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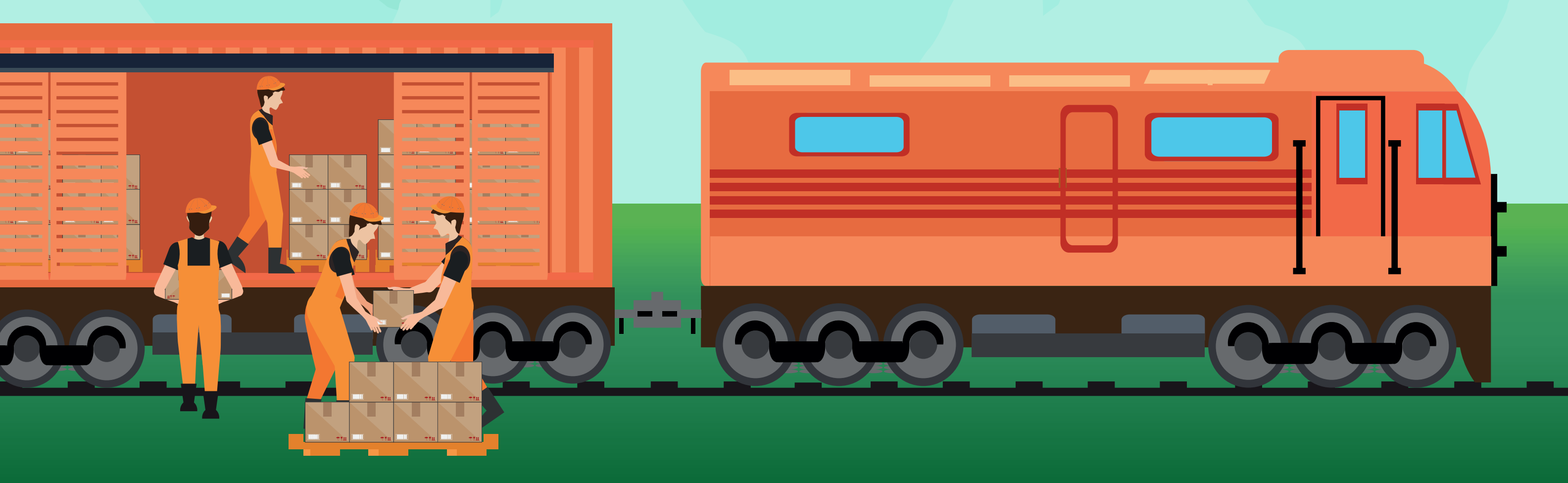
MOVING TOWARDS A LOW-CARBON TRANSPORT FUTURE

Increasing **Rail Share** in Freight Transport in India

Working Paper – Fly Ash



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About Shakti: Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that support energy efficiency, renewable energy and sustainable mobility.

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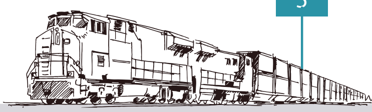

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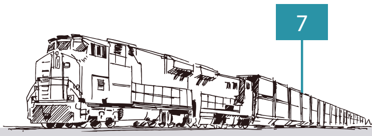

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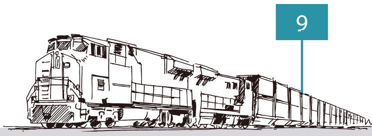


FLY ASH

With a share of over 60% in total electricity generation, the volume of fly ash generated by the thermal power plants in India is significantly high. Fly ash, which is a by-product of coal-based power generation, is a fine hazardous powder. It is produced by the combustion of powdered coal and collected in electrostatic precipitators (ESPs).

Over the past decade, the generation of fly ash by the Indian thermal power plants has increased significantly. Indian coal, which is used in power plants, has a low calorific value and high ash content (30–45%), which generates huge quantities of fly ash. Country's track record of utilizing fly ash has also been poor. Fly ash finds several applications in areas such as agriculture, cement manufacturing, brick industry, construction of road and rail embankments, reclamation of low-lying areas, mine fillings, etc. The pozzolanic property of fly ash/lime reactivity makes it suitable for use in manufacturing of cement and concrete.

Any thermal power station, generally, has four kinds of fly ash, which are:

Hopper ash: This kind of ash comes out of the boiler along with flue gases. It is collected by ESPs in a dry form. This dry fly ash is collected from different ESP fields and is of varying fineness. The fly ash collected from the ESP fields nearer to the boiler is coarser than that collected from the ESP fields away from the boiler (that is, nearer to the chimney).

Bottom ash: This kind of ash gets collected at the bottom of the boiler furnace and is, thus, referred to as bottom ash. It is coarser than dry fly ash/hopper ash.

Pond ash: When dry fly ash and bottom ash, or both mixed together, is carried in the form of water slurry and deposited in ponds where water gets drained away, the deposited ash is termed as pond ash.

Mound ash: When fly ash and bottom ash, or both mixed in any proportion, gets deposited in a dry form in the shape of a mound, it is termed as mound ash.

Aim of the Study

The study aims to examine the existing scenario of fly-ash transport in India, with a specific emphasis on the movement of fly ash through the Indian railways, as well as to come up with strategies to increase the share of railways in transporting fly ash.

Objectives

In order to fulfil the aim of the study, the following objectives have been formulated:

- To understand the existing scenario of fly-ash generation and utilization in India
- To understand the existing transportation scenario of fly ash in railways
- To identify the potential supply-and-demand clusters of fly ash
- To identify the factors responsible for the low modal share of fly ash in railways
- To develop fly-ash-specific strategies to increase the modal share of railways in transportation of fly ash

While the study team aimed at following above, lack of data and information regarding transport demand flows related to fly ash were areas of limitations in certain instances.

Guidelines and Policies for Fly-Ash Transportation in India

There are a two major guidelines issued by government agencies, which have been listed in this section. These guidelines are issued by the Central Pollution Control Board (CPCB) and the Ministry of Environment, Forests and Climate Change (MoEF&CC). It is to be noted at the outset that since these are guidelines, the parties involved in the generation, transportation, and utilization aspects of fly ash are not bound to adhere/follow. Interactions with the stakeholders indicate that specialized wagons or trucks are not deployed to transport fly ash from production point to consumption point.

CPCB Guidelines for Fly-Ash Transportation

The CPCB has framed guidelines for loading, unloading, utilization, and nuisance-free transportation of all types of fly ash, including dry fly ash and bottom ash generated by thermal power stations (TPS). Considering the various aspects of handling and transportation of fly ash, the CPCB suggests the following modes of transportation for different end users of fly ash so as to avoid dust emission (CPCB, 2013).

