AGRO-RESIDUE FOR POWER

Win-win for farmers and the environment?

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1. Stubble burning—a serious issue in Northwest India

During the last decade, Northwest India has been experiencing dreadful pollution due to crop residue burning, especially in Punjab, Haryana and Uttar Pradesh.[1] After rice is harvested in October, farmers have only a handful of days to remove crop stubble from their fields before rabi crops are ready to be sown. Earlier, only a small portion of the stubble used to be burnt, but in recent years, shortage of labour, use of common harvester technology (that leaves longer stubble out in the fields), a short lead time between kharif and rabi crops, and insufficient market linkages to utilize crop residue have resulted in a significant shift towards agro-residue burning.

NASA's satellite images reveal that the operative area of crop burning in northern India extends from the India–Pakistan border into Uttarakhand, Haryana, Himachal Pradesh, Delhi and Uttar Pradesh. According to two 2014 studies,[2&3] the country generates 600–700 million tonnes of crop residue, of which around 16 per cent was burnt on farms.[4] The government has come out with various policies to curb crop burning, but recent figures of residue burning vary between 85–100 million tonnes.[5,6&7] Three states—Uttar Pradesh, Punjab and Haryana—contributed around 60 per cent of the crop burning in 2008–09.[8] In Uttar Pradesh, nearly 22 million tonnes (23 per cent of the total) of agro-residue was burnt; 20 million tonnes (21 per cent) in Punjab; and 9 million tonnes (10 per cent) in Haryana.[9]

Crop residue burning adds significant emissions load to our already choked cities. When 1 tonne of crop residue is burnt on the field, it releases approximately 1,400 kg of CO_2, 58 kg of CO, 11 kg of particulate matter (PM), 4.9 kg of NO_x and 1.2 kg of SO_2.[10] Due to such high emissions, crop residue burning has become a major environmental problem.

CSE analysis shows that PM emissions from crop burning in one year are more than 17 times the total annual particulate pollution in Delhi from all sources—vehicles, industries, garbage burning, etc. Similarly, the total national annual emissions of CO_2 from crop residue burning are more than 64 times the total annual CO_2 emissions in Delhi.[11] For SO_2, the total national annual emissions from crop residue burning are about five times the total annual SO_2 emissions in Delhi.[12] Burning of crop residue releases sooty black carbon which is one of the most prominent contributors to climate change. Another study estimated 42,000 premature deaths in 2010 were attributable to crop residue burning alone.[13]

Around 85–100 million tonnes of crop residue is burned across India every year

According to the System of Air Quality and Weather Forecasting and Research (SAFAR), crop residue burning contributed around 10–20 per cent to Delhi–NCR's air pollution during October–November 2019. This rose to

Peak agro-residue burning contributes as much as 44 per cent to pollution in Delhi–NCR

as high as 44 per cent during peak burning days.[14&15] During this period, air pollution in Delhi is about 12–20 times higher than the threshold for safe air as defined by the World Health Organization.[16]

Besides increased levels of PM and smog that cause health hazards, crop residue burning also causes loss of biodiversity of agricultural lands, and deterioration of soil fertility. Further, it is a huge nutrient loss to the farmers as frequent residue burning leads to catastrophic loss of microbial population and reduces the levels of nitrogen and carbon in the top soil profile, which is important for crop root development. It is a huge monetary loss in terms of health impacts on people and soil.

2. Agro-residue generation, theoretical surplus and actual availability in India

Agro-residue or crop residue is the sum total of plant materials left after removal of the main crop. The residue could be of different sizes, shapes, forms, and densities like straw, stalks, leaves, fibrous materials, etc. Crop residue can also be byproducts of the post-harvest processes of crops such as cleaning, threshing, linting, sieving and crushing, e.g., rice husk and sugarcane bagasse.

Crop-wise agro-residue generation

Different crops generate different amounts of gross residue. The proportion of crop yield to residue yield is termed residue production ratio (RPR). For example, a tonne of rice and wheat crop yield generate 1.5 tonne gross crop residue, so their RPR is 1.5.

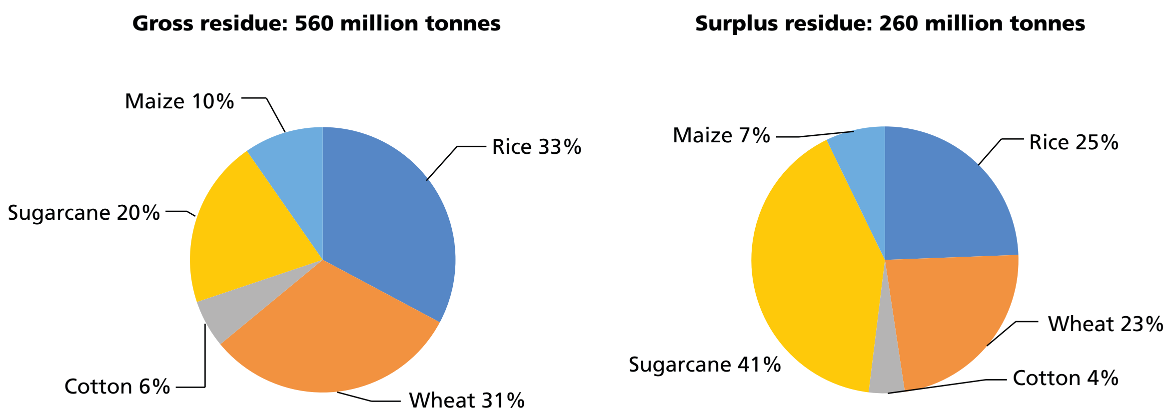
Surplus residue is the residue left after competing uses (such as cattle feed, animal bedding, heating and cooking fuel, organic fertilizer, etc.) are fulfilled. Research suggests that different kinds of crops have different utilizations in terms of fodder, fertilizer, and in households; in turn, their surplus availability varies as well.[17] For example, 60–70 per cent of wheat residue is directly consumed or stored as fodder, whereas for certain rice varieties, use of residue as fodder can be as low as 10–20 per cent. Thus, surplus residue availability may vary from 10–70 per cent depending on other competing uses of a crop. Based on crop utilization in various states, on an average, nearly one-third of gross residue can theoretically be considered surplus residue.[18] Bagasse (sugarcane residue) is considered an agro-industrial waste that does not have any competing use, so, in theory, all of it is considered surplus residue.

In India, one-third of gross residue can theoretically be considered surplus residue

Sugarcane, rice, wheat, maize, and cotton contribute over 90 per cent to India's crop production. Hence, the bulk of India's agro-residue comes from these crops (see *Graph 1: Crop-wise agro-residue generation in India*). As per CSE's analysis of these five major crops for the year 2016–17, India generated around 560 million tonnes of gross agro-residue. Rice (33 per cent) contributed the most to the gross residue, followed by wheat (31 per cent) and sugarcane (20 per cent). The theoretical surplus of 260 million tonnes can be further categorized into: (i) residue left on the field, 140 million tonnes (rice, wheat, cotton and maize) and, (ii) agro-industrial residue of 120 million tonnes (100 million tonnes bagasse, and the rest rice husk and wheat pods).

Graph 1: Crop-wise agro-residue generation in India

Rice, wheat and sugarcane alone contribute nearly 80 per cent of the agro-residue

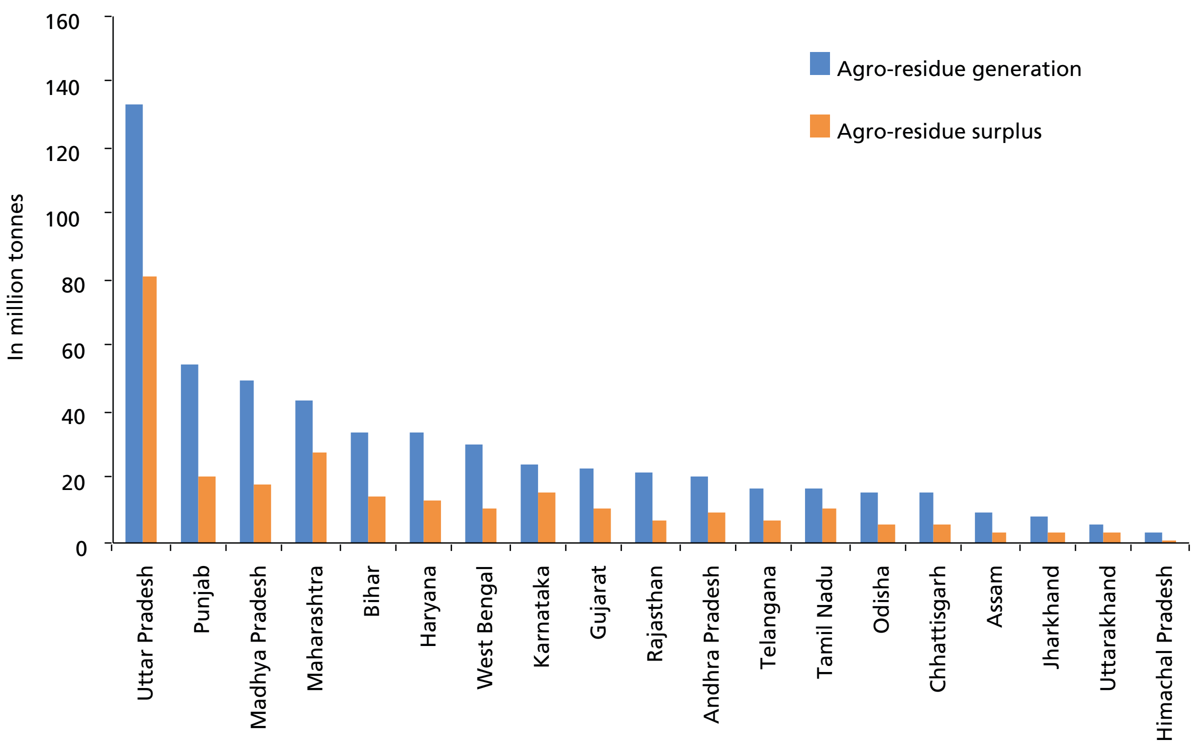


Note: One-third of the gross residue is considered theoretical surplus. For bagasse, gross residue is itself considered as theoretical surplus.

