# STATUS OF BIOMASS CO-FIRING IN COAL THERMAL POWER PLANTS IN DELHI NCR

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# 1. Introduction

The Indian government, in its third biennial update report (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC), states that greenhouse gas emissions from the electricity sector in India is responsible for almost 40 per cent of the total emissions in the country.[1] Despite an unprecedented growth in the renewable energy sector over the last few years, coal continues to dominate the electricity sector in India, its share amounting to almost 74 per cent of the total electricity generated in the country.[2]

On an average, 675 million tonnes (MT) of coal is burnt annually for generating power,[3] releasing almost 1,120 million tonnes of $CO_2$ emissions.

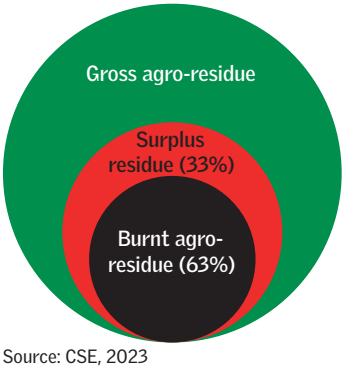
According to the Central Electricity Authority (CEA), India will continue to rely on coal for its energy security until 2030 and beyond. Therefore, thermal sector decarbonisation is imperative if India is to meet the Nationally Determined Contributions (NDC) submitted to the United Nations Framework Convention on Climate Change (UNFCCC).

Biomass co-firing has been recognised as a potential way through which the carbon footprint of the sector can be reduced. It entails the partial replacement of coal with agricultural residue (or agro-residue) in a coal thermal plant. According to government estimates, biomass co-firing at seven per cent in power plants has the potential to reduce 38 million tonnes of annual $CO_2$ emissions.[4]

In addition to reducing the carbon footprint of the energy sector, the supply of agro-residue for co-firing will also generate income for farmers as well as medium- and small-scale entities involved in the supply chain.

A 2018 study titled, "Estimation of surplus crop residue in India for biofuel production", conducted by the Indian Agricultural Research Institute (IARI) and the Technology Information Forecasting and Assessment Council (TIFAC)—the two autonomous organisations under the Ministry of Agriculture and Department of Science respectively—estimated that the country generates 683 million tonnes (MT) of gross annual crop residue. While 74 per cent of this residue is used as animal fodder—as soil mulch and manure, or roof thatching—a massive 178

**Figure 1: Share of surplus and burnt agro-residue**




Source: CSE, 2023

million tonnes (MT) still goes unutilised. More than half of the unused biomass (84–140 MT)[5] is set on fire annually to clear the fields, primarily in the Indo-Gangetic plains.[6] This practice further aggravates the existing air pollution in the region.[7]

India's energy policy has seen some recent shifts towards addressing the twin challenges of curbing emissions from coal power plants and pollution from burning crop residue. The Union Ministry of Power (MoP) has made biomass co-firing mandatory for all coal thermal power plants in the country.[8] According to the Ministry of Power's policy on biomass utilisation, nearly 0.25–0.3 million tonnes of biomass pellets are required for every gigawatt power generation capacity at seven per cent co-firing.

At present, the power plants in Delhi NCR co-fire biomass only intermittently depending on the availability of fuel. The escalated cost of biomass pellets and the lack of clarity in regulatory mechanisms are some of the major apprehensions when it comes to the implementation of the government's mandate on co-firing biomass in coal thermal power plants.

# 2. Policy scenario

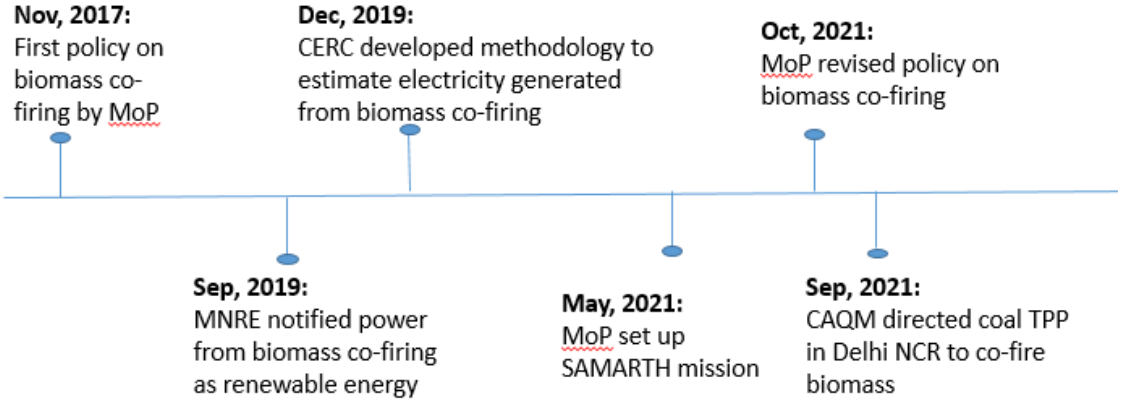
India has been struggling with burning of crop residue in its agricultural fields for the last decade. This presents a problem, particularly during winters, when unfavourable atmospheric conditions lead to severe air pollution, especially in the Indo-Gangetic belt.[9]

Several initiatives by both Central and State governments have been floated to curb these open fires.[10] One of these is co-firing of crop residue with coal in coal-based thermal power plants.

Early in 2017, the National Thermal Power Corporation (NTPC)—the biggest player in India when it comes to generating and distributing power from coal—demonstrated seven per cent co-firing of biomass in its Dadri Thermal Power Plant located in Ghaziabad, Uttar Pradesh. Following this, in November 2017, the Union Ministry of Power (MoP), introduced a policy titled "Biomass utilisation for power generation through co-firing in pulverized coal fired boilers".

Coal power plants are based on one of three types of mills for coal pulverisation—ball-mill, ball-and race-mill, and ball-and tube-mill. In order to address the challenges of stubble burning, the MoP encouraged all coal thermal power plants (except those with ball-and tube-mill) to utilise agro-residue along with coal for controlled combustion. Plants with ball and tube mills were exempted due to higher risks of fire hazard from biomass co-firing.

**Figure 2: Timeline for policy scenario of biomass cofiring in thermal power plants**




Source: CSE compilation, 2023

In September 2019, the Ministry of New and Renewable Energy (MNRE) notified that the power produced from biomass co-firing in coal-based power plants is renewable energy and will be eligible for non-solar renewable purchase obligation (RPO).[11]

In the same year, MNRE requested CEA to formulate a methodology to quantify the energy produced from biomass that was co-fired in coal-based thermal power plants—a significant step towards ensuring the utilisation of agro-residue for power generation in the country .

In December 2019, Central Electricity Regulatory Commission (CERC) took suo moto cognizance of the MNRE request and came out with a methodology titled, "Methodology for estimation of electricity generated from biomass in biomass co-fired thermal power plants."[12]

In October 2021, the Ministry of Power (MoP) revised the biomass policy and made it mandatory for all (captive and non-captive) coal-based thermal power plants to co-fire biomass replacing 5–10 per cent of coal by weight *(see Table 1:* ***Deadlines for compliance with co-firing agro-residue in coal-based thermal power plants).*** The revised policy makes it mandatory for coal power plants to use a blend of coal with five per cent biomass pellets. This is to come into effect one year from the issue of the revised policy. The share of agro-residue for co-firing needs to be increased to seven per cent after two years of the issue of the policy. The biomass that is to be used for co-firing should only be pellet form, according to the revised policy. Power plants seeking exemptions from co-firing are required to submit their case to the Central Electricity Authority for consideration.

The policy will remain in effect for 25 years from its day of inception or till the operational life of the thermal power plant. Also, to safeguard the interests of the pellet manufacturers and ensure a continuous, reliable supply of pellets, the MoP has made the provision of a contract for a minimum of seven years between pellet

**Table 1: Deadlines for compliance with co-firing agro-residue in coal-based thermal power plants**

| S. no. | Type of mill | After one year of issue of revised guidelines (September 2022) | After two years of issue of revised guidelines (September 2023 onwards) |
|---|---|---|---|
| 1 | Ball-mill based | 5 % | 7 % |
| 2 | Ball- and race-mill based | 5 % | 7 % |
| 3 | Ball- and tube-mill based | 5 % | 5 % |

Source: CSE compilation, 2023

## BOX 1: SAMARTH BY MINISTRY OF POWER

In May 2021, the Ministry of Power established the Sustainable Agrarian Mission (SAMARTH ) on the use of agro-residue in a thermal power plant.[13] The mission has been created with the objective of increasing the level of co-firing from five per cent to higher, in order to have a larger share of carbon neutral power generation from thermal power plants. The mission will undertake research and development (R&D) activity in boiler design to handle larger amounts of silica and alkalis in the biomass pellets. This will help to achieve a higher percentage of co-firing. It will also address the constraints in the supply chain of biomass pellets right from the collection of agro-residue from agricultural farms to its transport to the power plants.

