

# Biobriquetting Experience of Nepal and Nepal Academy of Science and Technology (NAST)

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## ABSTRACT

Animal dung briquettes are widely used in rural Nepal as they are cheap, easy to make and based on local materials. But their combustion and use, have negative impact on the health of women and children. Likewise, fuelwood is also still widely used for cooking and heating, causing adverse impact on forest conservation, environment and climate change. Search for alternatives to dung and fuelwood is a continuous process and fuel briquettes based on agro-forest waste is an attractive option. NAST, since its inception in 1982, has been continuously working in this area, introducing different technologies through many projects. It extended R&D and financial support to different individuals and industries working on biobriquetting. It was able to establish a biomass laboratory and Briquette Training Centre with workshop facilities to extend R&D and pedagogic support to university, college students and private sector. Many trainings were conducted under the Biovillage program and different projects. NAST even deputed its staff as JICA expert on biomass briquetting, brought teachers and engineers from Rwanda to be trained in NAST briquette training center. Many projects on briquetting were accomplished making NAST a credible institution in the area of biobriquetting.

**Keywords:** Banmara, Biobriquettes, Biocoal, Biovillage, Ecofuel

## 1. INTRODUCTION

Nepal still relies heavily on traditional sources of energy to meet its energy demand. About 79.65% of the overall energy consumption comes from traditional sources, i.e. fuelwood supplies nearly 71.06%; agricultural residues 3.51% and animal wastes 5.08 % (WECS 2010). Among many fuel alternatives, briquetting of waste biomass to produce biobriquettes is one reliable and sustainable

option (Bhattacharya & Shrestha 1991; Grover & Mishra 1996). Biomass briquetting can use a wide range of waste biomass such as agricultural residues, agro-industrial residues, forest wastes, etc. (Eriksson & Prior 1990; Tyagi 1990). Forest residues such as pine needles, leaves are fire hazardous, therefore, utilization of these waste materials for briquetting can prevent and reduce the damages of the forest areas (Singh & Poudel 2013; Dulal 2017).

In Nepal rural people have been using animal dung briquettes “Guitha” for cooking since time immemorial. These low pressure briquettes, made from locally available materials are cheap and popular, but are inefficient and polluting during combustion (Pant 2010); hence improving fuel efficiency and quality through briquetting is the key technological intervention (USAID 2010); (Wright *et al.* 2010).

## 2. MATERIALS AND METHODS

Among the 23 working groups formed by RONASt (Now NAST) in 1983, the Alternate Energy group had suggested to form a national level research center on alternate energy to make the country more reliable on energy related matters (RONAST 1984). The Academy then put forward the proposal of “Establishment of a National Research and Development Center (NRDC) for Alternative Energy” in RONASt. This became a reality in 1992 with technical and financial assistance of Japan through JICA for 3 years. The Joint R&D project on NRDC was focusing mainly on 3 sectors: Hydro Sector for river current technologies, Solar Sector for photovoltaic technology, Biomass Sector for briquette fuels (Rana 1986).

### 2.1 Resource Base for Briquetting

Nepal has abundant sources of waste biomasses - forest as well as agro-residues. Two types of agro-residues available for use are:

i. Field residues, coming after harvesting of crops such as rice, wheat, millet, and barley

straws, maize, oilseed, soybean stalks and waste from sugarcane, tea, coffee, cotton etc.

ii. Industrial residues that come from the agro-processing industries such as rice husk, bagasse, corn cobs, tea, coffee, cotton, tobacco waste, etc, indicating their potential for briquetting (Singh *et al.* 2010).

Forest residues, derived directly or indirectly from forest area can be divided into four types.

i. Leaf litter and waste biomass found in the forest area.

Waste generated from forest itself, such as leaves, weeds and invasive plants can be used for briquetting. All these resource are plentiful and fire hazardous during the dry seasons (Tyagi 1990). A lot of alien invasive species of biomass (Banmara, *Lantana camara*, *Mikania macrantha*) also have shown huge potentials for briquetting (CEEN 2014).

ii. Second is the large amount of waste generated from wood processing such as saw mills, veneer, plywood, parqueting industries, furniture factories etc. (IWMB 1999; FAO 2009).

iii. Biomass growing under high tension electricity transmission lines indicated in the Subsector Report of Nepal Industrial Development Corporation (NIDC) on Fuel briquetting (NIDC 1990) mentions huge amount of biomass, which can be used for production of briquette fuels.

iv. Industrial waste from processing of Medicinal aromatic plants for oil extraction, yield residues as high as 90-95 percent, is another potential raw material. Herb Production and Processing Company Ltd. (HPPCL) in Kathmandu alone give 7016 tons annually, while branch-stations yield as much as 200,000 tons residues (Shakya & Shakya 2002).

The different types of agroforest residual biomass in Nepal available for briquetting is given in Table 1. Most of this residual biomass, when used as fuel, leads to harmful emissions, causing environmental problems.

