13.6

3. PROPERTIES OF BIOMASS RESIDUES

3.1 Efficiency of Briquette-fired Stoves

The efficiency expressed in terms of useful heat extracted per unit weight of fuel depends on the following:

- Moisture content of the fuel,
- Primary air supply,
- Secondary air supply,
- Stove design,
- Ash content,
- Completeness of combustion, and
- Ambient temperature

Efficiency test was conducted on a briquette-fired double-tiered stove. Efficiency obtained from a series of tests conducted using 2 kg rice husk briquettes for boiling 3.5 kg to 4 kg water was 27% to 35% as shown in Table 7.

Table 7 Water boiling test for efficiency of stove (double-tiered stove).

Fuel (RH) (kg)	Quantity of Water Used (kg)	Amount of Water Evaporated (kg)	Time Taken To Boil Water (min)	Evaporation Time (min)	Total Time of Ignition (min)	Weight of Charcoal Left (kg)	Weight of Ash Left (kg)	Efficiency (%)
2	3.5	2.97	15	75	90	0.22	0.26	32.1
2	4	2.74	30	60	90	0.42	0.11	34.5
2	4	3.05	20	90	110	0.23	0.26	33.7
2	4	2.13	25	65	90	0.32	0.18	26.7

Source: RONAST Laboratory Test

4. POTENTIAL OF RAW MATERIALS FOR BRIQUETTE PRODUCTION

The data generally available for any given area in relation to cereal production are on grain yields; residue yields are only occasionally measured and reported, as they are clearly of much less general interest. Therefore, estimates of residue production often depend upon knowledge of grain/residue ratios, which may be applied to grain statistics to derive estimates of residue production. However, in practice residue yields are also somewhat influenced by factors other than the cereal crop species.

Biomass, though abundant, is a scattered resource. With an increase in agricultural productivity, human and livestock population, urbanization and industrial output, the production of waste materials (that may be used as a source of energy) has also increased. The database in this area is however very deficient. The data available are usually 'normative' rather than actual - although the norms themselves may be derived from some isolated sample surveys.

The quality and quantity of residues available at each site depends not only upon the specific agro-climatic conditions of a region but also on the scale and efficiency of the processing unit. Thus the database on the availability of crop residues is very inadequate. However, estimates based on normative residue to crop yield ratios indicate paddy as the largest source of agricultural residue, nearly 8 x 10^6 MT [2] as shown in Table 8. Maize, wheat, grain legumes, oilseeds, millet, and barley follow in order.

Table 8 Area, production and available residue from principal crops, 1999-2000

Crop Type	Area (ha)	Crop Production (MT)	Yield (kg/ha)	Residue Production (MT/ha)	Total Residue Production (MT)
Paddy	1,514,210	3,709,770	2,450	5.20	7,871,975
Maize	802,290	1,345,910	1,678	6.28	5,038,516
Wheat	640,802	1,086,470	1,695	2.99	1,917,315
Grain legumes	308,008	228,840	743	1.20	370,402
Oilseeds	100,429	119,731	629	3.40	341,732
Millet	263450	295380	1121	1.20	370402
Barley	28196	30817	1093	3.40	341732

Source: MoA, HMG/N [2].

In Nepal the potential raw materials for briquetting are of three major types:

- Agricultural crop residues
- Forestry products and residues
- Medicinal plant residues

4.1 Agricultural Crop Residues

The potential of briquette manufacturing at a regional level is evaluated on the basis of rice husk availability in the districts as well as the ease in transporting the briquetting equipment to these areas. The hilly regions have a potential of over 35 thousand tons while the potential in the Tarai regions is about five times this amount, i.e., 150 thousand tons as shown in Table 9. Where road accessibility exists, 25% of the husk is assumed to be available for briquette production. With most agricultural activities being largely concentrated in the lower or Tarai belt of the country, it is not surprising that most of the briquetting industries, whose main source of raw materials is agro-based, are situated in this belt.

Table 9 Briquette manufacturing potential in Nepal (tons).

Physiographical Region	Paddy Production	Rice Husk Production	Husk Available	Briquette Producing Potential
Hills	820,389	205,097	39,282	35,354
Tarai	2,681,887	670,472	167,618	150,856
Total	3,578,830	894,708	206,900	186,210

Note: 25% availability is assumed in road accessible districts and 0% in other districts
Source: MoA, HMG/N [3].

5. STATUS OF POTENTIAL ALTERNATIVE RAW MATERIALS FOR BRIQUETTE PRODUCTION

5.1 Forest-Based Biomass Resources

Forest and shrubs cover 39.6% of the total land area (including protected areas) of Nepal. According to a study conducted by Forest Resources Survey Department, the potential of total growing stock (i.e., total biomass of stems, branches, leaves of tree from ground level to the top) is nearly 285 million m^3 while the available volume per hectare is about 131 m^3 (HMG/N, DANIDA, 1999).