Source: CSE estimate using 2016–17 crop yields of five major crops. Residual production factor from Holdoiet al[19]

Graph 2: State-wise theoretical agro-residue generation and theoretical surplus availability

Uttar Pradesh alone produces one-fourth of India's agro-residue



Note: Since all of bagasse (sugarcane residue) is considered theoretical surplus, while only one-third of the gross residue of other crops is considered theoretical surplus, states with higher sugarcane production will have higher theoretical surplus

Source: CSE analysis based on 2016–17 data from Department of Agriculture

State-wise potential

India is a largely agrarian country with around 50 per cent of its population engaged in farming activities.[20] Uttar Pradesh produces nearly one-fourth (130 million tonnes) of India's total agro-residue. Punjab, West Bengal, Madhya Pradesh, Maharashtra and Bihar are the other top agro-residue producers.

Estimates of theoretical agro-residue generation and surplus availability

As per information available on the Ministry of New and Renewable Energy (MNRE) website, current availability of biomass in India, covering both agricultural and forestry residue, is an estimated 500 million tonnes per year and surplus biomass availability is estimated at about 120–150 million tonnes per year.[21] As per the Central government's biomass portal (biomassportal.gov), surplus biomass availability from agriculture is 145 million tonnes and from forestry it is about 104 million tonnes, which gives us a total of about 250 million tonnes. As per NITI Aayog's *Expression of Interest* (EOI),[22] 620 million tonnes of agro-residue is generated annually in India, based on an estimate for 2014. Thus, the government itself is not able to provide clear figures of biomass availability.

Nearly 550–650 million tonnes of gross agro-residue is generated in India, 160–190 million tonnes is available for bio-energy

In 2018, Technology Information, Forecasting and Assessment Council (TIFAC), an autonomous organization under the Department of Science and Technology, surveyed a total of 662 districts of India. The data collected by the survey covered production statistics from 2010–11 to 2015–16 (based on data availability and accessibility) for eleven selected crops—rice, wheat, maize, sugarcane, cotton, gram, tur, groundnut, mustard, soybean and castor. The study estimated that the total dry biomass generated annually from the selected eleven crops in the three seasons averaged at about 682.61 million tonnes. Rice straw and husk (33 per cent), wheat straw (22 per cent), sugarcane tops and bagasse (17 per cent) and cotton (8 per cent) accounted for almost 80 per cent of the residue among the selected crops. The top five states in terms of biomass generation were Uttar Pradesh, Maharashtra, Madhya Pradesh, Punjab and Gujarat. **It was estimated that 178 million tonnes of surplus crop residue is available in India annually; 26 per cent of the overall identified crop residue generation.**[23] Other research suggests that agro-based residue generation is around 686 million tonnes, out of which 234 million tonnes residue is estimated as surplus for bio-energy generation.[24]

Estimation of actual surplus availability of agro-residue

Based on government data and research estimates, and CSE's own analysis, theoretical availability of surplus residue in India is around 260 million tonnes (100 million tonnes bagasse + 160 million tonnes non-bagasse). It is very difficult to estimate actual surplus availability. Based on use of biomass in power generation, ethanol production, pulp and paper industry and some others sectors, a rough estimate can be obtained (see *Table 1: Current estimates of agro-residue utilization in India*). This estimate is around 160–190 million tonnes—a huge resource for the country.

Table 1: Current estimates of agro-residue utilization in India

Actual estimates are difficult to determine, so rough estimates have to suffice

	Bagasse	Other agro-residue	Total
	In million tonnes		
Theoretical generation (approximate)	100	470	570
Theoretical surplus availability	100	160	260
Utilized in bagasse cogeneration	40–50		
Utilized in biomass power plants		4–6	
Utilized in industrial sector (MSME)		5–10	
Utilized in pulp and paper sector	5–7	1–2	
Utilized in other areas (ethanol production, mushroom cultivation and upscale products)	10–20	1-2	
Total utilization	55–77	11–20	66–97
Actual surplus availability	23–45	140–149	163–194

Source: CSE analysis

3. Agro-residue for power: How can it be a win-win situation?

Stubble burning is a major source of pollution in Northwest India. To deal with this problem, significant investments are required in the form of direct capital and as subsidy to improve farming practices, set up costly biomass plants, or find other uses for agro-residue. This economic support has to be a continuous intervention.

On the other hand, it is also a well-established fact that even with the rapid growth in the renewable sector, India has to continue its reliance on coal to meet its base load demand. Coal-based power plants are resource-intensive and add up to a significant pollution load on the environment. Many of these power stations have become old and will be shut down due to their higher emissions, and replaced with new plants using cleaner coal technology. The dilemma for India is that at a time when countries around the world have stopped investing in new coal power plants, will it be prudent for the country to replace old coal power plants with new ones?

It is clear that standalone solution to these two problems (stubble burning and use of coal to generate power) will burn a hole in the exchequer's pocket, and even after that, returns on investment cannot be guaranteed. But what if we were to see the broader picture and make one problem the solution to the other problem? This can be achieved by identifying older units operating at a satisfactory efficiency within safe operating parameters, and promoting co-firing of biomass in them—a cost-effective method to address pollution as well as a clear climate change mitigation strategy.

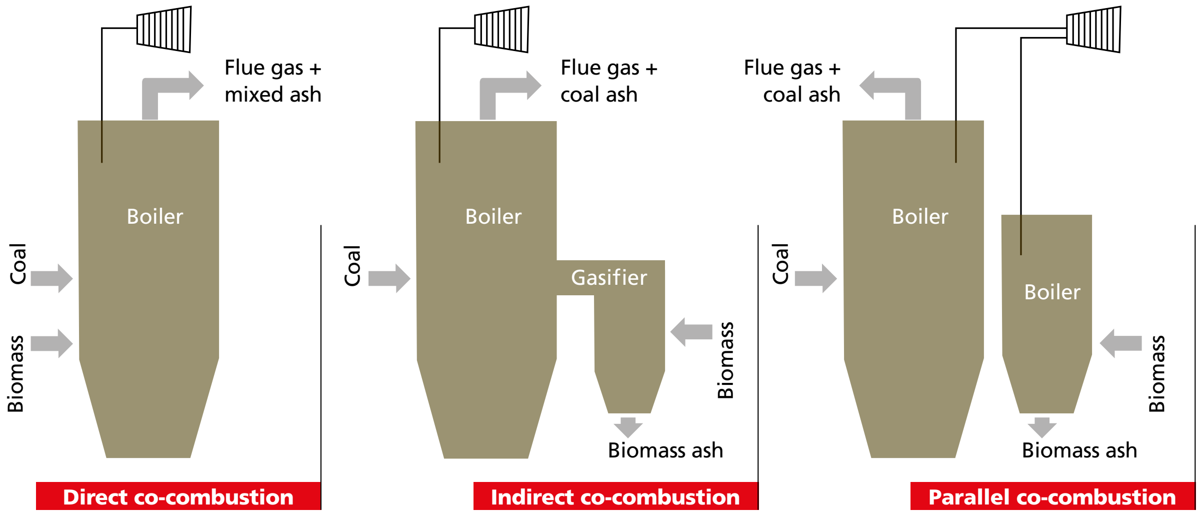
Stubble burning and coal power plants are the two major contributors to air pollution, especially in Northwest India

What is biomass co-firing?

Co-firing is the process of utilization of a certain portion of biomass with the existing base fuel. Currently, three co-firing technologies are widely used in coal plants: direct co-firing, indirect co-firing, and parallel co-firing. Co-firing is direct when biomass and coal are fired in the same boiler; and indirect when combustion or gasification of biomass occurs in a separate unit (see *Figure 1: Various methods of biomass co-firing*).

As biomass enters the coal boiler, some technical issues may arise, depending on its properties and the boiler type. However, direct co-firing has been undertaken in stoker, cyclone, fluidized bed combustion (FBC) and pulverized coal combustion (PCC) boilers. FBC boilers are designed to utilize a wide variety of fuels, hence they are technically much more suited to co-firing very high percentages of biomass.

