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A review on methods of flue gas cleaning from combustion of biomass

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ABSTRACT

Application of renewable energy technology is essential for achieving zero carbon buildings within the timescale envisaged by the UK government and the EU because the carbon intensity of the grid will still be high (well above 70% of current level) by 2016 and 2019. The biomass is a key renewable energy source, but its use in buildings is often affected by the emission of particulates and other pollutants in the waste gas, resulting in significant resistant to the technology by building users. The proposed research investigated various ways of removing pollutants, from the exhaust gas of biomass boilers. The review of literature shows that low cost and low maintenance technologies e.g. cyclones are preferred choices however they come with some limitation in removal of particulates. Recent advances in flue gas cleaning came with novel hybrid solutions to overcome traditionally used technologies for flue gas cleaning. Use of electrostatic preceptors with combination of other technologies is one example. The study found that it is difficult to obtain high removal efficiency for smaller particle range and require combination of technologies and improved hybrid solutions.

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1. Introduction

Over 80% of fuel delivered to public buildings is used for heating [1]. Most of it comes from non-renewable energy source. The building sector accounts for nearly half of the total energy consumption in UK and so for CO_2 emissions as well [2]. There are various means to reduce the emissions and use of biomass is one of them. Biomass is renewable source of energy and produce little net CO_2 emissions to the atmosphere.

The biomass boiler is a key renewable energy system for integration with buildings, but its use in buildings is often affected by the emission of particulates and other pollutants in the waste gas, resulting in significant resistant to the technology by building users and owners [3,4]. The relation between rate of death and level of PM10 concentration in the air is being established [4,5]. It is being claimed that long term exposure to PM2.5 may increase 6–8% risk of cardiopulmonary and lung cancer mortality [5]. A certain amount of particulates produced by combustion is released to the atmosphere. Improved techniques to reduce particulate emission are essential for the wider application of biomass boilers, especially as tighter legislation to reduce particulate emission is already proposed for certain areas of England and Scotland. There is a various range of emission sources that contribute to PM10 concentrations in the UK [6]. These sources can be categories as,

- Primary particle emissions which are derived directly from combustion sources, including road traffic, power generation, industrial processes etc.
- Secondary particles which are formed by chemical reactions in the atmosphere, and comprise principally of sulphates and nitrates.

In recent years many advanced flue gas technologies being reported in the literature [7–11] however extensive research work is also being reported in previous decades [12]. The pollutants in the flue gas stream are mainly in two forms gas and particulates [12]. In order to remove toxic gases different types of solvents are used ranging from widely available water to carbon sorbents. However removal of particulates from flue gas stream requires either their deposition or attachment to a surface. These surfaces [12] may be continuous e.g. cone of a cyclone, collection of plates in electrostatic precipitator, or the surface can be discontinuous spray water droplets used in wet scrubber. Removal of particulates generally falls into five main categories; gravity, centrifugal, electrostatic precipitator, fabric, and wet scrubbers. Many advanced level studies on covering different topics of flue gas cleaning methods have been reported in the literature. However, thorough review on flue gas cleaning from the combustion of biomass is lacking in the present literature.

The primary aim of the present research is to thoroughly envisage the existing technologies used in flue gas cleaning from combustion of biomass. Also the comparative performance study in terms of suitability of the technologies for residential building sector will be another highlight. The review paper also provided comprehensive analysis of suitability of different flue gas cleaning options.

2. Biomass: a renewable energy source

The capture of solar energy as fixed carbon via photosynthesis is the key initial step in utilising biomass:

$$CO_2 + H_2O + \text{light} + \text{chlorophyll} => CH_2O + O_2 \quad (1)$$

The very important photochemical process as the plants can actually capture and store solar energy. This stored energy can be used as a fuel source. In order to get energy back from the plants; various methods being adopted are combustion [13–15], controlled and un-controlled burning [16–18], digestion [19–22] and many others. In these processes biomass returns the CO_2 that was absorbed by the plant in the process of photosynthesis. It is commonly stated that biomass have no net release of CO_2 if the cycle of growth and harvest is sustainable. Recent experimental study on sustainable production [23] of switchgrass for bioenergy and feedstock production claimed that early spring harvest may be the best option if the thermochemical processing is the goal. However choice may change if moisture and transportation are other big issues. Sustainable growth and harvest of biomass have many indicators [24] e.g. biodiversity, carbon life cycle, hydrology, soil productivity, etc. and may differ for different types of biomass crops. It is being reported that [25] major barrier for sustainable biomass production for energy in china included technical, financial, policy and institutional.

Biomass is a collective term for all plant and animal material [26]. A number of different forms of biomass can be burned or digested to produce energy. Examples include wood, straw, poultry litter and energy crops such as willow and poplar grown on short rotation coppice and miscanthus. Biomass is a very versatile material and can be used to produce heat (for space and water heating), electricity and a combination of heat and power (electricity). The UK has some of the largest examples of the use of Biomass to generate electricity in Europe [1].

Various sources of biomass are shown in Fig. 1 and also a flow chart (Fig. 2) is given to show the classification of major sources of

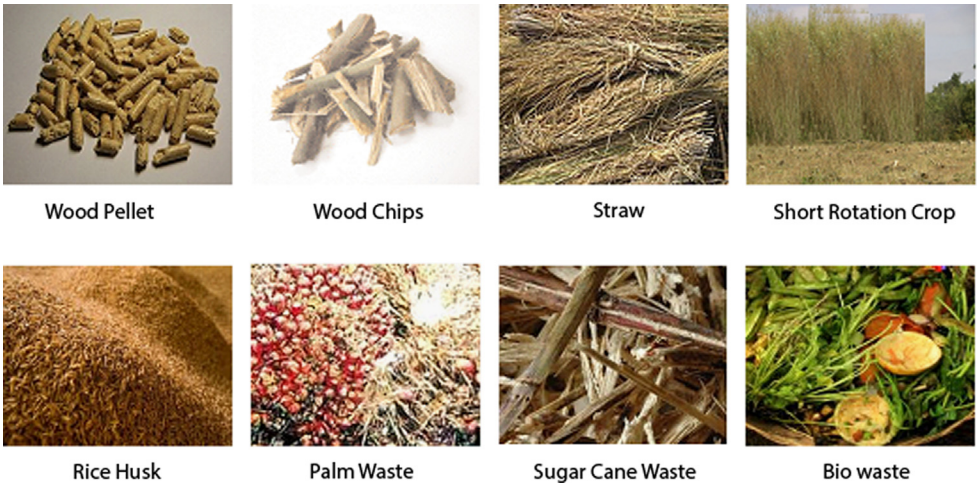

Fig. 1. Various sources of biomass [modified 26].