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BIOBRIQUETTING IN NEPAL - SCOPE AND POTENTIALS: A REVIEW

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ABSTRACT
Nepal still relies heavily on traditional sources of energy for cooking, heating and livestock feeding. In search for alternatives to fuel wood and utilization of waste biomass, briquetting was introduced in 1982 by the private sector to produce charred rice briquettes and rice husk briquette in 1987. A close analysis of the situation during the 1980ies reveals that the entire briquetting efforts came from the private sector, without any government support in terms of policies, incentives and motivation. Also there was no technical backstopping and very little R&D to support briquetting. So because of various techno-economical problems, most of the briquetting industries closed down. The situation in the country after 2010, nearly thirty years later, is entirely different. With the increase in awareness, about briquettes as renewable source of energy; climate change and global warming issues from fossil fuel use and concept of utilizing waste for energy; with the change in kerosene and briquettes fuel prices; briquettes are slowly emerging as a viable alternative source of energy for cooking, heating and many briquetting industries are again being established in the private sector. The Nepali experience on briquetting shows that, almost all of the Biobriquetting technologies have been introduced in the country. R&D institutions have emerged and research and development activities supporting biomass briquetting are constantly increasing. The assessment of agro-forest waste shows that there is a huge raw material base that can be utilized for briquetting. The technological capability in fabrication, reproduction, repair and maintenance has been well developed. Many funding, promotional and R&D organizations are now actively involved in briquetting. The Government through the AEPC is formulating policies, plans and programs, including incentives for the promotion of Biobriquetting. With the introduction proper policies and incentives biomass briquetting has big potentials and scope for the promotion of biobriquettes in near future.

KEYWORDS: Biobriquetting, beehive briquette, agro-forest waste, briquetting technologies

INTRODUCTION
Nepal still relies heavily on traditional sources of energy to meet its energy demand. In spite of Nepal's huge potential of hydro energy resources, its per capita energy consumption of 15 GJ is one of the lowest in the world. Nepal relies mainly on traditional sources of fuel for cooking, heating and livestock feeding. According to Water and Energy Commission Secretariat (WECS) the traditional fuel accounts for more than 87 percent of the overall energy consumption i.e. fuel wood supplies nearly 78 percent; agricultural residues and animal wastes supply over 9 percent and the imported petroleum products, coal, hydroelectricity and renewable and other forms of energy meet over 12 percent of the total energy demand of the country [1].

Heavy dependence on traditional sources of energy such as fuel wood, animal dung and agro-forest residues causes deforestation, soil erosion, floods, climate change and global warming. Among many alternatives, briquetting of waste or residual biomass to produce Biobriquettes is one reliable option[2-3]. Biomass briquetting can use a wide range of waste biomass such as agricultural residues, agro-industrial residues, forest waste, etc. [4-6] Waste biomass especially forest residues such as pine needles, leaves are fire hazardous during the dry seasons causing extensive damage to the forest areas. Therefore, utilization of these waste materials for briquetting can prevent and reduce the damages of the forest areas [5]. Briquetting technology based on the use of waste biomass has been practiced successfully in many developing countries in Asia and Africa.[7-9]

In Nepal rural people have been using manually made traditional animal dung briquettes (Plate1), for cooking since time immemorial. Animal dung particularly, cow and buffalo dung as binder, is mixed with fillers such as straw, jute sticks and other biomass materials to produce guitha - traditional low pressure biobriquettes [10]. Such low pressure fuel briquettes are quite common in Asian and African countries. These low pressure briquettes, made from locally available materials are cheap and popular, but produce a lot of smoke and indoor air pollution. Traditional dung briquettes and loose biomass during combustion are inefficient and polluting; hence improving fuel efficiency and quality through briquetting is the key technological intervention[2-3].

In search for alternatives to fuel wood and utilization of waste biomass to produce briquettes, the private sector introduced charred rice briquettes in 1982 and screw extruder rice husk in 1987, but these industries did not survive long due to various techno-economical problems, lack policies and programs related to renewable energy [11]. However, after about three decades, Nepal is experiencing a big change in the briquetting scenario after the establishment of research and promotional institutions, introduction of favorable policies and programs of the government[12-13]. It has been observed that after 2010, Briquetting industries are again slowly increasing in the country. In the year 2013 alone three piston press briquetting industries approached Center for Energy and Environment Nepal (CEEN) to have their products analyzed [14-16].

The main aim of the study is to assess the briquetting experience of Nepal during the 1980ies, the attempts to promote biomass briquetting, the problems of briquetting industries and reasons for closing down. Further, the study also examines the reasons for the establishment of new briquetting industries after 2010, the scope and opportunities for the promotion of briquettes in the changed context nearly after three decades after the 1980ies.

MATERIALS AND METHODS

The desk study carried out is followed by the scientific literature review in biomass briquetting, scientific literature such as journal articles, conference papers, books and documents, including research/project reports, thesis, and test/analysis reports. Besides, first hand information collected during field visits, interactions and discussion with the briquette entrepreneurs were also part of this review article. The observations and experience of long time affiliation involvement with briquetting sector through different projects also served as supportive materials for the study. Research findings while conducting different studies related to biomass briquetting also served as the basis of this article.

