Coal and Biomass Co-firing Prospects in India

Renu Kumar Rathnam, JanneKärki*, MattiNieminen, and ArvoLeinonen, Priyank Jain and T.N. Raju

The writers discuss the prospect of coal and biomass co-firing in India highlighting the challenges in each space [coal, biomass], the advantage of co-firing and the technology options for this concept.

Energy Challenges in India

Shortage in indigenous coal production

Coal based thermal power plants generate about 132.3 GW of electricity (as on 31.07.2013) which is around 58.6% of the total installed capacity in the country. Sub-critical pulverised coal (PC) technology is usedin most of the coal based thermal power plants.Coal is required in large quantities for power generation and India has abundant reserves of this fossil fuel. As on 01.04.2012, according to the Ministry of Coal, India's coal resources stand at a grand total of around 293.5 billion tonnes, the proven non-coking coal resources, used primarily for power generation, are about 100 billion tonnes.

However, indigenous coal production hasn't been able to meet the demands and hence significant proportion of coal is imported from overseas. Currently, about 25% of the coal used in India is imported from overseas and this number may increase in the future. The increase in the coal import over the last 5 years is shown in Figure 1. The shortage of coal for power generation is one of the major issues in the Indian power sector.

Renu Kumar Rathnam, JanneKärki* [Corresponding Author], **MattiNieminen**, and **ArvoLeinonen**, VTT Technical Research Centre of Finland. **Priyank Jain,** Auctus Advisors, New Delhi, India. **T.N. Raju,** Future Eco friendly Technologies (India) Pvt. Ltd., Hyderabad-500018, Andhra Pradesh, India.

Electricity deficit

India has been a net importer of energy for quite some time now. According to the IEA, India's total net import of energy increased (almost trebled) from 11 to 35% in about two decades from 1990 to 2009[1]. Although India has significantly increased its installed capacity over the years, the energy deficit has remained constant; it is forecasted that the electrical energy requirement will double during the next ten years[2]. It is going to be a great challenge to see how India reduces the power deficit and simultaneously electrify the rural areas. The Ministry of Power, Government of India, has envisaged about 16 Ultra Mega Power Projects (UMPP[3,4]) of 4000 MW capacity each. The aim of these UMPPs is to drastically address the power shortage problems in India using highly efficient supercritical technology in order to reduce CO_2 emissions. However, progress of UMPP's has been slower than expected as only 4 UMPP contracts (out of the 16) have been awarded[5,6].

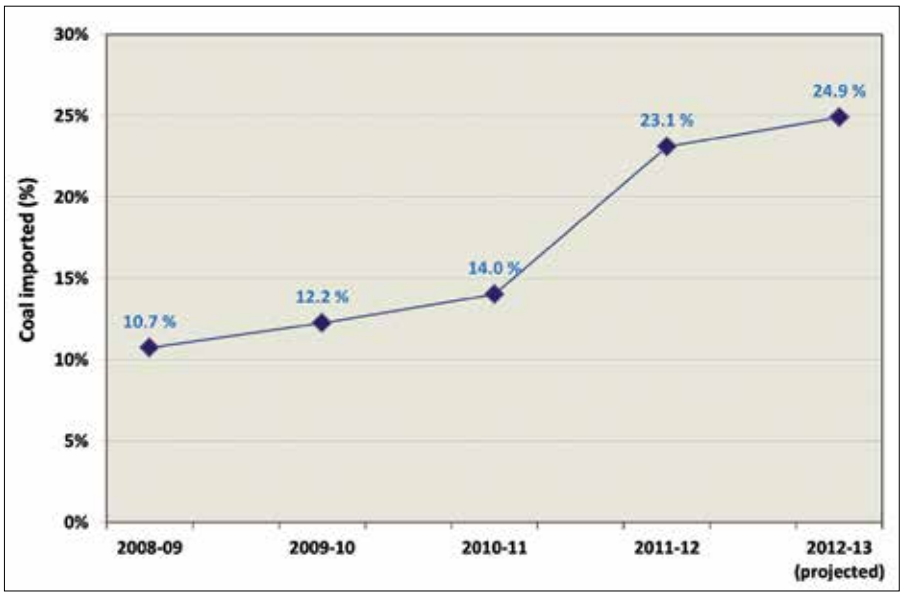


Figure 1. Overview of coal imported by India during the last 5 years.
Source: Annual Report 2011-2012, Ministry of Coal, Government of India. (http://www.coal.nic.in/annrep1112.pdf)
Annual Report 2012-2013, Ministry of Coal, Government of India. (http://www.coal.nic.in/annrep1213.pdf)