Figure 1 : Various methods of biomass co-firing



Source: Gil, María V., and Fernando Rubiera, 2019

Major drivers of biomass co-firing in coal power plants

Replacement of coal with agro-residue in power generation can result in a sharp decrease in the pollution load, especially in regions where agro-residue burning is prevalent. Firstly, it will directly reduce crop residue burning. Secondly, it will directly reduce the equivalent emissions from existing coal use. Thirdly, when agro-residue is burnt in power plants in controlled conditions in the presence of pollution control technologies, emissions of PM, SO_2, NO_x and CO will significantly decrease. It can save susbtantial investment in new biomass power plants and coal power plants by renovating old power plants at a minimum cost.

Key drivers of biomass co-firing are as follows:

I. Initial capital investment

Biomass co-firing banks on existing investment and infrastructure at coal-fired power plants and incurs only relatively modest retrofitting cost. Retrofitted boilers can fire biomass when supplies are plentiful but switch back to coal when supplies are low. The major driver of this initiative will be the capital cost requirement per MW. At lower co-firing ratios of 5–10 per cent, there is no or miniscule capital cost and even for higher co-firing ratios, the cost will be just 10–20 per cent of a standalone biomass plant.

The major driver of biomass co-firing will be the lower capital cost per unit power

II. Efficient burning for biomass

Co-firing increases efficiency of biomass–energy conversion, by firing in a larger plant that can accommodate superheaters, economizers and reheaters compared with a smaller plant firing biomass alone. Biomass co-firing has little or no-impact on the efficiency of existing power plant operations. Thus, they operate at an efficiency of 34–38 per cent in comparison with 24–30 per cent efficiency of biomass power plants.

III. Mechanism for extending life of existing power plants

Co-firing has played an important transitional role in the decarbonization of the coal fleet and has extended the lives of power plants in Europe, USA and UK.

IV. Breaking supply chain constraints for biomass utilization

Transportation constitutes a significant portion of the total cost of biomass utilization. Biomass needs to be shredded onsite before transportation to increase its density. Transportation in any form over more than 50 km becomes unviable for a 10–15 MW biomass plant. This is not a constraint for bigger coal power plants where biomass can be used in co-firing. Economies of scale and the comparative cost of transporting coal and biomass tilt the balance in favour of the latter in such cases.

A major constraint in the use of biomass is the non-availability of agro-residue around the year. Since agro-reside is generated at a specific time in the year, i.e., at the time of harvest, it can be procured in bulk only at that time. However, smaller industries or biomass power plants do not have the capacity to buy or pre-order in large quantities. In turn, this affects the biomass procurement capacity of pellet or briquette manufacturers since they have limited working capital available. It is possible to have a perennial biomass supply chain, but that will make it costlier than coal. By paying higher and fixing contracts with pellet manufacturers, availability of sufficient working capital to procure the required biomass and to store it for round-the-year use can be made possible. At lower co-firing ratios (0–10 per cent), the variation in the cost will be too little to matter, but it will keep increasing as the co-firing ratio goes up. A higher co-firing ratio will require government support in terms of subsidy or other incentives as received by renewables, or the additional cost will need to be passed on to consumers through tariffs.

Co-firing has played an important transitional role in reducing the carbon footprints of the coal fleet in Europe, USA and UK

V. Tackling pollution as well as climate change simultaneously

One of the key drivers of the introduction of biomass co-firing to conventional coal-fired power stations was its potential to reduce CO_2 footprints of the sector. It can help meet climate change mitigation targets as well as pollutant compliance regulations.

CO_2

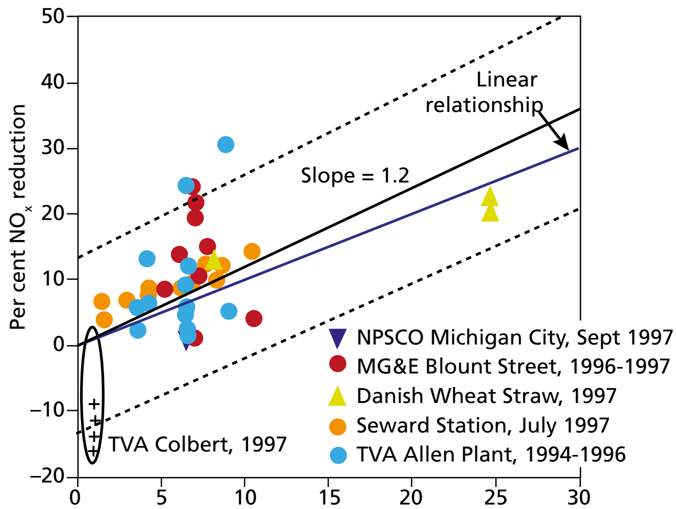
The greatest advantage of biomass co-firing is that it reduces CO_2 emissions. Co-firing is a cheap and quick method to achieve modest scaling-down of CO_2 emissions at a coal-fired power plant. The calorific value of agro-residue pellets is comparable to Indian coal. Thus, technically, it can directly reduce CO_2 emissions equivalent to the coal it replaces. However, since biomass supply has higher transportation footprints with respect to coal because of its scattered availability, for 10 per cent biomass co-firing, CO_2 emissions reduction may be slightly lower (than 10 per cent), depending on the distance over which it needs to be transported.

NO_x

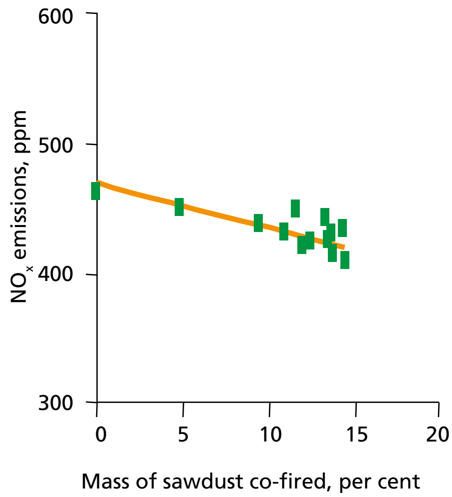
NO_x emissions from biomass co-firing are difficult to predict because they vary depending on the type of biomass, and the firing technology (boiler or

Graph 3: Reduction in NO_x levels at different co-firing percentages

Inherent nitrogen in the fuel and thermal NO_x determine the final NO_x content in emissions



Source: NREL, 2002



Source: IEA, 2012

NO_x and SO_2 emissions decrease with increase in blending percentage

burner) and operating conditions. NO_x content in the emissions is due to two factors—inherent nitrogen in the fuel and thermal NO_x. Different types of biomass can have higher or lower nitrogen content with respect to coal. While burning biomass, a greater proportion of nitrogen is released as volatile compounds, thus results in lower NO_x emissions. Thermal NO_x emissions concentration is dependent on the combustion temperature. The moisture content in biomass can lower peak flame temperatures and, thus, thermal NO_x. As per research studies, NO_x emissions from biomass firing tend to decrease linearly with respect to the blending percentage.[25]

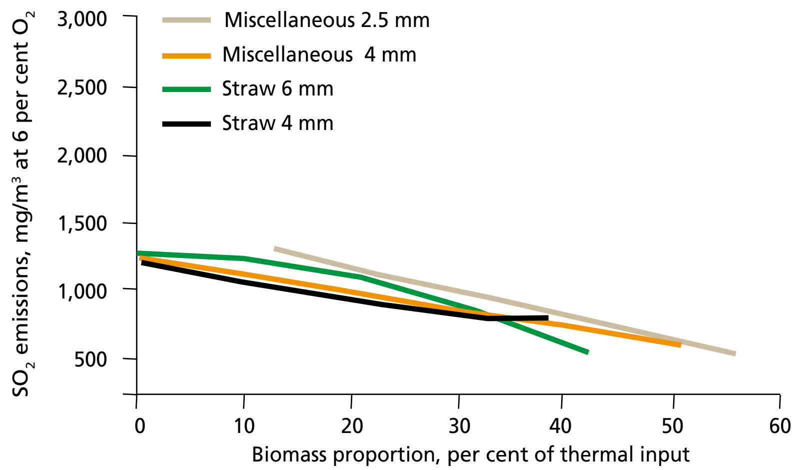
SO_2

SO_2 emissions depend solely on the sulphur content in the fuel. Agro-residue has much lower sulphur content (0–0.2 per cent) with respect to coal (0.3–0.7 per cent). Moreover, biomass ash contains higher levels of alkali and alkaline earth compounds than coal ash and can retain a greater fraction of sulphur. The proportion of sulphur retained typically increases from 10 per cent in coal ash to 50 per cent in pure biomass ash.[26] Biomass co-firing can, therefore, significantly reduce SO_2 emissions (see *Graph 4: Reduction in SO_2 emissions with different types of biomass*).