Cement/Asbestos Manufacturing

- Only specially designed road tankers/bulkers or mechanically designed, covered trucks provided with automatic loading and unloading system should be used.
- Specially designed railway wagons should be used for transport by rail.

Manufacturing of Fly-Ash-based Brick, Tiles and Blocks

- Tankers/ bulkers or mechanically designed, covered trucks shall be used.
- In case of tractors, trolleys which have the provision of a box-type cover on top with a hydraulic unloading system should be deployed for transporting dry or wet fly ash.

Mine/Abandoned Quarry Backfilling

- Tankers/bulkers or mechanically designed, covered trucks shall be used.
- Based on topography considerations and feasibility of the system, pipe conveyors can also be used.
- Ash slurry pipeline systems can be used to transport ash slurry directly from thermal power plants to abandoned mines, if permitted.

Road Construction and Filling of Low-Lying Area

- Tankers/bulkers or mechanically designed, covered trucks shall be used.

MoEF&CC Guidelines for Fly-Ash Utilization

To address the issue of fly-ash disposal in ash ponds and to reduce the problem of pollution caused by fly ash, the MoEF&CC has issued various notifications on fly-ash utilization. The first notification was issued on 14th September, 1999, which was subsequently amended in 2003, 2009, and 2016 vide notifications dated 27th August 2003, 3rd November 2009, and 25th January 2016, respectively.

To enhance the efforts for gainful utilization of fly ash, the latest MoEF&CC's notification of 25th January 2016 mandates (MoEF&CC, 2016) :

- Every agency engaged in construction within a 300-km range of any coal- or lignite- based thermal power plant must use only fly-ash-based materials for construction. This shall be applicable to all construction agencies whether government or private.
- No agency, person, or organization is allowed to construct or approve the design of road or flyover embankments with top soil within a 300-km range of any coal- or lignite- based thermal power plant. Also, the fly ash used for such embankment construction shall strictly adhere to the guidelines specified in IRC SP:58 of 2001, as amended from time to time.
- No agency, person, or organization shall undertake or approve or allow reclamation and compaction of low-lying areas with soil within a 300-km radius of any coal- or lignite-based thermal power plant. Only fly ash shall be used for compaction and reclamation.
- The cost of transportation of fly ash for road-construction projects, or manufacturing of ash-based projects, or any agricultural activity where ash is being used as soil conditioner within a 100-km radius of any coal-based thermal power plant has to be borne entirely by TPS and equally divided between the user and the thermal power station for distances more than 100 km and up to 300 km. In case of road-

construction projects under the Pradhan Mantri Gram Sadak Yojana and asset-creation programmes of the government, involving construction of buildings, roads, dams, and embankments, power plants shall bear the entire cost of ash transportation to the site within a 300-km radius.

- Pond ash should be made available free of cost on an 'as is where is' basis to the manufacturers of bricks, tiles, or blocks, including manufacturing units that make clay based fly ash products; farmers, the central and state road-construction agencies, the Public Works Department, and agencies engaged in backfilling or stowing of mines.
- It is also mandatory to use fly-ash-based products in all government schemes or programmes, for example, Pradhan Mantri Gram Sadak Yojana, Mahatma Gandhi National Rural Employment Guarantee Scheme, and Swachh Bharat Abhiyan.
- No person or agency shall undertake or approve stowing of mines without using at least 25% of fly ash on weight-to-weight basis of the total stowing materials used within a 50-km radius of a coal- or lignite-based thermal power plant.

Fly-Ash Transportation

Fly-ash transportation has many challenges as fly-ash particles are lightweight and can potentially get airborne easily and pollute the environment. Furthermore, its airborne character requires it to be transported in an enclosed container. As fly ash is used for a variety of purposes discussed earlier, proper and adequate measures should be undertaken while handling and transporting it.

Handling and Disposal of Fly Ash within the Power Plant

Fly ash collected from ESPs can be disposed of either in dry form or wet-slurry form. Dry ash is typically conveyed pneumatically from ESPs to storage silos, where it is kept dry till further processing, while bottom ash, which is collected from the bottom of the boiler, is disposed of into ash ponds in the form of wet slurry.

The following technologies are conventionally used for handling and disposal of fly ash and bottom ash from ESPs within the plant or up to the ash-pond area (CPCB, 2013) :

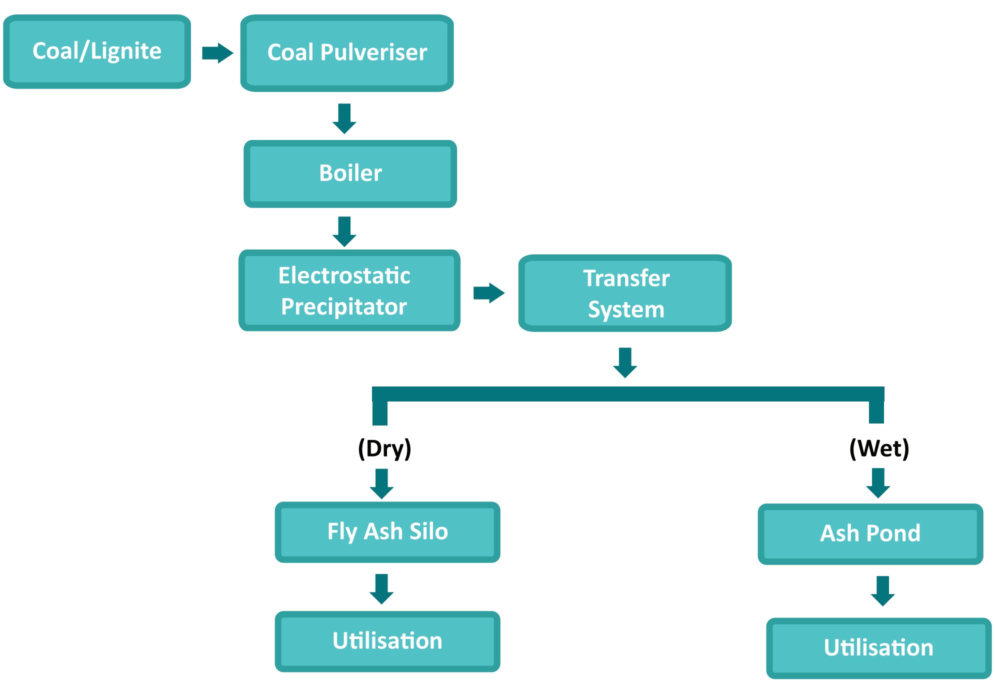


Figure 1: Process showing Handling and Storage of Fly Ash
Source: CPCB Guidelines for Transporting Fly ash, 2013

- Pneumatic conveying
- Lean slurry disposal system
- Medium concentration slurry disposal system
- High concentration slurry disposal system
- Dry (moist) conveying system through belt conveyor/ tube-belt conveyor

Handling and Disposal of Fly Ash outside the Power Plant

Fly ash is generally transported either from fly-ash silo or ash pond. The modes of fly-ash transportation are discussed ahead.