CO_2 emissions

India is mainly dependent on fossil fuels for its energy needs and hence generates significant quantities of CO_2. Although the per capita CO_2 emission in India is considerably lower when compared to other countries, it is possible that India could still work on reducing its CO_2 emissions from a global perspective. According to the IEA, the global CO_2 emissions in 2050 is estimated to be about 58 Gt out of which 7.4 Gt will be emitted by sources in India. By adopting various CO_2 reduction technologies, the global CO_2 emissions could be reduced to 41 Gt, while India could reduce the CO_2 emissions to 2.3 Gt in 2050.

BioEnergy in India

Significance and potential

India is a land of agriculture. It also receives regular sunshine almost throughout the year and hence suitable for the growth of energy crops as well. Consequently, there is an abundant supply of bioenergy that has the potential to complement the fossil fuels, mainly coal, in generating power

TABLE 1. BIOMASS POWER POTENTIAL IN INDIA

Source	Area (Mha)	Crop Production (Mt/annum)	Biomass Generation (Mt/annum)	Biomass Surplus (Mt/annum)	Power Potential (MW_e)	Installed capactity* as on 31.07.2013 (MW_e)	Achievement (%)
Agricultural residues	287.1	750.4	511.1	145.0	18,730.7	2,123.1	6.4
Forest	64.6		89.1	59.7	8,355.0		
Wasteland	54.3		66.4	44.4	6,212.0		
Cogeneration from sugar mills					5,000.0	2,337.4	46.7
Total					**38,297.7**	**4,460.5**	**11.6**

Source: MNRE (http://www.mnre.gov.in/schemes/grid-connected/biomass-powercogen/). Biomass Resource Atlas of India (http://lab.cgpl.iisc.ernet.in/Atlas/)
* Includes power from waste

for the steadily increasing population in India. The overall power potential from various biomass resources and cogeneration plants in sugar mills in India is estimated to be around 38.3 GW (Table 1). According to IREDA (Indian Renewable Energy Development Agency), biomass could supplement coal and hence result in financial savings of about INR 250 billion per annum. Biomass has the potential to change the rural energy landscape of India in two ways:

- Electrification of nearly 75 million rural households currently un-electrified in India (25,000 MWe)
- Using bioenergy has a multiplier effect on the development of the economy as about 60% of the total plant cost is circulated back into the rural economy and could also offer employment opportunities to the rural community

Overall utilization of biomass resources

Power generated from biomass energy sources is considered CO_2-neutral and renewable. Hence, it is important that weoptimally utilize the bioenergy available to us in order to create a sustainable energy future. Biomass power plants and cogeneration plants mainly use combustion for converting biomass to power and/or heat. Cogeneration plants, mostly integrated with sugar mills, utilize the bagasse for generating both heat and power; excess power generated is supplied to the grid.

In India, as on 31.07.2013, the power generated from biomass and waste amounted to 4460.49 MW[7] (2% of the total installed capacity). More than 80% of the total power generated by biomass sources was attributed to biomass power and bagasse-based cogeneration plants and was available to the grid (Figure 2). The off-grid/captive power is mainly generated by biomass gasifiers and non-bagasse cogeneration plants. Biomass gasifiers are mainly small scale units that utilize locally available biomass sources in rural areas to generate power for local needs.

As seen from Table 1, the overall biomass utilization in India is less than 12%, which is a very low value. It could also be seen that almost 50% of the cogeneration power potential has been achieved currently. However, the achievement of biomass power from the utilization of various biomass sources is about 6.4%. Figure 3 compares the installed capacity of currently commissioned biomass power and cogeneration units with the estimated biomass power potential of various states in India. It is quite clear that the biomass resources have been underutilized in India.

Issues in the bioenergy sector in India

Several issues in the biomass energy sector have hindered the optimal utilization of biomass resources available in the country. Some of the major issues are described below.

