# PROSPECTS FOR BIOMASS GASIFIERS FOR COOKING APPLICATIONS IN ASIA

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ABSTRACT: Biomass constitutes the biggest source of energy in rural Asia. However, its utilization in the domestic sector is mostly inefficient and polluting, resulting in resource wastage and indoor air pollution. Traditional cook stoves, predominantly used in the households for domestic cooking, have been a major contributor to these ill effects. Improved cookstove programmes implemented in the developing world attempt to address these problems. Biomass gasification appears to have a significant potential in Asia for domestic cooking applications. A number of gasification-based cooking systems, which are more efficient than traditional stoves and are almost smoke-free, have been developed and demonstrated recently to highlight the potential benefits of introducing them in developing countries. These systems are based on two broad approaches, i.e., gasifier-stoves and central gas production with producer gas supply network.

Keywords: Gasifier Stove, Biomass, Cooking

## I. INTRODUCTION

Most of the Asian developing countries depend heavily on biomass to meet their household cooking energy requirements. Fuelwood often accounts for a major fraction of the total biomass use. Fuelwood is generally preferred to non-wood biomass residues due to its higher energy density and convenience in use and transportation.

Large quantities of biomass residues are available in the Asian region. These include ricehusk, rice straw, wheat straw, corncob, coconut shell, bagasse, and many other agricultural residues. The residues are normally difficult to use, particularly in small-scale systems, due to their uneven and troublesome characteristics

Although biomass offers itself as a sustainable and carbon-neutral source of energy, its inefficient use in household cooking results in wastage, indoor air pollution and related respiratory and other health problems. Excessive use of fuelwood is also exerting pressure on the region's forest cover. Although large quantities of surplus biomass residues are available in Asia, due to certain difficulties experienced in using them in the traditional cooking devices, their use has been severely restricted. The non-availability of suitable cost-effective technologies for utilizing biomass residues for household cooking has resulted in gross under-utilisation and neglect of biomass residues as a potential energy source in this sector.

## II. BIOMASS AS AN ENERGY SOURCE FOR COOKING IN ASIA

Domestic cooking accounts for the major share of the total biomass use for energy in Asia. However, use of biomass fuels in traditional stoves is characterised by low efficiency and emission of pollutants. In an effort to address these problems, many of the Asian countries have initiated national programmes to promote improved cook stoves. Although significant achievements have been reported in some of these countries, the potential for further efficiency improvements is still very large. A study by Bhattacharya et al. [1] estimated that the biomass saving potential in seven Asian countries (China, India, Pakistan, Nepal, Philippines, Sri Lanka and Vietnam) as 152 million tons of fuelwood and 101 million tons of agricultural residues, in the domestic cooking sector alone in early nineties. The amount of biomass that can be saved through efficiency improvement can serve as a source of additional energy and can potentially substitute for fossil fuels to reduce net GHG emission.

### 2.1 Biomass Gasifiers for Cooking Applications

Gasification is the process of converting solid fuels, such as wood, agricultural residues and coal, into a combustible gas. A biomass gasifier consists primarily of a reactor or container into which fuel is fed along with a limited (less than stoichiometric, or amount required for complete combustion) supply of air. Heat for gasification is generated through partial combustion of the feed material. The resulting chemical breakdown of the fuel and internal reactions result in a combustible gas usually called producer gas. The heating value of this gas is in the range of 4-6 $MJ/Nm^3$, or about 10-15 % of the heating value of natural gas. Producer gas is a mixture of the combustible gases hydrogen ($H_2$), carbon monoxide (CO), and methane ($CH_4$) and the incombustible gases carbon dioxide ($CO_2$) and nitrogen ($N_2$); the actual gas composition may vary considerably depending on fuel type and gasifier design. In small-scale gasifiers, solid fuels are gasified in a fixed bed; these can be of three types: updraft, downdraft, and cross-draft reactor.

Downdraft gasifiers were widely used in World War II for operating vehicles and trucks . During operation, air is drawn downward through a fuel bed; the gas in this case contains relatively less tar compared with the other gasifier types.

In updraft gasifiers, air passes from below up through a fuel pile. The producer gas leaving an updraft gasifier generally contains more tar compared to downdraft gasifiers.