Tree biomass for energy could come from a variety of sources such as from the standing forest to the wood processing plant. The sources can be divided into mill residue, logging residues, forest residues and short-rotation tree plantations. Mill residues are the by-product of processing operations. These operations include plywood, pulp and paper, and furnitures. Since this residue is the most readily available of all tree biomass sources, much of it is now being used. Logging residue is that portion of the tree biomass which is left after the harvest is completed. These residues include treetops and branches, standing live and dead trees and stumps. Forest residues include rough, rotten, tree biomass.

5.2 Medicinal Plants

The wealth of medicinal plants in Nepal may be considered as one of the important natural resources as raw material for briquetting. After extraction of oil from medicinal and aromatic plant, the by-product or residue available is as high as 90% to 99% by weight of the main plant. These residues can become a good source of energy.

About 28 plant species have been worked out in the herb-processing center. Annually 25 tons of oil is collected. The branch-stations produce nearly 200 thousand tons of raw material. Potential availability of residue is not estimated but only the percentage of residue or by-product collected from each plant species from the herb-processing center on an annual basis which is about 7016 tons.

6. PROXIMATE ANALYSIS OF SELECTED RESIDUES AND PLANTS

The knowledge of fuel properties of biomass residue is essential for developing an efficient energy utilization pattern. Proximate analysis gives the percentage of volatile matter content, fixed carbon, moisture content and ash content of biofuels. Table 10 shows the results of proximate analysis of selected air-dried agricultural, forest and medicinal residues and plants. The volatile matter is that portion of biomass which is given off in gas or vapor form when subjected to a standard temperature test. The fixed carbon represents that portion that burns in solid state in the fuel bed. The ash is the non-combustible residue after complete combustion of the biomass.

Moisture content should be as low as possible, generally in the range of 10% to 15%. High moisture content will pose problems in grinding and excessive energy is required for drying. Briquette formation is not good when moisture content is too high or too low. Further, the higher the moisture content the lower the heat or calorific value.

Biomass residues normally have much lower ash content (except for rice husk with 20% ash) but their ashes have a higher percentage of alkaline minerals. If ash content is high, machinery parts wear out and briquetting is inefficient. It should be in the range of approximately 5% to 10%. The higher the ash content, the higher the residue left which makes a big problem. The percentage of ash content that had been carried out in laboratory showed that sawdust, Banmara, and pine bark have low ash content i.e., 1.5%, 1.89%, 1.79%, respectively while rice straw and rice husk have higher ash content, i.e., 16.25% and 15.93%, respectively, as shown in Table 10.

7. CONCLUSIONS AND RECOMMENDATIONS

Biomass briquetting technology has great potential in an agricultural country like Nepal. The technology allows effective use of the residues which otherwise are used inefficiently or wasted. This is also true for the residues left after extraction of medicinal and aromatic contents from certain plants as well as forest weeds like Banmara.

Despite tremendous potential of biomass briquettes, the rural areas still heavily depend on

Table 10 Results of proximate analysis of selected air-dried agricutural, forest and medicinal residues and plants

Biomass	Ash content (%)	Volatile matter content (%)	Carbon content (%)	Moisture content (%)
Bhanti	3.42	66.01	16.13	14.44
Jatropa	8.73	64.51	16.49	10.27
Saw dust	1.50	68.47	19.55	10.48
Banmara (KTM)	1.89	73.62	15.27	9.22
Khar (Sarlahi)	5.98	70.19	15.05	8.77
Pine bark	1.79	59.36	25.28	13.57
Pine needle	2.97	59.34	25.22	12.47
Corn stalk	4.41	68.14	17.03	10.43
Rice husk (AIT)	13.38	63.06	14.49	10.60
Rice straw (Dolakha)	14.89	60.73	14.29	10.09
Rice husk (Khumaltar)	15.93	57.83	15.64	10.60
Rice straw (Khumaltar)	16.25	53.03	12.67	18.05
Vine (wild)	6.70	65.57	16.52	11.21
Wheat straw	4.21	73.28	13.30	9.21

Source: RONAST Laboratory Test

firewood the sources of which are getting depleted. Urban and rural areas with road connection depend upon commercial fuels like diesel and electricity; the supply of these fuels is not reliable and is frequently interrupted.

From this study, it is evident that the energy potential of residues generated from agricultural and medicinal plants is high. Thus efficient utilization of briquetted residues will not only help to meet the energy needs but also solve the disposal and pollution problems often created by these. There is a need to further assess the availability of residues, their method of collection and storage, chemical composition, calorific content and other characteristics, environmental implications of their utilization, and so forth. Appropriate machinery has to be developed or acquired for wider application of briquetting technology.

Presently subsidy is available for most alternative energy devices, even those consisting of mostly imported components. Briquetting machines, which are fully developed, locally manufactured and utilize local raw materials should receive due considerations for government support. The following recommendations are proposed for this purpose:

- Provision of necessary support to further develop and promote this technology;
- Promotion of its use in government institutions such as army barracks, canteens, hospitals, and educational/training institutions;
- Support for research and dissemination of the technology as well as organizations involved with this technology;
- Appropriate policy for promotion of the technology as well as the use of briquettes;
- Promote commercialization of the technology and briquettes by supporting research and development, setting up demonstration units, information and awareness campaign, and other promotional activities.

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