Rising biomass prices

Rising of biomass fuel prices is an important issue in the biomass market. Sudden hike in the biomass fuel prices has led to the shutdown of biomass power projects[8]; future projects in the planning phase will also stop and reconsider their plans. From 2009 to 2011, biomass (fuel) cost has increased from INR 1475/tonne to INR 3000/tonne (doubled) but the biomass plant tariff has only increased by 8% in that time period. The main reason for the irregularity in the cost of biomass is the lack of structured policies and a system; crop failures also add to this.Farmers tend to sell the surplus biomass to the brick making units due to their price competitiveness.

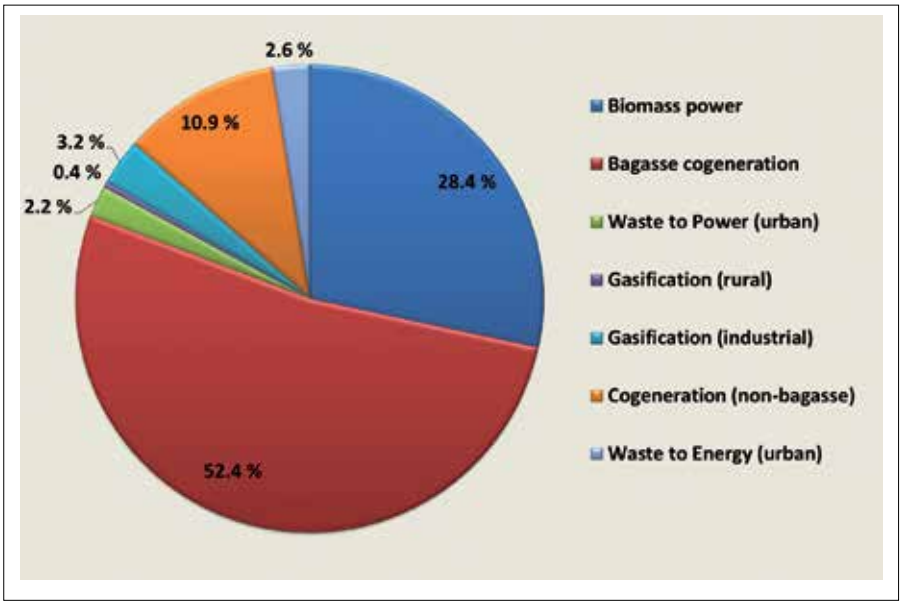


Figure 2. Breakup of overall biomass-based power generation in India as on 31.07.2013.
Source: MNRE (http://www.mnre.gov.in/mission-and-vision-2/achievements/)

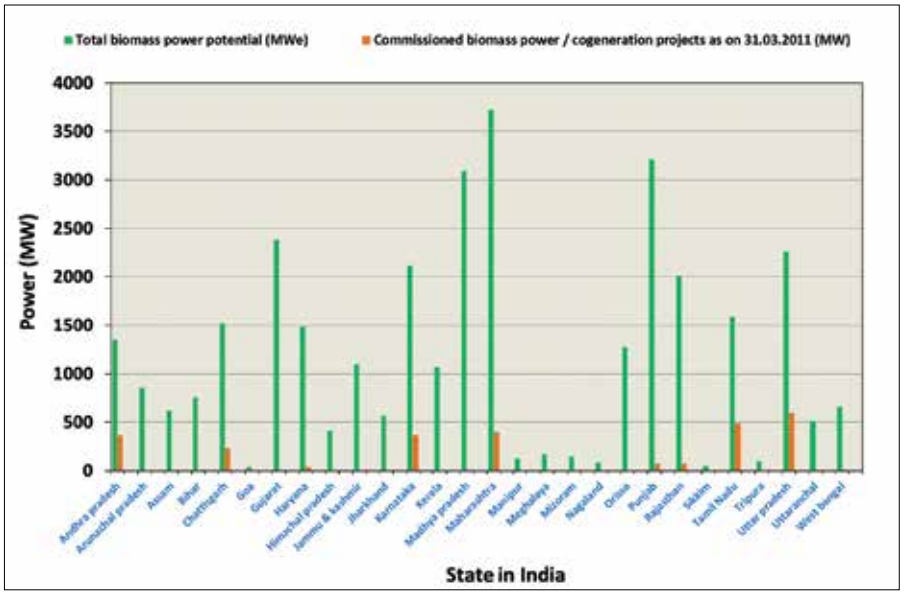


Figure 3. Comparison of biomass power potential and actual biomass power generation across various states in India
Source: MNRE (http://www.mnre.gov.in/schemes/grid-connected/biomass-powercogen/)
Biomass Resource Atlas of India (http://lab.cgpl.iisc.ernet.in/Atlas/)