A Steering Committee was also constituted to monitor and facilitate the mission with representation from Ministry of Power (MoP), Ministry of Petroleum and Natural Gas (MoPNG), Ministry of New Renewable Energy (MNRE), Department of Heavy Industries (DHI), Department of Science and Technology (DST), Ministry of Agriculture, Ministry of Small and Medium scale Enterprises (MSME), and Central Electricity Authority (CEA).

The committee is tasked with preparing action plans along with milestones for biomass use in coal power plants. They are also to provide the corresponding strategy for its implementation.

There are four sub-groups formed under SAMARTH –

**Sub-group 1:** The sub-group is responsible for carrying out research on the properties or characteristics of biomass to be used for co-firing. The sub-group is also responsible for exploring and addressing the challenges of co-firing municipal solid waste pellets.

**Sub-group 2:** The sub-group will carry out technical specification and safety aspects of biomass co-firing including research in boiler design etc. to handle the pilot project for higher amount of co-firing of biomass with coal in pulverised coal fired boilers. The sub-group will also study the impact of biomass co-firing on the operation of flue gas desulfurisation.

**Sub-group 3:** The sub-group is responsible for resolving the issues of supply chain during the mission period and conducting sensitisation programmes. Any issues regarding manufacturing of pellets shall be addressed by the group in addition to promoting activities related to business development.

**Sub-group 4:** The sub-group will select or establish designated labs and certification bodies for testing agro-based biomass pellets.

**Sub-group 5:** The sub-group is concerned with the regulatory issues in biomass co-firing and assesing its economics.

manufacturers and thermal power plants. The Ministry of Power has also floated a 'model contract' to all the coal thermal power plants for the procurement of pellets from vendors.[14]

In addition to this, unlike its predecessor, the current revised policy does not exempt power plants with ball and tube mill from use of biomass for co-firing.

Instead, it specifies the use of only torrefied biomass pellets with a volatile content below 22 per cent to reduce risks of fire hazards.

Apart from the Ministry of Power (MoP), the Commission on Air Quality Management (CAQM), has also directed 11 thermal power plants located within a radius of 300 km of Delhi to immediately initiate co-firing agro-residue in order to curb air pollution from burning paddy straw.[15] In addition to this, the Ministry of Power has issued a mandate to all power stations within a 300 km radius of Delhi NCR to use atleast 50 per cent paddy residue, sourced from Punjab, Haryana and National Capital Region, for co-firing.[16, 17]

It is to be noted that under the section 14 of the CAQM Act, 2021, the non-adherence to the CAQM direction on biomass co-firing will be considered as an offense 'punishable with imprisonment' for a term that may extend upto 5 years or with fine upto 1 crore or both. [18]

# 3. Biomass co-firing

## 3.1 What is biomass co-firing?

Co-firing can be defined as the "combustion of two or more fuels in the same energy plant in order to produce one or more energy carriers".[19] Co-firing in coal-based thermal power plants is the partial replacement of coal with biomass fuel for power generation[20] with coal being the dominant fuel.[21]

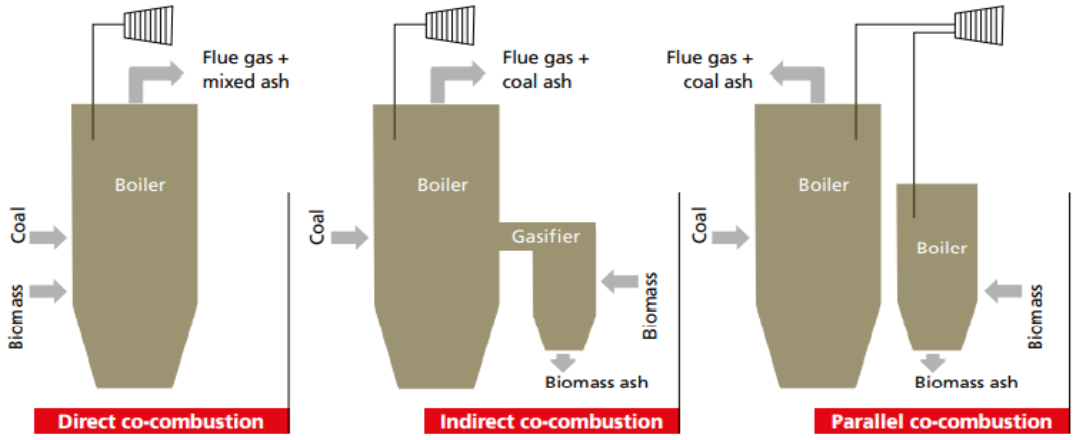
There are three ways of co-firing biomass in coal power plants: direct co-firing, indirect co-firing, and parallel co-firing *(see Figure 3: Various methods of biomass co-firing)*.

- Direct co-firing: Biomass and coal are fired in the same boiler. Direct co-firing has been undertaken in stoker, cyclone, fluidised bed combustion (FBC) and pulverised coal combustion (PCC) boilers.

- Indirect co-firing: The indirect co-firing option, also known as gasification, involves gasification of the biomass fuel in a separate gasifier; the combustion of the product gas takes place in the furnace of the coal boiler.

- Parallel co-firing: Biomass and coal are fed into separate boilers. The steam from biomass combustion is then mixed with steam from the conventional boiler.

**Figure 3: Various methods of biomass co-firing**




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

The efficiency of direct co-firing is two per cent higher than the efficiency from indirect or parallel co-firing due to conversion losses in biomass gasifiers and boilers.[22] However, the efficiency declines with higher share of biomass co-firing due to fouling and slagging and associated corrosion. [23]

## 3.2 Biomass specification for co-firing

A survey conducted by CSE indicated that pellet manufacturers majorly use sugarcane leaves, mustard straw, groundnut shell and paddy straw for the manufacture of pellets as these residues are available in abundance and not used as fodder.

### 3.2.1 Biomass as pellets:

There are two types of pellets that can be used for co-firing: torrefied and non-torrefied.

In the torrefication process, biomass is processed at 250–350°C in the absence of oxygen which leads to the decomposition of the biomass while preserving its energy content. This results in higher energy output from the pellets than in other solid biomass forms.[24]

As per the Central Electricity Authority's technical specification of agro-residue based biomass pellets, torrefied biomass is brittle and hydrophobic, with improved physical and chemical properties such as grindability, storage stability and energy density. Its use also has the potential to significantly reduce the cost of transportation, storage and downstream processing. The gross calorific value for torrefied and non-torrefied biomass pellets is 4,500 Kcal and 3,500 Kcal respectively, whereas the moisture content is to be maintained less than or equal to 14 per cent in both cases.[25]

The Central Electricity Authority (CEA) has clearly defined the clauses for penalty and rejection of biomass pellet consignments that are supplied by the vendors. Gross Calorific Value (GCV), moisture, ash, and fines are the determining factors for the acceptance or rejection of the product and variations in its prices. These factors are listed below-

a) **Gross calorific value (GCV):** The accepted GCV range, in case of non-torrefied pellets, is between 2800 to 3,500 Kcal/kg. Whereas in case of torrefied pellets, the accepted range is 3,600 to 4,500 Kcal/kg.