Table 1. Different types of waste biomass

S.N	Agro wastes	Forest wastes
1	Rice husk, Rice straw, rice bran	Invasive species such as Banmara, <i>Mikania macrantha</i> , <i>Lantana camara</i> , Besarmi jhar, etc.
2	Wheat husk, wheat straw, wheat bran, residues from millet and barley, Corn cobs, Corn stalks	Pine needles, Pine cones, Shorea robust (saal) leaves, etc.
3	Sugarcane leaves, bagasse from Sugar cane industries and Khandsari	Wood processing wastes - Sawdust, wood shavings, wood chips, veneer, plywood, particle board, furniture industry wastes
4	Waste from lentil & oil seed production,	Waste biomass under high tension electricity transmission lines
5	Other agro wastes- Cotton, Coffee, Tea plantation wastes, coffee husk, tobacco waste, etc.	Waste from herb processing – Bhojo, Jatamassi, Taxus, Eucalyptus, Citronella, Lemongrass, etc.
6	Coconuts husks, Peanuts husk, etc.	Twigs, leaves, shrubs, bushes, etc
7	Pruning waste from agro farms	All kinds of other forest and other wastes (water hyacinth)

In principle briquetting can follow different paths based on different technologies (Figure 1). Raw biomass (rice husk, saw dust, etc.) can directly be briquetted using screw extruder technology, piston press technology for bind-

erless briquetting (route 1), whereas other biomass and mixtures of coal with biomass, or charcoal with clay can be briquetted using roller press and compression technologies with some binders (route 2).

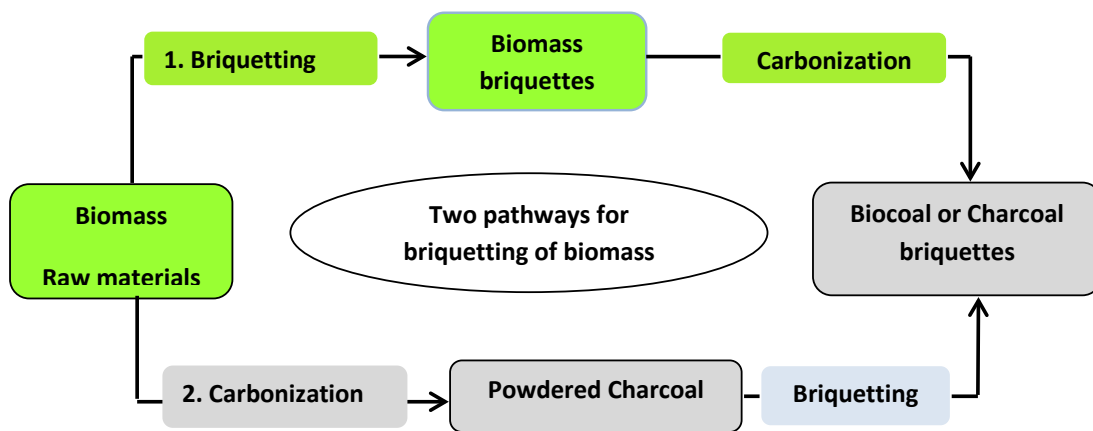


Fig.1. Different processes for briquetting

### 3. BIOMASS BRIQUETTING EXPERIENCE OF NEPAL AND (RO)NAST

The first biomass briquetting plant in Nepal “Nepal Bio-Extruder” was established in 1982 in Kathmandu based on pyrolyzing technology of rice husk. Thereafter, two dozen such types of factories were established or planned to be established till 1990. Most of these industries were based on pyrolysis of rice husk which caused

technical and environmental problems leading to their closure (WECS 1988).

The then RONAST (NAST) had initiated few supportive activities to address the problems of briquetting industries. Mr. Mohan Dhoj Basnet tried to ratify the problems of these industries, through research on briquetting under the sponsorship of RONAST during 1984-86. The pyrolyzing of rice husk and briquette production was done on a household scale. The charring was

done in an earthen vessel bottom-up, normally used for washing clothes, with small modification for smoke outlet. The mixture of charred rice husk with molasses was manually pressed into small oval shaped briquettes. Later, for better compaction the compression was carried out in old bottomless bottles to produce briquettes with higher density (RONAST 1985).

RONAST also facilitated the demonstration of rice husk briquetting unit of Fuji Conveyor Company in 1986 in Khumaltar Complex with support from the Embassy of Japan. This demonstration led to a sharp increase in registration of briquetting industries. Altogether 24 industries were registered with the Department of Industries (WECS 1988).

In 1987/88 four screw extrusion briquetting factories using Taiwan technology were established in Simara, Hetauda, Chitwan and Parwanipur. Few years later, two similar industries - Himalayan Briquette Udyog in Chitwan and another one in Nepalgunj, with machinery fabricated in Nepal, were established. These industries were in operation till 1995-97. They were closed due to lack of technical and financial support. Only one industry, Mhepi Briquette Udyog is still in operation despite many problems, showing that briquetting is still a viable option (Yoshida & Singh 1995).

After consultations with RONAST during 1994-95, a roller press briquetting machine was introduced first time by Sherpa Jongbu in Dang to produce pillow type coal briquettes using molasses as binder. These briquettes were stronger than hand pressed briquettes produced locally using cow dung and red clay. But the production was not regular as the machinery brought from India was old.

Later, in year 2000, Institute for Himalayan Conservation (IHC) of Japan and the then King Mahendra Trust for Nature Conservation (KMTNC) and now National Trust for Nature Conservation (NTNC) introduced a roller press briquetting machine from Calcutta for research and production of biobriquettes based on coal and biomass. In 2005 this machine was taken to Jhapa

to produce briquettes for the Bhutanese refugee camps.

RONAST and Asian Institute of Technology (AIT) went into agreement to implement a project “Development and Dissemination of Improved Biomass Briquetting Systems and Cooking Devices” in 2000 and introduced a simplified rice husk briquetting machine from Bangladesh.

### 3.1 Briquetting Activities of NAST

3.1.1. The first direct experience of RONAST was a financial support of Rs 10,000 to Mohan Dhoj Basnet in 1985/86 for research on charring of rice husk and briquetting already described above. The results were very positive but could not be upgraded to commercial scale (RONAST 1985).