- Fly ash is generally transported by tractor trollies or trucks by brick manufacturers, cement manufacturers, and construction agencies based upon the requirement and distance (CPCB, 2013).
- Thermal power plants generally construct silos for intermediate storage of dry fly ash. After fly ash is loaded into these silos, it is transported to cement plants either by bulkers or trucks covered with tarpaulins (see Figure 2).
- Fly ash is also transported to abandoned mines by trucks covered suitably with tarpaulins. However, due to the non-availability of abandoned mines, mine backfilling using fly ash is carried out in very few thermal power plants (CPCB, 2013). As per the 2009 notification, fly-ash disposal in abandoned mines or quarries should be carried out under the guidance of the Directorate General of Mine Safety (DGMS) and the power plant authorities shall regularly monitor the groundwater in the surrounding area to assess groundwater contamination.

Figure 2:Photograph showing Fly Ash Loading Silos and Road Bulkers
Source: TERI

Fly-Ash Generation and Utilization in India

Indian coal is low-grade with an ash content of 30–45%, in comparison to imported coal which has low ash content, that is, 10–15%. (CEA, 2016-17) This results in the generation of large quantities of ash by coal-/lignite-based TPS in the country.

Fly-Ash Production

The Central Electricity Authority (CEA) has been monitoring the status of fly-ash generation and its utilization in the country since 1996. As per the CEA report, (CEA, 2016-17) data collated from 155 TPS across the country has been presented here to arrive at the present status of fly-ash generation and utilization in India.

Fly-ash generation has increased from 68.9 million tonnes in 1996–97 to 169.3 million tonnes in 2016–17 (CEA, 2016-17). Figure 3 shows the progressing fly-ash generation from 1996–97 to 2016–17.

Similarly, the utilization of fly ash has increased from 6.6 million tonnes in 1996–97 to 107.1 million tonnes in 2016–17 (CEA, 2016-17). Figure 4 shows the progressing fly-ash utilization from 1996–97 to 2016–17.

A large number of technologies have been developed for the gainful utilization and safe management of fly ash. As a result, both the generation and utilization of fly ash have increased significantly over the past decade. Figure 5 represents the total annual production of fly ash along with its corresponding utilization figures. The percentage of fly-ash utilization has increased from 9.6% in 1996–97 to 63.3% in 2016–17.

Although it appears from the Figure 5 that the utilization of fly ash has increased significantly in recent years, it does not entirely reflect the reality of the situation. It is important to note that the annual backlog tonnage of fly ash has been neglected in this analysis to arrive at the exact utilization level; hence, it is necessary to include the same to arrive at more realistic figures, and if we were to do so, the utilization level will go down significantly.

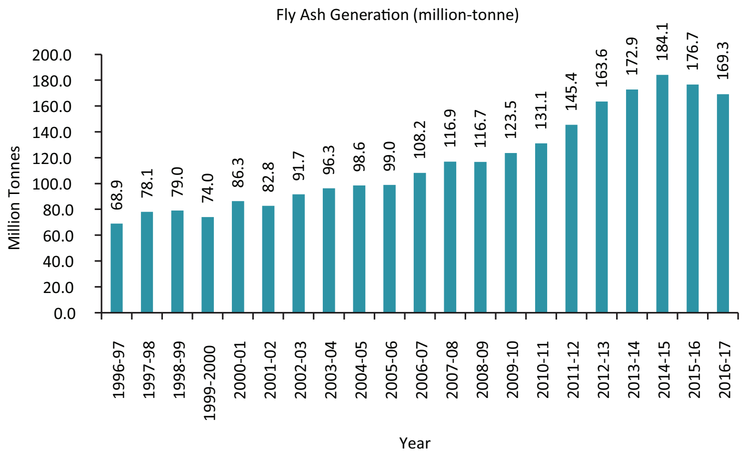


Figure 3: Scenario of Fly Ash Generation in India
Source: Report on Fly Ash Generation, Central Electricity Authority (2016-17)

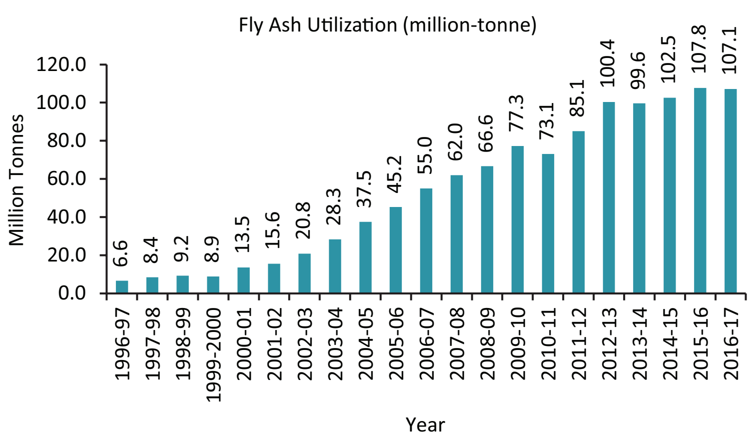


Figure 4: Scenario of Fly Ash Utilization in India
Source: Report on Fly Ash Generation, Central Electricity Authority (2016-17)

