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Research Article

The release of smoke and air pollutants produced domestically when cooking and it solution

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Abstract

In general, biomass energy is characterized by low energy efficiency and emission of air pollutants. Biomass fuels currently used in traditional energy systems could potentially provide a much more extensive energy service than at present if these were used efficiently. For example, new stove designs can improve the efficiency of biomass use for cooking by a factor of 2 to 3. Thus, the energy service provided by biomass in this case could be potentially provided by one third to half of the amount of biomass used currently; the amount of biomass saved through efficiency improvement can be used to provide further energy services. According to a recent study, the total potential of saving biomass used for domestic cooking through substitution of the traditional stoves by improved ones in six Asian countries (China, India, Nepal, Pakistan, Philippines and Sri Lanka) is about 277 million tons/year (Bhattacharya et. al, 1999); the saving amounts to about 36% of the biomass consumption for cooking in these countries. Exposure to smoke from indoor biomass burning is known to cause acute respiratory infection and chronic lung disease. As pointed out by Kammen (1999), some studies have also linked wood-smoke to an increased incidence of eye infections, low birth weight and cancer. Considering the severity of indoor air problem, Reddy et al. (1997) cautions, "because a large portion of the population is exposed, the total indoor air pollution exposure (from domestic biomass combustion) is likely to be greater for most pollutants than from outdoor urban pollution in all the world's cities combined." Gasification of biomass (and use of the product gas) appears to be an interesting option for its clean and efficient use for cooking. Networks of producer gas supply have been reported to exist in Shandong and Hubei provinces of China (Keyun, 1993), for heating and cooking. A gasifier stove is essentially a small gasifier-gas burner system. The main advantage of a gasifier stove is the almost total elimination of smoke is possible with this design. [1] (Biomass-fired Gasifier Stove CGS3: Design, Construction and Operation Manual under Renewable Energy Technologies in Asia: A Regional Research and Dissemination Programme (RETs in Asia) Sponsored by Swedish International Development Cooperation Agency). Examples of the fuel used by the gasifying stove are: Dry firewood, Sawdust, Agricultural waste (e.g. coconut shells, husks, and twigs), Wood shavings, chunks or twigs. The burn time varies with amount and type of fuel used, mainly within the range of 30 minutes to 1 hour. This kind of cooking is less expensive and will go a long way in reducing the rate at which trees are cut down in the rural areas (deforestation) and used for cooking in the three legged mud type of cooker used mainly for cooking in the rural areas. The use of the gasifying stove turns into charcoal which can then be used as a fuel again for cooking.

Keywords

pollutants, biomass energy, efficiency, emission, combustion, Gasification.

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Contents

1. Introduction

Based upon field research in Mexico, Johnston et al. estimate that the carbon abatement cost from improved stove introduction is \$5 – 8 tCO2-1 (60% adoption rate, including community and monitoring & verification costs) - a very competitive abatement cost and similar to the values. The double-dividend of health and climate benefits arising from improved stoves appears viable, holding out the prospects for financial support via credits for carbon dioxide (equivalent) reduction. As Simon et al. put it: "There is indeed tremendous potential for both localized 'intensive' benefits and also global 'extensive' advantages emanating from scaled up carbon-financed ICS (improved cook stove) programs". Johnson et al discuss and review the potential problems with validating ICS for the purposes of carbon markets, such as variability in: fraction of fuel used which is from non-renewable biomass (since CO2 emissions from renewable biomass cannot be included), context of use, and type of application, the baseline emissions and fuel consumption (i.e. of the open-fire stove). Simon et al. additionally discuss other potential problems including: whether to include non-CO2 gases or not, leakage (i.e. impacts of change in resource use upon resource extraction by others or elsewhere), and longevity of carbon finance and climate policy. They also note that mutual 'support' between health and climate benefits could become an impediment: e.g. the "distribution economies of scale and technology standardization may be ill equipped to satisfy diverse household requirements, leading to the allocation of inappropriate stoves and to continued levels of indoor air pollution" . Distribution of stoves which are not suitable for household practices could result in their abandonment or decreased used, hence reducing net greenhouse gas abatement. On balance, however, Simon et al.'s review appears to be cautiously optimistic that the mutual support will be beneficial and that financing through the carbon markets is credible. [2]Biochar Stoves: an innovation studies perspective by Sarah Carter Dr Simon Shackley 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 characterized 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. estimated that the biomass saving potential in seven Asian countries (China, India, Pakistan, Nepal, Philippines, Sri Lanka and Vietnam) as 152 million tons of fuel wood 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. [3] PROSPECTS FOR BIOMASS GASIFIERS FOR COOKING APPLICATIONS IN ASIA S. C. by Bhattacharya and M. Augustus Leon.

