Biomass Gasifier Systems for Thermal Applications in Rural Areas

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Introduction

Biomass fuels continue to play an important role both in the domestic and industrial sector in India, as it is an agricultural-based economy. Biomass is the main source of energy for a large number of small, rural, and cottage industries along with the majority of rural households. The majority of these enterprises belong to an unstructured sector and hence information and data on these industries are scarce. These industries provide employment to millions of people and form a very important part of the rural economy. The biomass-consuming industries can be divided into two categories, namely traditional industries and new or potential industries.

Traditional biomass-based industries are essentially rural cottage and small-scale industries. These industries depend predominantly on biomass fuels such as wood, agricultural residues, and animal dung because biomass is cheap and its supply is assured. Biomass energy is used in these industries for direct heating (firing of bricks, lime), indirect firing (drying, baking), boiling, steam raising and distillation.

New or potential biomass-based industries include many medium- and small-sized enterprises that currently use fossil fuels and are willing to switch over, at least partially, to biomass fuels available locally at lower prices. Examples of these industries include textile mills, brick kilns, mini cement plants, steel re-rolling and lime kilns.

This situation calls for the development of a biomass-based but energy efficient and environment friendly system with better environmental acceptability, economic viability, and good process control. The biomass gasifier system is ideal for such applications as it can offer all these qualities.

Biomass gasification is the process of conversion, through partial combustion of solid biomass feed material into combustible gas. The technology may be regarded as fuel switching to convert solid fuel to gaseous fuel. Gasification is achieved in the presence of heat and a limited supply of oxygen, resulting in incomplete combustion of the solid biomass material. The resulting combustible gas mixture can be burnt directly in an oven/burner for thermal applications or cooled, cleaned and fed into a diesel engine to generate electricity.

For over two decades, TERI (The Energy and Resources Institute) has been working on the development of various biomass gasifier designs (downdraft, updraft and natural draft) for both thermal applications as well as for decentralized power generation. So far, more than 350 TERI gasifier systems have been successfully installed in the field throughout India with a cumulative installed capacity of over 13 MW_{th}. This paper gives an account of TERI's efforts in developing and promoting biomass gasification as a sustainable and eco-friendly option to meet energy demand for three selected rural applications: cardamom drying, arecanut processing and community cooking.

Gasifier system for community cooking

In a developing country like India, biomass is still and will remain the major fuel for cooking energy. There are several residential schools and religious places that consume substantial quantities of fuelwood daily. Apart from contributing to deforestation, it also consumes a lot of time and labour in its collection. TERI has designed both downdraft and updraft gasifier based cooking systems and installed these at residential tribal schools at Doimukh in Arunachal Pradesh and Kankia in Orissa (Figure 1 and Figure 2). The updraft gasifier system can also be operated without a blower under natural draft mode in unelectrified villages. The fuel consumption data and time required for cooking using the gasifier system is tabulated in Tables 1 and 2 along with a comparison to the traditional stove.

Wood gas system for large cardamom curing

With an annual production capacity of more than 4 000 Metric Tonnes (MT), India is the largest producer of large cardamom with a 54% share in world production, followed by Nepal and Bhutan. Within India more than 85% of production comes from Sikkim and Darjeeling. To achieve a long storage time and to bring out the characteristic aroma, cardamom capsules have to be dried to reduce the moisture content from about 70-80% to below 10% . Traditionally, an inefficient smoking method is employed, using a bhatti (oven) system. Out of the total large-cardamom cultivation area in Sikkim, more than 85% plantations are very

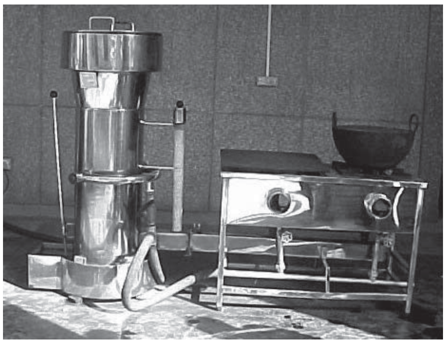

Figure 1 Downdraft gasifier for cooking (*photo: Dr Sanjay Mande & Debajit Palit*)

Figure 2 Updraft gasifier for cooking (*photo: Dr Sanjay Mande & Debajit Palit*)