With the escalating costs of fossil fuels and gas as a preferred cooking fuel (than fuelwood, residues, kerosene etc.), biomass gasifiers are attracting renewed interest. The possibilities for biomass gasification technology for cooking applications are leading to a number of initiatives to demonstrate the potential benefits of introducing them in developing countries. Wider use of the gasifiers stoves in developing countries could save on cooking fuel costs, improve the reliability of fuel supply by making rural communities more self-reliant and improve indoor air quality. Gasifier-based cooking systems have some very attractive features, i.e., high efficiency, smoke free clean combustion, uniform and steady flame, ease of flame control, and possible attention-free operation over extended duration. While these make them an attractive choice in the kitchens of the developing world, there are cost and technology barriers which limit their wider adoption.

Gasification based cooking systems can be classified in to two broad types: gasifier stoves and central gas production with pipe network for producer gas supply for cooking.

Gasifier stoves, which are basically compact gasifier-gas burner devices, have been tried since mid-nineties for cooking applications. Several hundred biomass gasifier cookstoves are already in operation in countries such as China and India. In many countries, policy measures (such as governmental support in the form of subsidies on investments) are in place to stimulate biomass gasification [2].

Apart from being fuel efficient, gasifier stoves are also emission efficient in comparison to traditional cook stoves. The traditional cook stoves, because of their very low efficiency, emit more than 10% of their carbon as products of incomplete combustion (PIC) comprising varying amount of tars. In addition, about 100-180 g of carbon monoxide and 7.7 g of particulate matter are also emitted per kg of wood. Gases such as methane, total non-methane organic compounds (TNMOC) and $N_2O$ are added to this. These PIC emissions are even higher in the case of loose biomass or cow dung used as fuel in these stoves [3].

Some of the natural draft stoves (based on combustion of gas produced from biomass) developed so far are listed in Table 1. The capacity of these stoves ranges from $3kW_{th}$ to $20kW_{th}$, making them suitable for domestic as well as community cooking applications. Compared to the 5-15% efficiency of traditional cook stoves in the Asian region [1], the efficiency of these gasifier stoves is in the range of 25-35%. The design of the inverted downdraft type stoves are illustrated in Figures 1-5.

Table 1. Natural draft gasifier stoves developed worldwide for cooking applications

| Sl. No. | Name of Stove | Developed by | Reference |
|---|---|---|---|
| 1. | Wood-Gas Cook Stove | Thomas Reed and Ron Larson | [4] |
| 2. | Charcoal Making Wood Gas Cooking Stove | Elsen Karstad | [5] |
| 3. | Natural draft cross flow stove models IGS2 , DGS2 and CGS3 | Asian Institute of Technology, Thailand | [6, 7] |
| 4. | Briquette gasifying stove | Richard Stanley (Legacy Foundation, USA) and Kobus Venter (Venter Forestry Services, South Africa) | [8] |
| 5. | IISc Gasifier Stove | Indian Institute of Science | [9] |
| 6. | San San Rice husk Gasifier stove | U Tin Win (under guidance from P.D. Grover and G. R. Quick) | [10] |

The Wood-Gas Cook Stove of Reed and Larson use small wood chips and sticks for operation, and produce very low CO emission, and hence suitable for indoor cooking. The rate of gas production can be controlled by controlling the primary air supply to the gasifier. The gasifier produces charcoal as a by-product [4].