3.1.2. During 1992-1995, RONAST implemented a joint JICA-RONAST research project “National Research and Development Centre for Alternative Energy” in which the biomass sector was involved in briquetting. Coal briquettes (pillow type) also called ‘Mametans’ and coal bee hive briquettes were first introduced in Nepal by this project. Initially the coal bee hive briquettes were tested using Ceramic stoves from Japan. Preliminary tests showed one briquette of ~1kg weight could burn with blue flame for more than 3hours. Pillow shaped coal briquettes “Mametans” with good combustion properties were also demonstrated.

This project established a Biomass laboratory in 1993 to undertake research works on briquettes and solid fuels. Scientific equipment such as Maruto Breaking strength equipment, Bomb calorimeter and Muffle furnace, Analytical balance, etc. were introduced to focus research activities on three issues.

#### i. R&D on biocoal/biobriquettes

Blends of low grade coal and biomass were used to produce briquette fuels and tested in Muglin, Abu Khairani and Bhutanese refugee camps. Biocoal BC-17 and BC-19 gave better results than FW and B-12 (Fig. 2, Table 2) (Singh *et al.* 1996; Singh *et al.* 1997; Singh *et al.* 2001).

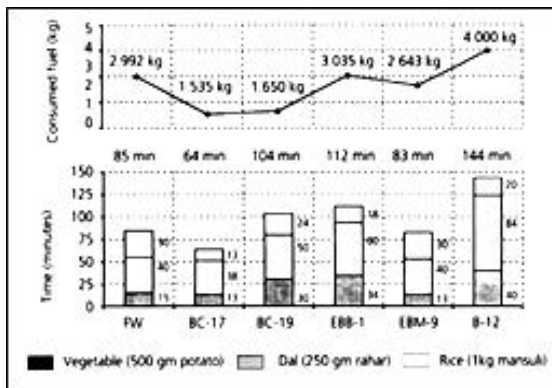


Fig 2. Results of cooking tests

ii. Analytical and advisory assistance.

Most of the coal samples analyzed had Sulphur up to 2 %, so desulphurization was required. Except for C1-C4A, all other coals were of low grade with

Table 2. Code of fuel used

FW	Fuelwood
BC-17	Biocoal (Ghorahi coal 75%, bagasse 25%)
BC-19	Biocoal (Ghorahi coal 40%, Lignite 40%, bagasse 20%)
EBB-1	Briquette (rice husk)
EBM-9	Extruded briquette (Abidhara coal 20%, with rice husk 80%)
B-12	Cow dung (Kathmandu)

calorific values < 4,000 kcal/kg (Table 3). Low quality hand pressed coal balls were widely used, so the project advised Jongbu Sherpa to produce high quality briquettes in Dang using roller press.

Table 3. Results of coal analysis - Proximate analysis, Sulphur content and calorific values

Code No.	Lignite	M C % wt.	Ash, % wt.	VM % wt.	FC %, wt.	CV kcal/kg	Total S% wt.	IncombS % wt.	Comb S (% wt.)
L1	Chapagaon	9.71	40.42	32.86	17.01	2375	1.94	0.96	0.98
L2	Tupek	7.55	54.02	24.46	13.97	2530	0.57	0.11	0.46
L3	Lele	6.73	58.31	23.64	11.32	-	1.04	0.26	0.78
L4	Lukhundole	10.29	33.3	32.8	23.61	3198	1.68	1.11	0.57
<b>Coal</b>									
C-1	Abidhara, Tulsipur	0.89	42.49	22.07	34.55	4530	1.37	0.02	1.34
C-2	Lawarpani, Ghorahi	17.21	21.62	25.98	35.19	4440	0.71	0.04	0.67
C-3	Jumlepani, Ghorahi	18.1	19.78	26.65	35.46	4170	0.77	0.03	0.75
C-4	Thanti, Ajimara	2.8	27.7	3.9	65.5	6533	0.93	0.11	0.82
C-4A	Thanti, Ajimara	2.1	0.6	5.6	91.7	8210	-	-	-
C-4B	Thanti,	4.9	34.3	24.5	36.3	3166	1.92	0.03	1.9
C-5	Tosh, Shewja	1.45	61.67	15.18	21.71	2655	1.63	0.04	1.59
C-6	Monahari	8.27	38.13	25.33	28.27	3798	0.66	0.06	0.6
C-7	Indian Powder coal	7.5	15	35.39	42.11	5905	2.78	0.04	2.74
C-8	Indian Hard coal	9.9	14.07	31.1	44.93	4358	0.52	0.03	0.49
C-9A	Barahachhetra-hard	0.5	87.1	7.1	5.3	560	0.1	-	-
C-9B	Barahachhetra-soft	0.5	78.1	11.4	10.4	1390	0.1	-	-

### iii. Technical support to rice husk briquetting plants

Half a dozen rice husk briquetting plants, operating in Chitwan, Hetauda, Simara, Nepalgunj and Nawalparasi had 2 major problems (a) fast wearing of the screw of the extruder machine and (b) high cost and abrasive nature of rice husk. Hard-surfacing welding rods were introduced, first from Japan and later from India, for hard surfacing of the screw of briquetting machines (Singh *et al.* 1994 ; Singh 2000). The results were very promising, increasing the operation time from 3 to 8-15hrs (Table 4).