b) **Moisture content in pellets**: The accepted range of moisture content in

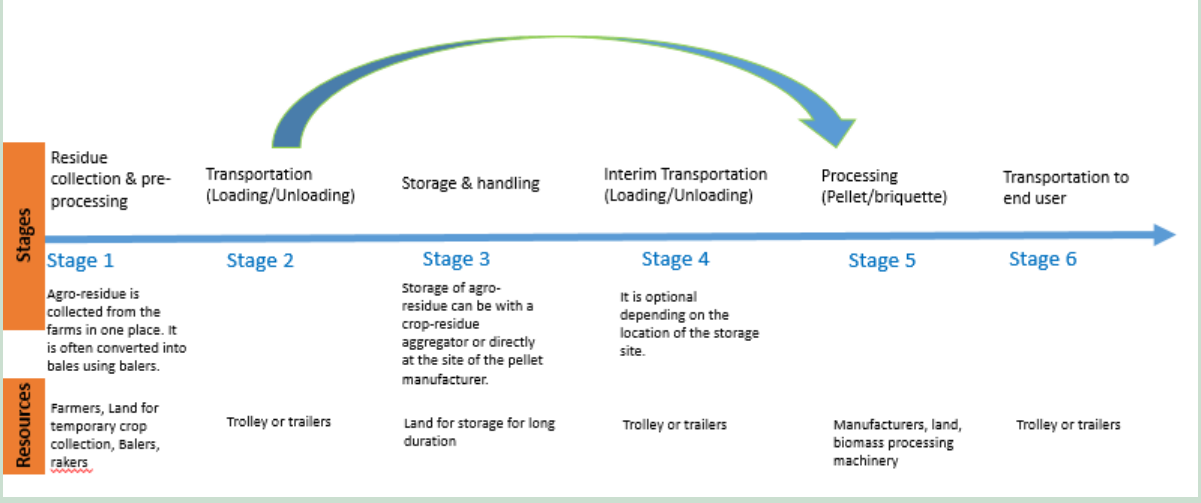
both torrefied and non-torrefied pellets is between 9–14 per cent. Pellets with more than 14 per cent moisture take longer to burn and therefore cannot be used for co-firing.

c) **Ash content in pellets**: The ash content in non-torrefied pellets is usually between 13–15 per cent, whereas it is 18–19 per cent by weight in torrefied pellets. Exceeding the range would affect the cost of the pellets adversely.

## BOX 2: SUPPLY CHAIN OF BIOMASS

Supply chain management (SCM) of agro-residue involves multiple stakeholders at each successive stage of the supply chain—starting from the collection of agro-residue at farms to the transportion of processed biomass to the end user. It requires a dense network of agro-residue aggregators, pellet manufacturers and extensive storage facilities supported by farm equipment customisation service providers. Centre for Science and Environment (CSE) survey shows that typically, the procurement of agro-residue by the pellet manufacturers happens within a radius of 30–50 km. However, currently, pellets are being supplied to the power plants over a wide range of distance from 200–600 kms in the Delhi NCR region.

### Supply chain management scheme for agro-residue co-firing in coal based power plants:




The supply of pellets to power plants is not constant and is based on "projected demand" of the power plant. Central Electricity Authority's technical specification for biomass pellets states that the scheduled quantity of pellets to be supplied by the bidder to the power plant may change. In such cases, the power plant shall send the changed delivery schedule to the supplier three days in advance through e-mail or by other means. The power plant will specify the revised quantity of biomass pellets to be delivered (which may even be zero) in the schedule and the supplier shall dispatch the consignment accordingly. In case of a low energy demand, the plant runs at lower plant load factor and therefore the demand for pellets also declines.

d) **Fines**: Fines is biomass dust; crushed, broken or damaged pellets that are less than 3mm in size. The selling price of the pellets received by the power plant is adjusted based on the excess fines in the consignment.

**3.2.2 Biomass as briquettes:** Briquettes can be used in a Circulating Fluidized Bed Combustion (CFBC) boiler in consultation with the original equipment manufacturer.[26] When it comes to their manufacturing, the process remains the same as in the case of non-torrefied biomass pellets, except that the raw biomass is not processed to a finer size.

It is important to note here that the CEA has only issued specifications for the characteristics of agro-residue pellet. The Standard Operating procedure issued under the National Mission on Use of Biomass in Coal Thermal Power Plants for the use of briquettes in CFBC boilers, does not mention any specific requirement for briquettes that are to be co-fired in such boilers.

# 4. Biomass co-firing in coal thermal power plants in Delhi NCR

## 4.1 Current status of co-firing in coal thermal power plants

According to records of the National Mission on the Use of Biomass in Coal Thermal Power Plants, cumulatively, by 31 December, 2022, 24,426 tonnes of biomass pellets had been co-fired in the 11 coal power plants in the Delhi NCR region. Table 2, gives the status of co-firing of biomass pellets in individual coal power plants in Delhi NCR.

Since the initiation of co-firing in the 11 thermal power plants in Delhi NCR, the amount of biomass pellets co-fired in these plants individually is less than one per cent of the coal consumed in each of these TPPs annually. Only NTPC Dadri TPP has achieved a co-firing ratio of 0.5 per cent which is the highest among all the coal-based power plants in Delhi NCR.

Based on the 'model contract' floated by the Ministry of Power,[27] power plants have issued long-term tenders—for a period of seven years—for the supply of biomass pellets for co-firing. Cumulatively, power plants in Delhi NCR have issued long-term tenders for approximately 12 million tonnes of biomass pellets.

However, in the absence of fulfillment of long-term tenders due to unavailability of suitable vendors, some of the power plants have also floated short term tenders for a period ranging from one month to two years.

The government records show that short term orders have been placed for 0.08 million tonnes of biomass pellets, another 0.28 million tonnes orders are under process. In case of long term tenders within a period ranging from two to seven years, orders have been placed for 2.9 million tonnes of biomass pellets and tenders for 8.8 million tonnes are still in the pipeline.

Records show that until December, 2022, power plants under the ownership of Haryana state government—Rajiv Gandhi TPP, Yamuna Nagar TPP, and Panipat TPP—have issued both short-term and long-term tenders, however none of these orders have been awarded yet. The remaining power plants in Delhi NCR have

successfully awarded short-term tenders.

Mahatma Gandhi TPP, Dadri TPP, and Indira Gandhi TPP are the only coal-based power plants in Delhi NCR that have successfully placed the long-term orders as well by December, 2022.

**Table 2: Status of co-firing in coal thermal power plants in Delhi NCR and tender details**

| S. No. | Name of the Plant | Biomass co-firing status | Cumulative biomass usage (tonnes) till 26.12.2022(*) | coal consumed (tonnes) per annum (**) | percentage cumulative biomass co-fired in comparison to coal consumption per annum (in tonnes) | Details of the tenders issued by TPP in tonnes (*) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Short term (1 month to 1 year) | Long term (2-7 years) |
| 1 | Rajiv Gandhi TPS, Hisar | Initiated in August, 2021 | 95 | 17,91,788 | 0.005 | 6,000 | 7,60,000 |
| 2 | Yamuna Nagar TPS | Initiated in June, 2021 | 455 | 17,48,787 | 0.026 | 4,000 | 6,70,000 |
| 3 | Panipat TPS | Tender floated | 0 | 18,45,817 | 0 | - | 4,90,000 |
| 4 | Mahatma Gandhi TPS, Jhajjar | Initiated in February, 2022 | 71 | 51,97,076 | 0.001 | 5,200 | 3,50,000 |
| 5 | Harduaganj TPS | Initiated in February, 2021 | 760 | 10,24,196 | 0.074 | 1,02,900 | 13,30,000 |
| 6 | Talwandi Saboo TPP, Mansa | Tender floated | 50 | 59,60,032 | 0.001 | 75,050 | 25,00,000 |
| 7 | Nabha TPP (Rajpura TPP) | Tender floated | 30 | 64,68,187 | 0.000 | 62,550 | 17,90,000 |
| 8 | Guru Gobind Singh Super Thermal Power Station (Ropar TPS) | Tender floated | 61 | 11,62,256 | 0.005 | 3,000 | 76,400 |
| 9 | Guru Hargobind Thermal Power Station (GH TPS Lehra Mohabbat) | Tender floated | 39 | 13,44,884 | 0.003 | 3,000 | 1,20,000 |
| 10 | Dadri TPP | Initiated in November, 2019 | 20,581 | 38,34,926 | 0.537 | 20,000 | 17,62,900 |
| 11 | Aravali TPS (Indira Gandhi STPP), Jhajjar | Initiated in September, 2021 | 4,286 | 47,24,311 | 0.091 | 77,700 | 18,65,500 |
| Total | | - | 24,426 | 3,51,02,258 | 0.744 | 359400 | 1,17,14,800 |

Source: (*) RTI no. 21/16/2020-DVC dated 17th January, 2023 by Ministry of Power

(**)Based on actual electricity generation (April 2021-March 2022) and specific coal consumption [28] (0.67 kg per Kwh)[29]

