Renewable and Sustainable Energy Reviews 26 (2013) 265–285

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Design, development and technological advancement in the biomass cookstoves: A review

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ARTICLE INFO

Article history:
Received 6 September 2012
Received in revised form
1 May 2013
Accepted 7 May 2013
Available online 20 June 2013

Keywords:
Biomass cookstove
Sustainable development
Environmental impact
Health hazards

ABSTRACT

The use of biomass resources for cooking and heating is as old as the origin of human civilization due to the fact that biomass is available almost everywhere and can be burnt directly. Biomass accounts for a large fraction of the domestic energy needs in the developing countries. However, very often biomass is burnt inefficiently in open three-stone fire and traditional cookstoves for cooking and heating applications which causes severe health problems in women and children and also affects the environment. Many efforts have been made worldwide to increase the dissemination of improved cookstove but have not succeeded in their targets. The new cookstove dissemination programs can be funded through carbon revenue and other funding organizations; further these funds can be utilized for further R&D and cookstove market. The successful cookstove dissemination programs can lead to the sustainable development of the rural areas besides helping in the commercialization of cookstove. Therefore, this article presents the review on the design, development, and technological advancement of biomass cookstoves and the effects of traditional biomass burning devices on the emission, health hazard, and environmental pollution.

Contents

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http://dx.doi.org/10.1016/j.rser.2013.05.010

1. Introduction

It is estimated from the historical evidences that fire has been used for cooking of meals for about 100,000 years [1]. However, during the earlier ages, the cooking was done over an open-fire for roasting of meat and to protect from the wild animals. The modification in the pots of various shapes and sizes led down in the development of the open-fire to shielded-fires. The simplest and most common form of the shielded-fire was the three-stone fire arrangement and later on with the developments, it had changed to a U-shape mud cookstove called traditional cookstove [2]. Early development of biomass based cookstoves started in India during the 1940s [3]. More extensive research and development activities on the improved cookstoves took place all over the world after the 1970s oil crisis due to which many improved cookstove programs (ICPs) were initiated in a number of developing countries including India to tackle the energy crisis, deforestation, smoke reduction in the kitchen and so on. Although these programs started in different countries implemented by various different government agencies, NGOs, donor organizations etc., they could not achieve the required objectives due to various reasons and constraints [4]. During the 1980s and 1990s, the research work mainly was devoted to household energy issues in the developing countries because at that time, the problem was viewed mainly as an inter-fuel substitution or biomass energy-efficiency issue, which was about fuel scarcity and deforestation [5].

In the beginning of the 1990s, more focus was shifted toward the research on issues involving the indoor air pollution (IAP) and its effects on health [6]. As stated by Smith et al. [7], the burning of biomass fuels emits very high levels of smoke containing hazardous pollutants that include respirable particulate matters (SPM), carbon monoxide (CO), nitrogen oxides (No_x), sulfur oxides (SO_x), and a host of organic compounds, some of which (e.g. benzo(a) pyrene, benzene and 1,3-butadine) are commonly known as human carcinogens. Fullerton et al. [8] presented the health impacts and associated risks of the indoor air pollution due to biomass fuel use. They stated that different types of health risks were associated with the indoor air pollution, such as respiratory infections including pneumonia, tuberculosis, and chronic obstructive pulmonary disease, low birth weight, cataracts, cardiovascular events and all-cause mortality in household members. Kleeman et al. [9] studied the adverse health impacts of the particle size distribution and result of deposition of that pollution in different areas of lungs. Venkataraman et al. [10] stated that the biomass fuels had a heavy burden of time and money on the world's poorest groups. The world health organization (WHO) has estimated that every year around 1.5 million people died and many others became victims of different diseases due to smoke from open fires and traditional cookstoves [11]. Ramanathan and Carmichael [12] recently studied that the black carbon is playing a major role in the global warming.

To curb all these effects mentioned above, numbers of efforts have been made worldwide. Zhang et al., [13–15] reported a comprehensive database for CO emission ratios and CO emission factors for both per-fuel mass basis and per-cooking-task basis, respectively. Further, the estimation of CO concentrations and exposures were also presented a hypothetical village kitchen resulting by using a range of fuels with different cookstoves, commonly used in the developing countries. The emission factors for different combinations of fuels and stoves were tested in China for direct and indirect green house gases (GHGs) as well as other airborne pollutants, such as, carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), total non-methane hydrocarbons (TNMHC), nitrous oxide (N_2O), sulfur dioxide (SO_2), nitrogen oxides (NO_x), total suspended particle (TSP) etc. for a typical set of operating parameters [15]. The Global Alliance for Clean Cookstoves (GACC), a new public–private partnership led by the UN Foundation, took initiatives to create a thriving global market for clean and efficient household cooking solutions [16]. The newly designed cookstoves which are known as advanced biomass cookstoves are based on better design principles, as they have the better combustion efficiency and thus, reduce the fuel consumption to a greater extent. These cookstoves can then deal with both the emissions and health issues, resulting from cooking with open fires or traditional biomass cookstoves. These cookstoves have the ability to get carbon credits [17] not only because of their contribution to climate-change mitigation but also they can yield major co-benefits in terms of energy access for the poor people, besides they may result in improved rural health, environmental, agricultural and economic benefits [6].

2. History of cookstove

The history of cookstove had started with the invention of fire and from archeological excavations at Chou Kutien in China. It had been shown that the Homo erectus pekingnensis used the fire for heating during the first ice age of about 400,000 years ago [18]. However, the human civilization had started by making the use of refined stones, the mastery of fire, and the domestication of several animals and cultivation of plants [1]. During the earlier age cooking especially, the roasting of meat was done mostly over an open-fire and the fuel used to be arranged in a pyramid configuration for cooking. The development of open fire to improved cookstove took place with time as the human civilization progressed and some of the facts are given as below:

2.1. Open fire to traditional cookstoves

Initially, the development of pots was a major step toward the development of other types of cookstoves. Later on, the open-fire transformed into shielded-fires to balance the pot over the fire. The initial and simplest form of the shielded-fire was a three-stone arrangement. In this arrangement, the stones were arranged at suitable angles on the plain ground to support the pots of various sizes, which improved the cooking efficiency and reduced the scattering of fire from windy conditions. With the developments of the shielded-fire, the three-stone fire gradually changed into a U-shaped mud enclosure. Also, for induction of secondary air required for better combustion of volatile matter and for the exit