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Bioenergy technologies for carbon abatement

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Abstract

In this paper, bioenergy technologies (BETs) are presented as potential carbon abatement opportunities substituting fossil fuel or traditional (less efficient) biomass energy systems. Cost of energy (produced or saved) of BETs is compared with fossil fuel and traditional biomass energy systems to estimate the incremental cost (IC). The IC of carbon abatement for each of the selected BETs (in $\$\,kWh^{-1}$ or $\$\,GJ^{-1}$) is estimated using the carbon emission ($tC\,kWh^{-1}$ or $tC\,GJ^{-1}$) reduction obtained by substituting fossil fuel and traditional biomass alternatives. The abatement costs are estimated and compared for ten combinations of BETs (with seven technology alternatives) substituting conventional technologies. The analysis indicates that out of the ten project cases six have negative ICs in the range of -37 to -688 $\$\,tC^{-1}$ and four have positive ICs in the range of 52–162 $\$\,tC^{-1}$ mitigation. The negative ICs indicate that the suggested alternatives are cheaper than the original technologies. Thus, results indicate that the chosen BETs are cost-effective mitigation opportunities and are currently aggressive candidates under Clean Development Mechanism.
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Keywords: Bioenergy technologies; Incremental cost; Carbon abatement; CDM

1. Introduction

With the ratification of Kyoto Protocol, Clean Development Mechanism (CDM) has become a reality. The CDM Executive Board is already in place and the guidelines and methodologies are also available to operationalize CDM. In this context identification of appropriate carbon abatement technologies and analysis of their cost effectiveness becomes critical to promote them as CDM projects. There is a need to analyze the potential and costs of modern bioenergy technologies (BETs) to substitute greenhouse gas (GHG) or carbon-emitting fossil fuel (FF) and even the less efficient traditional biomass energy systems (TBES) (significant share of firewood used for cooking is procured through unsustainable means) for reducing GHG emissions [1].

In India, biomass accounts for about a-third of primary energy supply and is projected to account for a significant component even in the future [1]. Traditionally, biomass energy is used in cookstoves with an efficiency level ranging between 10% and 15%, thus providing opportunity to increase efficiency levels to the extent of 30–35% with the adoption of improved cookstoves and conserve biomass and thereby reduce the adverse impacts on the environment. However, the versatility of biomass resource is not just limited to meeting cooking energy needs; there are technological opportunities to transform this resource into modern energy carriers (e.g., electricity, gas) for other energy end-uses. Vast degraded lands in India also provide excellent opportunity to produce biomass sustainably for modern BETs, particularly, for power generation [2].

In this paper, an attempt is made: (i) to consider various modern BET options available for substituting FF and low-efficiency TBES; (ii) to compare the cost of energy service among the FFs (and less efficient biomass energy) and modern bioenergy system; (iii) to compare the carbon abatement potential of bioenergy systems on the basis of per unit of energy; and (iv) to estimate the incremental costs (ICs) of per tonne of carbon abatement. The databases for comparison of FF, TBES and modern BETs are from the reports of a research project carried out by the

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authors [3,4] and the summarized input data are presented in the paper as tables (discussed later in the paper).

2. Primary energy use and GHG emissions in India

2.1. Primary energy use in India

The total primary energy [5,6] use in India is dominated by coal accounting for about 36% of the total, followed by oil for about 24% and fuelwood accounting for 20% (Table 1). Fossil fuels, including coal and oil, account for nearly 67% of total primary energy use and biomass accounts for 31%. Projections for future show that consumption of all energy sources will increase and FFs will continue to dominate by accounting for approximately 77% by 2010, and the share of petroleum products is likely to be close to 24% in the final energy consumption [5,6]. Dependence on biomass will continue, due to increase in rural population and continued lack of access to FFs in rural areas, particularly for cooking [2]. However, these projections show a possible decline in the relative share of biomass in total energy. Possible reasons could be a shift to other energy carriers for meeting cooking needs and efficient use of biomass energy.

2.2. GHG emissions from energy sector in India

The CO_2 equivalent GHG emissions from energy sector in India during 1990 were estimated to be 508 Mt CO_2, with coal dominating the emissions (Fig. 1). The GHG emission is projected to continue to increase in the early decades of the current century. The total energy sector emissions are projected to increase by over 5 times to 2862 Mt CO_2 by 2020.

Thus, in the present scenario countries such as India may have to consider options to reduce CO_2 emissions, without affecting economic development. Among the carbon abatement options, indications are that BETs provide large and relatively low-cost mitigation opportunities [1,8]. The estimated renewable energy potential of India is quite high and if exploited can meet significant proportion of projected energy needs (Table 2). For example, a comparison could be made between total renewable energy-based power generation potential of 82 GW (excluding solar PV and ocean thermal-based potential) with a projected total additional generation capacity of 100 GW required by 2012 [9].

3. BETs for substituting fossil fuels and traditional biomass energy systems

There are mitigation opportunities in every energy subsector: transportation, residential, energy supply, industrial, etc. [8]. The mitigation opportunities could be created either through environmental friendly energy supply technologies or through technologies for efficient utilization of energy. Among the abatement technologies, renewable energy and particularly BETs are shown to have significant opportunity to mitigate climate change and promote sustainable economic development. In this paper, a set of BETs with a potential to substitute FF or TBES are evaluated for carbon abatement. There are a large number of abatement opportunities but only 10 opportunities as project cases are explored based on the following

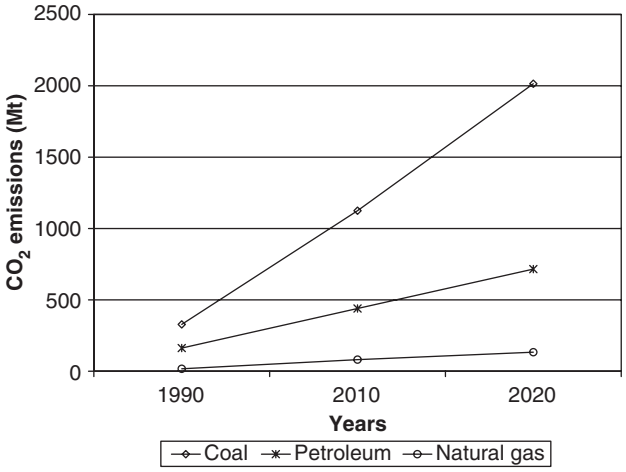

Fig. 1. GHG emissions from energy sector (in Mt CO_2) in India [7].

Table 1
Current and projected energy consumption pattern in India

Energy sources	Energy consumption in 1998–1999		Energy consumption in 2010–2011	
	PJ	%	PJ	%
Coal	5775.27	36.36	12,267	46.37
Petroleum	3868.60	24.36	6,322	23.90
Natural gas	983.90	6.19	1,758	6.65
Hydroelectricity	262.51	1.65	628	2.37
Nuclear energy	35.17	0.22	—	—
Fuelwood	3199.97	20.15	3,660	13.84
Crop residue and dung	1758.46	11.07	1,816	6.87
Total	15,883.88	100	26,453	100

Source: [5,6].

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