Lack of up-to-date information on availability of biomass resources

Information on the availability of biomass resources across the country is vital and needs to be updated frequently. Data from the 'Biomass Resource Atlas of India' is a about a decade old and needs to be updated.

Biomass transportation and handling issues

There are also possible issues associated with the collection, handling, and transportation of biomass, especially agro-residues, in India. These issues, mainly related to the use of less advanced technologies, are specific to Indian biomasses. The lack of a proper system to supply biomasses to the power plants affects the fuel availability and the power generation significantly.

A synergetic solution to the issues in the coal & biomass sectors

Co-firing of coal and biomass could be considered as a promising solution to some of the issues in the coal power sector and also a better way to utilize the biomass resources in India due to the following reasons:

- Biomass as a substitute to imported coal
  - IREDA claims that 460 million tonnes of agricultural wastes - which could replace about 260 million tonnes of coal - are produced every year. This quantity is more than the quantity of imported coal estimated for 2012-13 (192.54 million tonnes). Hence, the use of indigenous biomass could significantly reduce the import of coal. It is also important to note that, in the future, the supply of coal from overseas can't be assured
- Reducing CO_2 emissions by better utilization of the biomass resources
  - The IEA has proposed various technologies and methods that could be used for reducing the CO_2 emissions significantly in the near future (The 2°C scenario, Figure 4). It could be seen from Figure 4, that the use of renewables and fossil fuel switching could account for 30% of the CO_2 emissions reduction. This 30% also includes the use of biomass resources which is considered CO_2 neutral
- Coal-based thermal power generation is the dominant technology currently and in the near future. Coal power plants are spread all over the country and hence local biomass resources could be utilized for co-firing
- Comparatively cheaper capital cost in comparison to other biomass-based power generation technologies (Figure 5)
- Biomass can be utilized as per the availability; power plant could still be operated with coal if biomass is unavailable due to unexpected reasons
- Significantly better utilization of biomass in large-scale power plants with higher efficiencies in comparison to the

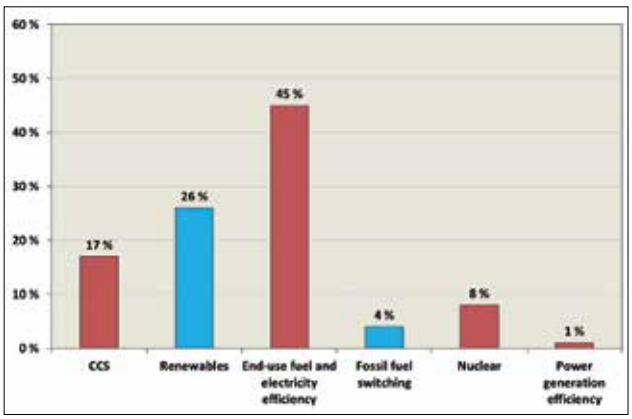


Figure 4. Estimations of percentage contributions of various options available for reducing CO_2 emissions in India in 2050.
Source: IEA, Energy Technology Perspectives 2012 data visualisation, http://www.iea.org/etp/explore/