Theme

Table 1 Summary of performance data of gasifier-based cooking system at Doimukh, Arunachal Pradesh

Item	Fuel consumption (kg)		Cooking time (hrs)	
	Traditional oven	Gasifier system	Traditional oven	Gasifier system
Rice (~ 30 kg)	18 – 20	15 - 20	1.30 – 1.45	1.45 – 2.15
Dal (~ 5 kg)	15 - 20		1.00 – 1.30	
Total	33 - 40	15 - 20	2.30 – 3.15	1.45 – 2.15

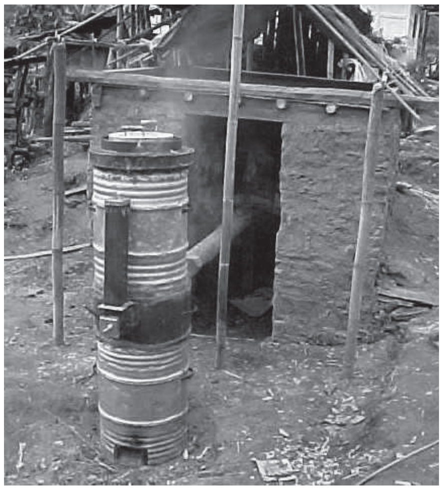

Figure 3 Gasifier for cardamom drying (*photo: Dr Sanjay Mande & Debajit Palit*)

small with an area of less than 2 ha, with over 34 000 traditional bhattis, making it a small farmer's business.

The bhatti is made-up of locally available construction materials. It has a 0.60 m thick stonewall structure on three sides and a wide opening in the front for burning large wood logs. About 400-600 kg fresh, large-cardamom capsules are loaded as a thick bed on a bamboo or wiremesh platform and placed on the stonewalls. Large wood logs from within plantations are fed and burnt in the front opening of the bhatti, and the capsules are exposed to a large amount of smoke to dry them. Thus the cardamom bed is exposed to the thick smoke generated during the burning of wet wood and it takes about 30-50 hours to dry the cardamom (Mande et al. 1999).

TERI has developed an appropriate gasifier-based large-cardamom dryer system (Figure 3) to suit local conditions. The system is made of locally available material and can be easily transported into remote forested areas where cardamom plantations are found. More than 150 systems have been installed in the state in collaboration with the state Horticulture Department and these systems have also been pilot tested in Nagaland state in India, as well as in Nepal and Bhutan. Through extensive field performance monitoring it was observed that use of gasifier not only resulted in more than 62% fuelwood saving but also resulted in improving the quality of the product, as the dried cardamom retained 35% more volatile oils and natural reddish colour (Figure 4). Thus induction of a gasifier system cannot only help in the preservation of natural forest but also in increasing the income for farmers. A greater oil content without a burnt smell could also open new industries for large-cardamom by way of extracting its oil.

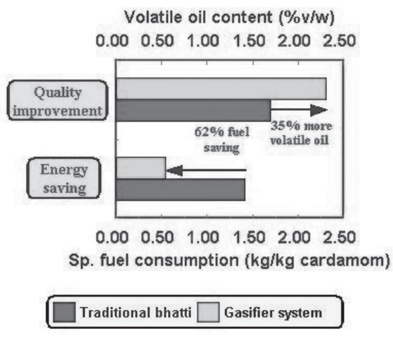

Figure 4 Comparative performance of traditional and gasifier based cardamom-curing system *(Diagram: Dr Sanjay Mande)*

Arecanut processing

Arecanut palm (Areca catechu L.) is cultivated for its kernel, which is chewed in its tender, ripe or processed form. The north-eastern region of India is a major producer of arecanut in India, producing 21% of the total national production. Most of the production is exported to outside the region. The major processing clusters are in northeast India with large (5-7 tonnes of processed arecanut produced weekly) and medium sized (2-3 tonne of processed arecanut produced weekly) units located in Rupahi and Howly, in the state of Assam. Apart from these clusters, thousands of cottage-level processing units are also found in Cachar, Karimganj, Darrang, Dhubri and Kokrajhar districts of Assam.