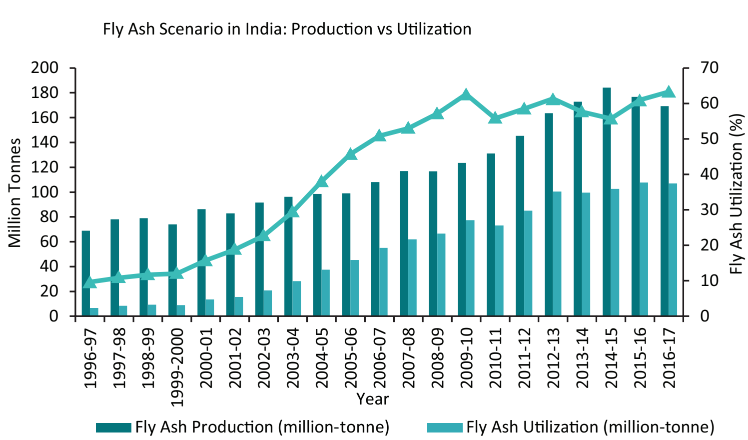


Figure 5: An Overall Scenario of Fly Ash Production in India
Source: Report on Fly Ash Generation, Central Electricity Authority (2016-17)

Table 1 represents the details of fly-ash backlog along with the utilization percentage. Lower utilization of fly ash over the years has led to the piling up of huge stocks of fly ash. The table makes it evident that a total of 1,332 million tonnes of fly ash has been stocked on ground as of 2016–17, of which only 107 million tonnes were utilized, that is, only 8% of the total fly ash available on ground. The table also highlights the significant difference between percentages of utilization before and after, including the backlog stocks of fly ash. It is to be noted that the utility of fly ash diminishes with time due to contamination.

Table 1: Annual Backlog of Fly Ash along with Percent of Utilization

S. No.	Year	Fly Ash Production (Million-Tonnes)	Fly Ash Utilization (Million-Tonnes)	Fly Ash Utilization	Cumulative Backlog of Fly Ash (Million Tonnes)	Fly Ash Utilization in % (After Including Backlog Tonnage)
1	1996-97	68.9	6.6	9.6%	62.2	-
2	1997-98	78.1	8.4	10.8%	131.9	6%
3	1998-99	79.0	9.2	11.7%	201.6	5%
4	1999-2000	74.0	8.9	12.0%	266.8	3%
5	2000-01	86.3	13.5	15.7%	339.5	4%
6	2001-02	82.8	15.6	18.8%	406.8	4%
7	2002-03	91.7	20.8	22.7%	477.6	4%
8	2003-04	96.3	28.3	29.4%	545.6	5%
9	2004-05	98.6	37.5	38.0%	606.7	6%
10	2005-06	99.0	45.2	45.7%	660.4	7%
11	2006-07	108.2	55.0	50.9%	713.6	8%
12	2007-08	116.9	62.0	53.0%	768.5	8%
13	2008-09	116.7	66.6	57.1%	818.6	8%
14	2009-10	123.5	77.3	62.6%	864.8	9%
15	2010-11	131.1	73.1	55.8%	922.8	8%
16	2011-12	145.4	85.1	58.5%	983.1	9%
17	2012-13	163.6	100.4	61.4%	1,046.3	10%
18	2013-14	172.9	99.6	57.6%	1,119.6	9%
19	2014-15	184.1	102.5	55.7%	1,201.2	9%
20	2015-16	176.7	107.8	61.0%	1,270.1	8%
21	2016-17	169.3	107.1	63.3%	1,332.3	8%

Source: Report on Fly Ash Generation, Central Electricity Authority (2016-17)

State-Wise Scenario of Fly-Ash Production

State-wise generation trends for 2016–17 suggest that Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Maharashtra, Uttar Pradesh, and West Bengal are the most significant states contributing to more than 50% of the total fly-ash generation in the country. Figure 6 shows the state-wise production of fly ash in the country.

It is evident from the map that Uttar Pradesh and Chhattisgarh produce the maximum fly ash, whereas Punjab, Haryana, Karnataka, and Telangana are the states with least production.

The reason these states have higher production is the number of power plants installed within their boundaries. These states have the highest number of thermal power plants installed in the country (see Table 2). Although Gujarat is an exception, as despite the total installed capacity of 15,472 MW, it has generated only 3.5 million tonnes of fly ash. Most of these power plants use imported coal with ash content as low as 6–7%, as compared to Indian coal with ash content of 30–45%. Hence, the amount of ash produced is also comparatively less. Table 2 shows the generation and utilization figures of all the states.