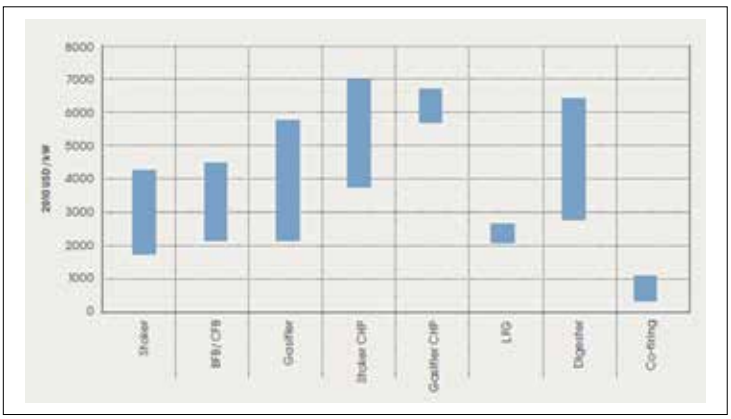


Figure 5. Comparison of the installed capital cost of current technologies in use for biomass utilization (power generation).
Source: RENEWABLE ENERGY TECHNOLOGIES: COST ANALYSIS SERIES, Volume 1: Power Sector, Issue 1/5. Biomass for Power Generation, June 2012. International Renewable Energy Agency (IRENA).

CO-FIRING OF COAL AND BIOMASS COULD BE CONSIDERED AS A PROMISING SOLUTION TO SOME OF THE ISSUES IN THE COAL POWER SECTOR AND ALSO A BETTER WAY TO UTILIZE THE BIOMASS RESOURCES IN INDIA

efficiencies of dedicated biomass power plants

- Co-firing with biomass could improve the combustibility of the high-ash Indian coal
- World-wide experience in co-firing biomass and coal already exists

Mythili and Venkatachalam from the Tamil Nadu Agricultural University in India have also recommended and supported co-firing of coal and biomass for the Indian energy scenario. The Annual Energy Outlook 2013 predicts that biomass utilization/consumption will be higher through co-firing rather than dedicated biomass power plants (Figure 6). The annual growth rate of biomass consumption through co-firing is about 10%, while that of dedicated biomass power plants is less than 3%. Figure 7 and Figure 8 present estimations of the theoretical maximum percentage of coal that could be replaced by biomass in Indian coal-based thermal power plants. Estimations show that significant percentage of coal, up to 30%, could be replaced by biomass; however, there exists optimum levels of biomass that can be co-fired with coal based on technical and economic limitations.

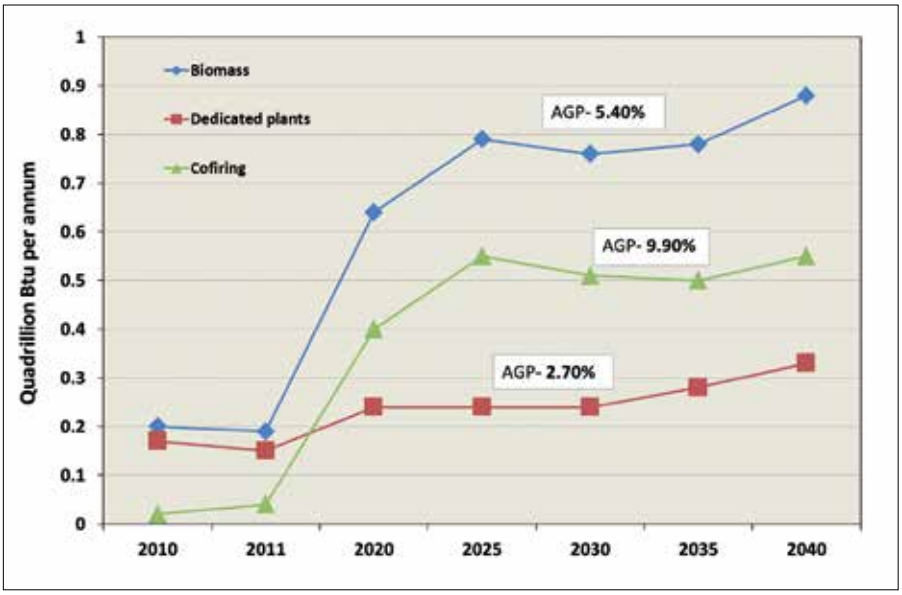


Figure 6. Forecasts of biomass renewable energy consumption.
AGP – Annual Growth Percentage 2011-2040
Source: Data from Annual Energy Outlook 2013, U.S. Energy Information Administration, April 2013 (http://www.eia.gov/forecasts/aeo/)