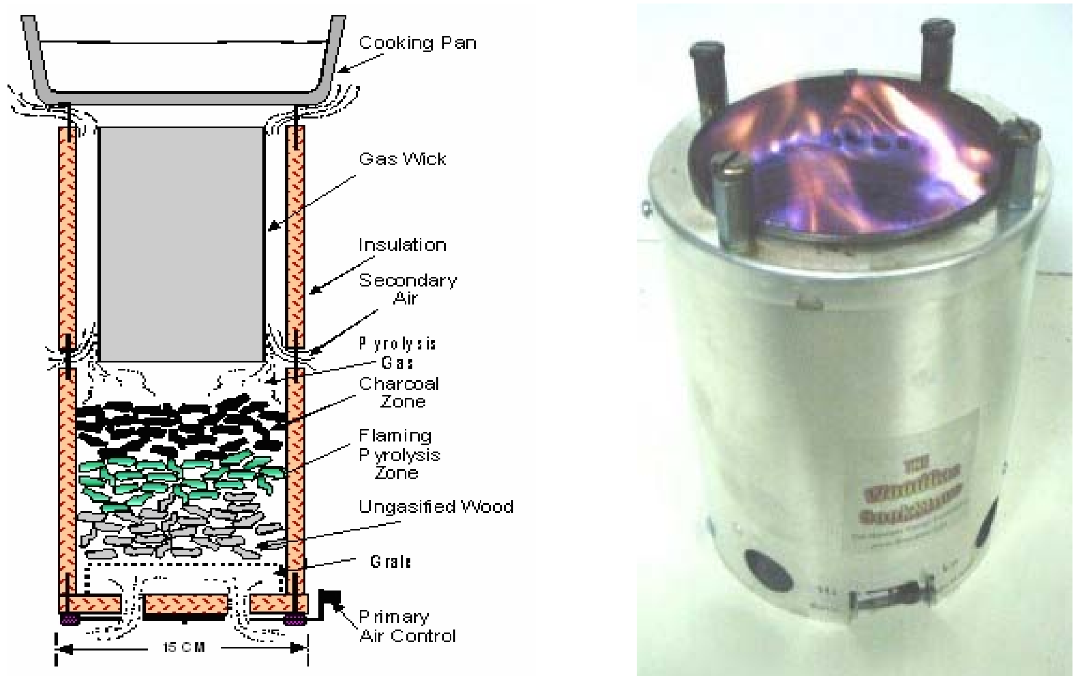



Figure 1. Wood-Gas Cook Stove developed by Reed and Larson

Elsen Karstad's Charcoal Making Wood Gas Cooking Stove is a simple stove developed for the East African households [5].

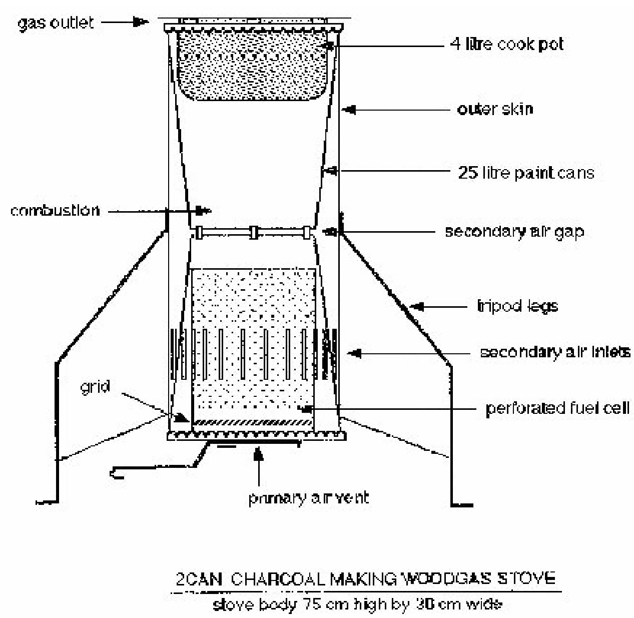



Figure 2. Elsen Karstad's Charcoal Making Wood-Gas Cook Stove

The Holey Briquette Gasifier Stove developed by Stanley and Venter (2003) operates using a single biomass briquette with a central hole (typically produced in extrusion type briquetting machines) placed in the middle of the combustion/gasification chamber. At about 1.1 kW power, the stove offers efficiency of up to 35%.