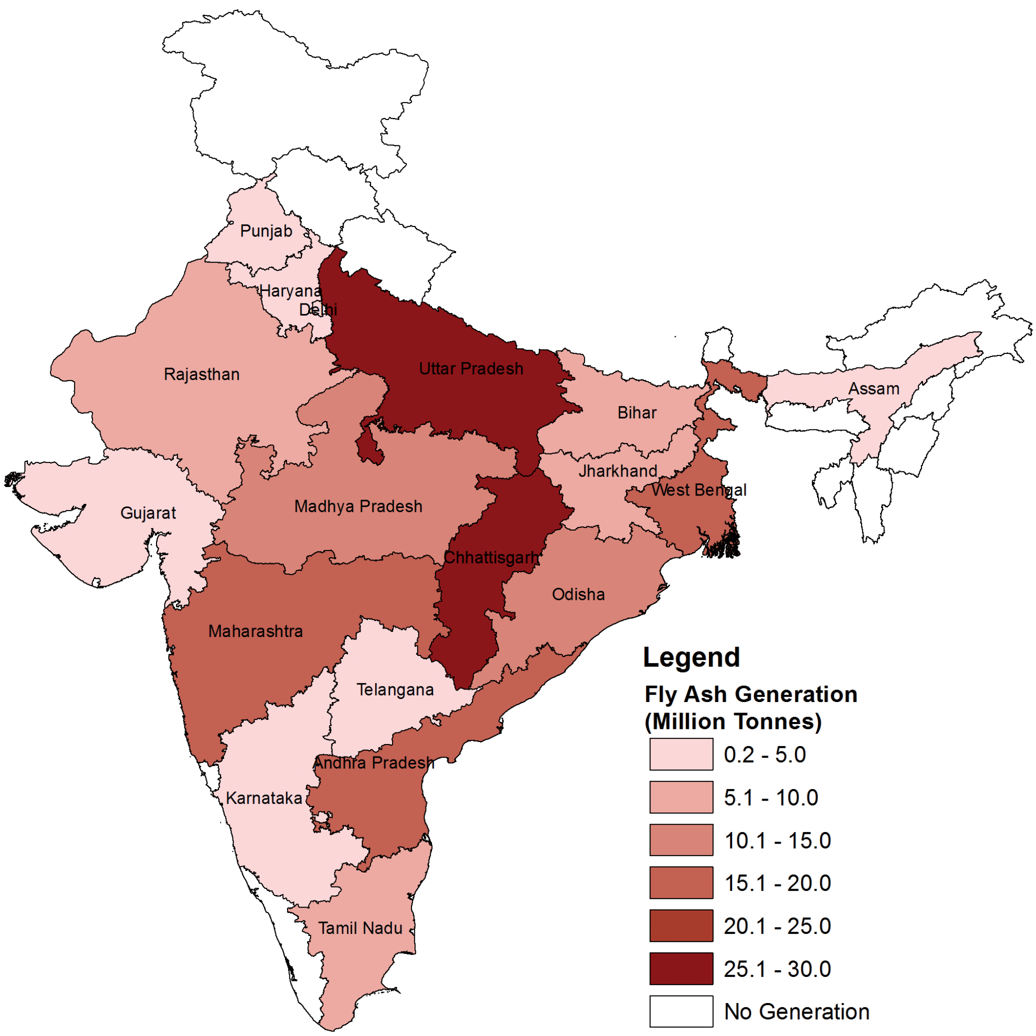


Figure 6: State wise Scenario of Fly Ash Production in India (2016-17)
Source: Report on Fly Ash Generation, Central Electricity Authority (2016-17)

Table 2 : State wise scenario of fly ash production in India

S.No.	State	No. of Thermal Power Stations	Installed Capacity (MW)	Fly Ash Generation (Million-Tonnes)	Fly Ash Utilization (Million-Tonnes)	Fly Ash Utilization in %
1	Uttar Pradesh	18	19,104	28.3	13.2	47%
2	Chhattisgarh	20	17,740	25.2	10.8	43%
3	Andhra Pradesh	10	10,973	17.8	12.7	71%
4	West Bengal	17	14,142	16.7	13.8	83%
5	Maharashtra	20	21,556	16.5	11.8	71%
6	Odisha	5	5,188	11.5	6.4	56%
7	Madhya Pradesh	7	10,640	11.4	4.1	36%
8	Bihar	4	4,100	7.4	2.4	32%
9	Rajasthan	8	7,840	6.8	6.4	95%
10	Jharkhand	7	5,613	6.7	7.3	108%
11	Tamil Nadu	10	8,430	6.2	4.6	75%
12	Haryana	5	5,550	4.1	5.3	128%
13	Gujarat	11	15,472	3.5	3.5	102%
14	Karnataka	4	5,480	3.1	1.7	56%
15	Telangana	3	1,820	2.7	1.0	36%
16	Punjab	3	2,640	0.9	1.4	162%
17	Delhi	2	840	0.4	0.6	157%
18	Assam	1	250	0.2	0.0	0%
	Grand Total	**155**	**1,57,377**	**169.3**	**107.1**	**63%**

Source: Report on Fly Ash Generation, Central Electricity Authority (2016-17)

As evident from Table 2, states generating more fly ash do not necessarily have a higher percentage of utilization when compared to other states. States like Jharkhand, Haryana, Gujarat, Punjab, and Delhi are utilizing more than what they are generating, hence acting as consumption centres of fly ash. On the contrary, the utilization figures of states like Bihar, Chhattisgarh, Madhya Pradesh, and Telangana hover around 30–40%, which is the lowest amongst all the states.

Plant-Wise Scenario of Fly-Ash Production

Most of the fly-ash generation can be attributed to TPS located in the states of Uttar Pradesh, Madhya Pradesh, Chhattisgarh, West Bengal, and Andhra Pradesh. Figure 7 shows the location of these power plants. It is evident from the map that most of the fly-ash production clusters are located in the middle-eastern part of the country. The size of the circles in the map represents the corresponding generation values of each power plant in million tonnes.

Table 3 lists the top 20 power plants in the country in terms of fly-ash generation. NTPC Vindhyachal tops the list with an annual production of 7.6 million tonnes in 2016–17 followed by Anpara, NTPC Talcher in Odisha, and NTPC Sipat and Korba in Chhattisgarh. As mentioned earlier also, these thermal power stations may not necessarily be the ones with the highest installed capacity, but since they use coal with comparatively higher ash content, the fly-ash generation values are higher irrespective of their installed capacity.

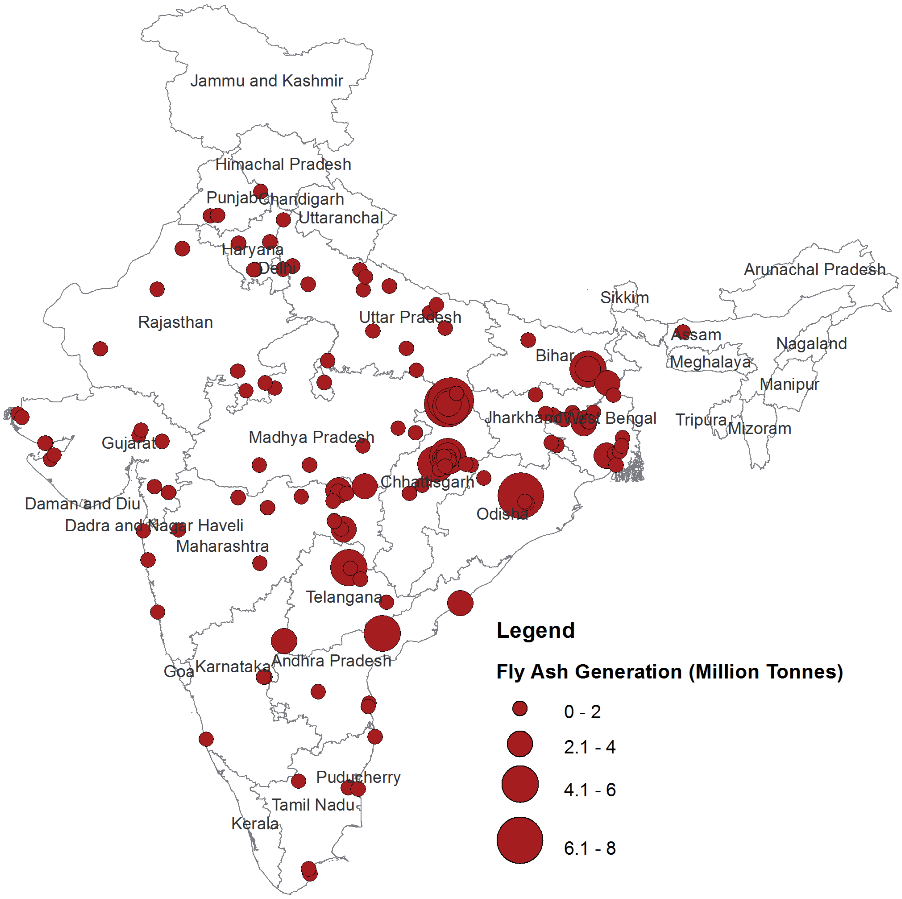


Figure 7: Location of Coal/Lignite based Thermal Power Stations in India
Source: Report on Fly Ash Generation, Central Electricity Authority (2016-17) & TERI Analysis