**Table 3: Status of the tenders for biomass pellets**

| Status of tenders | Short term (1 month to 2 year) (Million Tonnes) | Long term (4 to 7 years) (Million Tonnes) |
|---|---|---|
| Placed | 0.0809 | 2.8794 |
| In the pipeline | 0.2801 | 8.8435 |

Source: RTI reply no. 21/16/2020-DVC dated 17th January, 2023, Ministry of Power

**Table 4: Disparity in pellet quantity required vs pellets to be procured by the power plant**

| Name of plant | Tenders quantity for biomass pellets as per long term contracts (tonnes per annum)* | Biomass requirement at 5 % co-firing (tonnes) |
|---|---|---|
| Rajiv Gandhi TPS, Hisar | 1,09,000 | 89,589 |
| Yamuna Nagar TPS | 95,286 | 87,439 |
| Panipat TPS | 71,371 | 92,291 |
| Mahatma Gandhi TPS, Jhajjar | 55,000 | 2,59,854 |
| Harduaganj TPS | 1,90,000 | 51,210 |
| Talwandi Saboo TPP, Mansa | 3,57,143 | 2,98,002 |
| Nabha TPP (Rajpura TPP) | 2,55,500 | 3,23,409 |
| Guru Gobind Singh Super Thermal Power Station (Ropar TPS) | 38,200 | 58,113 |
| Guru Hargobind Thermal Power Station (GH TPS Lehra Mohabbat) | 60,000 | 67,244 |
| Dadri Thermal power station | 2,95,643 | 1,91,746 |
| Aravali TPS (Indira Gandhi STPP), Jhajjar | 2,66,500 | 2,36,216 |

Source: (*)RTI no. 21/16/2020-DVC dated 17th January, 2023 by Ministry of Power.

We calculated the quantity of coal to be replaced by biomass pellets at five per cent co-firing in the coal-based power plants. It was noted that five of the 11 plants—Panipat TPP, Mahatma Gandhi TPP, Nabha TPP, Ropar TPP, and Guru Hargobind TPP—have issued orders for much lesser quantity of biomass pellets than estimated. The biomass pellet requirement is based on the coal consumed for 'actual' generation of electricity in the last financial year (April, 2021–March, 2022).

The tenders issued by power plant developers in Delhi NCR region have a clause that states that 50 per cent of the raw material used in manufacturing pellets should be stubble/straw/crop residue of paddy sourced only from Punjab, Haryana or NCR Region. While assessing issued tenders, Centre for Science and Environment (CSE) discovered that barring two thermal power plants—Talwandi Saboo TPP

and Indira Gandhi TPP—all the others have included this clause in their tenders.

A contractor is required to provide a self-declaration document along with monthly bills from the state authority from where the paddy straw has been sourced. CSE, in its survey of pellet manufacturers, found that these documents are rarely audited by the plant owner as they are more concerned with the gross calorific value (GCV) and moisture content of the pellets as these are the aspects that they need to regulate in order to successfully operate the plant. However, there is no laboratory test that can determine the composition of a pellet. Therefore, considering the challenges of paddy storage and losses that may be incurred due to damage of the stored crop, it is unlikely that manufacturers will be willing to utilise paddy as mandated.

Also, paddy straw is only available from roughly 15 September to 20 November each year, and has to be then stored for the remaining eight to nine months. Indian Council on Agricultural Research (ICAR), in its survey, found that "due to weather changes and long term storage in changing weather conditions the paddy straw in the top few layers get damaged". [30]

It is important to note that some of the power plant developers, such as the National Thermal Power Corporation Limited (NTPC), have provided a clause disallowing the allocation of an entire tender to a single pellet manufacturer. In its tender, NTPC allows a manufacturer a maximum supply of 100 tonnes per day (TPD) per plant. Also, cumulatively a manufacturer will not be allotted a work order for more than 200 TPD by NTPC.

For example, the Dadri thermal power plant is to be supplied with 680 tonnes of pellets per day. A contract with multiple manufacturers encourages development of more pellet manufacturing capacity in the country and also ensures that any default in supply by a manufacturer does not hamper the continuous co-firing in a power plant.

Unlike other power plants in Delhi NCR, the Aravali thermal power station in Jhajjar (Haryana), has issued a tender for setting up a pellet manufacturing unit within the plant's premises. The prospect of setting up pellet manufacturing sites within plant premises is being discussed by the National Mission on Use of Biomass in Coal Thermal Power Plants, as it will ensure the timely and desired supply of agro-residue pellets required for co-firing.

# 5. Electricity tariff determination in case of biomass co-firing by TPP

## Determination of tariff

The electricity tariff consists of two components: fixed cost and variable cost. Fixed cost includes the capital cost of investment by the electricity generator. The cost is received by the plant as long as it is available to generate, even if it does not actually generate electricity. The second component which is the variable cost, comprises the cost of fuel and is incurred only when electricity is generated. It is paid in proportion to the units of electricity actually generated.

The price of electricity paid by consumers is regulated by respective Electricity Regulatory Commissions (ERC). The tariffs for thermal power plants under Section 62 of the Electricity Act, 2003, are determined by the appropriate Electricity Regulatory Commission. This tariff is calculated to include the recovery of all prudent costs, plus a profit. Respective (Central, State, or joint) ERCs stipulate and regulate these tariffs according to the provisions of Tariff Regulations.

In accordance with these regulations, ERCs are tasked with ensuring prudence in expenditure, and approving any changes to the tariffs of thermal power plants that come under Section 62, such as additional expenditure and tariff impact incurred due to adherence to environmental norms.

Thermal power plants that fall under Section 63, on the other hand, have their tariffs 'discovered' through the process of competitive bidding, where the distribution company signs a contract with the plant that will supply electricity at the lowest rate (also known as the discovered tariff). The contract that incorporates and makes the discovered tariff binding is called the Power Purchase Agreement (PPA), which also specifies the extent and conditions under which the discovered tariff can be modified. This includes instances of change in law, where changes in tariff can be attributed to government action and the modification of an existing Indian law, such as the 2015 amendment.[31] According to the provisions in the PPA, the costs incurred due to adherence to such changes in law should not adversely affect the economic position of the TPPs, and can be passed on to the consumer.

The revised policy for biomass co-firing has clarified that the cost of biomass

co-firing for coal power plants that fall under Section 62 of the Electricity Act, shall be passed through in the Energy Charge Rate (ECR). Whereas, the power plants covered under Section 63 of the Electricity Act, shall claim the increase in cost of electricity generation under the provision of 'change in law'.

**Change in law** includes any changes in the Indian law or enactment where changes in tariff can be attributed to government action. These are considered as justifiable grounds to pass the cost of the expenditure for adherence with the norms to the consumers. The same provision has formed the basis of the inclusion of the cost of the Flue gas desulfurisation unit as an additional capital asset.

## Change in cost of electricity after biomass pellet co-firing

In order to adhere to the biomass co-firing policy, power plants will incur the cost of modifications or additional provisions to be made in the plant infrastructure, as well as the price of biomass pellets that is almost double to that of domestic coal. According to a survey of power plants conducted by the Centre for Science and Environment (CSE) in Delhi NCR, no major capital investment would be required for five to ten per cent co-firing, and the only major cost incurred would be that of the biomass fuel. This increase in cost of fuel will result in increase in price of electricity generated by the power plant.

## Relevant clauses of the tariff regulations

According to the tariff regulation 2019 of the Central Electricity Regulatory Commission, the capacity charge is levied, "for recovery of annual fixed cost, consisting of the components as specified in Regulation 15 of these regulations".[32] The components covered under Regulation 15 are- (i) return on equity, (ii) interest on loan capital, (iii) depreciation, (iv) interest on working capital, and, (v) operation and maintenance expense.

Whereas, energy charge is computed, "for recovery of primary and secondary fuel cost and cost of limestone and any other reagent, where applicable as specified in Regulation 16 of these regulations"[33] and is variable in nature. It comprises (i) landed fuel cost of primary fuel, (ii) cost of secondary fuel oil consumption, and (iii) cost of limestone and other reagents.

An additional capital investment, in case of biomass co-firing, is the biomass pellet handling system[34] which will be covered under the "capacity charge". As the power plant does not require any major retrofits at five to ten per cent of biomass pellet co-firing there is no other additional capital investment involved. However,

additional land may have to be allocated and infrastructure maintained for the handling and storage of biomass pellets and material testing.