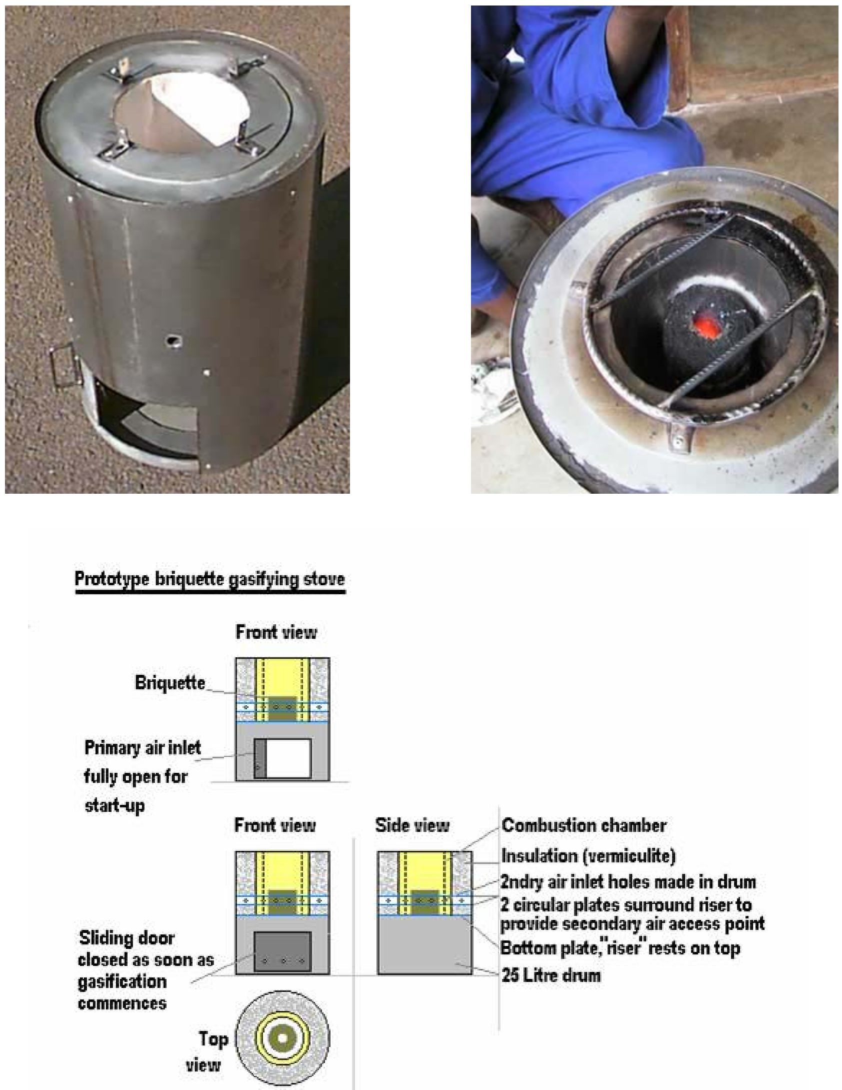



Figure 3. Holey Briquette Gasifyer Stove developed by Stanley and Venter
(1.1kW power; 35% efficiency)

The IISc Gasifier Stove can be operated using small wood sticks and pelletised waste, and has a thermal output of 3-4 kW. Offering a water-boiling efficiency of 25-35%, the stove can operate continuously for about 2 hours for a single fuel loading. Emission from the stove has been found to be low [9].

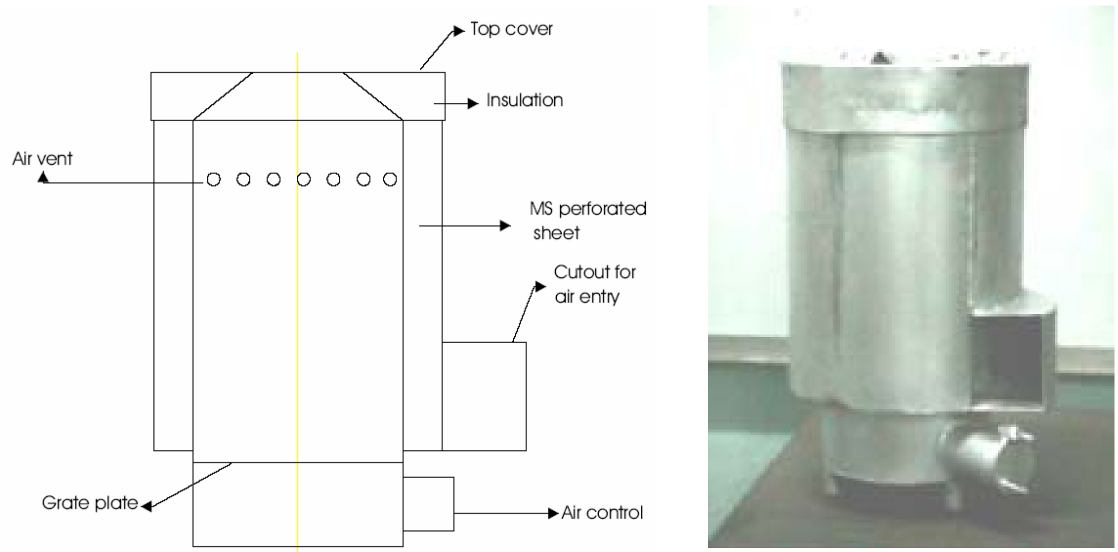



Figure 4. IISc's Gasifier Stove

The San San Rice husk Gasifier Stove developed in Myanmar offers smokeless combustion of rice husk in an efficient manner. Gasification can be improved by mixing kitchen wastes such as potato peels, green leaves and fresh biomass, chopped into half inch pieces, with the rice husk [10].