Biomass briquetting

The basic concept of biomass briquetting means the compaction of loose biomass material using pressure or force in a die or mold to get a compact solid as per the shape of the die after removal of the force or pressure. The simple model given below in figure 1 illustrates the basic concept of biomass briquetting.

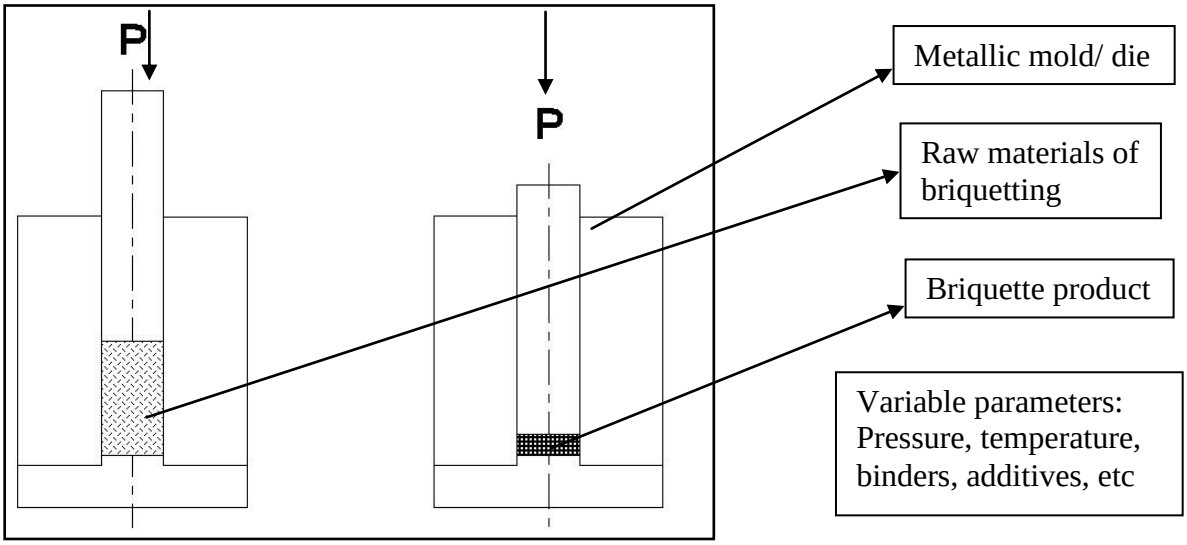

Figure 1: Prerequisites for briquetting

Reviewing different technologies that are being use [2-3] a simple classification for Biobriquetting in the context of Nepal can be derived, based on the existing technologies, for both biomass and charred materials. (Figure 2):

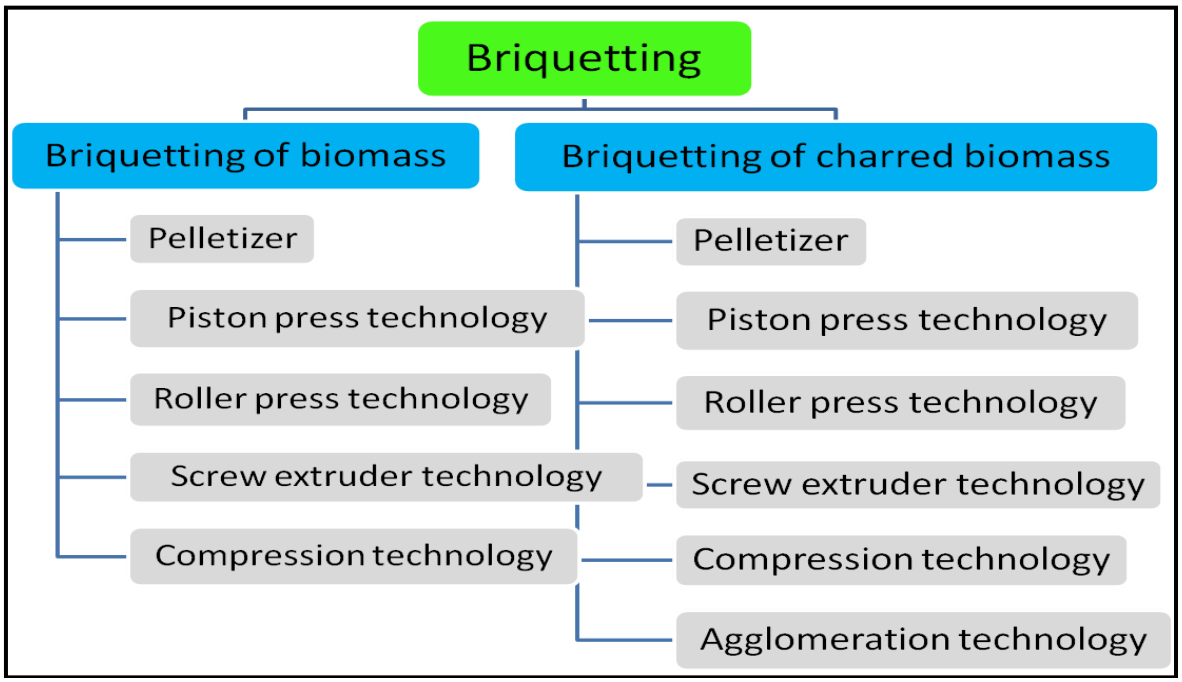

Figure 2 : Classification of briquetting technologies

Pelletizing press technology or Pelletizers (both disc as well as ring matrix technology) is used mainly for biomass with low ash content. In case of using charred material, a suitable binder is used and heat is not required. Piston press technology or Ram piston too is also used both for biomass and charred material. A binder is used with charred material so high temperature and pressure is not required as in the case of biomass. Roller press technologies can vary from low pressure to high pressure depending upon the briquetting material and additives. Binderless briquetting of biomass requires high pressure, whereas, briquetting charred materials and coal with additives and binders do not require high pressure. The screw extruder technology is also similar in conditions for biomass and charred materials [2-3].