At the Central level, the 2019 policy also has a provision for the adjustment of costs for blending of biomass with coal. It states that the "the landed cost of biomass fuel shall be worked out based on the delivered cost of biomass at the unloading point of the generating station, inclusive of taxes and duties as applicable".[35] The landed

**Table 5: Status of tariff petitions for incurring cost on account of biomass co-firing in coal thermal power plants in Delhi NCR**

| Electricity Regulatory Commission | Thermal power plant (TPP) | Covered under which section of the Electricity Act (2003) | Tariff petition | Status |
|---|---|---|---|---|
| Central | Dadri TPP | Section 62 | - | Provision for biomass co-firing in the tariff regulations |
| | Indira Gandhi TPP | Section 62 | - | |
| Uttar Pradesh | Harduaganj TPP | Section 62 | Yet to file the tariff petition* | Tariff Regulations do not have any provision for biomass co-firing |
| Punjab | Talwandi Saboo | Section 63 | No need to file tariff petition | Tariff will be modified as per the extent and the conditions of the Power Purchase Agreement |
| | Nabha TPP | Section 63 | No need to file tariff petition | |
| | Guru Gobind | Section 62 | The Commission in its order dated 27th October, 2022, allows the addition of cost of biomass pellets along with coal and oil to add to the total fuel cost of PSPCL TPPs | CERC guidelines on co-firing are being adopted by the Commission and no separate regulations have been framed in the matter** |
| | Guru Hargobind | Section 62 | | |
| Haryana | Rajiv Gandhi TPS, Hisar | Section 62 | The Commission grants approvals on dealing with pass-through of additional fuel cost incurred on account of usage of biomass pellets cofired with coal in thermal power plants | |
| | Yamuna Nagar TPS | Section 62 | | |
| | Panipat TPS | Section 62 | | |
| | Mahatma Gandhi TPS, Jhajjar | Section 63 | No need to file the tariff petition | Tariff will be modified as per the extent and the conditions of the Power Purchase Agreement |

(*)- as on 3rd January, 2023

(**)- as per RTI dated 24th January, 2023

cost of biomass fuel will form the component under "energy charge" computation. In the first year of implementation of the revised policy, the tariff will be computed for biomass consumption at five per cent blending, and in the following year, it will be computed for seven per cent.[36]

The latest tariff regulations for Uttar Pradesh, Haryana, and Punjab, do not have any specific clauses for the inclusion of the cost incurred by the thermal power plants to comply with the direction for biomass co-firing. However, all these regulations carry the clause of 'change in law'.

In addition to this, the Punjab ERC and Haryana ERC have issued orders that allow power generators to pass-through the cost of biomass co-firing, as elaborated in the Box-3 below.

## Impact on the consumer bill

Indian Council of Agricultural Research in its report "Ex-situ crop residue management options," (July, 2021) finds that substituting coal with biomass pellets at a rate of ten per cent of the coal, will increase the cost of production by 20 paisa per unit of power.[37] At present, the cost of electricity is Rs 6 per kilowatt hour (kWh).[38] Therefore, at ten per cent biomass blending with coal, the cost of electricity is expected to be revised to Rs 6.20 per kWh.

## Merit order despatch

The Merit Order ranks the various power plants in the ascending order of their variable costs and is determined for each distribution company separately. Generators with the lowest variable cost are at the top of the list, are run (or dispatched) first, to address the utility's demand. It is followed by those with progressively higher variable costs, in accordance with Merit Order Dispatch.

The policy on biomass co-firing by the Ministry of Power has clarified that any additional impact on the cost of electricity due to biomass co-firing shall not be reflected in the rating of the power plant in merit order despatch. Thus, this clause in the policy on biomass co-firing protects the interest of the power plants that do not co-fire biomass vis-a-vis plants that co-fire biomass and incur additional variable cost.

## BOX 3: TARIFF PETITIONS BY THERMAL POWER PLANTS TO ELECTRICITY REGULATORY COMMISSION FOR INCLUSION OF PRICE OF BIOMASS PELLETS IN THE ELECTRICITY GENERATION COST

**Petition filed by Haryana Power Generation Corporation Ltd. (HPGCL) regarding biomass fuel cost.**[39]
In February 2021, Haryana Power Generation Corporation Ltd. (HPGCL) had filed a petition with Haryana Electricity Regulatory Commission (HERC) to frame the methodology for "claiming the biomass fuel cost as mandated to be utilised in HPGCL units" under 'Change in Law'. The HPGCL also requested HERC to allow HPGCL to seek exemption from the Ministry of Power for biomass co-firing under 'Revised policy for biomass utilisation for power generation through biomass co-firing in coal based power plants'. The exemption was requested on the ground of unavailability of torrefied pellets at economical cost.

In April 2022, HERC dismissed HPGCL's request to seek exemption from biomass co-firing. HERC opined that it would not be appropriate to seek exemption in the "absence of response to the bids to be floated at a future date". The HPGCL also failed to submit a consent form from the original equipment manufacturer (OEM) regarding the feasibility of biomass co-firing in its boilers. The petition was found to be 'immature'[40] and the HPGCL was directed to approach HERC with the appropriate consent from OEM, a detailed analysis of availability of biomass pellets in the state, and impact on the financial as well as technical parameters caused by such co-firing of biomass.

The HPGCL sought review of the order as it petitioned that without the decision of the HERC in the matter, HPGCL is unable to carry out the mandate of the Government of India and may have to face criminal prosecution under environmental law (under section 14 of the CAQM Act, 2021)[41] on non-adherence.

Hence, in another order by HERC on 19 September, 2022, the Commission granted approval for the pass-through of additional fuel cost provided that the biomass pellets manufacturers are based in Haryana to avoid additional transportation costs and that the biomass used for pellet manufacturing is procured from within Haryana.

**Petition filed by Punjab State Power Corporation Ltd. (PSPCL) regarding biomass fuel cost (reference- petition no. 32 of 2022)**[42]
The Punjab State Power Corporation Ltd. (PSPCL) filed a petition with the Punjab State Electricity Regulatory Commission (PSERC) for allowing the inclusion of the cost of biomass pellets along with the cost of coal and oil in the total fuel cost of PSPCL Thermal Generating Units- Guru Gobind Singh TPP and Guru Hargobind TPP.

PSPCL, in its petition, also stated that the cost of generation of electricity after biomass co-firing will increase by approximately Rs 0.13 per unit of electricity for both its coal power generating stations considering the landed fuel cost of coal and biomass as Rs. 5,000 and Rs. 9000 per tonne respectively.
The Commission— in its order dated 27 October, 2022—adopted the Central Electricity Regulatory Commission's (CERC) order that was issued on 18 February, 2020, in Suo Moto Petition No. 12/SM/2019, and allows the inclusion of the cost of biomass pellets, along with coal and oil, to add to the total fuel cost of PSPCL Thermal Generating Units (GGSSTP Ropar & GHTP, Lehra Mohabbat).

# 6. Challenges in biomass co-firing in coal-based thermal power plants

The challenges in biomass co-firing in coal-based thermal power plants can be broadly placed under— (i) challenges faced by the coal power plants and, (ii) challenges of supply chain management.

## 6.1 Challenges faced by coal power plants

### 6.1.1 Ambiguity regarding ERC regulations

Biomass co-firing was mandated in the coal power plants of Delhi NCR in October, 2021. However, the State Electricity Regulatory Commissions (SERC) have only recently clarified their position on passing through the cost of complying with this mandate.

Punjab ERC issued the confirmation of passing through the cost in October, 2022, whereas Haryana ERC allowed for pass-through of the cost incurred on account of biomass co-firing in August, 2022. However, these orders are applicable only for the power plants covered under Section 62 of the Electricity Act, 2003. This implies that the regulations for pass-through of cost on account of biomass co-firing is clear in eight out of total 11 power plants in Delhi NCR.

In early January, 2023, the Centre for Science and Environment (CSE) was informed that the Harduaganj power station in Uttar Pradesh was in the process of filing a petition for the inclusion of the cost of biomass co-firing in tariff. However, we could not trace any other petitions or orders on the Uttar Pradesh Electricity Regulatory Commission (UPERC) website for further clarity on their position with respect to passing through the cost of biomass co-firing in energy charge rates.

In case of power plants covered under Section 63, there is ambiguity regarding the inclusion of any capital expenditure and fuel cost to be made by the power plant on account of the adherence to the direction for biomass co-firing. Though there is a provision in power purchase agreement to add capital cost based on change in law, power generating companies, such as Nabha Thermal power station told CSE that they want in-principle approval before they incur these costs.