2. Literature Review

Most of the Asian developing countries depend heavily on biomass to meet their household cooking energy requirements. Fuel wood often accounts for a major fraction of the total biomass use. Fuel wood 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 rice husk, 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 fuel wood 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 underutilization and neglect of biomass residues as a potential energy source in this sector. 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 cook stoves 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.

3. Materials

- Outer chamber - galvanized iron sheet gauge 28. Aisheet of average weight 8 kg can produce lining for 3 stoves.

- Inner chamber - galvanized iron sheet gauge 26. A sheet of average weight 8 kg can produce lining for 5istoves.

- Stand (legs) and pot holder - scrap metal. 2kg of scrap metal would make 'legs' and 'pot holders' for 3 stoves.

- Air flow to combustion chamber - larger amount of iairflow leads to faster rate of cooking.

- Diameter of fuel canister - larger diameter leads to ifaster rate of cooking.

- Air flow to gasification chamber - must be neither too large nor small for effective gasification to occur.

- Volume of fuel canister – a larger volume will lead to a longer cooking period.

- Overall height of stove – the taller the stove, the more effective is its natural draft, and also ensures that the stove burns clean.

4. Results

Simple manual draft gasifier stoves are within reach of technicians in the informal fabrication (Jua Kali) sector. They require only basic raw materials such as sheet metal, tin cans, screws and pop rivets, and can be made with simple hand-tools such as tin snips, pliers, hammers and screwdrivers. The biomass-fired gasifier stove (Figure 1) consists of four main parts i.e. fuel chamber, reaction chamber, primary air inlet and combustion chamber. Different parts of the stove could be attached together by bolts and nuts. CGS3 works as a cross-flow gasifier stove. Primary air enters into the reaction chamber at one side, flows across the fuel bed and out in to the gas burner. Producer gas is generated while the primary air passes through the hot fuel bed, and the gas leaves the reaction chamber at the other side.

(i) Reaction chamber: The reactor is the heart of the stove where producer gas is produced. The outside wall of the reactor is made of 2mm thick mild steel sheet. Outside dimension of the reactor frame is 56 x 56 x 56 cm. The inside wall is made of a layer of bricks, cemented together by Castable-13 refractory cement with a open top and a grate welded to its base, is fixed inside the reaction chamber. The cylinder has perforations, through which primary air enters into the reaction chamber at one end, and the producer gas exits the reaction chamber at the other end.

(ii) Pot support: it is designed to hold three pots of 47cm diameter each, with a depth of about 27cm. hot flue gases from the burner enters the first pot at the bottom of the pot support. The exhaust from the first pot support enters the second pot support at one side and enters the third pot support and exits through a chimney at the other side. The pot support is made of 2mm thick mild steel sheet and insulated with a 2cm layer of Cartable 13 refractory cement. A 110 cm high mild steel chimney is attached at the flue gas exit of the third pot support. To reduce heat losses from the chimney, its outer surface is insulated with a 2.5cm thick slab of fiberglass wool and clad with aluminium sheet. A GI pipe or mild steel ‘L’ angle leg is attached at the bottom of the second pot support for better stability.

(iii) Air flow combustion chamber: A mild steel grate is welded to the base of the perforated cylinder. The grate (Figure 8) is made of mild steel round rod of 40 mm diameter, and ash falls through the grate into the ash pit. An ash scraper (Figure 9) is fixed below the grate, to break the lumps of ash accumulated inside the reaction chamber. Ash scraper is especially useful while using fuels of high ash content, such as rice husk briquettes. Ash could otherwise block the flow of fresh fuel from the fuel chamber into the reaction chamber. The ash scraper slides through a cylindrical guide bush, which is welded to the body of the reaction chamber. For easy assembling, the slider rod is connected to the ‘fingers’ by a threaded joint. The ash scraper is operated by sliding it in and out horizontally. Its frequency of operation is generally once in 10-20 minutes, depending on the ash content in the fuel. [4] (Biomass-fired Gasifier Stove CGS3: Design, Construction and Operation Manual under Renewable Energy Technologies in Asia: A Regional Research and Dissemination Programme (RETs in Asia) Sponsored by Swedish International Development Cooperation Agency).

5. Discussion

A key starting point for the study arises from innovation studies which, over the past several decades, has highlighted that innovation is a distributed process involving inventors, innovators, users and [distributors; and that, consequently, tradition, perception, inertia, practice, routine and behaviour all play key roles in understanding the response to, uptake of and popularity of new technologies. This led to the view that the uses’ perception of stoves would depend not only upon objective measures of mitigation of indoor air pollution (IAP) or resource use efficiency, but also upon their perception of new designs, the fit with existing cooking practice, preference and habits and with other cultural factors. Furthermore, in offering-up a ‘solution’, a community has to agree with the identification and definition of a corresponding ‘problem’ to which the proposed innovation is an answer. Garrett et al highlight that no ‘one stove size fits all’ and promote the concept of a ‘cook stove user space. They advise that more understanding of different user communities is necessary and that stove design needs to respond to the cooking requirements of each of these user communities. This work attempts to contribute to such an effort. The motivations for innovation are many but can include the attempt to address a perceived ‘social problem’. In such cases, there is often a deliberate effort to engage the potential users of the technology or new design using one of the repertoire of methods which have been tested by firms and social scientists.