During a field trip in 1993 to Sagarnath Forestry Project in Janakpur, RONAST technical staff

discussed with local project staff to undertake analysis of Banmara, that was creating a big problem in forest propagation and explore the scope of using it for briquetting. Based on the analysis of RONAST, Xan Coal Pvt. Ltd. of Simara acquired Banmara and successfully used it for briquetting (Yoshida & Singh 1995). Thus, the problematic weed Banmara (*Adenophorum eupatorium*) was identified as alternative, less abrasive raw materials for briquetting. The charcoal of Banmara was later used for producing beehive briquettes as an alternative cooking fuel. RONAST conferred the Mohan Dhoj Basnet award to Dr. Krishna Raj Shrestha in 2005 for R&D works on Beehive briquetting (Shrestha 2006).

Table 4. Results of screw tests

S.N	Type of Welding rods	Rate of wear	Life of screw	Wearing of the flights of the screw ( $\Delta D$ ) %			Country of origin
	(Code)	(g/h)	(h)	Ist	IIInd	IIIrd	
1	HF-450	44.3	1.58	27.5	20	3	Japanese
2	HF-600	19	2.42	15	10	5	Japanese
3	H-600	37.1	2.72	16	8	3	Indian
4	HF-1000	4.3	7.5	12.5	6	2	Japanese
5	CXA-41	8.5	8.5	12	4	2	Japanese
6	HF-1000 + Eutalloy 10000	1.3	15.5	19	12	6	Japanese- spray welding with Eutectic alloy 10000

From 1999, NAST was engaged in AIT/SIDA Biomass Briquetting Project till 2004. The project introduced a simple and cheap rice husk briquetting machine, an efficient and nonpolluting burning devices for briquettes called Institutional Gasifier stove (IGS), which could use a wide range of solid biomass such as corn cobs, pine cones, wood chips, briquettes, etc. (Shakya & Shakya 2002).

### 3.1.3 Roller Press Briquetting

In 2000, (RO)NAST was also involved in another Biobriquetting project sponsored by Institution for Himalayan Conservation (IHC) of Japan, to produce biobriquette using a roller press briquetting machine. The biobriquettes were tested and demonstrated for cooking in several fuel scarce

areas such as Jomsom. The research results was discussed in a Seminar organized in Kathmandu and presented in the final report (Singh *et al.* 2009; Sharma 2003).

### 3.1.4 Ecofuel Research

Low grade coal from Dang area and lignite from Kathmandu valley, have low calorific values <3000kcal/kg and waste plastics in the Municipal Solid Waste (MSW) is a constant problem. A senior researcher from (RO)NAST undertook research through a JSPS fellowship program during in 2002 to blend waste plastics with low grade coal to produce Ecofuel briquettes. Research results showed that fuel briquettes produced from the blends of PE and PS plastics and

coal had lower ignition temperature and higher calorific values (Table 5). Also blends of biomass with lignite were tested as substitute for fuel-wood in cooking. The comprehensive results of the research works (Singh 2003; Singh & Kim

2006; Singh *et al.* 2009; Kim *et al.* 2003) show that blends of coal and lignite briquettes with up to 80% PE, 80% PS and 80 % Banmara with coal are easy ignite and have higher calorific values (Table 5&6).

Table 5. Ignition temperatures

Polystyrene (PS) and coal mixture	Ign. T.(°C)	Decrease in Ign. T (°C)	PE& coal mixture	Ignition temp. (°C)	Decrease in Ign. T. (°C)
Dang Coal	436		SZ coal	413	
Dang coal + 20% PS	391	45	SZ coal + 20 PE	-	
Dang coal + 40% PS	392	44	SZ coal +50 PE	396	17
Dang coal + 80% PS	398	38	SZ coal +80 PE	373	40
PS	398		PE	373	

Table 6. Calorific values of plastic and Banmara containing briquettes (kcal/kg)

Wt. content (%)	Assam (A) +PE	Abidhara (Ab) +PE	Lignite (L) +PE	Dang (D) +PS
Coal only	6327	1769	1673	6238
Coal20+Plastic 80	9943.8	9031.8	9013	9076.4
Coal60+Plastic 40	8135.4	5399.4	5343	7657.2
Coal80+Plastic 20	7231.2	3583.2	3508	6947.6
Banmara (BM) and lignite (L) briquettes				
Banmara (BM)	L	L+ BM20	L+ BM40	L+ BM80
4138	1673	2166	2659	3645

The combustion duration of briquettes are almost double (15, 25& 15 mins) than the same loose biomass (10, 12& 8 mins) respectively, explaining the advantage of briquettes (Fig. 3). The combustion of

solid fuels (coals & biomass) undergo volatile combustion, with fast burning and big flames, followed by char combustion with slow and long burning with little flame (Fig. 4).

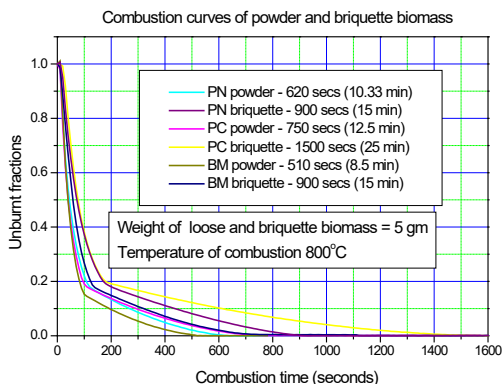


Fig 3. Briquettes (PC, PN, BM briquettes)

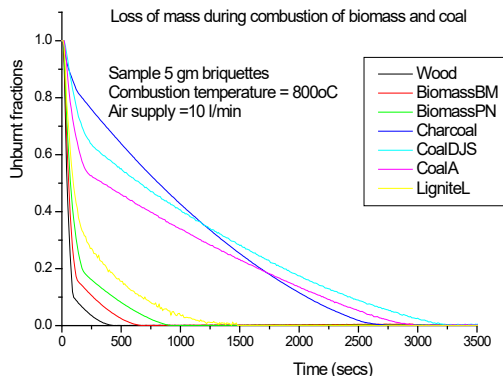


Fig 4. Two steps of combustion – volatile and char burn twice as long as loose biomass

All lines coming down steeply in the graphs, characterizes volatile combustion with rapid loss of 60-80% volatile matter, followed by a small bend, showing the shift to char combustion (Fig. 3, 4).