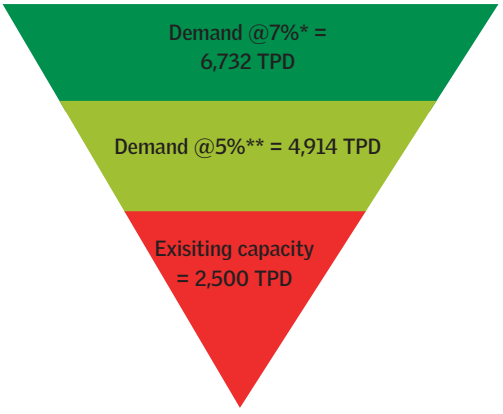
### 6.1.2 Skewed demand-supply of biomass pellets

According to the Ministry of Power's (MoP) policy on biomass utilisation, nearly 0.25–0.3 million tonnes (MT) of biomass pellets are required for every gigawatt capacity at seven per cent co-firing. There is an intense gap in demand and supply as there are a limited number of pellet manufacturers in the country. At present, the pellet manufacturing capacity for the entire country is 7000 tonnes per day while the requirement is for approximately 95–96 thousand tonnes per day, according to the inventory maintained by the National Mission on Use of Biomass for co-firing in coal thermal power plant.

The website of National Mission on the Use of Biomass (as accessed in August, 2022) lists only 23 pellet manufacturers in and near the Delhi NCR region with a cumulative capacity of approximately 2,500 tonnes per day, whereas the pellet demand in Delhi NCR is for approximately 5,000 tonnes per day.

The gap is even more intense in case of torrefied biomass pellets. Eight out of the 11 power plants have issued tenders for the supply of torrefied biomass, whereas there are only three suppliers of torrefied biomass listed on the National Mission on the Use of Biomass web portal, with a cumulative capacity of 54 tonnes per day (TPD). However, according to the tenders assessed by CSE, the requirement for torrefied pellets in coal-based power plants in the Delhi NCR region is for 2,884 TPD.

**Figure 4: Biomass pellet demand-supply gap in case of Delhi NCR coal-based power plants**




Source: (*)- as calculated, (**)- as per tenders issued, Existing capacity as per Ministry of Power, At present, the capacity of agro-residue pellet manufacturers ranges from 10 tonnes per day (TPD) to 400 tonnes per day (TPD).

The National Thermal Power Corporation Limited-Dadri started co-firing biomass in November 2019 after demonstrating successful trial runs in 2017. But the co-firing is being carried out only intermittently based on the availability of biomass. The plant uses approximately 25,000 tonnes of coal for its daily generation, whereas in the last two and a half years, it has co-fired only 20,581 tonnes of biomass as of May, 2022. This significant gap is due to the fluctuation in the supply of biomass pellets.

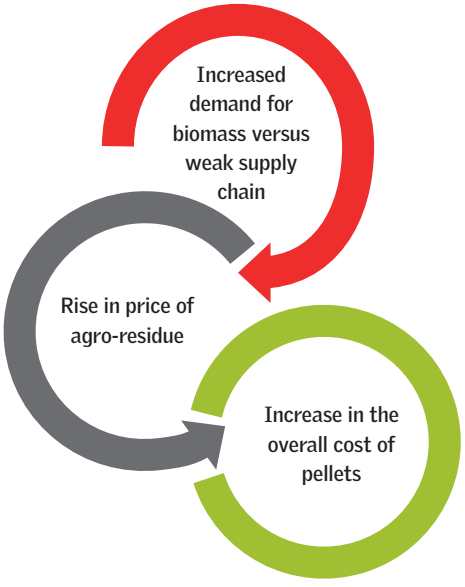
### 6.1.3 Soaring prices of biomass pellets for coal power plants

The cost at which pellets are supplied to power plants has increased from Rs 8–9 per kg in January, 2021 to Rs 12–14 per kg in June, 2022.

The steep rise in cost of pellets within a short period can be attributed to the increased demand for biomass post the mandate issued by the Commission on Air Quality Management (CAQM) and MoP on the use of biomass in industries (in Delhi NCR) and power plants respectively. This mandate was not supported by a robust supply chain. In addition to this, a CSE survey shows that in most cases, the price of agro-residue has doubled in the last two years, thus escalating the cost of biomass processing *(see Table 4)*.

Although a higher rate of agro-residue implies an increase in farmers' income and consequential decline in stubble burning, it also results in an increase in the cost of fuel needed for power generation and consequently, higher consumer bills.

**Figure 5: Chain of events leading to the escalation in cost of biomass pellets**




Source: CSE, 2023

## 6.2 Challenges in supply chain management

### 6.2.1 Supplying briquette to industries more lucrative than supplying pellets to thermal power plants

A CSE survey shows that the cost per tonne of manufacturing pellets is much higher compared to that of briquettes (*see table 6: Manufacturing cost for briquette and pellets*). The growing demand for biomass in the form of both raw agro-residue and briquettes in Delhi NCR acts as an incentive for manufacturers or biomass suppliers because of the following reasons:

1. No tedious process of tendering in case of supply to industries
2. Assured demand from the industries
3. Less investment in briquette manufacturing set-up (*the costs of briquette machine and pellet machine has been discussed in 7.2.7 : Lack of standardisation of pelletisation machines*)

In addition to this, the agro-residue is procured by pellet manufacturers either directly from the farmers or from aggregators, from a distance of 30–50 km, which is economically unviable and further adds to the manufacturing cost of biomass pellets.

### 6.2.2 Unavailability of biomass for pellet manufacturing during monsoon

The low availability of agro-residue during the monsoon season and an increase in moisture in the raw materials, requires mechanical drying of the crop-residue which is an energy intensive process. It therefore imbalances the cost of manufacturing. As a result, several manufacturers who were interviewed, such as A.K. Construction, Agarwal Agro Industries and others, mentioned that they remain shut for business or decrease production during the monsoon season.

The manufacturing industry is at a nascent stage of development and is highly season-dependent. Therefore, none of the tenders assessed by CSE had a clause regarding a penalty on irregular supplies to power plants.

**Table 6: Manufacturing cost of briquette and pellets**

| Form of biomass | Cost per tonne (to manufacturer) |
|---|---|
| Raw agro-residue | 2,500–4,500 |
| Briquette | 3,500–5,600 |
| Pellet | 4,200–7,200 |

Source: CSE survey

### 6.2.3 Uncertainty in the tendering process

***Delay in awarding work orders by TPP***—The supply of pellets to power plants by vendors is undertaken through the process of tendering. During a CSE survey, manufacturers claimed that there was delay in awarding work contracts from the power plant's end. Without an assurance of demand, manufacturers have not been able to scale up their production.

The entire process—from tendering to awarding work orders to vendors—usually takes approximately six to eight months. The manufacturer is then given another nine months to prepare the consignment for delivery to the power plant. In case of a failure of the delivery, the power plant will issue a notice to the vendor for two to three months. However, in case there is no response to further delays, a new tender will be issued. Such delays—of one year or more— are discouraging for both power plants and manufacturers.

***Delays in tendering process***—In case of Delhi NCR, all the 11 plants have issued tenders for the procurement of biomass pellets in March–April, 2022 (*see Table 2: Status of co-firing in coal thermal power plants in Delhi NCR and tender details)*. CSE, in its survey of pellet manufacturers, found that most of these tenders have been retendered, or processes delayed, without any clarification from power generators. Records show that tenders for 9.1 million tonnes are still under process and work order for only 2.9 million tonnes of biomass pellets have been awarded until December, 2022 by power plants in Delhi NCR *(see Table 3: Status of the tenders for biomass pellets)*.

### 6.2.4 Issues regarding storage of biomass

Manufacturers and aggregators interviewed by CSE informed that the storage of agro-residue in raw form as well as pellets is challenging in several ways. The agro-residue is susceptible to absorbing moisture, especially if it is stored in the form of bales, like in the case of paddy straw. Storing agro-residue for long periods initiates biodegradation in the biomass, resulting in loss of raw material.

Biomass is susceptible to decomposition and absorption of moisture. The decomposition of biomass results in reduced mass and lowered energy content of the biomass. The decomposition of biomass is influenced by its exposure to moisture, temperature and duration of storage.[43] Another challenge that biomass storage faces is the risk of natural and accidental fires.