CSE estimate of overall emissions reduction estimation potential of biomass co-firing

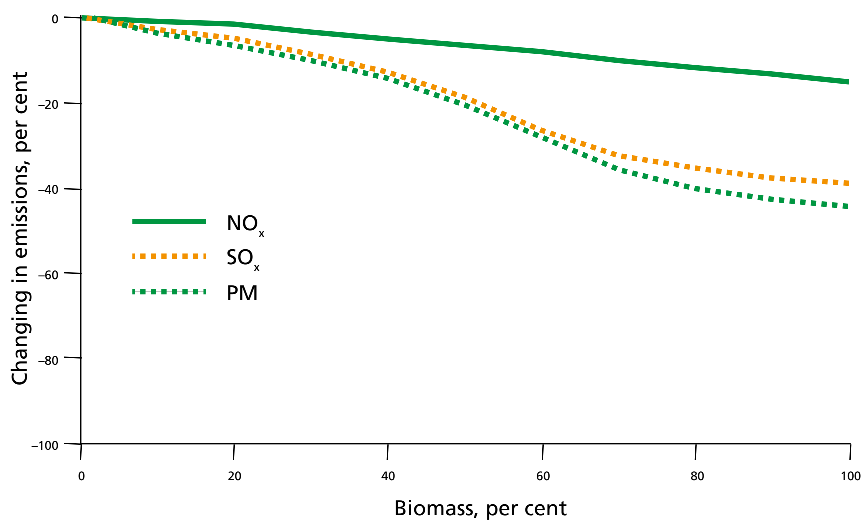
When 100 million tonnes of crop residue burns in the fields, it releases approximately 140 million tonnes of CO_2, 5.8 million tonnes of CO and 1.1 million tonnes of PM. Various scenarios of agro-residue utilization yield between none to almost 100 per cent use potential (see *Table 2: Percentage reduction in CO_2 and other pollutant load when agro-residue is burnt in thermal power plants* and *Graph 6: Impact on CO_2 and other emissions under various agro-residue utilization scenarios*).

Graph 4: Reduction in SO_2 emissions with different types of biomass
SO_2 emissions depend solely on the sulphur content in the fuel



Source: IEA, 2012

Graph 5 : Average emissions impact of co-firing biomass with coal
Emissions levels of key pollutants decrease with biomass co-firing



Source: Demirbas, 2005

As per our estimate, the impact on emissions from the baseline under different agro-residue utilization scenarios will be:

- CO_2 emissions will decrease by up to 47 per cent
- PM emissions will decrease by up to 73 per cent
- SO_2 emissions will decrease by up to 98 per cent
- CO emissions will decrease by up to 99 per cent
- NO_x emissions may decrease by up to 5 per cent (NO_x emissions reduction is dependent on the firing technology and properties of the biomass used.)

Table 2: Percentage reduction in CO_2 and other pollutant load when agro-residue is burnt in thermal power plants

The potential of reducing CO_2 and other pollutant load through biomass co-firing is immense

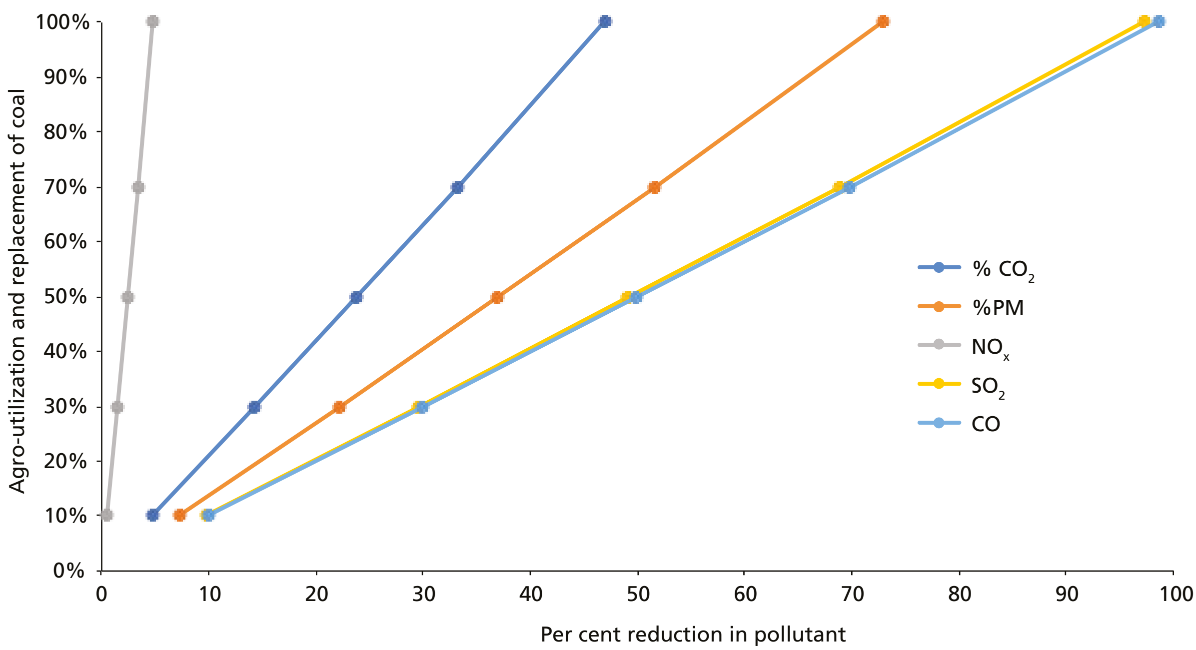
Scenario	Quantity	CO_2*	PM	NO_x	SO_2	CO
Emissions from crop residue (million tonnes) (uncontrolled)	100	140	1.1	0.05	0.01	5.8
Emissions from coal (with equivalent calorific value) burnt in power plants (million tonnes) (controlled)	90	126	0.34	0.45	0.68	0.02
Total existing pollution load		266	1.44	0.50	0.70	5.82
Emission from biomass used in replacing coal in power plants (controlled)	100	140	0.38	0.48	0.01	0.03
Maximum GHG and pollution reduction possible (per cent)		47.4	73.6	4.81	98.3	99.6

*For this calculation, agro-residue burning is not considered carbon neutral.

Source CSE analysis

Graph 6: Impact on CO_2 and other emissions under various agro-residue utilization scenarios

Various scenarios of agro-residue utilization yield between none to almost 100 per cent use potential



*For this calculation, agro-residue burning is not considered carbon neutral.
*NOx emissions reduction is dependent on the firing technology and properties of the biomass used.
Source: Centre for Science and Environment,2020

VI. New source of income for farmers and employment generation

The average pellet and briquette manufacturers' factory-gate price of agro-reside is between Rs 2–2.5 per kg (Rs 2,000–2,500 per tonne). These prices vary significantly with different varieties of crop residue. The main components of this cost are labour cost for collection of agro-residue from the fields, its loading–unloading and transportation. Farmers may earn between Rs 500–1,500 per tonne of crop residue after deducting the labour and transport

Table 3: Pellet and briquette manufacturers' purchasing cost for agro-residue at the factory gate

Prices vary significantly with different varieties of crop residue

Crop residue	Rs per tonne of agro-residue (including transportation and labour cost)
Mustard	2,700–2,800
Paddy straw	1,250–1,300
Wheat	3,100–3,200
Cane trash	1,800–1,900
Maize	2,200–2,300
Cotton	2,200–3,400

Source: Data collected from briquette and pellet industry units by CSE

cost. Moreover, pellet manufacturing, storage, handling and transportation generates employment in rural areas.

Global progress on biomass co-firing

Biomass co-firing can be considered a transitional option towards a completely carbon-free power sector. According to the International Energy Agency's (IEA) *Roadmap on Biomass Heat and Power*, biomass-based power generation will increase by at least a factor of ten from today until 2050, accounting for 7.5 per cent of the global electricity generation. For the foreseeable future, this biomass-based power generation will be almost entirely based on combustion and co-firing technologies.[27]

To promote biomass co-firing, European countries and US offer policy incentives or have mandatory regulations to increase share of renewables in the electricity sector. Currently, 230–250 power and combined heat and power plants using co-firing techniques are in operation, a significant portion of them in Europe. Apart from UK, Denmark, Germany and Netherlands, many other European countries such as Finland, Sweden, Russia, Belgium, Austria, Hungary, Italy and Spain are using biomass co-firing technologies in their power plants. All major coal-fired power plants in UK have adopted biomass co-firing. Currently, 86 out of 560 coal-fired power plants in the US use biomass co-firing technologies and this number is expected to increase in the coming years. A number of Asian countries such as Japan, China and South Korea have already adopted co-firing technologies. In 2018, a 50 MW (84 per cent co-firing) circulating fluidized bed (CFB) plant was installed at Mombetsu, Japan. Another, 112 MW thermal power plants was commissioned at Hibikinada in 2019. At this plant, coal and wood pellets are separately pulverized and fed into the boiler. Its biomass blend ratio is approximately 30 per cent.[28]

Leapfrogging to a higher biomass ratio can greatly benefit older units

Biomass production and trading have also increased in countries where new investors are becoming more interested in investing in biomass co-firing. China, the world's largest agro-residue generator, has drafted extensive policy to manage it. The country's predominant focus has been on biogas and co-firing.

Torrified pellets for biomass waste utilization

Torrified biomass pellets are regarded as one of the most efficient biofuel manufacturing processes to produce coal substitutes. In the torrification process, biomass is processed at temperatures of 250–350°C in the absence of oxygen, decomposing the biomass while preserving its energy content. The result? Energy density of the torrified biomass in pellet or briquette form is much higher than other solid biomass forms. A variety of biomass can be utilized in existing coal power plants in the form of torrified pellets.