### 3.1.5 Japanese Partnership Program (JPP) project

During 2009, a new type of project “Technical Cooperation in Dissemination of Alternative Energy Fuel (Biobriquettes) for Firewood and Kerosene” under the JPP was launched with two NGOs - New Energy Promotion Association (NEPA), Japan and Centre for Energy and Environment Nepal (CEEN) and NAST as research partner. The project addressed three issues of beehive briquettes – development of a better briquetting mold, efficient stove and easy ignition method. NAST contributed by fabricating the Sajilo mold to produce more compact briquettes within 30 secs, and Agni stove with thermal efficiency of more than 30 %. CEEN introduced ignition tablets made of saw dust and traditional oil lamp (Fulbatti) that burn for 10-15 minutes with a flame of 15-18 cms for easy ignition of briquettes (Singh 2012). The beehive briquettes could be ignited indoors with these tablets.

### 3.1.6 Compression Briquetting

The coal beehive briquettes from Japan were introduced in Nepal for the first time by (RO) NAST for adaptive research in 1993, but could not be promoted. Later, with the transfer of technology for using charcoal instead of coal,

beehive briquettes based on charcoal became popular.

To facilitate research of beehive briquettes, NAST continued to contribute by i. Undertaking research activities in some critical issues, ii. Collaborating with educational institutions, iii. Providing analytical and test services for biomass briquettes, iv. Undertaking training activities and setting up a training center on briquetting.

i. The research activities of NAST focused on some of the following critical issues of beehive briquette technology: Improving the quality and yield of charcoal using different charring techniques; Selection and optimum use of different binders (Bentonite, Red, Black or ordinary clay) otherbinders (Carboxymethyl cellulose, Starch, molasses, pulp black liquor); Role of pressure applied in briquetting; Mixing ratio of clay and charcoal to obtain strong and good quality briquettes; Insulation and efficiency of stove.

Results illustrating these important issues were achieved through the research activities of NAST on different projects, Junior Research Assistantships, Assistant Research Fellowship, Bachelor’ and Masters’ theses, to address the



issues of bee hive briquettes are summarised below.

Different clays, ranging from Bentonite (potters clay) to red clay were used. Research results show that the calorific value decreases as the amount of clay increases (Fig. 5). The breaking strength of briquettes with bentonite clay as binder

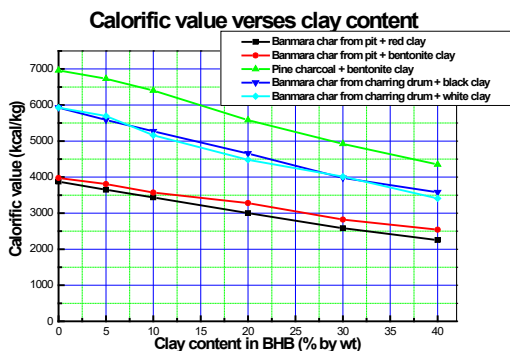


Fig. 5. Calorific value and clay content

Briquettes made using pressure ~10 MPa are denser and heavier. They perform better in terms of efficiency (38 %) with combustion duration of 154 minutes compared to ~ 90 mins for normal briquettes. Normal briquettes produced using manual pressure weigh around 300-450 g, while briquettes using hydraulic machine weighed more than 600g (Bajarcharya 2008).

Metallic stoves without insulation lose a lot of heat through radiation than insulated ones. The surface temperature of the metallic stove reached ~359°C whereas for the insulated one it is around 150°C only. The amount of water evaporated in the insulated stove was 1343 g whereas in the metallic stove it was only 901 gm. Smoke emission tests (Bacharach Oil Burner test in 0-9 scale) for BHB show that very little smoke is emitted (~0-3 smoke number) and

is twice as much as that of red clay (Fig. 6) (Bajarcharya 2008). Briquettes produced using large amount of clay, loose heat in baking the clay rather than transferring it to the cooking pot. The tests of commercially available BHB from the Kathmandu market has 60-73% ash, showing their poor quality (Karki & Sharma 2007).

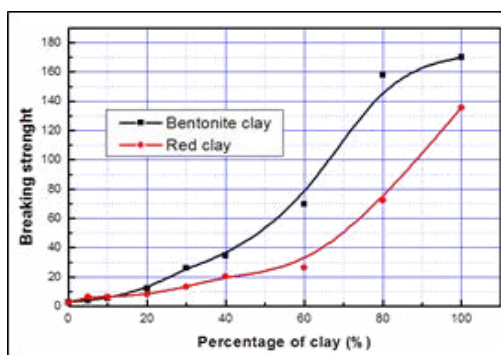


Fig. 6. Breaking strength of briquettes

they are less polluting than ICS or traditional stoves (Pandey 2009).