The Compaction/compression briquetting is a technology principally similar to the piston press technology. However, they are different in the sense that piston press technology uses electro-mechanical force to drive the piston back and forward and gives high compaction strength. It is a continuous process used for large scale production. The Compaction or Compression technology in Nepal basically uses manual compaction force. It is used in small scale production like producing beehive briquettes, cylindrical charcoal briquettes, FOST briquettes from paper and biomass waste [17] (a local version of Legacy foundation method) etc. Except for the agglomeration briquetting technology, all the above mentioned technologies are found to be used for briquetting of both charred and biomass materials in Nepal.

Biobriquetting Experience of Nepal

The first biomass briquetting plant Nepal Bio-Extruder Industry Pvt Ltd was established in 1982 in Thapathali, Kathmandu with the annual production capacity of 900 metric tons. It used the rice husk pyrolyzing technology to produce charcoal briquettes (brand name Jwala briquettes) from charred rice husk. Later, similar factories with annual production capacity of 1200 tons of briquettes were established in Butwal (1984) and a third one followed in Dharan (1984) with annual production of 600 tons [11, 18]. Over a dozen such factories were registered with the Department of Industries and only 5 were in operation till 1990. These factories were very much polluting, giving out a lot of smoke and smell from the charring units. Besides, they also had certain technical problems of screw extruder and coal tar during production leading to their closure.

Nepal has experience with all kinds of briquetting technologies shown in the above figure 2, except for the Agglomeration technology which is mostly popular in Africa. Among all the technologies introduced in Nepal three technologies, the rice husk briquetting technology (plate 2), the beehive briquette technology and briquettes from waste paper and biomass seemed to have been practiced in a wider scale and drawn attention of both the government and the public[12-13].

Plate 1. Animal dung briquettes-Guitha

Plate 2. Rice husk briquettor in NAST

The screw extrusion technology to produce rice husk briquettes was first demonstrated in 1986 in Khumaltar Agricultural Complex by a Japanese private company, Fuji conveyor, supported by Japanese Embassy (plate 3). After demonstration the briquetting unit, donated to the Agricultural Complex at Khumaltar, was later taken to Janakpur Tobacco farm to replace the fuel wood for curing tobacco in curing barns. This demonstration event seemed to have fostered the promotion of rice husk briquetting industries in Nepal. Over two dozen briquetting industries were registered in the Department of Industries [11].

During 1987-88 four extrusion type briquetting plants were imported from Taiwan by private parties and rice briquetting factories were established in Simara, Hetauda, Chitwan and Parwanipur. Normally these industries were running 8 hour shift only. But during the trade-transit conflict with India in 1999, the Chitwon Briquette Koila Udyog running 3 shifts (24 hours) had saved many industries, including the Brikuti Paper Factory of Gaidakot, by providing briquettes as boiler fuel to many important industries [12].

Plate 3. Fuji conveyor briquetting unit in Janakpur

Plate 4. Mhepi Briquette Industry

Later, the high cost of this imported technology, even led to fabrication of simple briquetting units within Nepal and two more industries using similar type of technology came in operation - one in Chitwan (Himalayan Briquette Udyog) and another one in Nepalgunj (Bageswori Briquette Udyog) [12]. These rice husk briquetting industries, which were in operation till 1995, closed down due to various technical, market and economic problems, as there was no support from the government. Among them only one "Mhepi Briquette Udyog Pvt. Ltd. (Chawasoti) of Nawalparasi" (plate 4) survived and is in operation till today.

Despite the closure of old industries, it is interesting to note that, new industries - JD Apparels industry (with Chinese machine) in Biratnagar (2005), Ganesh Trading Center (with Chinese machine) in Birgunj (2010) and Jiabik Urja Udyog (with Bangladeshi machine) in Bhairawa (2011) were established, showing that there is still ample scope and potentials of rice husk briquetting industries[12]. Furthermore, during year 2013 more industries with bigger production capacities (Shubha Biomass Pvt Ltd, Chitwon; Indira Sugar and Agro Industries P. Ltd, Nawalparasi, Mahakali Sugar Industry Pvt Ltd, Rampur Bilaspur VDC) have been established in the private sector. All of these are using the piston press (Ram Piston) technology from India to briquette saw dust and sugar cane bagasse[14-16].

Briquetting experiences of NAST

During 1992-95 (RO)NAST and JICA first introduced pillow type coal briquettes from Hasimoto Sangio Co., Japan and coal beehive (honeycomb) briquettes (plate 5) along with stoves. Both these products could not be promoted because Nepalese coal was low grade and had a lot of sulfur. Later in view of utilizing the low grade coal (including lignite), Biocoal – a blend of coal, biomass and desulfuring agents was introduced and tested by (RO)NAST at different places of Muglin and Khairenitar [19].