Table 4 : Status of biomass co-firing in different countries

Many European countries, as well as US, China and some other Asian countries have taken giant leaps in this field

Country	Policies	GHG emissions reduction target	Biomass utilization Target	Number of co-firing plants	Average co-firing mixing rates	Co-firing methods	Boiler type	Primary feedstock	Future outlook
Nether-lands	MEP (6.5 cents/kWh wood pellet subsidy), SDE (successor of MEP) and Energy Accord	30 per cent decrease from 1990 emissions by 2030	30 per cent replacement of fossil fuels with biomass (long-term)	10	5–34 per cent biomass	Direct and indirect	Pulverized coal boiler, fluidized bed cyclones and grate	Imported wood pellets, palm kernel shells, waste wood and cocoa shells	Decreased subsidies, lack of funding and expensive international imports make it economically less viable
Denmark	Green Growth Plan, Renewable Energy Act (2 c/kWh subsidy) and Public Service Obligation	20 per cent GHG reduction in 2020 compared to 2005	30 per cent renewable energy in total consumption by 2020; 100 per cent renewable energy supply by 2050	7	5–100 per cent biomass (100 per cent for parallel boilers)	Direct and indirect	Pulverized coal boiler and fluidized Bed cyclones	Straw, and wood pellets, chips and waste	Co-fired plants may fully transfer to biomass plants in the near future. International import costs will still be a problem
UK	Renewable Obligation, Energy Crop Scheme, Climate Change Act, Energy Act, Climate Change Levy, Feed in Tariffs, Contract for Difference and Carbon Price Floor	30 per cent decrease from 1990 emissions by 2030; 80 per cent decrease from 1990 emissions by 2050	15 per cent renewable share by 2020	14	3 per cent by heat input	Direct	Pulverized coal boiler	Wood pellets, miscanthus, short rotation coppice, and olive and palm residues	Coal-fired plants may switch to dedicated biomass to remain operational and receive subsidies.

Country	Policies	GHG emissions reduction target	Biomass utilization Target	Number of co-firing plants	Average co-firing mixing rates	Co-firing methods	Boiler type	Primary feedstock	Future outlook
Japan	New Renewable Energy Target, Support for Deployment of Renewable Energy, Renewable Portfolio Standard, the Cool Earth Energy Innovation Technology Plan	3.8 per cent reduction from 2005 levels by 2020; 80 per cent decrease from 1990 emissions by 2050	NA	13	Mostly 3 per cent by mass; up to 85 per cent in new plants	Direct	Pulverized coal boiler, fluidized Bed cyclones, and IGCC	Wood pellets	47 new coal-fired plants are either in planning, construction, or environmental assessment
Brazil	Pro-Alcool	Intended reduction of 43 per cent by 2030	45 per cent share of renewables in the energy mix by 2030	NA	Expected 30 per cent share of biomass on heat basis	NA	Test run in pulverized coal boilers	Rice straw	Co-firing is still in the early stages
US	225 incentive programmes that promote biomass in the industrial sector, but none of them are specific to co-firing	Reduce net GHG emissions by 17 per cent from 2005 levels by 2020	Increase non- hydro renewables generation to 20 per cent of total electricity by 2030	86	Typically around 5 per cent on energy basis	Direct	Stoker, pulverized coal boiler, and fluidized bed cyclones	Wood pellets, chips and wastes, and railroad ties	Biomass is expected to be 6.4 per cent of the targeted 15 per cent Renewable Energy Stand by 2020 according to JP Morgan
Germany	Renewable Energy Sources Act and Electricity Feed-In Act	Cut down 80–95 per cent GHG emissions compared to 1990 levels	35 per cent renewable energy share by 2020	31	5–20 per cent	Direct	Stoker, fluidized bed cyclones, dry bottom and wet bottom	Sewage sludge, straw, waste wood and organic residue	Has begun shifting away from dedicated energy crops to biomass from waste organic residues

Source: Roni et al, 2017

Co-firing percentages of 5–10 are well tested and can be adopted without major modifications and additional investment. Many plants across the world have adopted co-firing of up to 20 per cent with minor modifications and little investment. However, very few plants have gone beyond 20 per cent co-firing because of technical issues that arise due to differences in fuel composition and other operational issues. These issues may be of less importance if a power plant is approaching the end of its operating life.

4. Implementation of biomass co-firing

There are three major points of interest regarding implementation of biomass co-firing in thermal power plants: modifications required in the existing setup, impact on various performance parameters, and data on actual implementation from plants that have adopted co-firing.

Modifications required in the existing plan

The delivery, storage and handling of biomass pose challenges different from those posed by coal for the following reasons:

- Due to its geographically scattered availability, it is mostly transported on trucks
- Low density and high volume require comparatively larger storage areas that should be covered because of hygroscopic nature of biomass
- High flammability and high abrasion resistance requires dedicated fire prevention and suppression systems
- Increased fire risk from pellets may also require large-scale dust extraction systems to minimize the hazard
- Covered conveyor and storage facilities are required to minimize the spread of dust for prevention of fire and to protect biomass from ingress of water, which reduces the quality of the fuel

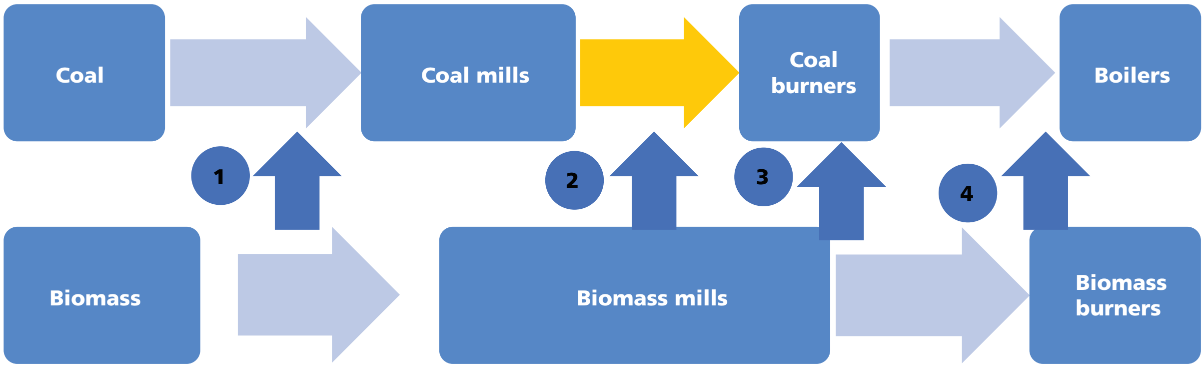
Trials at existing power stations suggest that existing infrastructure is sufficient for low co-firing ratios (< 10 per cent). Modifications to existing infrastructure and operations might be required depending on the nature of the biomass utilized, the co-firing ratio and the delivery method. Several modifications to existing coal plants might be required based on the above parameters. These include:

- Dedicated covered storage areas
- Modified fuel feeding systems
- Modified or new milling equipment
- Modified or new combustion systems
- Possible boiler modifications
- Modifications in existing emissions control technologies

Storage, handling and transportation of biomass require more attention than coal

There are five possible ways to utilize biomass at coal-based power plants (see *Figure 2: Ways to utilize biomass in coal-fired boilers* for four of these five options). Option 1 is the co-milling of coal and biomass in an existing coal mill and the use of coal combustion infrastructure. Maximum achievable co-milling ratio is determined by the design of the coal mill and achievable throughout the mill. Typically, less than 10 per cent biomass (on an energy basis) can be utilized in this way.

Figure 2 : Ways to utilize biomass in coal-fired boilers



Source: Ben Dooley and Patrick E. Mason, 2018

Option 2 requires investment in dedicated biomass mills after which biomass can be mixed with coal at several locations. Biomass is fed into the main coal feed after the mill and before it is split and fed to each burner. This option requires minimal modification to existing post-mill coal infrastructure, helping to reduce conversion costs. Co-firing ratios of up to 50 per cent (on an energy basis) may be achieved without modification to the burner if the correct biomass fuel is chosen. However, this may require further pilot studies to increase the co-firing ratio progressively.

Co-firing of up to 5–10 per cent biomass requires nominal additional investment and has negligible impact on plant performance

Option 3 requires separate biomass mills, mixing of biomass locally and feeding it into a modified burner which can help prevent any potential feed-in issues using existing coal infrastructure. This option requires the installation of new biomass pipe work in each burner and also modification of the burner, all of which increases the cost.

Option 4 requires new dedicated biomass burners that need to be added to existing boilers. The new burners must sit within existing burner belts—a difficult proposition as it requires penetration of the existing boiler system. In addition, new and extensive air and fuel infrastructure is required to supply the new burners. The operation of the boiler may be negatively impacted due to the changes in operational behavior and slagging and fouling may become an issue.

Option 5 requires conversion of existing units into 100 per cent biomass plants. Doing so will require changes in existing mills, burners and boilers. Converting such large units into 100 per cent biomass plants might face supply chain constraints.

Impact on critical parameters[29]

The majority of biomass fuels tend to be relatively rich in alkali metals, especially potassium. In some cases, they are rich in phosphates. They have higher moisture content, relatively high chlorine content, and relatively low sulphur and ash contents. The impact of these parameters on various power plant performance parameters can be discussed as follows.

Co-firing at higher biomass ratio can provide economic as well environmental benefits

Boiler efficiency

Lower energy density of biomass may pose limitations in existing fuel handling systems; for example, conveyors, mills or primary air pipe work can reduce the primary energy delivered and, hence, the boiler output. In addition, increased propensity for slagging and fouling at co-firing ratios greater than 10 per cent can also decrease heat transfer in the boiler. However, as the co-firing experience in existing power stations demonstrates, this increased risk can be managed without any loss of boiler performance.