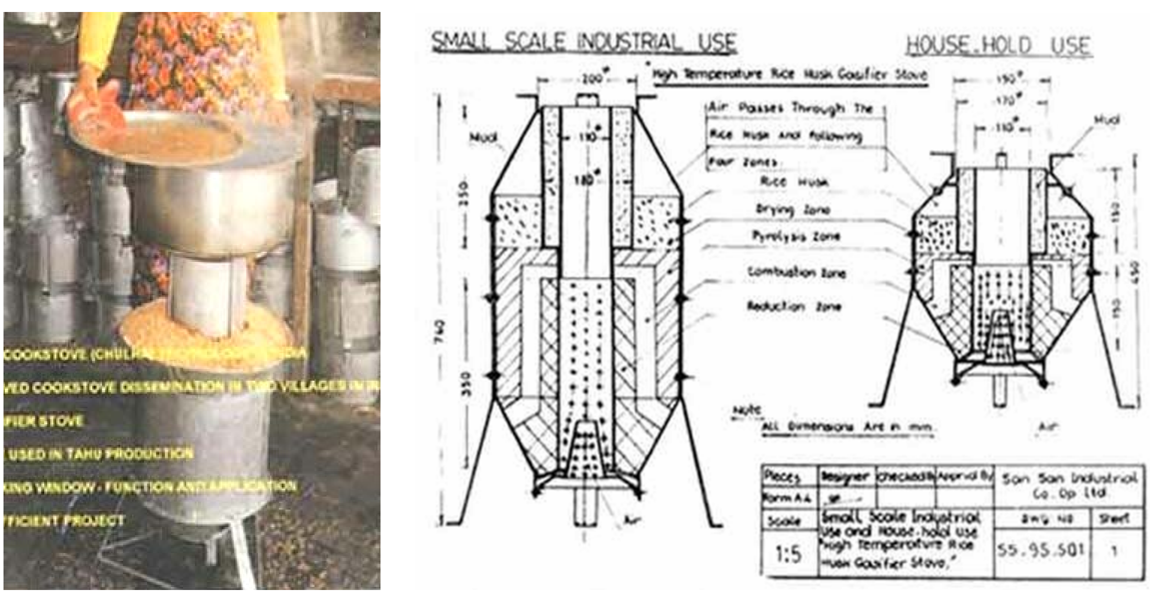



Figure 5. San San rice husk gasifier stove developed in Myanmar

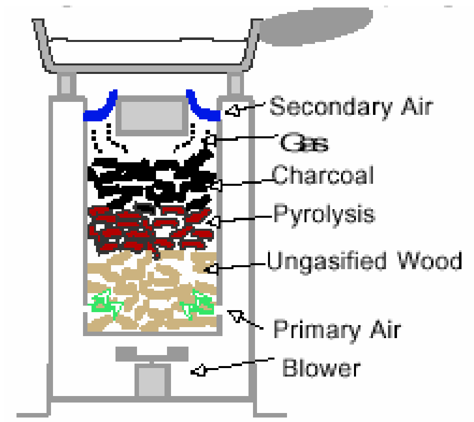
The three models of gasifier stoves developed at AIT (Institutional Gasifier Stove/IGS2, Domestic Gasifier Stove/DGS2 and Commercial Gasifier Stove/CGS3) operate on cross-draft principle, using wood chips, wood twigs, coconut shells and ricehusk/sawdust briquettes as fuel (Figures 6 and 7). Water-boiling efficiency is in the range of 22-31%, depending on the type of stove and fuel used. Combustion is clean and steady, and no tending is generally required during operation [6, 7].

Figure 6: Institutional Gasifier Stove IGS2 developed at AIT
(5.5 kW; 29% efficiency with woodchips)

Figure 7: Commercial Gasifier Stove CGS3 developed at AIT
(11.5 kW; 31% efficiency with woodchips)

Forced draft type gasifier stoves, which use a small battery-operated blower to supply primary and secondary air, are more recent developments. The advantages with this type are that they have higher wattage for the same stove size, easier to start and operate, and flame control is much more effective in comparison with natural-draft stoves. The natural-draft Wood-Gas stove of Reed and Larson described earlier was later modified as a forced-draft stove, to build the ‘Turbo Wood-gas Stove’ [11, 12]. A similar stove has also been developed by the National Engineering Research and Development (NERD) Centre, Sri Lanka [13]. Following the success of the Turbo Wood-gas Stove, the ‘WoodGas Camp Stove’, ‘Juntos Gasifier Stove’ [14] and Sierra stove [15] were introduced later. However, these stoves are mostly aimed at campers in the developed countries, for outdoor cooking applications.