Plate 5. Coal beehive briquettes (NAST)

Plate 6. Biocoal briquettes from roller press

As a follow up of the JICA-RONAST project, in 1999/2000, Institute for Himalayan Conservation (IHC) of Japan in cooperation with RONAST and King Mahendra Trust for Nature Conservation introduced a roller press briquetting machine (plate 6) for production and demonstration of Biocoal briquettes [20]. This machine was later taken to Jhapa to supply briquettes for the Bhutanese refugee camps as the compressed coal dust briquettes from India were very much polluting and problematic.

Almost during the same time in 2000, RONAST joined the Renewable Energy Technologies (RETs) Project in Asia of AIT, which introduced a simple screw extruder biomass briquetting technology from Bangladesh (plate 2). This technology proved to be far simpler in terms of operation and cheaper than the technology from Taiwan (plate4). In addition, the project addressed the technical issue of screw wear using hard facing welding rods, smoke removal systems (plate 2), briquette burning devices, etc. [21]

In 1997 Beehive (honeycomb) briquettes (plate 7) from charcoal and clay after some adaptive research was introduced and promoted by the Center for Energy and Environment (CEE). This technology became popular among the rural communities as it is simple to adapt and cheap, requiring local materials only [22]. Later, this work was recognized by (RO)NAST in 2005 and awarded the Mohan Dhoj Basnet Renewable Energy Award, which brought this technology in the limelight. Now this technology is practiced in more than 50 districts in Nepal. In 2010, the demand for beehive briquettes in Kathmandu alone is over 500,000 pcs and the government has a target of promotion of these briquettes as cooking and heating fuel to 200,000 urban household in the current 3 year Interim plan 2010/11-2012/13) [23].

During 2002/03 Foundation for Sustainable Development (FoST) introduced the concept of making briquettes from waste materials using simple compression technique similar to that of Legacy Foundation. Trainings and promotional programs were organized and different types of stoves and briquettes produced from waste paper and biomass (plate 8) were promoted as a substitute for fuel wood [17]. Recognizing this genuine effort NAST awarded the S&T promotional award to FoST in 2010.

Plate 7. Beehive briquetting

Plate 8. FoST briquetting

In 2009 CEEN initiated a project on biomass briquetting with NAST as research partner and Mhepi Briquette Udyog as industrial partner with support from NORAD through the Renewable Energy Program (RENP) of Kathmandu University. This project introduced a new design of portable screw extruder briquetting machine (plate 9); similar to the briquettor of RETS in Asia project. Besides using different hard facing welding rods, it also introduced the Eutectic (Spray) welding technology to address the wearing of the screw. Also different types of cooking and heating devices (plate 10,11) using briquettes were tested and demonstrated [24].

Plate 9. Portable Briquetting unit

Plate 10. Space heating stove

Plate 11. Low cost tin stove

Thus many different technologies which the country has experienced are given in table 1. The table shows the chronological order of introduction and promotion of the different briquetting technologies. The table attempts to reflect some problems and shortcomings faced by the promoters of briquette products and the technologies.

AVAILABILITY OF BIOMASS RESIDUES IN NEPAL

One of the important components for establishment of briquetting industries is the cheap and abundant residual biomass, which may be agro-residues, forest residues and other waste biomass. The use of biomass feed stocks in energy generation essentially promotes the development of healthy and sustainable local economies [5]. Virtually any agricultural crop (cereal or cash crop) in the process of harvest and processing will yield plenty of residual biomass. Table 2 shows some of the common biomass which can be used for production of briquettes in the country.

Table 1. Chronological development and promotion of briquettes and briquetting technologies in Nepal