Particulate matter and fly ash

Most biomass fuels have lower ash content than typical coals. Still, it is difficult to predict the PM and fly ash generation. The effect is site-specific, and depends on the type of biomass and the performance of the installed particulate collection equipment. The concentrations of some trace elements can be significantly higher in certain biomass materials than in coal. However, there is no evidence that these elevated levels have led to compliance issues in existing plants that have switched to co-firing.

Biomass fly ash behaves differently from coal ash. Biomass ash can have electrical properties that reduce effectiveness of electrostatic precipitators (ESPs) in capturing fine particles from the fuel (flue) gas stream. Modifications in ESP operations may be required to mitigate this effect at higher co-firing ratios.

Impact on fly ash properties

Thermal power plants are required by law to ensure 100 per cent utilization of the ash they produce. Potential uses of fly ash and bottom ash depend on their composition. Coal ash is already in demand for various applications. Co-firing coal and biomass should also allow use of the ash in a similar manner. Experts believe that up to 10 per cent co-firing will only have a minor impact on fly ash properties. However, at higher co-firing ratios, fly ash should be tested or analyzed on a case-by-case basis depending on chemical characteristics of the co-fired biomass.

In fact, in some respects, biomass fly ash outperforms coal fly ash. Biomass enhances the pozzolanic reaction (CaOH with fly ash) significantly, presumably because it contains amorphous rather than crystalline silica, the former reacting more readily with CaOH in the mix. This reaction ultimately improves the strength of the concrete beyond that developed by cementitious reactions. Experimental studies have shown that biomass-containing fly ash is superior to pure coal fly ash. Other studies indicate only a modest impact of biomass-containing fly ash on concrete properties, with an increased aerating agent requirement being one issue needing further attention. Otherwise, biomass-containing fly ash qualitatively behaves similar to coal fly ash.

It is essential that Bureau of Indian Standards (BIS) analyze and define fly ash quality standards at various co-firing ratios so that fly ash can be utilized in the construction sector. Biomass ash may have more widespread applications, including as a soil improver and fertilizer, adsorbents and as a source of high value char.

Fouling and slagging is a major issue, but can be tackled

Most biomass fuels tend to have higher proportions of alkali materials such as potassium. They are also rich in chlorine, silicon, aluminium and calcium. These elements tend to form solid-phase mineral deposits. Potassium, in combination with these elements, has the effect of reducing the melting temperature of ash deposits. The majority of potassium in coal ash is not considered volatile. In biomass, however, potassium is the dominant alkali metal and does volatilize. Hence, fouling indices for biomass are based on total alkali content. Apart from reducing the effectiveness of heat transfer and boiler efficiency, severe fouling may require more frequent or longer maintenance shut downs for removal of deposits. Depending on the type of biomass fuel used and the composition of the ash, the proportion of co-firing may be limited by the need to control fouling (or slagging).

European experience suggests that slagging and fouling are unlikely to be a problem for co-firing ratios of less than 10 per cent. Clearly, issues related to slagging and fouling must be considered when co-firing at higher biomass ratios. At higher co-firing ratios, pilot experiments need to be carried out with respect to the chemical composition of the agro-residue to predict fouling levels.

Co-firing in old power stations

In India, older units are retired based on a combination of one or more of the following factors:

- If they are more than 25 years old
- If they are unsafe to operate
- If they have poor efficiency, high coal consumption and high CO_2 emissions (15–25 per cent higher than new plants)
- If they emit high levels of SO_2 and NO_x due to absence or non-viability of pollution control technology
- If cooling towers to reduce water consumption are absent or non-viable

In India, the safe operating life of a power plant is considered to be 25 years. But experts believe that 25 years should not be used as a direct benchmark as a number of coal-fired plants operating across the world are as old as 40–50 years. The operational life of a plant is greatly dependent on the quality of operation and maintenance. Even in India, units do invest in renovation and modernization, and life extension projects to extend the life of power plants beyond the operating life of 25 years. Under such circumstances, retiring plants at the age of 25 can have an impact on cost recovery and financial sheets of distribution companies (discoms). It would be unwise to retire an old unit working safely and efficiently, unless other reasons push it towards retirement.

It is unwise to retire old power plants that are efficient and safe to operate

Other reasons for retirement can be higher CO_2 emissions in comparison to new clean coal technology plants and not meeting environmental compliance standards. New supercritical plants have an average efficiency of 38–40 per cent whereas old units can have efficiencies in the range of 32–36 per cent. In terms of CO_2 emissions, new supercritical and ultra-supercritical units will have CO_2 emissions in the range of 750–850 g/kWh in comparison to 950–1,100 g/kWh in older units using subcritical technology. Clearly, an older unit will emit 15–25 per cent higher CO_2 per unit of electricity generated if it is not replaced with new efficient units. With the introduction of new environmental

Higher biomass co-firing can bring down specific CO_2 emissions of older plants to levels below those of new coal plants

norms in 2015, plants need to make huge investment in reducing their PM, SO_2 and NO_x emissions. Additional investment in older units for pollution control means that these units need to be operated for more years to recover the cost. This investment will ensure compliance with standards for critical pollutants from older units but questions about high CO_2 emissions will still remain. Question about high CO_2 emissions will become more prominent as countries are rapidly retiring their coal capacity.

Economics of biomass co-firing

The cost of conversion of coal power plants is dependent on biomass co-firing ratios and the technological choices made in each individual case. Recent estimates of the CAPEX for co-firing have reduced by 40 per cent and for full conversion by 48 per cent since 2011.[30] CAPEX costs include pre-development and construction costs including boiler modifications, construction of biomass storage facilities and modifications in the material handling system. The OPEX costs comprise mainly of fixed and variable operation and maintenance costs, insurance, labour and use of service (UoS), which is the use of the transmission network. The majority of the OPEX cost is associated with labour requirements for operation of the plants.

To assess the cost impact and benefits achieved, we have analyzed two scenarios. The first scenario is illustrated through a new 800 MW supercritical unit and the second scenario is illustrated through four old units of 200 MW each. The units are shifted to biomass co-firing at different co-firing ratios.

A new supercritical or ultra-supercritical plant has a capital cost of around Rs 4–6 crore per MW, and is equipped with flue gas desulphurization (FGD) and selective catalytic reduction or selective non-catalytic reduction (SCR/SNCR) to meet stringent pollution norms. All this cost amounts to around Rs 4,500–5,500 crore for an 800 MW supercritical or ultra-supercritical plant. If installed today, such a plant will need to be run till 2050 or more to recover the cost. Recovery is getting progressively difficult due to continuously falling plant load factor of coal power plants with rapid growth in the installed renewable energy capacity. The new coal plant will replace an older one with carbon footprints of 1,000 gm/kWh, and will have 15–25 per cent lesser carbon footprints with respect to the older power station.

In the second scenario, if we renovate an old power station for biomass co-firing, we minimize the investment made and maximize the benefits achieved. For example, an older plant with CO_2 emissions of 1,000 g/kWh, through 50 per cent co-firing, can effectively bring down its specific CO_2 emissions to 600 g/kWh, which is 10–20 per cent lesser than the specific CO_2 emissions of a supercritical or ultra-supercritical plant. With that, units can also achieve significant reduction in their SO_2, NO_x and even PM emissions levels without a lot of additional investment. SO_2 and NO_x emissions reduction will be based on the proportion of biomass co-firing, existing coal quality and emissions. A power plant utilizing coal with a sulphur content of around 0.4 per cent can even meet sulphur emissions norms through leapfrogging co-firing percentage from 10 to 40–60 and, hence, avoid investing in FGD. Similarly, NO_x emissions can also be reduced in proportion with biomass

Table 5 : Economic analysis of new plants vs co-firing scenario in old units

Although new power plants improve performance significantly, the cost is heavy. Co-firing, on the other hand, provides many benefits at low cost

Parameter	New plant (800 MW)	Co-firing percentage (in four units of 200 MW each)		
		10	25	50
Capital cost	Hard cost = Rs 4, 600 crore	Biomass storage = Rs 10 crore	Biomass storage = Rs 50 crore Biomass mills = Rs 25 crore	Biomass storage = Rs 50 crore Biomass mills= Rs 25 crore Biomass burners = Rs 25 crore
Pollution control technology cost	FGD = Rs 320 crore SCR = Rs 200 crore	FGD or DSI cost = Rs 40 crore SCR or SNCR = Not required	FGD or DSI cost = Rs 40 crore SCR or SNCR = Not required	FGD = Not required SCR or SNCR = Not required
Total capital cost	Rs 5,250 crore	50 x 4 = Rs 200 crore	75 x 4 = Rs 460	~ 100 x 4 = Rs 400
SO_2 reduction	Will meet emissions standards	10 per cent direct reduction	25 per cent reduction	50 per cent reduction can meet SO_2 emissions standards
NO_x reduction	Will meet standards only if SCR installed	Meeting 600 mg/Nm^3 NO_x standards, additional 0–5 per cent reduction possible	Meeting 600 mg/Nm^3 NO_x standards, additional 0–5 per cent reduction	Meeting 600 mg/Nm^3 NO_x standards, additional 0–5 per cent reduction
CO_2 footprints	750–850 g/kWh	900–1,000 g/kWh	750–800 g/kWh	500–600 g/kWh
Tariff (Rs/kWh)	Fixed cost = Rs 2.57 Variable cost = Rs 1.45 Total tariff = Rs 4.04	Fixed cost = Rs 0.89 Variable cost = Rs 1.99 Total tariff = Rs 2.89		
Return on investment	20–25 years	5–10 years		

Source: CSE analysis

co-firing. As per a CSE analysis in Maharashtra, UP and Madhya Pradesh, some of the older units are able to meet applicable NO_x emissions standard of 600 mg/Nm^3; through biomass co-firing they would be able to achieve additional reduction in NO_x emissions levels based on co-firing percentages.