Char from earth pit has higher ash content (39.24%) and lower calorific value (3876 Kcal/kg), whereas char from simple drum has low ash content (8.20%) and higher CV (5928 Kcal/kg) (Table 7). Similarly, charring in the pit can also be improved by smearing the walls and bottom of the pit by mixture of cow dung and red clay. Alternatively, simple and cheap charring drums made from an oil drum can be used in charring. A better charring drum developed by Indian Institute of Technology (IIT), India can be used to get up to 30kg of good charcoal. If larger amounts of high quality charcoal is required, the retort type drum developed by Appropriate Rural Technology Institute (ARTI) of Pune can be used (Bajarcharya 2008).

Table 7. Proximate analysis of char

S.N	Name of Biomass/char	Moisture Content (%)	Ash Cont. (%)	Volatile Matter Content (%)	Fixed Carbon Content (%)	Calorific Value (Kcal/kg)
1	Banmara	7.42	1.99	80.79	17.22	4511
2	Banmara (charring pit)	9	39.24	15.51	36.25	3876
3	Banmara (charring drum)	5.2	8.2	49.95	37.07	5928

The honeycomb briquettes were tested for cooking of food in the Nepalese context. The nineteen-hole briquettes with 20-30 % of clay and 80-70% charcoal were used. The briquette burns

smokeless for about ~1 1/2 hours with bluish flame. One briquette can be used for cooking a three item meal (dal, bhat & tarkari) for 3-5 persons family (Table 8) (Bajarcharya 2008).

Table 8. Result of cooking with BHB

Stove used	CEE stove	Item & order of cooking	Cooking time
Type of Fuel used	Beehive briquette	1. Rice-1 kg	50 mins
Amount of fuel	1 piece	2. Daal – 250g	21 mins
Wt. of briquette	384 g	3. Potatoes -500g	24 mins
Combustion time	115 mins	Total cooking time	95 mins

The amount of time taken and fuel used in cooking, compared with other fuels, are reflected in Figs.7 and 8. The graphs clearly show that beehive briquettes are competitive fuel for cooking. Since

it burns smokeless with a blue flame, it is better than biomass fuels such as animal dung B-12, rice husk, fuelwood, which produce smoke during combustion and can compete even with LPG.

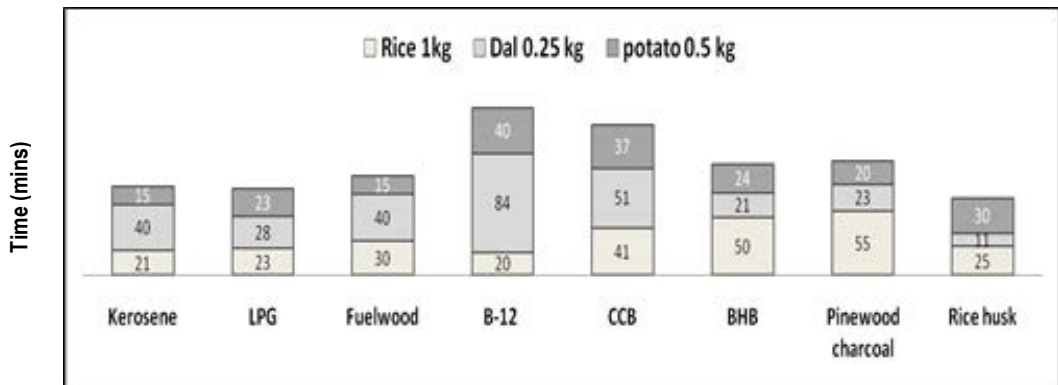


Fig. 7. Time taken to cook by different fuels (B-12 Animal dung, CCB–Refugee camp Compressed coal briquette, BHB–Beehive briquette)

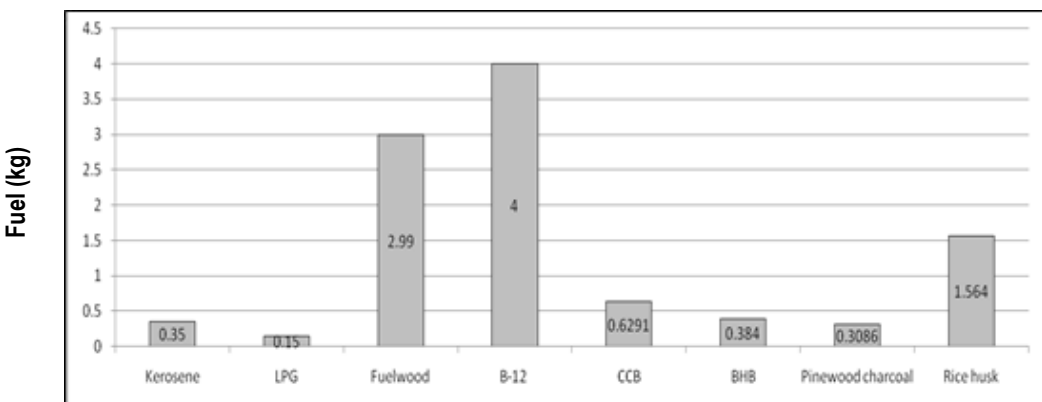


Fig 8. Amount of fuel (kg) used and energy consumed (kWh) to cook same amount of food

ii. Collaboration with institutions

(RO)NAST has been actively collaborating with educational institutions mainly in research and thesis works of students. Many students from Tribhuvan University, Kathmandu University, Khwopa College, College of Applied Sciences, etc. completed Masters, Bachelors and Case studies. Some important Master’s thesis and their results are reflected below.

a. Energy Recovery from Municipal Solid Waste by Briquetting Process (2011), TU.