No	Technology/Product introduced	Year	Company/person or Organization involved	Produced or introduced product	Situation/Problems	Remarks
1	Screw Extruder technology from India,	1982	Nepal Bio-Extruder Industry P. Ltd Thapathali	Charred rice husk pellet (Brand name-Jwala briquette)	Environmental pollution, wearing of the screw, Problems of coal tar, etc. Closed long time ago	PECO was involve in fabrication and later produced in Nepal
2	Charred rice husk pellets, self made local technology	1985/86	Mohan Dhoj Basnet, Tehe Bhal, supported by RONAST	Charred rice husk pellets	Individual effort, No moral and financial support (NAST offered some financial support later)	Small scale attempt to address problems of screw extruder/charring
3	Coal briquettes imported from India*	1986	Imported by Fuel Corp, Baneshwor (Depo behind Hotel Everest)	Pillow type coal briquettes	Introduction of product without any study/assessment of product and stoves	People were not able to accept due to insufficient information & unavailability of proper stoves
4	Screw extruder briquetting, Fuji Conveyor, Japan	1986	Khumaltar Agro-complex, Patan	Rice husk briquettes	Demonstration event assisted by Japanese Embassy	Event fostered establishment of many such industries
5	Screw extruder rice husk briquetting, (Taiwan made)	1987/88	Chitwon Briquette Koila Udyog, Jan Coal (Simara), Quality wood & Fuel Industry (Hetauda), Chawasoti Briquette Industry, Birgung (renamed Mhepi Industry later)	Rice husk briquettes and saw dust briquettes	High cost of machinery & loan payment, Problems of screw wearing, no proper stoves, high cost of raw materials, market problems, No R&D and technical back up support	Private initiative with no government support. Some technical support from RONAST from 1992, Mhepi -only industry still in operation till today
6	Screw extruder rice husk briquetting (Nepal made) Simple & cheaper than Taiwan Technology.	1990-92	Himalayan (Chitwon) and Bageswori (Nepalganj) Briquette Udyog	Rice husk briquettes	Technical problem of screw, market and raw material problems, no R&D and technical back up support	Private initiative with no government support. Some technical support from RONAST from 1992,
7	Pillow type coal briquettes & coal beehive briquettes, Biocoal briquettes	1992-95	(RO)NAST and JICA joint research project	Coal beehive briquettes, pillow type coal briquette and Biocoal	Nepali coal is low grade with high sulfur and polluting	Biocoal was tested at Muglin, Khairenitar for cooking
8	Manually made Coal briquettes from coal dust, cow dung and clay	Noticed in 1992	Local people of Dang area	Manually made Coal ball briquettes	Not strong and stable briquettes emitting smoke and smell, Pollution from SO2	People produced manually and used for cooking in place of wood and coal
9	Roller press briquetting machine	1994/95	Jongbu Sherpa, Dang	Pillow type coal briquettes	Second hand old machine did not operate for long time	Introduced to make strong and pollution free briquettes
10	Beehive (honeycomb) briquettes from charcoal & clay	1997	Center for Energy and Environment (CEE), Kathmandu	Beehive (honey comb) briquettes from charcoal	Initially not known but after NAST award came to lime light and became popular.	Produced and used in more than 50 districts for cooking, space heating & oil massage.

11	Screw extruder briquetting machine	1999	NAST through RETs in Asia project (from Bangladesh)	Rice husk briquettes	Experimental unit to conduct research only but not promoted	Introduced as simple and cheap alternative to Taiwanese technology
12	Roller press briquetting machine from Calcutta, India	2000	Institute for Himalayan Conservation (IHC), Japan	Pillow type Biocoal briquettes	Demonstration/experimental unit to conduct research and trial production and testing only	Taken to Jhapa to produce Biocoal briquettes to replace CCD briquettes
13	Piston press briquetting machine from Gorakhpur	2002	Entrepreneur in Kalaiya, Birgunj*	Rice husk and saw dust briquettes	Production started but closed because of marketing problems	The plant operated for about one year only
14	Compression technology (Local version) of Legacy foundation but simple & compact mold	2003/04	Foundation for Sustainable Development (FOST), Kathmandu	Briquettes from waste paper and biomass	Production and sales of briquettes and stoves. Also regular training provided to interested group/communities	Used by many people as replacement of wood, gas, kerosene, etc. Received NAST promotional award
15	Rice husk briquetting (Chinese machine)	2005	Harish Todi of JDA Apparel, Biratnagar	Rice husk & saw dust briquette	Production/operation problem of the die. 3 piece die with different cross sectional areas. Briquette formation very difficult. Plant sold out to India.	Approached NAST with screw and die, but unwillingness to provide small fund prohibited assistance from NAST
16	Screw extruder briquetting (portable multipurpose briquetting unit)	2009	Center for Energy & Environment Nepal (CEEN)	Saw dust, rice husk, Mikania, RDF, charcoal briquette, etc	Small prototype machine which can be operated by micro hydro. Needs improvement and increase motor power.	Fabricated and introduced with AEPC support and installed in Tandi, Chitwan
17	Rice husk briquetting (Chinese machine)	2010	Ganesh Trading Center, Birgunj	Rice husk briquette (Production not started)	Similar machinery like JDA apparel imported but not yet installed.	Owner has automatic rice mill and rice husk is by product. Currently selling rice husk only
18	Rice husk briquetting (New design similar to Bangladeshi machine)	2010	Center for Energy and environment Nepal (CEEN)	Rice husk briquettes	Introduced through support from RENP, KU. Also introduced improved version of Portable unit.	Being tested in NAST & RECAST premises
18	Rice husk briquetting (Bangladeshi machine), machine like in NAST (RETs in Asia), with different power transmission system.	2011	Jaibik Urja Udyog, Bhairawa	Rice husk briquette (Production started in beginning of 2011)	High cost of rice husk is creating some problem. Market is not a problem as there is big demand. Local people use for cooking.	Establishment took more than a year for selection of technology. Cost wise equipment from Bangladesh was cheaper and simpler than Indian. But transportation from Bangladesh is a big problem.
19	Piston Press briquetting (from India)	2011	Watabaran Nepal, Budhanilkantha, Kathmandu	Saw dust briquette	Factory shut down due to political intervention	Factory being shifted to Chitwan. Now it is running as Subha Biomass Pvt Ltd
20	Piston press briquetting	2013	Shubha Biomass Pvt Ltd	Saw dust, Bagasse,	Factory shifted from Kathmandu	Production started from February 2013
21	Piston Press briquetting	2013	Indira Sugar Mills Pvt Ltd	Sugar cane bagasse	Established within Sugar Industry	Product analyzed by CEEN
22	Piston Press briquetting	2013	Mahakali Sugar Mills Pvt Ltd.	Sugar cane bagasse	Established within Sugar Industry	Product analyzed by CEEN