Case studies on biomass co-firing

Drax Power Plant, United Kingdom[31]

Drax initiated its co-firing pilot in 2003.Trials began using a wide variety of biomass. Biomass was used in the form of pellets, stored in covered sheds and added to the coal conveyors, and processed through the existing coal milling and combustion system with little or no modification. Drax was able to achieve 10 per cent co-firing, further addition was restricted by the biomass reception, handling and mixing system.

100 per cent biomass firing or complete conversion of a coal power plant to a biomass plant

It should be noted that most power plants that reached 100 per cent biomass firing use wood pellets or torrified pellets. The properties of wood or torrified pellets are similar to coal, thus, even at 100 per cent biomass firing, huge investment in modification can be avoided. Further, supply chains are a major issue for biomass, and most of these plants are importing wood pellets from different countries. Thus, a 100 per cent biomass plant raises eyebrows of environmental experts. Because of their excessive use of wood pellets and the questionable sustainability of supply chains, their actual GHG emissions reduction impact is debatable.

In case of India, we have not promoted the use of wood pellets in coal power plants, and co-firing agro-residue at higher percentages will certainly pose technological challenges due to difference in chemical composition vis-à-vis coal. We can't afford to import biomass pellets. Torrified pellets can be game changing for biomass co-firing in India.

In 2005–06, a dedicated biomass hammer mill was installed and the milled biomass was added to the milled coal and combusted in existing coal burners. Between 2007 and 2010, this system was extended to all six generating units and improvements to the rail reception, storage and conveying systems were included in it.

Over the period 2010–17, Drax converted three of its units to firing 100 per cent wood pellets with further upgradation in biomass reception storage and handling systems, conversion of existing vertical spindle, ball and ring coal mills and the installation of new biomass burners. The majority of the wood pellets are delivered by train and fed either directly into the generating units or stored in one of four newly installed large storage domes. Each of the domes has a 75,000-tonne capacity, enough to supply the three converted units for four days. The domes include nitrogen purge systems and CO_2 extinguishing systems to mitigate the increased fire risk associated with biomass. The maximum power output of the three converted units and the overall cycle efficiency of the station has not been adversely affected by firing biomass.

Brief on some other plants in Europe[32]

- The iron bridge plant in UK attempted to modify existing large ball and tube mills for biomass co-firing but found that new hammer mills were required. They also modified existing coal burners to run on 100 per cent biomass.
- The Amer plant in the Netherlands has also undergone several modifications. Amer 8 plant has dedicated hammer mills and biomass boilers while Amer 9 plant uses existing modified coal mills and unmodified burners. Units 8 and 9 are both 600 MW units and have undergone several modifications for different co-firing ratios. In 1999, several types of biomass including wood, palm kernel, rice, soya and coffee husks were co-fired by premixing with coal at co-firing ratios of 5 per cent by mass with existing infrastructure. Gradually, milling infrastructure was upgraded for higher co-firing ratios. Wood pellets are stored in concrete silos. In Unit 9, a closed conveyor system was installed and modification in its primary air unit was carried out, which is expected to increase its co-firing ratios to 50 per cent by 2018 and up to 80 per cent by 2022.

Torrified pellets can be game changing for biomass co-firing in India

NTPC, Dadri, Uttar Pradesh, India

National Thermal Power Corporation's (NTPC) Dadri plant has successfully co-fired biomass up to 10 per cent. In the first stage, they initiated with 2.5 per cent co-firing, gradually increased it up to 5 per cent, and subsequently up to 10 per cent. Biomass is fed into existing coal mills. It is interesting to note that the calorific value of the biomass is in fact slightly higher than coal (see *Table 6: Comparison of coal and biomass parameters for NTPC, Dadri*). Biomass ash has a low fusion temperature and high alkali content. Low ash fusion temperature may result in frequent fouling or slagging and requires more maintenance for efficiency and safety parameters.

Cost–benefit analysis of biomass co-firing must include its benefits to the environment and society

Due to its hygroscopic nature (ability to absorb moisture), high volatility and fine dust formation, biomass requires special attention during transportation, handling and storage. The increase in the heat rate is miniscule. Fly ash generated with 10 per cent biomass mix is accepted by cement plants. With regard to impact on major pollutants, SO_2 emissions decrease due to lower sulphur content in the biomass (0–0.2 per cent), but for getting conclusive impact on PM and NO_x emissions, operating hours need to be increased.

The cost of the biomass is 10–20 per cent higher than coal for biomass co-firing up to 5–10 per cent. At higher co-firing ratios, the cost may go higher since longer biomass supply chains need to be maintained. Thus, to maintain a sustainable supply chain, plants might need to pay higher in comparison to coal.

For 5–10 per cent biomass co-firing, all the issues related to slagging, storage, handling and transportation are quite manageable. Overall cost may be slightly higher due to higher biomass cost, and additional cost of handling and storage. However, it should be looked at in the context of the immense environmental benefits accrued through biomass utilization, especially as agro-residue use and coal replacement.

Table 6 : Comparison of coal and biomass parameters for NTPC, Dadri

The calorific value of the biomass is in fact slightly higher than coal

Parameter	Coal	Biomass pellets
Carbon (percentage)	34–35	10–15
Volatile material (percentage)	20–21	50–66
Ash (percentage)	38	15
Moisture (percentage)	12–18	8
Calorific value (kcal/kg)	3,500	3,750
Ash fusion temperature	1,150	850–900
Ignition temperature	454	280
Grindability	Brittle	Fibrous
Cost		10–20 per cent more than coal

Source: CSE compilation

5. Feasibility of biomass co-firing in old power stations in Punjab, Haryana and Uttar Pradesh

The three Northwestern states of India—Punjab, Haryana and Uttar Pradesh—immensely contribute to the agricultural production of the country. But unfortunately, in recent times, the three states have had to bear the stigma of excessive stubble burning. Some of the power plants located in these states can opt for higher percentage of biomass co-firing at their older power stations. These states can easily meet co-firing needs of their older plants by utilizing the available surplus agro-residue.

As per the National Electricity Plan of 2018, around 10.8 GW capacity was schedule to retire in these states by 2027. Out of this, 5.3 GW falls in the Central sector and 5.5 GW in the state sector. About 0.7 GW capacity is located in Delhi and has already been retired. This includes the Rajghat power station (2 x 67.5 MW) and Badarpur power station (2 x 95 MW and 2 x 210 MW). Rajghat power station's land is planned to be utilized for a solar park whereas NTPC Badarpur, spread over 884 acre, will be converted into an eco-park.

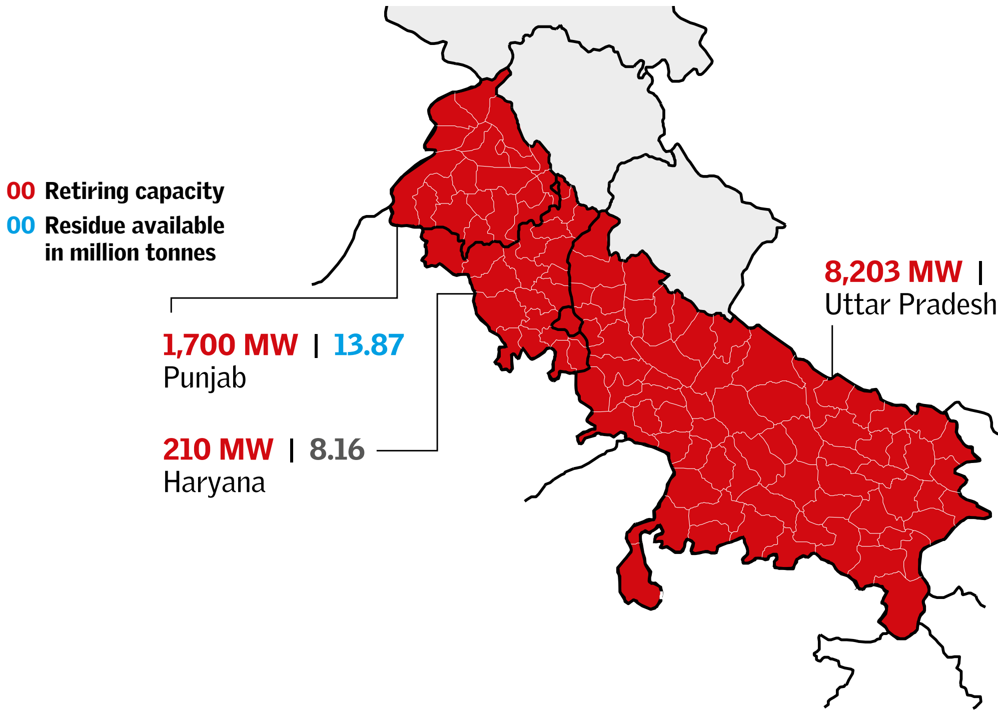
In Haryana, Unit 5 (210 MW) at the Panipat power plant is schedule to retire. This operational life of this unit, along with other units that are 17–20 years old, can be extended through biomass co-firing.