Table 3: List of Top 20 Thermal Power Stations (TPS) in India in terms of Generation of Fly Ash

Name of TPS	Power Utility & State	Installed Capacity (MW)	Fly Ash Generation (Million Tonnes)	Fly Ash Utilization (Million Tonnes)	Percentage Utilization (%)
Vindhyachal (Madhya Pradesh)	NTPC Ltd. (Madhya Pradesh)	4,760	7.6	1.8	23.5%
Anpara (Uttar Pradesh)	UPRVYNL (Uttar Pradesh)	2,630	7.2	0.0	0.4%
Talcher (Odisha)	NTPC Ltd. (Odisha)	3,000	7.1	3.1	43.2%
Sipat (Chhattisgarh)	NTPC Ltd. (Chhattisgarh)	2,980	5.4	1.2	22.8%
Korba (Chhattisgarh)	NTPC Ltd. (Chhattisgarh)	2,600	5.1	2.3	45.0%

Table 3: List of Top 20 Thermal Power Stations (TPS) in India in terms of Generation of Fly Ash

Name of TPS	Power Utility & State	Installed Capacity (MW)	Fly Ash Generation (Million Tonnes)	Fly Ash Utilization (Million Tonnes)	Percentage Utilization (%)
Kahalgaon (Bihar)	NTPC Ltd. (Bihar)	2,340	5.1	2.2	44.0%
Rihand (Uttar Pradesh)	NTPC Ltd. (Uttar Pradesh)	3,000	4.9	0.8	15.5%
Ramagundam (Andhra Pradesh)	NTPC Ltd. (Andhra Pradesh)	2,600	4.7	4.4	93.1%
Dr. Narla Tata Rao TPS (Andhra Pradesh)	APGENCO (Andhra Pradesh)	1,760	4.0	3.0	75.4%
Mejia (West Bengal)	DVC (West Bengal)	2,340	3.7	4.0	107.0%
Singrauli (Uttar Pradesh)	NTPC Ltd. (U.P.)	2,000	3.7	0.3	9.1%
Adani Power Ltd. (Maharashtra)	Adani Power Ltd. (Maharashtra)	3,300	3.5	2.2	62.2%
Chandrapur (Maharashtra)	MSPGCL (Maharashtra)	2,340	3.4	1.6	47.6%
Simhadri (Andhra Pradesh)	NTPC Ltd. (Andhra Pradesh)	2,000	3.1	206	83.7%
NTPC Farakka (West Bengal)	NTPC Ltd. (West Bengal)	2,100	3.0	1.7	55.3%
Korba (West) (Chhattisgarh)	CSPGCL (Chhattisgarh)	1,340	3.0	0.1	2.2%
Raichur (Karnataka)	KPCL (Karnataka)	1,720	2.6	1.4	52.8%
Barh Super TPS (Bihar)	NTPC Ltd. (Bihar)	1,320	2.1	0.1	4.6%
Kolaghat (West Bengal)	WBPDCL (West Bengal)	1,260	2.1	2.4	117.6%
Khaparkheda (Maharashtra)	MSPGCL (Maharashtra)	1,340	2.0	0.7	36.2%

Source: Report on Fly Ash Generation, Central Electricity Authority (2016-17)

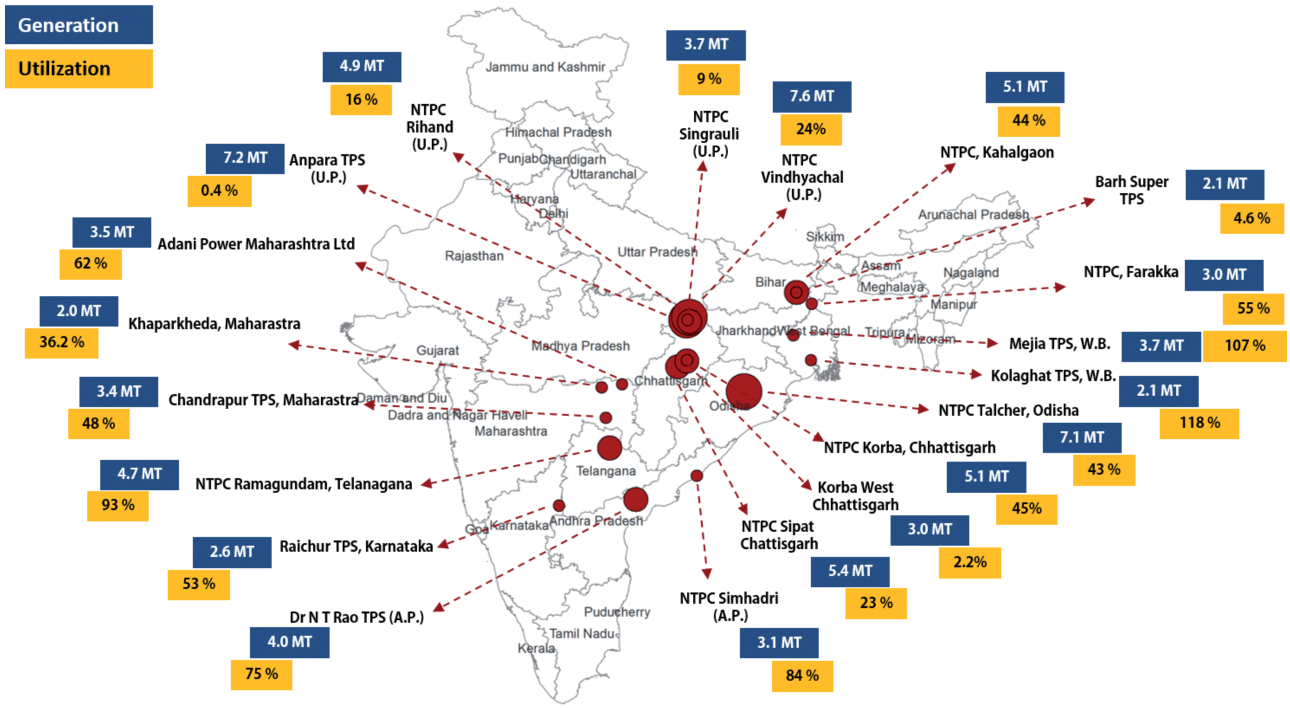


Figure 8: Top 20 TPS in India along with Production Figures (2016-17)
Source : Report on Fly Ash Generation , Central Electricity Authority (2016-17) & TERI Analysis

Mode of Fly-Ash Utilization

Fly ash, which was once considered to be 'hazardous industrial waste', has now acquired the status of a resourceful commodity. The current major modes of fly-ash utilization in the country as per the CEA are shown in Table 4.