Due to unavailability of agricultural residue throughout the year, especially in

case of paddy that has to be stored for long duration in bulk, the manufacturers interviewed by Centre for Science and Environment (CSE)—Agarwal Agro Industries, A.K. Construction, Vipul Industries—said that they are small and medium scale operations and therefore do not have sufficient financial support to keep a huge land spaces locked specifically for long-term storage of agro-residue. In order to prevent dust, reabsorption of moisture and biological decomposition of the processed biomass, the bales as well as pellets are either covered with tarpaulin or stored in a covered shed.

According to the information gathered by CSE from tender documents, the supply of biomass pellets to power plants have to be made on a daily basis. The majority of power plants interviewed or visited by CSE—Harudaganj TPP, Mahatma Gandhi TPP, Panipat TPP, Rajiv Gandhi TPP, Yamunanagar TPP and Nabha TPP—either have no provision or their facilities are inadequate for long-term storage of biomass pellets.

### 6.2.5 Use of paddy stubble in the manufacture of pellets

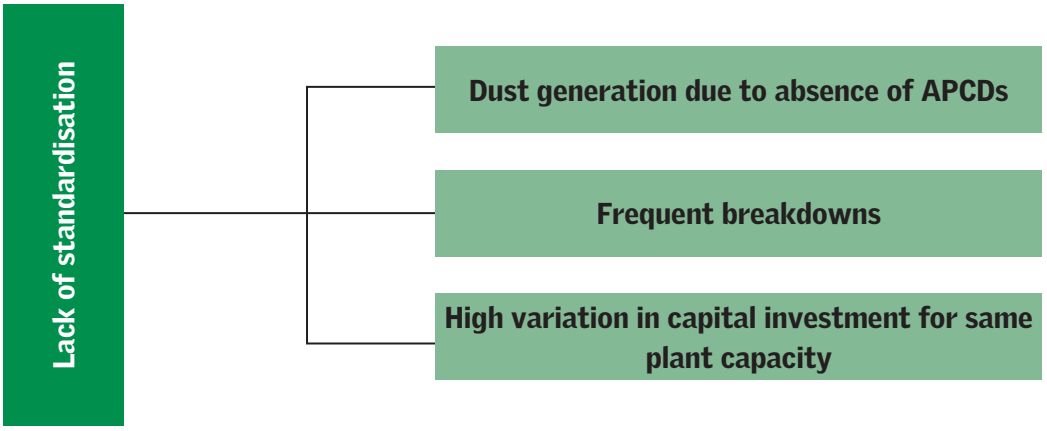
As stated in the previous sections, the government has mandated the use of paddy stubble to manufacture pellets for supply to the power plants in Delhi NCR. The financial support by the Ministry is only reserved for manufacturers who will use paddy for pellet manufacturing.

Paddy straw is only available from roughly 15–20 November each year. It has to be then stored for the remaining 8–9 months. The Indian Council on Agricultural Research (ICAR) in its survey, found that "due to weather changes and long term storage in changing weather conditions the paddy straw in the top few layers get damaged".

The long storage duration combined with low calorific value of the agro-residue, and difficulty in grinding due to the presence of silica in the residue, makes it less preferable compared to other crop residues.

Coal-based power plants have mandated that at least 50 per cent of the paddy procured from Punjab and Haryana should be used for the manufacture of pellets. However, at present, there are no laboratory tests available to determine which agro-residue has been utilised once it has been morphed into pellets. Therefore, there is a possibility that the manufacturer will rely less on paddy straw for pellet production and hence, co-firing of agro-residue in power plants may not be as effective in curbing stubble burning that is rampant during the winter season in the North-western belt in India.

**Figure 6: Major consequences of the lack of standardisation of machines**




Source: CSE, 2023

### 6.2.6 Lack of standardisation of pelletisation machines

Several technology providers such as New Lehra, Hi-tech, Ecostan, Shree Satyajit, and more, have built a strong catalogue of technological solutions for manufacturing of agro-residue pellets. However, there is no standardisation that is applicable to any of these machines used for processing of agro-residue for pellet manufacturing.

Some of the manufacturers provide bag filters or other air pollution control devices for different machines as biomass pelletisation is a dust generating process. However, as it adds further to the cost of machines, it is often avoided. Ground survey also shows that several manufacturers use 'stop gap' measures to manufacture pellets from briquette machines. These measures result in more frequent breakdowns and/or wear-and-tear.

The cost range of these farm machines is highly variable. A briquette manufacturing machine costs approximately Rs 2.5–4 million, whereas, the pelletiser machine costs Rs 15 million.[44] Therefore, for a small-scale industry, that mostly functions only 8–9 months in a year, setting up a pelletisation machine appears as an unsuitable investment considering, that there is already a growing market for the use of agro-residue directly or as briquettes at higher profit margins.

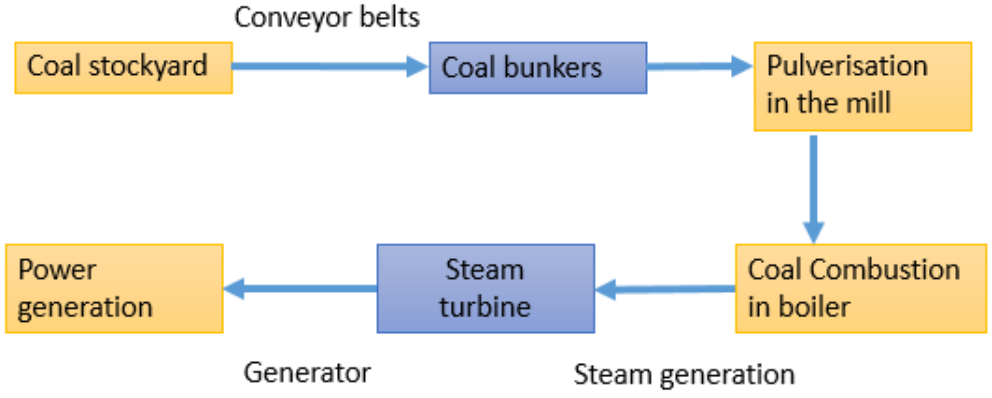
Lack of standardisation of machines results in more dust generation, uneven consumption of electricity, frequent breakdowns of machinery, more wear-and-tear, higher waste generation for the same material, and difference in the quantity of pellets generated because of the use of machines with different makes and models.

# ANNEXURE

## Annexure I: Working of a coal thermal power plant

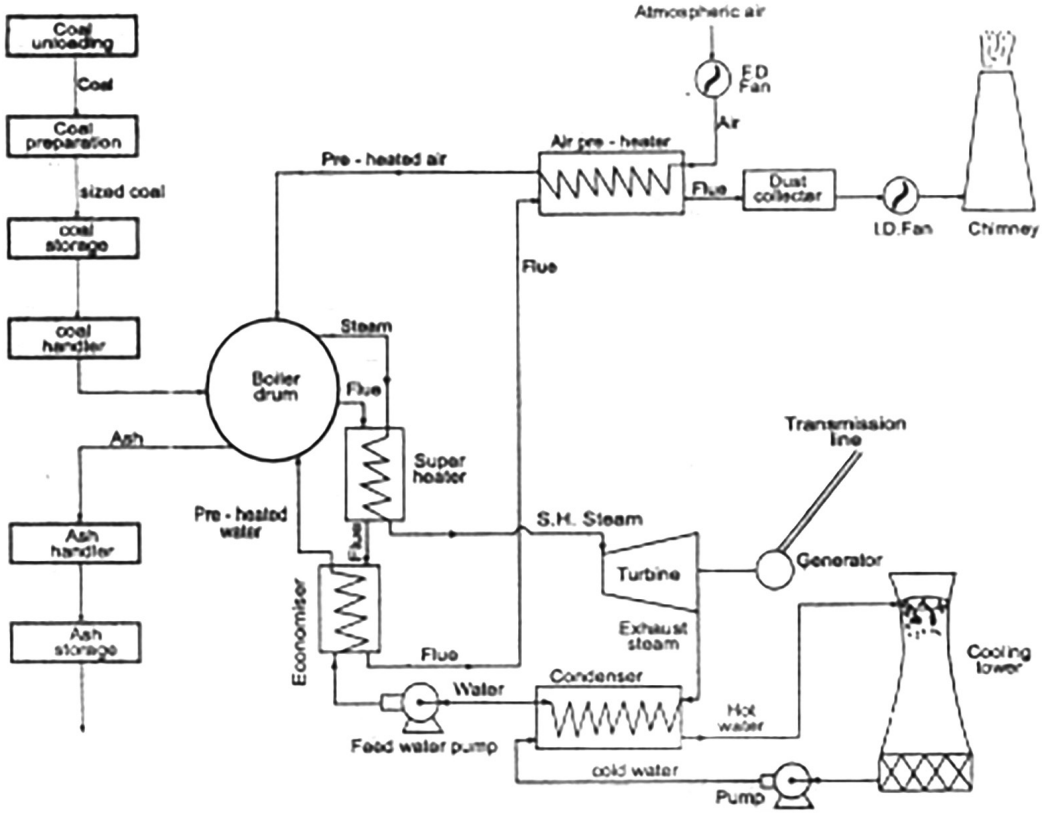
A basic understanding of the workings of a coal-based thermal power plant is important to understand the feasibility of biomass or agro-residue co-firing in it. The process starts with fuel sourcing followed by processing and combustion for power generation. Figure 3 illustrates a basic process flow diagram of electricity generation in power plants. Coal/lignite is pulverised into a fine size in a pulveriser and supplied to the boiler for combustion, where air helps with the process of combustion. The air is supplied as both fresh air (or pure oxygen) and preheated air. Water is supplied in a demineralized form, which is heated by the combustion of fuel and converted into steam under high temperature and pressure. The steam generated then passes through a series of turbines generating electricity through a turbo generator attached to the turbine.