Polyethylene from the municipal solid waste (MSW) was blended with different proportions of lignite to produce fuel briquettes, while refuse derived fuel (RDF) was also produced from the combustible portion of MSW. A small briquetting extruder was fabricated to produce briquettes. The combustion characteristics of briquettes were studied and tested. The CV values of briquettes increased from 1905 to 3517 kcal/kg with the increase of plastic portion, whereas for RDF it increased to 5179 kcal/kg (Table 9) (Shrestha & Singh 2011).

b. Potential of *Mikania macrantha*, An Invasive Alien Species of Chitwan National Park, as a Raw Material in Briquetting (2010), College of Applied Sciences.

An invasive biomass *Mikania macrantha* has invaded many parts of Nepal including Chitwan National Park. The thesis focused on attempting to a find solution for this invasive species.

Table 9. Calorific values (CV) of briquettes.

Fuel briquettes tested	CV (kcal/kg)
100 Lignite	1905
5% PE+95% lignite	2126
25% PE+75 lignite	3517
RDF (Mixture of rice husk, plastic and paper)	5179

Table 10. Water boiling test of briquettes

Fuels used	Wt.(g)	Water evap. (g)	Efficiency (%)
Pellets	250	380	~35
BHB	570	804	~30
Extruder briquettes	414	774	~40

A quick survey of Chitwan Park established that ~ 91,000 tons of Mikania is there in the park that can be used for making briquettes. The CV of Mikania biomass and char was found to be 3781 and 4399 Kcal/kg. Black and brown briquettes were produced and tested as cooking fuels. The water boiling test (Table 10) showed that making briquettes from Mikania can be a solution for the invasion of this plant, using it as raw material for briquettes (Singh & Poudel 2013).

c. Assistant Research fellowship

Most of coal from Dang area has low calorific value and high sulfur content. The research of this fellowship concentrated on increasing the calorific value and eliminating the sulfur in Ramche coal of Dang. Different blends of Ramche coal and plastic waste were produced to increase the CV from 2740 to 5205 kcal/kg (Table 11). Adding 10% slaked lime (CaOH<sub>2</sub>) in the briquette brought sulfur emission to almost zero (green line in Fig 9) during combustion (Rajauri 2011).

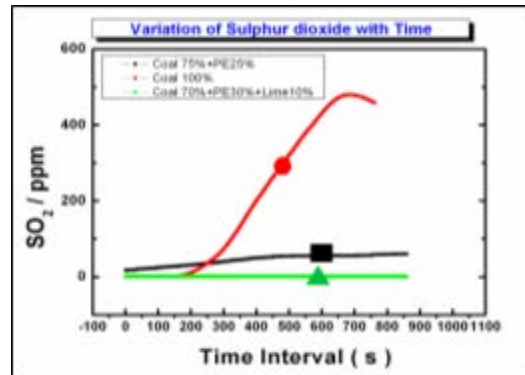


Fig 9. SO<sub>2</sub> emissions for 3 samples

Table 11. CV of mixtures

S.N	Raw material & Briquette Type	CV (kcal/kg)
1	Ramche Coal	2740
2	Ramche Coal75% + PE 25%	4794
3	Ramche Coal70% + PE30% + Lime10%	5205
4	Polyethylene granules	10955

#### d. Providing analytical services for biomass briquettes

Samples analyzed consisted of coals, local briquettes from market, stoves and briquettes of private parties. Beehive briquette stove of private company, Bhutanese Refugee camp GI stove, compressed coal dust briquettes and charcoal samples were among the first ones. Testing and analysis of Charcoal briquettes of different origin, beehive briquettes from Kathmandu market, charcoal from Micro Enterprises Development Program (MEDEP), etc. were conducted by researchers and students under different activities (Singh & Bajracharya 2007). Results of analysis of some selective materials (local biomass materials Banmara, pine needles, *Mikania macranta*, Tite pate, *Lantana camara*, Khar, rice husk, rice straw, water hyacinth, corn cobs, etc.); different Nepali coals, beehive briquettes; compressed coal briquettes; etc. were used to compile a data base as reference material (Bajracharya 2008; Pandey 2009).

#### e. Collaboration of Briquette training center

NAST started demonstration and trainings programs in the late nineties for different institutions and private parties through its briquette training center. Some of the important ones are:

- Training conducted in Mata Tirtha: “Ban Devi Briquette Production Group” from Mata Tirtha, Mahadevsthan VDC, Ward No 6, Thankot was probably the first to approach NAST offering a budget of Rs 20,000 to conduct a training program on briquetting. The technical staff successfully conducted the training for 24 participants mostly female from Asadh 1-2, 2065 (Singh *et al.* 2009).

- Training in Gamcha: Another training on “Making Beehive Briquettes” was conducted from March 11-13, 2009 in Gamcha, Sundarijal for Nepal Institute of Development Studies (NIDS). Altogether 20 females from the same village participated including a volunteer from Tajikistan. The objective was to encourage people to make briquettes from twigs and branches of shrubs like Banmara, Lantana plants and use them for cooking to reduce use of wood from forest (Singh & Bajracharya 2009).

- Collaboration with Ministry of Environment, Science and Technology (MoEST): Several programs on Bio-village including a Biobriquetting component, with support of MoEST were conducted in different places of Nepal. The main objective was to teach them produce biobriquettes locally and use them for cooking and space heating. The first phase in 2064/65 was conducted in Bode village of Bhaktapur and Second phase 2065/66 was in Matatirtha VDC and Chhampi VDC (ward No. 3, 7 & 9) (Singh *et al.* 2006).

