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BIOMASS CO-FIRING AND ITS IMPACT ON ENVIRONMENTAL PROTECTION

R. JAYASHREE

Department of Environmental Sciences,
Tamil Nadu Agricultural University, Coimbatore 641 003, T.N., India

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ABSTRACT

Biomass co-firing can have a very influential role in achieving this new energy target as it can reduce the potential environmental impacts associated with the combustion of fossil fuels. Greenhouse gases such as CO_2, NO_x, and SO_x emissions can be reduced by replacing a portion of coal with biomass during co-firing. Co-firing biomass with coal is an attractive energy generating option from both economic and environmental point of view. Co-firing could be economic in the sense that biomass co-firing does not require major capital investments and uses the existing coal-fired power plant infrastructure. This result in savings on investments in the infrastructure that is necessary attracts biomass supply. Moreover, co-firing is a low-risk option for the production of renewable energy since the risks associated with major capital investments and raw material supplies are much smaller compared to other alternative uses of biomass. Additionally, direct co-firing is one of the most interesting and effective means of reducing GHG emissions from the coal-fired power plants. Co-firing minimizes waste like wood waste, agricultural waste and the environmental problem associated with its disposal.

KEY WORDS : Biomass-Co-firing-GHG emission-reduction-Challenges

INTRODUCTION

Biomass co-firing is a promising technology to decrease the use of fossil fuels for energy generation and hence mitigate greenhouse gas emissions. Biomass is non-fossilized and biodegradable organic material originating from plants, animals, and microorganisms. This shall include products, by-products, residues, and waste from agriculture, forestry, and related industries as well as the non-fossilized and biodegradable organic fractions of industrial and municipal wastes. Biomass cofiring refers to the simultaneous combustion of a biomass fuel and a base fuel to produce energy, usually electrical power. The most common base fuel is coal. The most common sources of biomass fuel include low-value wood from forestry activities, crop residues, construction debris, municipal waste, storm debris, and dedicated energy crops, such as switch grass, willow, and hybrid poplar. Most biomass feed stocks must undergo significant processing before they can be utilized for cofiring. The shape, size, and moisture-content of feedstock particles need to be adjusted to meet specifications. Biomass also includes gases and liquids recovered from the decomposition of non-fossilized and biodegradable organic material. Biomass co-firing stands for adding biomass as a partial substitute fuel in high-efficiency coal boilers.

Impacts on environmental protection

Cofiring biomass could have positive impacts on environmental control from a coal-fired power plant (Sloss, 2010; Fernando, 2012). Cofiring torrefied biomass with coal can reduce SO_2 and NOx emissions further than raw biomass. HCl emissions from torrefied corn straw were lower than that from its raw precursor, as the former had a lower chlorine content (Rokni *et al*., 2018). The ash content of biomass is generally much lower than that of coal,

(Associate Professor (ENS)

resulting in an overall reduction of particulates and fly ash production. However, cofiring biomass changes the chemical properties of the fly ash and bottom ash and thus impacts ash utilisation

SO_2 Emission control

SO_2 emissions almost invariably decrease when cofiring, often in proportion to the amount of biomass used, as the majority of clean biomass contains significantly less sulphur but has a higher alkali and alkaline earth content than most coals. The high level of alkali and alkaline earth compounds (Ca, K) in many types of biomasses are effective in absorbing the sulphur released from the coal during cofiring. Sulphur can be removed using flue gas desulphurisation (FGD). Cofiring biomass has no significant negative impact on the operation and performance of the FGD system.