Punjab, Haryana and Uttar Pradesh are the three states where stubble burning is prominent

In Punjab, 1.7 GW of capacity is schedule to retire. Out of this capacity, GND Bathinda (4 x 110 MW) has been retired in 2018. The plant was under consideration for biomass co-firing, but recently a decision has been taken that the plant will be dismantled and the land will be sold[33] (see *Box: GND Bathinda—A missed opportunity*). At PSPCL Ropar (6 x 210 MW), two units (1 and 2) have already been retired, others are schedule to retire by 2022. This plant has a unique opportunity to shift to biomass co-firing. Doing so will avoid huge investment in new units, and also save the investment otherwise required for FGD installation and operation. Thus, these plants can continue to supply cheaper electricity with reduced CO_2, SO_2 and NO_x emissions.

In Uttar Pradesh, 8.2 GW of capacity is schedule to retire by 2027. At Obra thermal power plant, units 1, 2 and 8 of 40 MW, 50 MW and 94 MW respectively have already been retired. At Panki, Units 3 and 4, of 105 MW

Map 1 : Availability of surplus residue and retiring capacity in Punjab, Haryana and Uttar Pradesh



Source: CSE analysis, 2020

Table 7 : Residue availability for retiring plants in Punjab, Haryana and Uttar Pradesh

These states can easily meet co-firing needs of their older plants by utilizing the available surplus agro-residue

State	Gross residue* (million tonnes)	Residue available** (million tonnes)	Retiring capacity (in MW)	Maximum power generation possible (GW)
Haryana	30	8.16	210	1.27
Punjab	51	13.87	1,700	2.16
Uttar Pradesh	87	23.66	8,203	3.69
Total	168	45.70	10,113	7.12

* Non-bagasse residue.

** Considering only 34 per cent residue availability for bio-energy purposes after considering other usages, and considering at the most 20 per cent current utilization in small industry and biomass power plants.

Source: CSE analysis

each, have been retired. Theoretically, Uttar Pradesh can generate 3–4 GW of power based on surplus agro-residue availability. Power plants in the state have an opportunity to become a benchmark for other states when it comes to the utilization of agro-residue.

GND Bathinda—a missed opportunity

In 2018, to address air pollution and GHG emissions mitigation from coal-fired power plants in Delhi–NCR, Central Electricity Authority of India (CEA) and Japan Coal Energy Centre (JCOAL) collaborated in the following areas under the India Energy Dialogues:

- Co-firing of biomass with higher blending ratios
- Conversion of pulverized fuel-fired plants to 100 per cent biomass firing
- Generating energy from biomass

Target states for the collaboration are Punjab, Haryana and Uttar Pradesh, as stubble burning is widespread in these states and fuel cost is also much higher because of the long distances over which coal has to be transported.

In its preliminary study, JCOAL found that Punjab is the most suitable state, with an agriculture waste supply of 40 million tonne per year, that can produce up to 3,373 MW of power. Punjab State Power Corporation Limited (PSPCL) also showed interest, through CEA, for this collaborative work at its GND plant (110 x 4 MW). JCOAL analyzed rice husk for its utility as fuel at GND Bathinda. The plan was that JCOAL will initiate site surveys and submit a final report in March 2020 on the suitable technology and suggest critical points for introducing biomass co-firing or converting the plant to biomass.[34]

The internal committee constituted by PSPCL with regard to conversion of the coal-fired plant to paddy straw-fired power plant made the following observations:[35]

a) The cost of conversion was lesser as compared to establishing a new biomass plants. The conversion would also decrease the cost of power generation and lessen the burden on consumers.
b) Experts have submitted a report to Punjab State Power Corporation (PSPCL) to run this plant exclusively on paddy straw.

On 21 November 2018, PSPCL approved the proposal of conversion of one of its 120 MW coal-fired units into a 60 MW paddy straw-fired unit. The proposal was sent to the state government for approval in November 2018, the decision on which remained pending for almost two years. In June 2020, the government rejected the proposal and decided to dismantle the plant and sell the land.[36]

GND Bathinda was a unique opportunity for India to reinvent utilization of older coal thermal power stations to set a role model for such plants across the country.

6. Conclusion and recommendations

Utilization of agro-residue is an opportunity which India has neglected for decades. Being an agrarian country, every year, millions of tonnes of agro-reside are generated, but a significant quantity is wasted on the fields, stubble burning being one of the horrendous forms of this wastage. A country where around 50 per cent population is engaged in farming cannot afford to ignore this resource. Agro-residue co-firing in older power station can be a panacea for government's multiple problems.

1. **Improving farmers' income**: The government has set itself an ambitious goal of doubling farmers' income by 2022. Sale of agro-residue for pellet manufacturing can contribute to achieving this goal.

2. **Generating rural employment**: Pellets and briquette manufacturing, storage, handling and transportation can chip in the generation of employment at the local level.

3. **Easing financial burden on the government:** The future of coal is uncertain. Governments and private investors are suspicious about new investment in coal plants due to growing concern about pollution and climate change. Thus, by investing a miniscule amount in old power station, significant investment in new coal power plants can be avoided. If old power stations can be run with reduced CO_2 emissions, it is a win-win all around. The fixed cost from such plants would already have been recovered. The financial health of discoms will also improve. The money saved from this can be invested in renewable energy or cleaner technologies.

4. **Reducing GHG emissions with minimal investment:** Biomass co-firing is a cost-effective approach to reduce CO_2 emissions from thermal power plants.

Figure 3: Agro-residue co-firing in old power stations: A win-win for all

Rural
- Additional income to farmers
- Local employment generation through pellet or briquette manufacturing
- Saves soil as well as human health from negative effects of stubble burning

Power plants
- Can operate old power stations while simultaneously reducing their environmental footprints
- Power from co-firing is already considered under renewable purchase obligation by MNRE

Government
- Avoiding significant economic risk by limiting the investment in new coal plants
- Reduction or elimination of two key problems—air pollution due to coal power plants and stubble burning

Source: CSE

Roadmap for implementation

1. **A beginning must be made:** India lost the opportunity of converting GND Bathinda to a co-firing or all-out biomass plant. A beginning in a few plants will provide immense experience and confidence to the sector to address concerns associated with biomass utilization at thermal power plants.

2. **Start with low co-firing ratios and gradually increase them while upgrading the facilities:** Once we have sufficient experience of 5–10 per cent co-firing, older plants can gradually be moved to higher co-firing ratios, optimizing costs and benefits based on biomass quantity, quality and plant technology.

3. **Decide which plants to cover**: It is essential to make a list of old plants that can operate with biomass co-firing based on efficiency and safety parameters, and assessment of biomass and space availability so that higher co-firing ratios can be implemented with minimum investment. CEA should take a lead in identifying such plants. Identified plants may be considered on a trail or research and development basis for a couple of years. A team of experts may be formed to coordinate between various experimenting plants and share experiences to avoid repetition of mistakes.

4. **Separate, marginally relaxed environmental norms may be specified for co-firing plants:** As per CSE's survey analysis in Maharashtra, Madhya Pradesh and Uttar Pradesh, older coal-based power plants are able to meet PM and NO_x standards. However, to meet SO_2 standards, they need to invest in FGD technology. In fact, this is becoming an additional factor to expedite the retirement of older plants which do not have space for FGD installation. We recommend that old plants that can be operated safely and with good efficiency, can be chosen for biomass co-firing at higher ratios. This will automatically reduce SO_2 emissions and may make these plants complaint with SO_2 emissions norms. Simultaneously, keeping in consideration the various other environmental and social benefits of biomass co-firng, the SO_2 norms for these units can be marginally relaxed so that the investment which would be needed to install FGD can be utilized for installation of storage, transportation and safety facilities for higher biomass co-firing ratios.

5. **Promote torrified pellets:** Torrified biomass pellets are regarded as one of the most efficient biofuel manufacturing processes. Torrification can bring the properties of agro-residue closer to coal properties, making biomass co-firing at higher ratios economical feasible. Further, a wide variety of biomass can be torrified, i.e., municipal waste, sewage sludge, and agro-residue. Thus, MoP, MoEF&CC and other concerned agencies should promote torrified pellet manufacturing.

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Crop stubble burning is a major source of pollution in Northwest India. It will require significant and continuous investment to end the practice. On the other hand, despite the growth in 'renewables', India's reliance on coal to meet its base power load demand will continue in the foreseeable future. At a time when the world is moving away from coal power, is it prudent for India to replace old coal power plants with new ones?

It is clear that standalone solutions to these two problems (stubble burning and use of coal to generate power) will burn a hole in the exchequer's pocket. Even then, returns on investment cannot be guaranteed.

But what if we were to see the broader picture and make one problem the solution to the other problem? This report explores the possibility, impact and benefits of operating older coal power plants at higher biomass co-firing ratios.

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