*Source - Mr. Surendra Gorkhali of Mhepi Briquette Udyog Pvt. Ltd

Table 2. Some common types of waste biomass

No	Agro wastes	Forest wastes
1	Rice husk, Rice straw, Wheat husk, wheat straw, etc	Banmara, Mikania Micrantha, Lanatana Camara and other invasive plants
2	Corn cobs, Corn stalks	Pine needles, Pine cones from pine forests
3	Residues from lentil crops, oilseed plants, from tobacco plantation, etc	Sawdust, wood shavings, wood chips from saw mills and furniture factories
4	Sugarcane leaves, bagasse from Sugar cane industries and Khandsari	Waste biomass under high tension electricity transmission lines
5	Coffee wastes – coffee husk, Tea plantation and tea industry waste - prunnings, leaves,	Waste from herb processing – Bhojo, Jatamassi, Taxus, Eucalyptus, Citronella, Lemongrass, etc
6	Coconuts husks, Peanuts husk, Walnut kernels, etc	Twigs, leaves, shrubs, bushes, etc
7	Other agro wastes- Cotton plantation wastes, etc	All kinds of other forest wastes

Agro-residues of some important crops

In most of the Asian countries including Nepal rice is the staple food. Besides rice (paddy) there are many other crops as well. The agro-residues for some crops (Table 3) are provided as examples only. The residues of paddy is the largest source of agricultural residue at nearly 7,599,804 MT. Considering the residue to product ratio (RPR) value for rice husk to be 0.267 [25] the residue in the form of rice husk alone come to 1,207,826 MT. Following paddy, maize, wheat and Barley also generate considerably large quantities of residues. The total residue of maize including stalk, cob and husk comes to 4,774,544 MT, whereas for Millet, wheat and Barley the residue generated are 316098, 2351758 and 40,642 MT respectively, indicating their potential for briquetting.

Table 3. Production and available residue from cereal crops

Crop type	Crop Production [MT]	Residue type	RPR*	Total Residue Production [MT]
Paddy	4,523,693	Total residue	1.68	7,599,804
		Husk	0.267	1,207,826
Maize	1,930,669	Total residue		4,774,544
		Stalk	2	3,861,338
		Cob	0.273	527,072
		Husk	0.2	386,133.8
Millet	292,683	Stalk	1.08	316,098
Wheat	1,343,862	Straw	1.75	2,351,758
Barley	23,224	Straw	1.75	40,642

Source: Statistical information on Nepalese Agricultural 2008/2009
*RPR- (Bhattacharya, et el 1993)

Besides cereal crops, there are a large number of cash crops, which yield huge amounts of residues directly after harvesting of the crops. Industrial processing of these crops also yields additional residues as in the case of sugarcane which gives bagasse. The total residue generated from sugarcane including bagasse and leaves and tops alone comes to

1,389,103MT. The residue production of some of these crops is given in Table 4 [26]. Besides these crops there are many other crops like coffee, tea, cardamom, cotton, etc which also generate a lot of residues, which can be used for the purpose of briquetting. The data for these residues have yet to be established.

Table 4. Production and available residue from some cash crops

Crop type	Crop Production [MT]	Residue type	RPR	Total Residue Production [MT]
Oil Seed	135,494	Stalk	4.01	543,331
Sugarcane	2,354,412	Total		1,389,103
		Bagasse	0.29	682,779
		tops/leaves	0.3	706,323.6
Jute	17,658	Stick	2	35,316
Soybean	25,490	Total		89,215
		Straw	2.5	63,725
		Pods	1	25,490
Black Gram	25,964		1.66	43,100

Source: Statistical information on Nepalese Agricultural 2008/2009

Besides agricultural residues people have also been using forest wastes as fuel for cooking, animal bedding and compost preparation. Although these resources are also plentiful, they do not draw as much attention as agricultural residues and a reliable data base of these residues are not yet established in the country.

Forest based residues

Forest based residues can be mainly classified into residues coming from wood processing plants, management of perennial crop plantation and waste generated from the forest itself. There are many saw mills, private as well as government owned under the Timber Corporation of Nepal, located in different places throughout the country. The Timber Corporation of Nepal does not have the exact number of saw mills existing in the country, but has some estimates of the saw dust that is produced by the saw mills. It is assumed that about 9-11% of sawdust is obtained during the processing of timber. Taking the average as 10%, the volume of sawdust obtained is shown in table below in Table 5.

Table 5. Timber used & sawdust obtained in different fiscal years

S No.	Year	Timber used (ft^3)	Volume of sawdust & wood waste obtained (ft^3)
1.	2061/62	1227739.62	122773.96
2.	2062/63	924843.11	92484.31
3.	2063/64	1266008.80	126600
4.	2064/65	1271515.62	127151.56
5.	2065/66	1359099	135909.9
6.	2066/67	673275.07	67327.50

Source: TCN and Department of Forest, 2066

On the other hand during processing of timber substantial amount of the biomass such as twigs and branches are also obtained. Similarly substantial amounts of waste are generated from Plywood production, Particle board production and furniture industries. Another important resource which is also neglected and wasted is the biomass, under electricity transmission high tension lines, which is cut annually to prevent damage to the towers and

lines by climbers and trees. The Sub sector report of NIDC on Fuel briquetting [27] clearly mentions the huge amount of biomass under the high tension lines which is cut annually and wasted. It even recommends it as a very good raw material to the existing briquetting industries. Quantification and utilization of these resources are also important.