NOx Emission control

The nitrogen content of woody biomass is significantly lower than that of most coals but agricultural wastes, such as alfalfa stalks and rice husks, can contain higher nitrogen than a typical coal. In biomass cofiring, the main sources of NOx are from the nitrogen in the air and fuel nitrogen from coal, while NOx emissions from biomass fuel are minimal. Volatile matter released from biomass combustion is higher than that from coal, and during combustion volatilised tars convey fuel nitrogen to the volatile matter flame which can result in low NOx emissions, particularly in low NOx burners. The fuel nitrogen content of biomass is mainly converted to ammonia during combustion rather than hydrogen cyanide usually formed in coal combustion, and this could help prevent the eventual formation of NOx in flames. Adding biomass to coal could also decrease the nitrous oxide (N_2O) emissions from the boiler due to the higher oxygen: carbon (O:C) ratio of biomass. Flue gas cleaning systems for NOx such as selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) can be used in cofiring systems with little or no modification, but the vanadium-based catalysts in the system are susceptible to poisoning from biomass volatile inorganic compounds, such as alkalis and alkaline earth metals, and phosphates. Unit started cofiring with 3% wood and 2% olive residues (both by heat rate) the trace elements from the cofiring caused higher deactivation of the catalyst. Catalyst deactivation caused by biomass cofiring (Zakieh *et al*. 2014) Currently, honeycomb and plate type catalysts are available on the market. The mechanism for catalyst deactivation during biomass cofiring includes masking/fouling, plugging and poisoning (Buddhike *et al*. 2017). The deactivation is mostly due to the high potassium content of biomass, which results in submicron aerosols containing mostly KCl and K_2SO_4. The main mode of deactivation is neutralisation of the catalyst's acid sites – poisoning. The increased deactivation rates of SCR catalysts are a significant technical issue when cofiring biomass especially at a high ratio. Catalyst suppliers have enough experience of these issues to provide estimates of catalyst lifetimes for particular fuels and specific biomass firing/cofiring operating regimes in particular plants (Hodzic *et al*., 2018). Johnson Matthey developed a plate catalyst with high erosion resistance even at large particle size compared to a honeycomb catalyst. Erosion resistance was boosted significantly as its formulation was optimised for high mechanical resistance (Chen *et al*., 2012). Mitsubishi Heavy Power Systems deals with catalyst deactivation by injecting coal ash into the boiler furnaces (Chowdhury *et al*. 2019) Strategies to deal with SCR catalyst poisoning from a high potassium content include, remove potassium by adsorption; place the SCR unit at the tail-end; coat monoliths with basic substances; and use intrinsically potassium-resistant catalysts.

Particulate matter emission control

Biomass fly ash has a smaller particle size distribution than the fly ash from coal firing. The inorganic contents in biomass can generate a large amount of sub-micron fumes and vapour in the flame. Hence cofired fly ash can contain very fine aerosols which may not be collected by electrostatic precipitators. However, cofiring biomass with coal usually leads to a reduction of the total amount of fly ash produced due to the lower ash content of biomass. This means that emission limits can be achieved at lower levels of particulate collection. Thus, cofiring biomass has two competing effects on particulate emissions. There is not normally a requirement for major upgrades to the electrostatic precipitator (ESP) when pulverised coal boilers have been converted to biomass cofiring or 100% biomass firing depending on the type and ash content of biomass (Zagic and Smajevic, 2009).

Ash utilization

Cofiring power plants produce less fly ash due to the lower ash content of biomass. The ash composition of different biomass and coals varies. Where the biomass feedstock is particularly rich in trace elements it could impede utilisation of the ash, especially at a high cofiring ratio. The chemical species found in co-combustion ash are difficult to predict, even from a full characterisation of the contributory coal and co-fuel ashes, since complex interactions can occur between the 'parent ashes' in the solid and vapour phases (Sami *et al*., 2001). The composition of cofiring fly ash tends to be dominated by the composition of the coal due to the low ash content of biomass. This means there are limited implications for the utilisation of low ratio biomass cofiring ash. About 80% of the ash produced in a PC plant is in the form of fly ash from the ESP/bag filter, economiser and air heater hoppers. The remaining 20% of the ash is in the form of bottom ash or slags and is collected in the furnace ash hopper. The extent of utilisation of ash varies considerably from country to country. Worldwide the utilisation rate of fly ash exceeds 60%, although this figure can approach 100% in specific regions. The various industrial applications of ash have been reviewed extensively by the IEACCC (Wang *et al*., 2011) and include: Construction and engineering materials: concrete, bricks, blocks and geopolymers, construction materials, and structural road-fill material. Agriculture: to improve key soil indicators such as carbon content, water retention and fertility, Mineral extraction: of valuable elements, such as aluminium, rare earths and germanium from fly ash; and Advanced materials: composites, ceramics, fillers, zeolites and proppants. On a global level, a limited number of guidelines have been developed in the field of cofiring ash management. IEA Bioenergy Task 32 carried out a survey of ash management from biomass firing and cofiring ash in seven countries, namely Austria, Canada, Denmark, Germany, Italy, the Netherlands and Sweden. Of these, Denmark and the Netherlands have considerable experience of cofiring.