Tata Energy Research Institute (TERI) in India has developed a forced draft gasifier stove for community cooking applications [16]. The gasifier, with about 300 kW thermal output, uses two blowers to supply air for gasifier and burners. It uses a flue gas heat recovery unit, and can realize a 50% saving in fuel consumption compared to conventional stoves [17]. Potential users of TERI’s gasifier include hotels, hostels, hospitals, marriage halls, community halls and religious places like temples and gurudwaras.



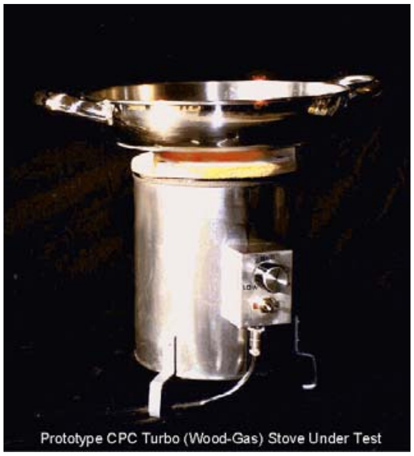




Figure 8. Turbo Wood-gas Stove (**Reed and Walt, 1998**).

Figure 9. Flame inside the burner of the Turbo Wood-gas Stove

Figure 10. Sierra Stove

The concept of large centrally operated gasifiers, supplying cooking gas to a community through gas supply lines has also been tested. Figure 11 illustrates the schematic of such a system, wherein the steps involved in the whole process are presented. Over 400 such systems are in operation China [18].

One such gasifier installed in the Henan Province of China in March 2000 has provided cooking gas for more than 100 homes for more than a year of satisfactory operation [19]. The gasifier, based on fluidized bed technology, has been built by ISU Institute for Physical Research and Technology, and uses peanut shells to generate producer gas (Figure 12). An up-draft gasifier design, also developed in China, uses crop residues as fuel. With a maximum energy output of 1,400 MJ/h, the system can provide 800 $m^3$ of gas fuel to ninety rural families daily by a gas supply net [20].

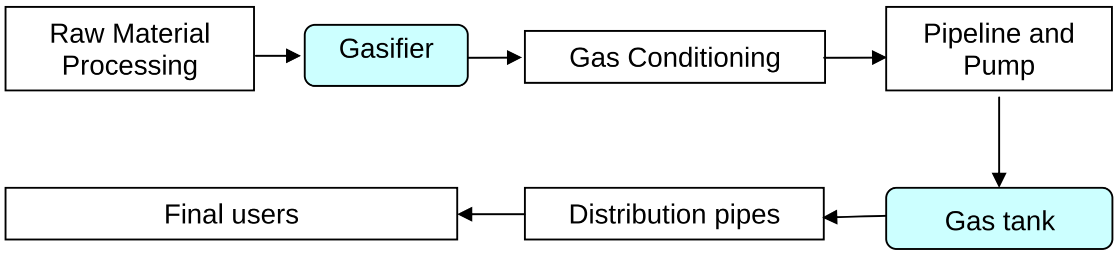



Figure 11: Schematic of a centrally operated gasifier, supplying cooking gas to a community through gas supply lines [18]

Figure 12: The Fludised Bed Gasifier generating producer gas from peanut shells, developed in China

## CONCLUDING REMARKS

Biomass is a major source of energy for cooking applications in Asia. Large quantities of surplus biomass residues are available in the Asian region, but are mostly under-utilized. Recent developments in gasifier technology for cooking applications offer an ideal opportunity by utilizing this surplus biomass cleanly and efficiently. Several biomass gasifier-based cook stoves have been developed since 1995, both for household cooking and community cooking. Centrally installed gasifiers supplying cooking gas for whole villages or communities have also been successfully demonstrated.

For wider adoption, the technology requires further refinement since there are some technical as well as social aspects which are still to be addressed. Cost is another barrier, which can be tackled to some extent by the economy of scale. Standards are needed for acceptance tests, guarantee and certification. Involvement of private entrepreneurs in commercialising gasification based cooking systems would be vital for large-scale promotion of biomass gasificatin-based cooking systems.

It is expected that the convenience, efficiency and safety advantages offered by gasifier stoves over other improved cook stoves will help their rapid adoption in rural households across Asia in the near future.

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