Waste generated from forest itself, such as leaves falling from the different trees, weeds and invasive plants, etc. can also be used for briquetting. A lot of trees shed leaves regularly during the winter season to given a thick bed of leaves. Likewise, where there are pine forests a thick layer of pine needles as well as pine cones are found in huge amounts. Then there are a lot of alien invasive species of biomass such as Banmara, Lantana Camara, Mikania micrantha, etc, which have invaded the forest as well as grassland and are destroying the forest as well as the habitat of many protected areas. All these resource are plentiful and are very fire hazardous during the dry seasons and cause tremendous amount of damage. Some preliminary estimates of some forest wastes are given in Table 6.

Table 6. Some estimates of forest residues

Forest residues	Av. amount	Project area	Project/Source
Banmara	Average 0.8 tons per hector	8800 tons (from11,000 ha)	Sagarnath Forestry Development project (1994)
Bhanti	1.5 tons per hector	NA	Sagarnath Forestry Development project (1994)
Pine needles	0.5 tons per hector	1,727,785 tons (from 345,557 ha of 35 districts)	Rosin and Turpentine factory, Dhangadhi
Mikania micrantha	91,088 tons dried material	279.6 Km^2 (coverage 30%)	Chitwon National Park survey Total area 932 Km^2
Residues from herb processing	7016 tons	Average 28 species of plants	Herb Processing & Production Center Ltd (HPPCL)
Many other biomass	NA	Available everywhere	Lantana camara (Dhungri Phul), Mugwort (Tite pati), Bokshi Kanda, etc, etc.

Source: [28-29]

Data for forest residues are not well established as for agro-residues, but some estimates of the forest residues already indicate the tremendous potentials the country has. The waste biomass resource base shows that the country has a huge amount and wide variety of biomass which can be used for briquetting purposes.

SITUATION ANALYSIS FROM 1980IES TILL 2013

Table 7 tries to reflect the situations in the country during 80ies and 2010 onwards, regarding biomass briquetting, taking into consideration the cost of different fuels, technical support services, market mechanisms and policies and programs of government. If we compare the cost of briquettes (Rs 5.00/kg) with kerosene (Rs 4.00/l) in the 1980ies, briquettes were more expensive. Now the situation is reverse. Kerosene costs more 4 times than briquettes. If during the 80ies there were no or few R&D and promotional organizations in the country and the technological capability was low; now there are many such organizations and competitors. Manufacturing and fabrication as well as repair maintenance capabilities have also been well developed in the private sector mechanical and engineering workshops nowadays.

The most important change is the priority of the government towards briquetting through the various program activities (awareness programs, assessment studies, exhibitions, formulation of incentives, etc) of the AEPC to support and promote biomass briquetting business. If earlier briquetting was just a business of a small group of private industries, now the stakeholders in biomass briquetting include many NGOs, INGOs, Donor agencies, Private companies, R&D institutions, etc. Also the issues of global warming and climate change, treating waste as a valuable resource in the concept of waste to energy and changing from fossil fuels to renewable energy has also created social awareness and the importance of biobriquettes.

Table 7. Different issues/indicators in relation to briquetting

Issues and Indicators	During 1980ies	Period of 2010-2013
Cost of kerosene (lit)	Rs 4.00	Rs 103.00 (NOC)
Cost of rice husk briquette (kg)	Rs 5.00	Rs 25.00
Cost of beehive briquette (pc)	Not available	Rs 20.00
Priority of Government	No	Yes in Govt. documents
• Policies/programs	No	Yes in Govt. documents of NPC, AEPC is soon going to provide incentives/motivation package
• R&D organizations	Few (RECAST)	Many (RECAST, NAST, KU, CES, NGOs)
• Promotional organizations	Few private companies	AEPC and Many NGOs/INGOs, Private companies and Donor agencies
• Promotional programs	Few	Many studies, seminars, exhibitions, etc conducted both by Govt and other bodies
Awareness regarding global warming and climate change	Low	High regarding use of renewable energy resources including briquettes
Technological capability (briquetting)	Low	High in manufacturing and repair/maintenance
Heating and cooking devices for briquettes	Very few	Many varieties to suit different purposes – space heating cooking, etc
Briquette information	Poor	Good awareness has been developed through pamphlets, brochures, media, exhibitions, seminars, etc
Market mechanism	Poor - only through links	Good selling outlets through supermarkets and personal networks (Mhepi and Himalayan Naturals, GEE, etc)

RESULTS AND DISCUSSION

a. Potentials for briquetting

The basic requirements for promotion of briquetting are **briquetting technologies including technological capability, raw material base, electric power source and programs and policies.** More important, the current energy situation in the country has changed drastically from the situation during the 1980ies, in terms of unit costs of different energy sources and policies and programs of the government.

As seen from the country's briquetting experience, most of the technologies available in the international market have already entered Nepal and some technologies are locally manufactured. The past experience of the capability (table1) for reproduction and fabrication of technologies have demonstrated that the technological capability of the country has very much enhanced and briquetting technologies can be locally fabricated or reproduced. With the emergence and establishments of well equipped engineering and mechanical workshops; repair and maintenance and technical problems and issues can now be very well addressed.