In other cases, mediators between inventors and users, such as finance houses, NGOs, government agencies, and companies with a dominant market position, play the critical role in shaping innovation. In order to improve stove design, the needs of the user have to be assessed. Women are likely to be the main users of stoves, and can be consulted regarding design innovation by accessing women’s groups and by user testing in households. Where questions specific to women are being discussed, it is beneficial if the enumerators are women to encourage discussion and to allow opinions to be voiced freely. A new technology is more likely to empower women where women are given some control in the development of the technologies and are involved at all stages of the process.

Since cooking is an activity that is closely-related to cultural practice and tradition, women should be directly involved in developing solutions which suit their preferences and circumstances. [5] (Sarah Carter, Dr Simon Shackley UK Biochar Research Centre (UKBRC), School of Geosciences, University of Edinburgh.

6. Analysis

Within the discipline of 'innovation studies' an important distinction is made between the 'inventor' and the 'innovator'. The inventor comes up with the novel design, technology or idea; the innovator is the one who makes that invention commercially viable (or successfully promotes the technology such that it is widely adopted). An invention can be made by a single individual, whereas innovation involves a number of individuals and usually organizations.

Innovation is rarely a linear process in which a technology is developed and launched on to an unsuspecting public (the 'supply-push' model). On the other hand, innovation tends not to be the direct result of the public (or sub-set of) demanding a specific technology (the 'demand-pull' model). A more realistic depiction is that innovation is the co-product of supply-push and demand-pull. In this version, some users get involved in quite detailed ways in the innovation process, as do distributors, sellers, marketers, consultants, advisors, enthusiasts and so on. For this reason, and because innovation rarely has a discrete endpoint, the co-production model has also been described as 'distributed innovation processes'. Another framework of use here is the concept of 'instituted economic processes' and 'embeddeness', whereby innovation is a process which takes place within a social context and in relation to institutions and social practices, a perspective often associated with Karl Polanyi. In practice, innovation has often failed to reflect and balance the needs of suppliers and uses. In some cases, technologists and designers have been guilty of pushing their ideas too hard and capturing the attention of potential funders and marketers, resulting in products and services which do not sufficiently reflect user needs. [6] (Sarah Carter, Dr Simon Shackley UK Biochar Research Centre (UKBRC), School of Geosciences, University of Edinburgh).

7. Findings

Cooking efficiency of the stove is defined as the ratio of the energy utilized in the cooking process to the energy content in the fuel consumed. The energy used in the cooking process or the energy entering the pot produces two measurable effects: raising the temperature of the water to its boiling point, and evaporating the water. By estimating the total energy used in raising the water temperature from ambient temperature to boiling point, and in evaporating a known quantity of water, the cooking efficiency could be determined. The lower calorific value of the fuel is used in the efficiency calculation. By measuring the total quantity of fuel used during the test duration, and using the calorific value, the total energy supplied can be estimated.

Wood and rice husk briquettes were used as fuels in this study. Wood cut from eucalyptus logs and sun-dried for days with sizes ranging from 25 to 50 mm, and rice-husk briquettes produced by a heated-die screw-press machine were used as fuel after splitting into small pieces. About five minutes later, the torch is removed and the ash pit door is closed. The ignition builds up slowly, and it takes about 20 minutes for the combustible gases (producer gas) to generate at the gas burner side. The gases are then ignited in the gas burner by showing a flame through the secondary air holes in the burner. Once the gas gets ignited, the flow of gas is continuous and smooth. The stove can operate continuously for several hours, until the fuel in the fuel chamber is used up. Additional fuel can be loaded through the top of the fuel chamber to further extend its operation. The ash scraper should be operated occasionally, to break up the ash accumulated inside the reaction chamber. This will facilitate easy flow of fresh fuel from the fuel chamber into the combustion chamber.

8. Results

A number of experiments were done to investigate the effects of different parameters on the performance of the gasifier stove. Different combinations of fuel, pot size, number of pots and gas burner height were tested.

Effect of pot size: The results showed that gasifier stove efficiencies were higher for bigger pot size; this seems attributed by the bigger surface area of contact of the bigger pot than that of the smaller pot.