- Collaboration with Nepal army: A team of Nepal army officers visited Technology Faculty in 2008, seeking help for alternative cooking system for 200 people at one time. Most of the barracks used kerosene turbo stoves and big aluminium vessels. The high flame temperature of kerosene stoves corroded the expensive aluminium pots fast. Also it was the policy within the army to reduce use of kerosene fossil fuel. A demonstration was arranged using the IGS and briquetting unit and in March 2008 a “Proposal for Installation and testing of IGS and Screw Press Briquetting system” was forwarded to Nepal Army.

A large IGS was designed and fabricated (Fig. 10) with provisions to cook for 200 persons using, one large pot of around 60cm feet diameter with volume of 150 liters and small pot 36 cm with 40 liters capacity. It had provisions of getting warm water from the exhaust heat of the chimney as well. Preliminary tests showed that the stove was sufficient to cook for more than 200 persons at one time (NAST 2008).

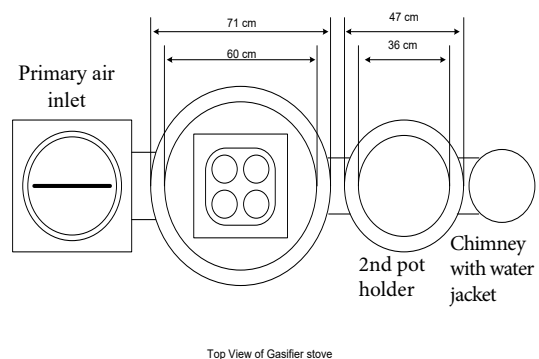


Fig 10. Top view of large IGS for fabrication

In 2009, an army student completed his Master’s thesis and graduated from Kathmandu University

using the gasifier and then fabricated a similar IGS in the barrack of Bhaktapur to cook food using solid waste biomass fuels.

- **Collaboration with Red Cross:** Red Cross had problems in cooking food for 10-20 people in prisons as kerosene became expensive and fuelwood was polluting. After discussions with Representative of International Red Cross in 2007, briquette stoves to cook for up to 20 people was designed and developed to use four and seven beehive briquettes. The thermal efficiencies were 32% and 33%, with burning duration of ~3 hours and 2hours for 4 BHB and for 7 BHB stoves respectively (Pandey 2009). In case BHBs were not convenient for continuous cooking, charcoal pellets was also proposed as cooking fuel and a small improvised unit to produce charcoal pellets was also fabricated and tested.

- **Demonstration/training with IGS:** NAST performed many demonstrations and trainings for students and representatives of IOE of Pulchowk campus, Purwanchal Campus Dharan, Center for Renewable Energy (CRE), etc. These activities further enhanced NAST collaboration with many educational institutions bringing many students to complete these works and graduated successfully.

- **Trainings conducted through JPP:** The Japan Partnership Program (JPP) project had conducted several trainings programs during the project period, through lectures, audio visuals, training manuals and direct interaction with buyers of briquettes, to train rural people for the adoption of beehive briquettes technology as alternative to fuelwood. About 95 participants from 31 districts (Table 12) got trained (Singh 2012).

Table 12. Training programs

S.N	Dates	Venue	Participants
1	18-20 January 2010	Biomass lab, NAST	20 participants from 9 district
2	31 Dec to 01 Jan. 2011	Mahadevsthan, Thankot	40participants from 10 districts
3	8-10 January 2012	RECAST, TU, Kirtipur	35 participant from 12 districts

- **Training for Engineers from Rwanda:** Involvement of a staff of NAST, in JICA project “Strengthening the capacity of Tumba College of Technology of Rwanda” from July 2007, opened doors for the training of Engineers and teachers of Tumba College of Technology (TCT) of Rwanda. The first training was conducted in December 2007, second in June 2008 and third in November 2009 with about 14 people taking part. If the first two trainings consisted of lectures and demos, the third consisted of hands on training in NAST biomass laboratory to train them on analysis of raw materials, briquette and stove production and product analysis (Singh 2009). It went down as a first memorable event in the history of NAST to train so many foreign engineers/teachers from Africa.

The project RENP-10-06-PID-172 “Production of Biomass Briquette Fuel Based on Agro-forestry Waste as Substitute for Fuelwood in the Domestic and Industrial Sector of Nepal” supported by Kathmandu University and NORAD, Norway was implemented with NAST, as research partner and Mhepi Briquette Udyog as industrial partner in Spetember 2010. The project fabricated an improved briquetting unit with 3 phase 20 HP motor, portable briquetting unit with single phase 5 HP electric motor and different types of briquette stove for domestic and institutional cooking purposes to displace firewood. The portable unit could be used with power from Micro hydro units in the rural areas. The machine produced about 60kg/h. of briquettes of 3.5 cm diameter. The weight of the briquetting unit was about ~120 kgs, which could be carried around by a porter from

one place to another in the rural areas (CEEN 2013). The technical assistants from NAST were trained in Spray Welding technique for hard facing of the screwextruder in Bangladesh.

#### 4. CONCLUSION

The works reported are just some important works that (RO)NAST had carried out till 2010 since its establishment. The institution went through the political turmoil of 2046 and 2062 BS, which changed its organizational structure and slowed the academy's course of development, with continuous interferences from outside. Nevertheless, it has been able to establish itself as a premier academic institution in different areas of science and technology, including biomass and biobriquetting in the country.

Since its establishment in 1982 in the past two and half decades, NAST was able to establish itself as a credible institution in the area of biomass briquetting to cater to the needs of educational institutions, students, NGOs, private organizations, industries through the biomass laboratory and briquette training center.

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