The second important element is the biomass resource base. The above section (availability of biomass resource) has clearly indicated large amounts of agro-residues from cereal as well as most common cash crops, which can be used for briquette production. The data of resource base for agro-residues, especially for cereal crops are more or less available, whereas for cash crops the data is scanty. Many cash crops which yield large amounts of residues such as coffee, tea, coconut, etc still have been left out. In the case of forest residues, there is still no data base as for the agro-residues. Even for byproducts of saw mills the data is difficult to quantify. Nevertheless, preliminary estimates from some projects and surveys have indicated huge potentials of saw dust and wood waste [27, 30], waste generated from forests (pine needles) [29], invasive plants (Banmara, Mikania, etc) [28, 31] for briquetting.

The electric power required for the operation of briquetting units can either be met from the central grid or from micro hydro installations for isolated rural areas, especially in the central mountainous region. Most of the micro hydro installations are mainly used for electricity generation during the night hours, whereas during the day they remain idle. Electricity generated during the daytime can be used to produce briquettes. In the worst case, if there is no electric power, generators can also operate briquetting machines [21], if there are no other alternatives.

Recently, with the establishment of R&D and promotional institutions like NAST, KU, CES/IOE, AEPC, etc the scenario in the country has become very much favorable for biomass briquetting. If earlier, briquetting was the business of the private sector only, now briquetting is reflected in the government planning documents and various studies and projects are undertaken by AEPC for the promotion and support of briquetting business [12-13, 23]. On the basis of the studies undertaken, AEPC is now in the process of formulation of package of incentives and motivations that will be for entrepreneurs interested in the promotion of briquetting.

b. Scope for briquetting

From the energy scenario and fuel use pattern of the country, assessment of Biobriquetting technologies and technological capability, waste biomass resource base and past experience on briquetting, there is ample scope for biomass briquetting in Nepal because:

1. Development of hydropower is very expensive and will take considerable amount of time to develop it before the country can totally rely on it. Till then biomass briquetting could serve as an alternative source of energy for domestic and industrial use.
2. New renewable technologies such as solar, wind, biogas are comparatively expensive and have its own application limitations. They cannot be applied everywhere as biomass or briquette fuels.
3. The price of fuel wood is constantly rising and unsustainable use of it causes serious environmental problems such as deforestation, foods landslides, desertification, global warming and climate change.

4. The price of commercial fuels such as coal, petroleum products are not only getting expensive but also require huge amount of foreign currency for import. Moreover, their supply is often interrupted and not reliable within the country. Locally produced biomass briquettes could be more reliable and eco-friendly.
5. There is a good resource base – agricultural biomass residues, forest waste and other resources which can be used as raw materials for producing different briquette fuels. This will not only rationally use the waste biomass (waste to energy) but also generate employment opportunities.
6. Briquette fuels are very versatile and come in many different forms like pure biomass briquettes, charcoal briquettes and different shapes to suit the requirements of domestic, commercial and industrial use. A large variety of heating and cooking devices are readily available now in the market for the use of briquettes.
7. The briquetting technologies available in the market offer a whole range of technologies from small scale production units to large scale briquetting plants. And beehive briquetting technologies are already prevailing in more than 50 districts within the country.
8. Research Institutions and organisations too have developed in terms of technical manpower and gained experience in R&D activities. With due financial and technical support services can be made available to briquetting industries.
9. The history and experience of Biobriquetting shows that many briquetting industries, initiated by the private sector had developed the technological capabilities required to run, maintain and operate them.
10. The recent changes in the situation of the country regarding policies, plans and programs; infrastructure and technological capability development; promotion and awareness creation all seem very favourable for briquetting business.

The question lies only with the selection of appropriate briquetting technology and introduction of attractive incentive and motivations to support Biobriquetting business.

CONCLUSIONS

1. A close analysis of the situation during the 1980ies reveals that the entire briquetting efforts came from the private sector, without any government support in terms of policies, plans, incentives and motivation. Also there was no technical backstopping and very little R&D to support briquetting. Marketing of briquettes was mainly on personal contacts and awareness about briquettes was low. At times of energy crisis, the briquetting industries saved many of the vital industries from closing down. Despite these efforts, briquetting did not receive any priority from the government and most of the industries closed down.
2. The Nepali experience on briquetting shows that, almost all of the Biobriquetting technologies have been introduced in Nepal. R&D institutions have emerged and research and development activities supporting biomass briquetting are constantly increasing. The technological capability in fabrication, reproduction, repair and maintenance has been developed.
3. The situation in the country after about thirty years has entirely changed with the change in fuel prices, particularly kerosene and briquettes, making briquettes competitive; with the increase in awareness about briquettes as renewable source of energy; awareness of climate change and global warming from use of fossil fuels and concept of utilizing waste for energy, making briquettes a viable alternative source of energy for cooking and heating.
4. Many funding, promotional and R&D organizations are now actively involved in briquetting and the Government is formulating policies, plans and programs, including incentives for the promotion of Biobriquetting.

5. The assessment of the abundant agro-forest raw material base, technological capability, awareness of renewable energy, introduction of new policies and programs regarding biomass briquetting show that there are huge potentials and scope for the promotion of biobriquettes in near future.

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