Effect of type of fuel: It is found that the efficiency of the stove using wood as fuel was higher as compared with using rice husk. As was found out during the experiment, accumulated ash at the reaction chamber was significantly higher in rice husk briquette burning than with wood; this was due to the fact that rice husk briquette fuel has a higher ash content as compared to wood. Another factor that reduces the efficiency of rice husk briquette compared to wood was with the falling ash, some small burning char particle was also with the rice husk ash resulting into higher combustible loss. [7] (Biomass-fired Gasifier Stove CGS3: Design, Construction and Operation Manual under Renewable Energy Technologies in Asia: A Regional Research and Dissemination Programme (RETs in Asia) Sponsored by Swedish International Development Cooperation Agency).

9. Recommendation

Table 1. Average properties of wood chips and rice husk briquettes Wood

Table 1. Average properties of wood chips and rice husk briquettes Wood		Rice husk
Apparent density, (kg/m³)	784	1006
Bulk density, (kg/m³)	350	620
Ultimate Analysis (dry basis)		
Carbon	51.85	41.44
Hydrogen	5.4	4.94
Oxygen	34.64	37.32
Proximate analysis (wet basis)	7.31	5.93
Moisture content, (%)	75.07	61.02
Volatile matter, (%)	17.09	16.59
Fixed carbon, (%)	0.53	16.46
Ash, (%)		

CGS3 is reasonably versatile in the types of fuels it can handle. These include rice husk and saw dust briquettes, wood chips, wood twigs and coconut shells. The fuel should be sized before loading into the fuel chamber. An average size of 25-50mm is acceptable size for the fuel pieces. The types of fuels and average size of fuel pieces that can be used in the stove. Average properties of wood chips and rice husk briquettes are presented dry.

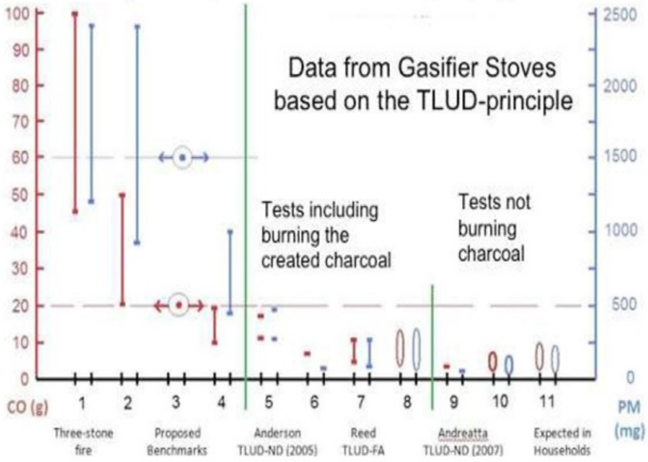

Figure 1. Emmissions of Carbon Monoxide (CO) & Particulate Matter (PM) from TLUD (Top-Lit UpDraft) Gasifiers and Other Cookstoves. (Measured by the Standard 5-Litre Water Boiling Test (WBT))

Figure 2. Fully assembled Gasifier Stove CGS3 with pot support

10. Conclusion

The improved gasifier stove CGS3 developed at AIT can be operated continuously with the highest efficiency reported at 31.8% with the three-pot support configuration using wood as fuel. The results indicate that gasifier stove efficiencies were higher for bigger pot size; this seems attributed by the bigger surface area of contact of the bigger pot compared to that of the smaller pot. The height of the gas burner has effects on the efficiency of the gasifier stove; it was observed that shorter gas burner resulted in the flue gas from the reactor not efficiently burned as some smoke emerged from the gas burner. Too high gas burner provides a cleaner combustion but lowered the efficiency of the stove, likely due to increased distance of the pot bottom from the flame. 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 gasifierbased cook stoves have been developed since 1995, both for household cooking and community cooking. Centrally installed gasifier 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 commercializing gasification based cooking systems would be vital for large-scale promotion of biomass gasification-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 Ghana in the near future.[8] (DEEP-EA Technical Factsheet – Gasifier Stoves: GVEP International – East Africa Regional office: Kijango House, Rose Avenue/Lenana Road Killimani, P. O .Box 76580-00508, Nairobi, Kenya).

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[2] DEEP-EA Technical Factsheet – Gasifier Stoves: GVEP International – East Africa Regional office: Kijango House, Rose Avenue/Lenana Road Killimani, P. O .Box 76580-00508, Nairobi, Kenya.

[3] Sarah Carter, Dr Simon Shackley: Biochar Stoves: An innovation studies perspective: UK Biochar Research Centre (UKBRC) School of Geosciences, University of Edinburgh.

[4] Swedish International Development Cooperation Agency: Biomass-fired Gasifier Stove CGS3: Design, Construction and Operation Manual: Renewable Energy Technologies in Asia: A Regional Research and Dissemination Programme (RETs in Asia).