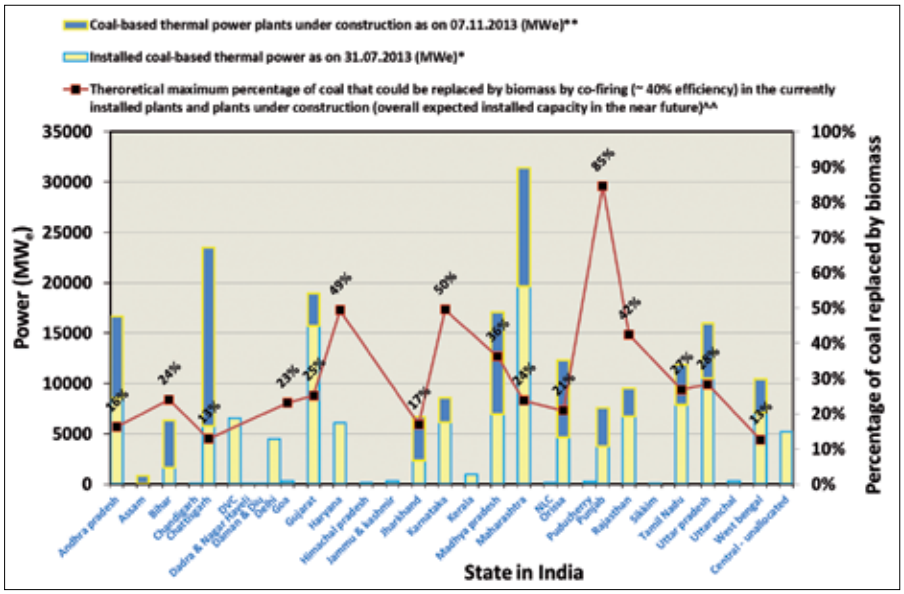


Figure 7. Theoretical maximum percentage of coal that could be replaced by biomass in existing coal-fired power plants across various states in India.
* http://www.cea.nic.in/reports/monthly/inst_capacity/jul13.pdf
** http://www.sourcewatch.org/index.php/Proposed_coal_plants_in_India
^^ The original biomass power potential estimations from the Biomass Resource Atlas of India (http://lab.cgpl.iisc.ernet.in/Atlas/) were doubled; biomass cogeneration potential from sugar mills (5000 MW) not included in the estimations.
- States having a theoretical maximum percentage greater than 100% are not shown in the figure; such an estimate is possible if the state has an estimated biomass potential greater than the overall expected installed capacity in the near future.

Technology options for co-firing coal and biomass

Background and state-of-the art

There are three major options generally available for co-firing biomass with coal; each of them has its own advantages and disadvantages. All the options have been successfully employed either on a demonstration- or commercial-scale. In direct co-firing,both biomass and coal are combusted in the same furnace. Both coal and biomass may use the same fuel handling and feeding systems or different ones depending on the biomass characteristics. Direct co-firing is the cheapest and most commonly used method. Indirect co-firing utilizes a gasifier to convert the solid biomass fuel into a gaseous fuel which could be co-combusted with coal in the same furnace. This method, although expensive, could be used for a broader range of biomass fuels; biomass fuels that are difficult to grind could especially be utilized through indirect co-firing. The other major advantage is that the gaseous fuel could be cleaned before co-combusting with coal and hence is less polluting. The final option is to use a separate boiler for the biomass fuel to help increase the parameters of the steam produced in the main coal-fired boiler[13]. Figure 9 illustrates the major direct and indirect biomass co-firing options used commonly.