Cofiring ash utilization requirements

Application Requirements Disposal and landfill No ban, preferred solution in many countries Use in forestry Leaching of heavy metals, or pelletised with binder to control soluble components releasing speed Fertiliser/soil amendment Leaching of trace elements, following legislations for fertiliser Addition to compost Up to 3–5%, legislation for fertiliser and REACH registration in EU Cement, raw meal constituent Bilateral contracts Cement and concrete filler EN 450 in EU Asphalt concrete filler Technical product regulation Underground mining For bottom ashes Civil engineering, road construction For bottom ashes As the types of biomass fuel are not always regulated directly for cofiring, the ash products show large variations in quality, making it challenging to meet the requirements for utilisation of ash from high ratio biomass cofiring. Landfill and disposal are often the easiest solution as there is no ban on disposal in landfill of biomass ash. A major drawback to the use of biomass cofiring ash in forests is their solubility and reactivity which may have a negative effect on vegetation and soil life. To reduce the instantaneous release of soluble components from ash, they can be pelletised with binders so that nutrients are released more slowly. Similarly, cofiring ash can be used for fertiliser or soil amendment but the trace elements in biomass ash are in more mobile compounds. The fraction can be up to 61% in biomass ash compared to just 0.2% to 7.2% in coal ashes. Heavy metals and trace elements should be leached prior to ash utilisation in forests and agriculture. Up to 5% ash can be added to compost to improve the composting process but in Europe it must follow the legislation for fertiliser and be Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) registered (Gil and Rubiera, 2019). The main use for coal fly ash is in cement or concrete. Paiman*et al*. (2018) found that the cement characteristics of the fly ash produced by agricultural/forestry residue cofiring in a PC furnace are more dependent on the primary fuel coal; a modest cofiring ratio.

Sustainable Development Goal (SDG)

Cofiring biomass with coal can play a role in the achievement of the SDGs, particularly those for: climate action; affordable and clean energy; industry innovation and infrastructure; sustainable consumption and production patterns; and partnerships for the goals.

