Renewable and Sustainable Energy Reviews 39 (2014) 575–586

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Coal–biomass co-combustion: An overview

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ARTICLE INFO

Article history:
Received 1 July 2013
Received in revised form
4 June 2014
Accepted 10 July 2014
Available online 3 August 2014

Keywords:
Co-combustion
Coal
Biomass
Co-fuel

ABSTRACT

The energy sector in the global scenario faces a major challenge of providing energy at an affordable cost and simultaneously protecting the environment. The energy mix globally is primarily dominated by fossil fuels, coal being the major contributor. Increasing concerns on the adverse effect of the emissions arising from coal conversion technologies on the environment and the gradual depletion of the fossil fuel reserves had led to global initiatives on using renewables and other opportunity resources to meet the future energy demands in a sustainable manner. Use of coal with biomass as a supplementary fuel in the combustion or gasification based processes is a viable technological option for reducing the harmful emissions. Co-combustion of coal with biomass for electricity generation is gradually gaining ground in spite of the fact that their combustion behavior differ widely due to wide variations in their physical and chemical properties. This article deals with the technical aspects of co-combustion with emphasis on the fundamentals of devolatilization, ignition, burnout and ash deposition behavior along with the constraints and uncertainties associated with the use of different types of biomass of diverse characteristics and the likely impact of partial replacement of coal by biomass on the emission of CO_2, SO_x, NO_x. Other issues of no less importance like sustained availability of biomass, transportation and storage, effect on biodiversity, etc., are left out in the study. The investigations reported in the study reflect the potential of biomass as co-fuel, and the scope of maximizing its proportion in the blend in the coal based power plants and the derived benefits.

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1. Introduction

Co-combustion is one of the most advantageous ways of utilizing biomass and waste for replacement of fossil fuels for

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http://dx.doi.org/10.1016/j.rser.2014.07.106
1364-0321/

stationary energy conversion. Much difficulties are being faced for retrofitting coal-fired boilers designed for pulverized coal combustion to operate in co-combustion mode. In Indian context the nature and gravity of such challenges are under explored. In India varieties of biomass products are available which do have tremendous potentiality for co-combustion with pulverized coal. Based on the emerging need, detailed investigations are felt necessary to examine the compatibility of different kinds of biomass with coal and to select suitable blend composition(s) before utilizing those biomass products in utility operation as co-fuels [1–4].

Power generations from coal/biomass blends are increasingly gaining importance as the biomass is a renewable energy source and is considered to be carbon neutral. Co-firing and co-gasification of fossil fuels and biomass (sawdust, rice husk, coconut coir, straw, corn cob, bagasse etc.) are presently being considered to have enhanced importance because partial replacement of precious fossil fuel is possible in such cases, which give extensive support to the growth of power sector in developing countries like India. Biomass co-combustion also represents a low cost, sustainable, and renewable energy option that ensures reduction in net CO_2, SO_x and often NO_x emissions and also in the anaerobic release of CH_4, NH_3, H_2S, amides, volatile organic acids, mercaptants, esters, and other chemicals [1–7] resulting in several benefits. The advantages of this technique as described above have been highlighted by several researchers [8–15].

Compared to dedicated biomass or waste fired plants, the addition of biomass or waste to high efficiency coal-fired power plants can greatly increase the efficiency of utilizing these fuels [11]. Besides, the cost of retrofitting an existing coal-fired power plant to a co-combustion plant can be considerably lower than building a new dedicated biomass or waste-fired plant [16]. Furthermore, to minimize the fluctuating supply of some secondary fuels (such as straw) and to secure the power generation, co-combustion can be operated in a flexible mode (i.e. with different shares of secondary fuels) [12].

Actually strictures in respect of GHG emission and scenario of fossil fuel depletion strengthened the foundation of the rationality for co-combustion. Biomass fuels have sometimes been reported to have peculiar combustion features particularly when they are subjected to thermal shock [17]. Biomass fuels having much volatile matter content, may find their possible utilization in co-firing with low volatile coals. Biomass fuels contain higher volatile matter with higher oxygen content and as such possibility of easy release of volatile matter in a combustor is more as compared to coal. All these characteristics of biomass have been found to have large influence on the burnout time of blends of coal and biomass [3,17–19].

1.1. Background

Increasing concerns about the environmental impacts of power generation from precious fossil fuels have promoted the development of more sustainable means of generating power. These have included increasing the fraction of renewable and sustainable energy in the national energy supply.

The co-firing of biomass with coal in conventional coal-fired boilers can provide a reasonability attractive option for utilization of biomass for power generation. Co-firing can use the infrastructure which is associated with the existing fossil fuel based power systems and requires some capital investment. In most of the countries co-firing is one of the most economic technologies available for providing significant reduction of CO_2.

1.2. Comparison of cost and emission

The net electrical efficiency of a co-fired coal/biomass power plant ranges from 36% to 44%, depending on plant technology, size, quality and share of biomass. While a 20% co-firing (as energy basis) is currently feasible and more than 50% is technically achievable, the usual biomass share today is below 5% and rarely exceeds 10% on a continuous basis. A high biomass share implies lower GHG emissions. It is estimated that 10% biomass co-firing in coal power plants could reduce CO_2 emissions from 45 million to 450 million ton/year by 2035, if no biomass upstream emissions are included. However, high biomass shares involve several technical issues including sustained availability of biomass and likely slagging, fouling and corrosion problems. The overall cost of co-firing is sensitive to the plant location and the key cost element is the biomass feedstock. The investment cost for retrofitting a coal-fired power plant for co-firing is in the range of USD 430–500/kW for

Table 1
Primary energy consumption by energy sources and region in 2006, PJ/year [22].

	Modern biomass	Traditional biomass	Other renewables	Conventional energy	Total primary energy	Modern biomass as % of primary energy
World	16,611	33,432	13,776	409,479	473,319	3.5
OECD	8442	42	6783	222,369	237,636	3.6
OECD North America	4158	–	3276	112,959	120,393	3.5
US and Canada	3801	–	2898	106,281	112,980	3.4
Mexico	357	–	399	6678	7392	4.8
OECD Pacific	882	42	798	36,561	38,283	2.4
OECD Asia	504	42	525	31,374	32,445	1.6
OECD Oceania	378	–	252	5208	5838	6.5
OECD Europe	3402	–	2688	72,828	78,939	4.3
OECD Europe–EU	3129	–	1785	69,384	74,298	4.2
Transition economics	693	–	1176	44,688	46,536	1.5
Russia	273	–	672	26,901	27,867	1.0
Developing countries	7434	33,432	5817	1362,69	182,994	4.1
China	315	8988	1323	49,602	60,144	0.5
East Asia	1092	3633	1197	20,202	26,145	4.2
Indonesia	126	1680	357	5418	7560	1.7
South Asia	1302	9828	504	18,627	30,261	4.3
India	1092	8043	357	15,582	25,074	4.4
Latin America	2394	1239	2373	15,834	21,840	11.0
Brazil	1680	357	1176	5502	8736	19.2
Middle East	21	63	105	19,341	19,551	0.1
Africa	2310	9702	315	12,726	25,074	9.2