Table 4 shows that cement manufacturing has the largest share of fly-ash consumption, followed by brick manufacturing, reclamation of low-lying areas, and mine filling. Also, a significant amount of fly ash is still not utilized. Figure 9 shows the modes of fly ash utilization during 2016–17. In this report, focus is on the use of fly ash by cement plants, since bulk movement of the product is possible by rail with consumption centres concentrated in select regions.

Table 4 : Mode of Fly ash Utilization

S. No.	Mode of Utilization	Million-Tonnes
1	Cement manufacturing	40.6
2	Mine filling	11.8
3	Bricks & tiles manufacturing	14.9
4	Reclamation of low lying areas	11.0
5	Ash dyke raising	11.9
6	Roads & flyovers	6.2
7	Agriculture	1.9
8	Concrete	0.8
9	Hydro power sector	0.0
10	Others	8.0
11	Unutilized fly ash	62.2
	Total	169.3

Source: Report on Fly Ash Generation, Central Electricity Authority (2016-17)

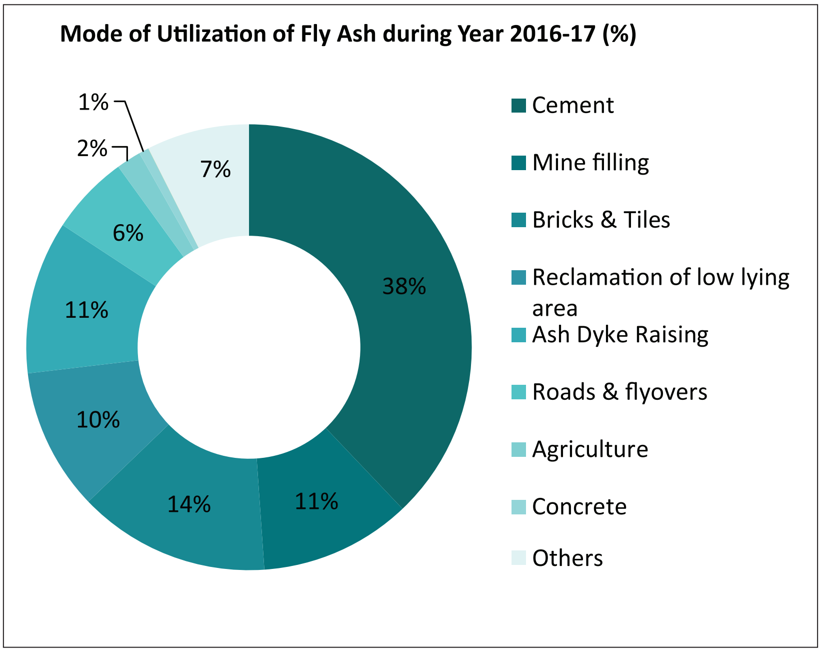


Figure 9: Major Modes of Fly Ash Utilization
Source: Report on Fly Ash Generation, Central Electricity Authority (2016-17)

Fly-Ash Transport in Indian Railways

As per the data received from the Centre for Railway Information Systems (CRIS), Ministry of Railways, the tonnage of fly ash carried by railways increased from 1.5 million tonnes in 2011–12 to 2.5 million tonnes in 2016–17. Although when compared to the total fly ash transported, the share of Indian Railways is substantially low. The modal share of railways in transporting fly ash, which was 1.7% in 2011–12, has slightly increased to 2.3% in 2016–17. As per CRIS, Indian Railways carried 1.8 million tonnes of fly ash during 2017-18. However, calculations regarding modal share of railways could not be done as data related to fly ash generation and utilization for 2017-18 were not released by the CEA (at the time of publishing this report).

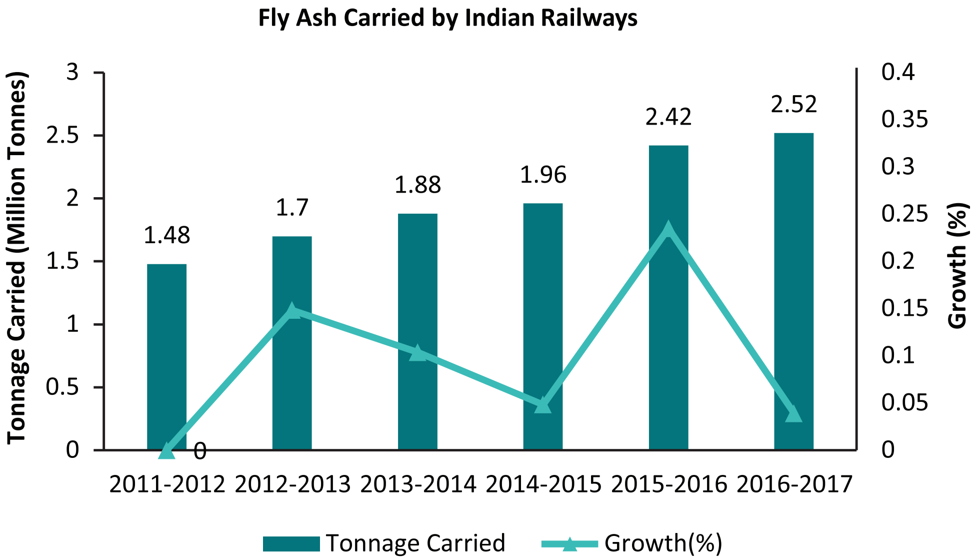


Figure 10: Fly Ash Tonnage Carried by Railways
Source: Centre for Railway Information Systems, Ministry of Railways (2016-17)

Figure 10 shows that although the tonnage of fly ash carried by railways increased significantly, from 2011-12 to 2016-17, the growth rate for the same has not been smooth. There was a substantial spike in growth from 5% in 2015 to 23% in 2016, but it has again declined to 4% in 2017, which is the lowest mark for railways in the past six years. Table 5 shows the various parameters related to fly-ash movement by rail.