Climate action: Climate change is disrupting national economies and affecting lives. Most countries adopted the Paris Agreement at the 2015 COP21 to strengthen the global response to the threat of climate change. However, in 2018 global energy consumption increased at nearly twice the average rate of growth since 2010, driven by a robust global economy and higher heating and cooling needs in some regions. As a result, global energy-related CO_2 emissions increased to a record 33.1 gigatonnes (Gt) CO_2, up 1.7% on the previous year. But global energy-related CO_2 emissions stabilised at 33.2 Gt in 2019. Coal continues to be the largest single source of electricity generation with a share of 36% in 2019; hence, coal-fired power generation remains the single largest emitter, accounting for 30% of all energy-related CO_2 emissions (IEA, 2019, 2020). There is a clear role for cofiring biomass at coal-fired power plants to lower CO_2 emissions and facilitate the achievement of Goal 13. Biomass, when it comes from a sustainable source of agricultural wastes or forestry by-products, is a renewable energy source for mitigating CO_2 emissions. Biomass combustion is considered a carbon neutral way to produce electricity as CO_2 generated from firing biomass has been previously removed from the atmosphere by photosynthesis of the growing plants. Cofiring biomass with coal is thus a means to reduce the emissions from existing coal-fired power plants while taking advantage of the existing power generation infrastructure. Goal 7 Affordable and clean energy: Access to electricity in the poorest countries has begun to accelerate, energy efficiency continues to improve, and renewable energy is making gains in the power generation sector. As mentioned above, coal remains as a cheap and abundant energy resource. Many emerging economies depend on coal for secure, affordable and reliable electricity generation and supply. Therefore, it is vital to ensure that coal is used efficiently with minimum environmental impacts. Cofiring biomass with coal can help to utilise agricultural and forestry wastes and keep generating electricity at high efficiencies and low emissions in these countries to provide energy at an affordable price. Goal 9 Industry, innovation and infrastructure: The aim is to upgrade certain aspects of industry by 2030 in order to make them more sustainable, with increased resource-use efficiency, whilst adopting clean and environmentally sound technologies. Some innovative materials have been applied to the boilers at coal-fired power plants to overcome ash deposition and corrosion issues from burning alkali agricultural wastes. Modifications to coal mills are also needed when high percentage biomass is cofired. Retrofitting coal-fired power plants to cofire biomass with coal has improved the plants' efficiency, reduced emissions, and extended the life of the power plants. Goal 12 Ensure sustainable consumption and production patterns: Biomass fuels can be created and used in a sustainable manner. Biomass used for cofiring includes wood pellets, waste wood, forestry residues, and agricultural by-products. Cofiring waste biomass gives it a value and ensures it is burned cleanly rather than being burned in the field for example. The wood pellets cofired at coal-fired power plants can be sourced sustainably. This relies on regulations, guided by solid principles. For example, the use of biomass in Europe is regulated under EU Timber Regulations and the Renewables Obligation. The Sustainable Biomass Program (SBP) was established in 2013 to enable certified companies to demonstrate that they produce, trade or use woody biomass from sustainably managed forests. Currently, there are more than 130 SBP certified biomass producers, biomass traders and biomass end-users representing a substantial proportion of all industrial woody biomass used for energy in Europe. Goal 17 – Partnerships for the goals: Revitalise the global partnership for sustainable development through improved international cooperation on topics that include energy technologies with a low environmental impact. Europe is a frontrunner with more than 20 years' experience of cofiring biomass with coal. Technologies have been developed and lessons learned. But cofiring activities are in decline with the closure of coal-fired power plants in Western Europe. According to the IEA (2020), there is a clear trend that primary coal demand has shifted to Asia. The need for cofiring has moved with it (Zhang, 2019). An international collaboration programme would be useful to enable the transfer of technologies and knowledge sharing. The IEACCC has been promoting such efforts by distributing their technical reports and organising cofiring workshops in China and Japan. The 2030 Agenda for Sustainable Development poses a critical challenge to the energy sector: how to provide clean energy to support rapid economic development and a growing population, while simultaneously decarbonising global energy supply. Cofiring biomass with coal is one of the short- to medium-term solutions.

Challenges in India

There is not much improvement in Biomass co-firing in India because,

Low Pellet manufacturing capacity: India's pellet manufacturing capacity is 7,000 tonnes per day at present despite a surplus of 228 million tonnes of agricultural residue available in the country.

Higher price in the open market: Pellet suppliers favour selling their product to industries such as textile, food processing, metal-based or in the open market at higher prices.

Increased demand from industries in NCR: Commission for Air Quality Management in National Capital Region and Adjoining Areas directed industries in Delhi-National Capital Region to switch to cleaner fuels by end of September 2022. Hence, the Biomass demand from industries escalated.

Challenges in biomass pellet storing: Only pellets with up to 14% moisture can be used for combustion along with coal. Storing biomass pellets for long durations at the plant sites is hard, since they absorb moisture from air quickly, rendering them useless for co-firing.

CONCLUSION

Biomass cofiring is widely considered as the most costefficient and easily deployed way for mitigating the CO_2 emissions from the coal power sector. Apart from policy and market benefits and bottlenecks, the implementation of cofiring in a coalfired power plant is affected by several technical and environmental concerns. A number of technical solutions have been developed and demonstrated for cofiring schemes, from the most common, direct cofiring scheme to the more sophisticated parallel and indirect cofiring systems. The impacts of cofiring relate mostly to the biomass fuel and ash properties and affect the fuel handling system, fuel conversion, slagging/fouling and corrosion, emissions, and ash utilization. Current operating experience and available solutions indicate that most technical concerns do not materialize or can be easily solved when cofiring woody biomass at relatively low thermal shares. As the biomass thermal share increases and more problematic fuels are utilized, further research and demonstration activities will be needed to evaluate potential impacts of cofiring.

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