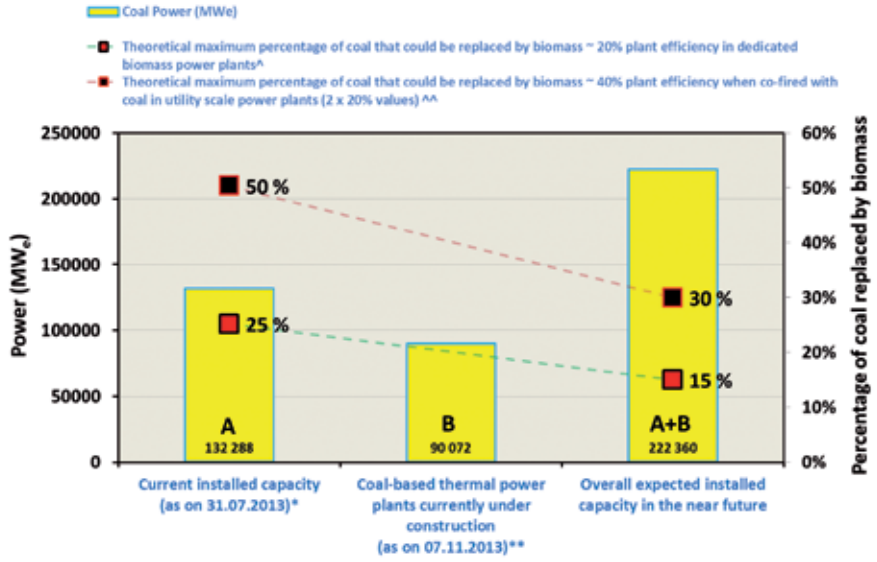


Figure 8. Theoretical maximum percentage of coal that could be replaced by biomass in existing and near future coal-fired power plants in India.
* http://www.cea.nic.in/reports/monthly/inst_capacity/jul13.pdf
** http://www.sourcewatch.org/index.php/Proposed_coal_plants_in_India
^Original biomass power potential estimations from the Biomass Resource Atlas of India used (http://lab.cgpl.iisc.ernet.in/Atlas/)
^^The original biomass power potential estimations from the Biomass Resource Atlas of India were doubled Biomass cogeneration potential from sugar mills (5000 MW) not included in the estimations.

Co-firing is currently practised in many countries around the world. A database[14] of power plants that use one of the co-firing technologies includes 243 units around the world. The database shows that co-firing is mainly practised in Europe and North America. Hence, there is enough operational experience worldwide. However, no record of any major power plant utilizing co-firing in India has been found.

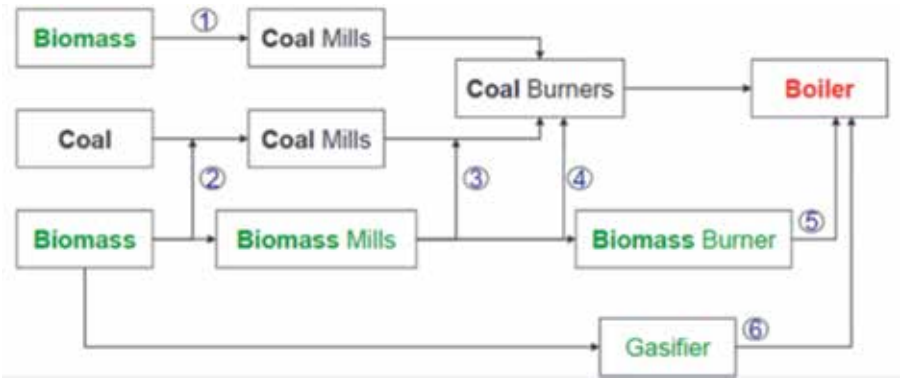
Instances of co-firing studies/trials in India

- Laboratory scale studies on combustion of Indian coal and biomass blends have been reported[15]
- Co-firing trials[16] have also been performed previously in an industrial scale cogeneration unit in India with an aim to optimize the biomass/coal blending ratio from an emissions point of view
- Thermax biomass boilers have been used to fire both biomass (mainly bagasse) and coal mainly in cogeneration plants located in sugar mills[17]
- Indian coal-based thermal power plants have been co-firing indigenous and imported coal for quite some time now[18]
- India is currently focusing on reducing the CO_2 emissions from its thermal power plants. As a major step towards meeting this objective, the EU has financed a project which aims at developing a cluster for Clean Coal Technologies (CCT) and Carbon Capture and Storage (CCS) Technologies for the Indian thermal power sector[19]. BHEL is a major partner in this project that also focuses on pilot-scale testing of co-firing[20].
- No literature on biomass/coal co-firing trials/experience in large utility scale units in India has been found. It would be interesting to know if co-firing trials were indeed performed in utility scale units in India before and what kind of issues were identified

Challenges in the implementation of co-firing in India

India has an ideal situation where co-firing of coal and biomass should be in optimal use. However, it has not been the case. The big question that immediately arises is why this technology has been overlooked? Has it been tried and tested enough to be ignored? A preliminary analysis on this issue points to the following factors:

- Technical problems arising from the combustion of biomass (even if minor) in furnaces designed for coal combustion
- Further capital investment in the power plant to accommodate biomass storage, processing, and feeding
- Fluctuating availability of biomass and unpredictable prices
- Diversity in the biomass available in India
- Utilities'concern about issues arising from the use of biomass and their effect on the plant availability and power production
- Utilities' mindset to only adopt conventional pulverised coal technology that has proven to be successful over the years with indigenous coal and now with imported coal as well
- Lack of government and industry initia-



1. The milling of biomass (pellets) through modified coal mills
2. The pre-mixing of the biomass with the coal, and the milling and firing of the mixed fuel through the existing coal firing system
3. The direct injection of pre-milled biomass into the pulverised coal pipework
4. The direct injection of pre-milled biomass into modified coal burners or directly into the furnace
5. The direct injection of the pre-milled biomass through dedicated biomass burners
6. The gasification of the biomass, with combustion of the product gas in the boiler.

Figure 9. The principal direct and indirect biomass co-firing options.
Source: http://www.ieabcc.nl/workshops/task32_2012_Copenhagen/Livingston-1.pdf

tives to study and test coal/biomass co-firing in Indian power plants

Solutions & recommendations

As discussed earlier, co-firing of coal and various kinds of biomasses is now amature technology and is currently being practised all over the world successfully. The technology has advanced and many limitations associated with it have been mitigated. If a proper system is established, co-firing could be successfully implemented in Indian coal-based power plants. A few recommendations in this regard are as follows:

- Technical issues could be sorted by using appropriate technologies and measures that are successfully followed by many other countries
- Additional capital and operating costs due to the inclusion of biomass could be compensated by earning carbon credits or avoiding carbon tax
- Biomass sector should be organised better to ensure constant supply of biomass to the power plants. The production of energy crops should be encouraged to aid in the regular supply of biomass to power plants
- The government should present subsidies or tax reductions and take initiatives to study the coal/biomass co-firing technology options in detail. Pilot co-firing projects need to be funded by the government / banks / collaborative projects to gauge the techno-economic feasibility
- A process similar to the allocation of coal resources should be followed to allocate biomass resources to the power plants. A minimum of 5-10% of coal should be replaced by biomass during co-firing
- Information on biomass resources should be updated frequently and be available to utilities during the design and planning phase. Effort should be made to include biomass as a supplement fuel. By doing this, new power plants will be designed to handle and co-fire coal and biomass
- Advanced and efficient technologies should be adapted to make optimum use of both coal and biomass resources in the country
- A clear policy (to begin with, a discussion paper) for co-firing, demarcating the role of the MOP and the MNRE needs to be in place

The document titled '*Strategy on R&D activities for Thermo-chemical conversion and promotion of biomass energy in the country*' prepared by IISc Bangalore and the MNRE highlights the R&D activities required in some of the areas, including co-firing, mentioned above[21].

The Indo-Finnish 'Cofindia' project

Finland is one of the leaders in adopting co-firing and multi-fuel usage in their power plants. Finnish companies working in this area are highly experienced and have the technologies for deployment. However, there are issues, as discussed in this article, that need to be studied before Finnish companies could offer anything to India. A consortium, comprising of Finnish and Indian organisations, are working together in the 'Cofindia' project to determine various concepts for co-firing biomass with coal in Indian coal fired plants. The consortium will carry out preliminary techno-economic and environmental assessments of these concepts, consider the policy, institutional and regulatory impacts and then determine the commercial attractiveness of introducing co-firing in the Indian power sector.

The project is currently studying the coal and biomass energy sectors in India and this article is based on the information gathered through the preliminary studies. During the next phase of the project, a survey would be carried out to assess the co-firing possibilities in Indian power plants. Case studies on co-firing in selected Indian coal-based thermal power plants will also be undertaken. The 'Cofindia' project is coordinated by the Technical Research Centre of Finland (VTT). Further information about the 'Cofindia' project and the contact person is available in the brochure[22]. Organizations interested in participating in the survey or collaborating in any other way in this project, could feel free to contact VTT. Suggestions/comments on this article are also welcome.The support and co-operation for this research project from Tekes (the Finnish Funding Agency for Technology and Innovation), participating Finnish companies and Indian research partners are gratefully acknowledged.

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