**Figure 1: Basic process flow diagram of a thermal power plant**




Source: CSE, 2022

**Figure 2: Brief description of the working process of an ideal thermal power plant**




Source: CSE report "Heat on Power", 2015

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4. Item no. 95, "Transition to carbon neutral economy", Budget Speech 2022-2023, Government of India. www.indiabudget.gov.in

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6. M. Mishra and Kulshrestha 2021. *Crop residue burning in Northwestern India: Need for alternative solutions.* JNU-Envis Geodiversity and Impact on Environment. www.researchgate.net/publication/350515907_Crop_Residue_Burning_in_Northwestern_India_Need_for_Alternative_Solutions, last accessed on 20 July, 2022

7. The three North-western states of India—Punjab, Haryana and Uttar Pradesh —are significant contributors to agricultural production in India. Together with Rajasthan, these states account for almost 44 per cent of the surplus agro-residue generated in the country as per the 2018 study titled, "Estimation of surplus crop residue in India for biofuel production", conducted by the Indian Agricultural Research Institute (IARI) and the Technology Information Forecasting and Assessment Council (TIFAC). The burning of agro-residue or crop residue to clear fields is a common practice in these regions. However, this practice has intensified in the last few years due to mechanised crop

harvesting, high cost of removing crop residue from fields, and a shortage of labour.

8. Anon 2021. *Revised Policy for Biomass Utilisation for Power generation through Co-firing in coal based power plants*. Ministry of Power, Government of India

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11. According to the Indian Electricity Act (2003) the Renewable Purchase Obligation mandates that all electricity distribution licensees should purchase or produce a minimum specified quantity of their requirements from Renewable Energy

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13. National Mission on use of biomass in thermal power plants under Ministry of Power. https://samarth.powermin.gov.in/

14. Anon 2022. *Section 2 (b) of Model contract for use of biomass in thermal power plants (TPPs)*. Ministry of Power

15. Ex-situ Paddy Straw Management through utilisation in coal based thermal power plants", CAQM direction no. 120015/25/TPP/2021/CAQM-/948-955, dated September 17, 2021

16. Anon 2022. *Section 2 (b) of Model contract for use of biomass in thermal power plants (TPPs)*. Ministry of Power

17. Punjab contributes the highest share of paddy straw (64%), followed by Uttar Pradesh (29%) and Haryana (7%). Although stray incidents of agro-residue

burning take place throughout the year, these incidents intensify at a massive scale during the months of October and November, especially in Punjab and Haryana. This is due to the fact that farmers in this belt have a very narrow window—only 20–25 days—between harvesting their paddy and sowing a new crop of wheat for the next season. This burning of crop residue from the paddy harvest leads to the worsening of air quality in the Indo-Gangetic belt.

18. Anon 2022. Section 14 (1), pg-10, Commission for Air Quality Management in National Capital Region and Adjoining Areas Act, 202, Section 14(1), pg-10. https://caqm.nic.in/

19. Emmanouil Karampinis et al. 2013. "Co-firing of biomass with coal in thermal power plants: technology, schemes, impacts, and future perspectives". *Advances in Bioenergy: The sustainability challenge*. Wiley

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21. Davis A. Tillman, Dao N.B. Duong and N. Stanley Harding. 2012. "Blending coal with biomass". *Solid fuel blending: Principles, Practices and Problems*. Elsevier.

22. Maria V. Gill and Fernando Rubiera. 2019. "Coal and biomass cofiring: fundamentals and future trends." *New Trends in coal conversion*. Elsevier

23. 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 volatilise. Hence, fouling indices for biomass are based on total alkali content.

24. Vinay Trivedi 2020. *Agro-residue for power: Win-win for farmers and the environment?* Centre for Science and Environment

25. CEA's technical specification of agro-residue based biomass pellets for co-firing in thermal power plant

26. Anon (n.a.): Standard Operating Procedure for biomass pellet cofiring in CFBC boilers, National Mission on use of biomass in thermal power plants

27. Anon 2022. Model contract for use of biomass in thermal power plants (TPPs), Ministry of Power (MoP)

28. Specific coal consumption i.e. the amount of fuel consumed per unit of output (power developed) per hour. It is a clear indication of the efficiency with which the plant develops capacity (power) from fuel.

29. Anon 2021. *46th Integrated Annual Sustainability Report*, 2021–22, NTPC Limited.

30. Most biomass types are characterised by seasonal availability. This seasonality leads to significant complications and increased requirements from the biomass supply chain. Almost all agro-residue biomass have a narrow time window for collection. Seasonal availability of crop residues entails storage of raw biomass in huge quantities with residue aggregators. This requires a huge amount of space, especially since crop residue is not available throughout the year. The safe storage of bales for their utilisation during off seasons presents an additional challenge for aggregators.

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34. Anon 2019. "Computation of Capital Cost." *Tariff Regulations 2019*, Computation of Capital Cost. Central Electricity Regulatory Authority. 43–51

35. Anon 2019. "Computation of Capacity Charges and Energy Charges", *Tariff Regulations 2019*, Central Electricity Regulatory Authority. 88-92

36. Ibid.

37 Anon 2021. *Ex-situ crop residue management options*. Indian Council of Agricultural Research

38. Anon 2021. *Impact of Energy Efficiency Measures, 2019–20*. Bureau of Energy Efficiency, Ministry of Power (MoP). Table 6, 13

39. Case no. HERC/Petition no. 23 of 2021 of Haryana Power Generation Corporation Ltd. under "Section 86(1)(a) 86(1)(e) read with Section 61 & 62

of the Electricity Act, 2003 for seeking indulgence of the Hon'ble Commission for framing the proposed methodology for claiming the Biomass Fuel Cost as mandated to be utilized in HPGCL Units under "Change in Law", with Haryana Electricity Regulatory Authority

40. Ibid.

41. Anon 2021. *Commission for Air Quality Management in National Capital Region and Adjoining Areas Act, 2021.* The Gazette of India.

42. Anon 2022. Petition no. 32 of 2022 dated 27th October, 2022 in the matter of Punjab State Power Corporation Ltd. (PSPCL) Vs. Punjab State Power Corporation Ltd. Punjab State Electricty Commission.

43. Vinay Trivedi 2020. *Agro-residue for power: Win-win for farmers and the environment?* Centre for Science and Environment

44. CSE survey; proce quote received from Ecostan

In October 2021, the Ministry of Power (MoP) mandated the use of biomass residue for co-firing in coal-based thermal power plants. The policy was introduced to address the twin challenges of curbing emissions from coal power plants and pollution from burning crop residue. According to the policy, coal is to be replaced with densified biomass, called pellets, by 5–10 per cent by weight.

The Centre for Science and Environment conducted an extensive field survey to understand the status of biomass co-firing, and what limits its uptake in the 11 coal-based power plants in Delhi NCR. Records show that not even one per cent of the coal used has been replaced with biomass in any of the coal thermal power plants in Delhi NCR. Co-firing is being carried out only intermittently based on the availability of biomass. Keeping a check on the escalating cost of biomass pellets and providing more clarity when it comes to regulatory mechanisms are two measures that can help with the implementation of the mandate.

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