There are two varieties of processed arecanut processed in the state of Assam and other states in India: Boiled, dried nuts (red in colour, called chikni) and non-boiled, sun dried nuts (called supari). Tender green arecanut are dehusked, boiled and dried to obtain the chikni. Boiling is done in batches in flat, open, iron pans (4-5 feet diameter) where chopped nut pieces are mixed with colour and boiled at 70–80°C, to cook and absorb the colour (Figure 5). The first batch of boiling in a day takes 50 minutes and subsequent batches take 30 minutes. Though the nuts should be boiled for 20 minutes to get a good quality boiled nut, owners restrict the boiling time to save the scarce fuelwood. The drying (slow heating) is done in brick-cement/brick-mud frame sheds (7 feet height and 7.5 feet width) with vertical partitions. Thick bamboo mats are used to spread the chopped nuts out for drying and wood is fired in each partition on the ground, well below the bamboo mats. In the large and medium sized units, fire curing is initially done for 12 hours at a temperature of 70-75°C and then the dried product is further sun dried for 2-3 days to remove any residual moisture.

On average 100 to 150 kg fuelwood is used to produce 100 kg of processed arecanut, of which 60% is used for boiling and the rest for drying. The average wood-burning rate for boiling is 115 kg per hour, with SFC (specific fuel consumption) of 0.70 kg wood per kg boiled nut. Detailed water boiling tests carried out on the vessel-bhatti combination currently used, revealed that the useful power requirement is 30-35 kWth.

TERI has successfully developed an integrated gasifier-based system for boiling, as well as drying, and has successfully demonstrated the application in the Rupahi cluster (Figure 6). The gasifier with a wood consumption rate of about 20 kg/hr capacity, was used for boiling arecanut in the existing boiling pan and also utilized the hot flue gases for drying. The gasifier could also be operated successfully using waste arecanut husk (a by-product during de-husking operation) that makes the gasifier option even more attractive

Table 2 Summary of performance data of gasifier based cooking system at Kankia, Orissa

Parameter	Fuel consumption (kg)			Cooking time (hrs)		
	Traditional oven	Gasifier system		Traditional oven	Gasifier system	
		With blower	Without blower		With blower	Without blower
Breakfast						
Upma - 6 kg	45-55	15-19	18-23	2.0-2.5	1.0-1.25	1.75-2.25
Lunch/Dinner						
Rice - 40 kg	45-60	15-19	20-23	2.0-2.5	1.0-1.25	1.50-2.00
Dalma: 6 kg dal+10 kg veg	65-75	23-27	25-28	2.5-3.0	1.5-1.75	2.50-3.00
Total (daily)	265-325	90-109	98-123	7.0-8.5	4.0-4.75	6.75-7.75

Table 3 Field performance of gasifier-based cooking system for arecanut boiling

Item	Traditional oven	Gasifier system
Amount of nuts processed (kg/batch)	140	140
Time required for boiling (hrs)	2.5	1.0
Total curing time (hrs)	4.0	3.0
Total fuelwood consumption (kg/batch)	125	45

Figure 6 Gasifier-based arecanut boiling (*photo: Dr Sanjay Mande & Debajit Palit*)

(Table 3). Further improvements in energy efficiency are achieved by utilizing the hot gases for drying instead of traditionally burning fuelwood.

Conclusions

Biomass gasification technology can help in taking a rural population using biomass as a fuel two steps up on energy ladder (from solid to gaseous fuel). Application of gasifier for heat applications in rural areas has significant fuel saving potential coupled with other benefits such as improving the working environment, improving product quality and processing rates, due to controlled burning of gaseous fuel obtained through gasification of solid biomass.

Figure 5 Traditional arecanut boiling (*photo: Dr Sanjay Mande & Debajit Palit*)

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Profile of the authors

Dr Sanjay Mande is a biomass energy technology expert. He has a Doctorate in Environmental Sciences and Masters in Mechanical Engineering (Thermal & Fluids Engineering), and more than 17 years experience in RDDD (research development demonstration and dissemination) of gasifier for both thermal as well as small scale power applications.

Debajit Palit has a Masters in Physical Sciences with PG Diploma in Non-conventional Energy Technology. He hasover ten years experience in biomass energy resource assessment, demonstration of gasifier technologies, technology evaluation of various renewable energy technologies and policy studies.