The number of rake movements containing fly ash has increased from 507 trips in 2011–12 to 856 trips in 2016–17 (see Figure 11). Similarly, net tonne km has also increased from 866 million to 1,403 million. The average lead over which Indian Railways has been transporting fly ash has stayed more or less constant over the past few years, ranging between 550 km and 600 km.

Table 5: Scenario of Fly Ash Transport by Indian Railways

Year	Trips Originating	Tonnage Carried (Million Tonnes)	Net Tonne Kilometres (Million)	Average Lead (Km)
2011-2012	507	1.5	866	586
2012-2013	576	1.7	954	562
2013-2014	644	1.9	1107	590
2014-2015	660	2.0	1137	579
2015-2016	833	2.4	1443	595
2016-2017	856	2.5	1403	556

Source: Centre for Railway Information Systems, Ministry of Railways (2016-17)

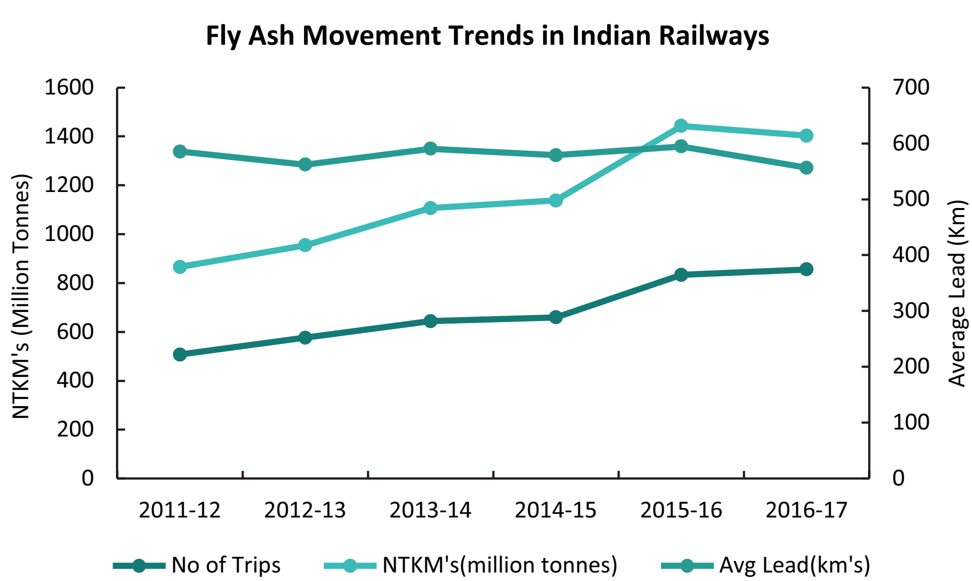


Figure 11: Fly Ash Movement Trends in Indian Railways
Source: Centre for Railway Information Systems, Ministry of Railways (2016-17)

Origin-Destination Analysis

An origin-destination (O-D) analysis has also been carried out to understand the spatial pattern of fly-ash transportation in India by Indian Railways. As evident from Table 6, Bihar, Jharkhand, Karnataka, and West Bengal have the major share of originating trips for fly-ash transport by railways, whereas Assam and Karnataka serve as the major attraction/consumption zones where fly ash is being transported by railways.

Further, the O-D data suggests that most of these originating trips have been concentrated in only a few origin stations rather than being distributed uniformly across the country, which means transport by railways has been restricted to selected stations. Table 7 shows the details of such stations.

A total of 4,076 rakes of fly ash have been moved by Indian Railways between 2011 and 2017, which gives an average of 679 rakes per year. It is evident from Table 7 that a total of 660 rakes in a year are originating from the above six stations, which means that around 97% of the total originating trips in a year are attributed to these stations only.

Similarly, Table 8 gives us a peek into the destination ends of the fly ash rakes carried by Indian Railways. Again, considering a total average of 679 rakes per year, which are reaching various destinations, the destinations of 641 rakes are concentrated in only 11 stations (shown in Table 8), which means that around 94% of the total destined trips are attributed to these stations only.

Table 6: Origin-Destination Table showing rake movement of fly ash by Indian Railways between 2011 and 2017 (Number of rakes)

O/D	Assam	Bangladesh	Bihar	Jharkhand	Kerala	Karnataka	MP	Tripura	UP	West Bengal	Production Ends
Assam	2										2
Bihar	720	28	53						1	4	806
Jharkhand	499	18	121	1					1	2	642
Karnataka					1	1,066					1,067
Maharashtra						11					11
MP									3		3
Odisha										1	1
Telangana						243					243
UP			1				1				2
West Bengal	1,242	31	19					1		7	1,300
Attraction Ends	2,464	77	193	1	1	1,320	1	1	5	14	4,076

Source: Centre for Railway Information Systems, Ministry of Railways (2016-17)

Table 7 : Major Origin Nodes in terms of Fly Ash Transport through Indian Railways

S.No.	Originating Stations	Avg. Rakes/Year
1	Siuri, West Bengal	180
2	ARV Cement Society and ACC Ltd. (Raichur KPCL), Karnataka	178
3	NTPC Private siding, Kahalgaon	134
4	Private siding of m/s TATA Power Company Ltd. at Jojobera	105
5	Kesoram Cement Ltd., Raghavapuram (NTPC Ramagundam)	35
6	Dhulianganga (NTPC Farakka)	28
	Grand Total	660

Source: Centre for Railway Information Systems, Ministry of Railways (2016-17)

Table 8: Major Destination Nodes in terms of Fly Ash Transport through Indian Railways

S.No.	Destination Stations	Avg. Rakes/Year
1	Digaru, Assam	184
2	Vasavadatta Cement Ltd, Karnataka	94
3	Ultra Tech Cement Limited (Unit of Rajashree Cement Works) , Karnataka	69
4	Tetelia, Assam	59
5	ACC Ltd. Siding (Wadi), Karnataka	56
6	Chang Sari, Assam	56
7	Lanka, Assam	38
8	New Guwahati Goodshed, Assam	30
9	Raxaul Junction, Bihar	30
10	Amoni, Assam	15
11	Barpeta Road, Assam	10
	Grand Total	641

Source: Centre for Railway Information Systems, Ministry of Railways (2016-17)

Figure 12 shows the major origin and destination nodes based on O-D analysis.

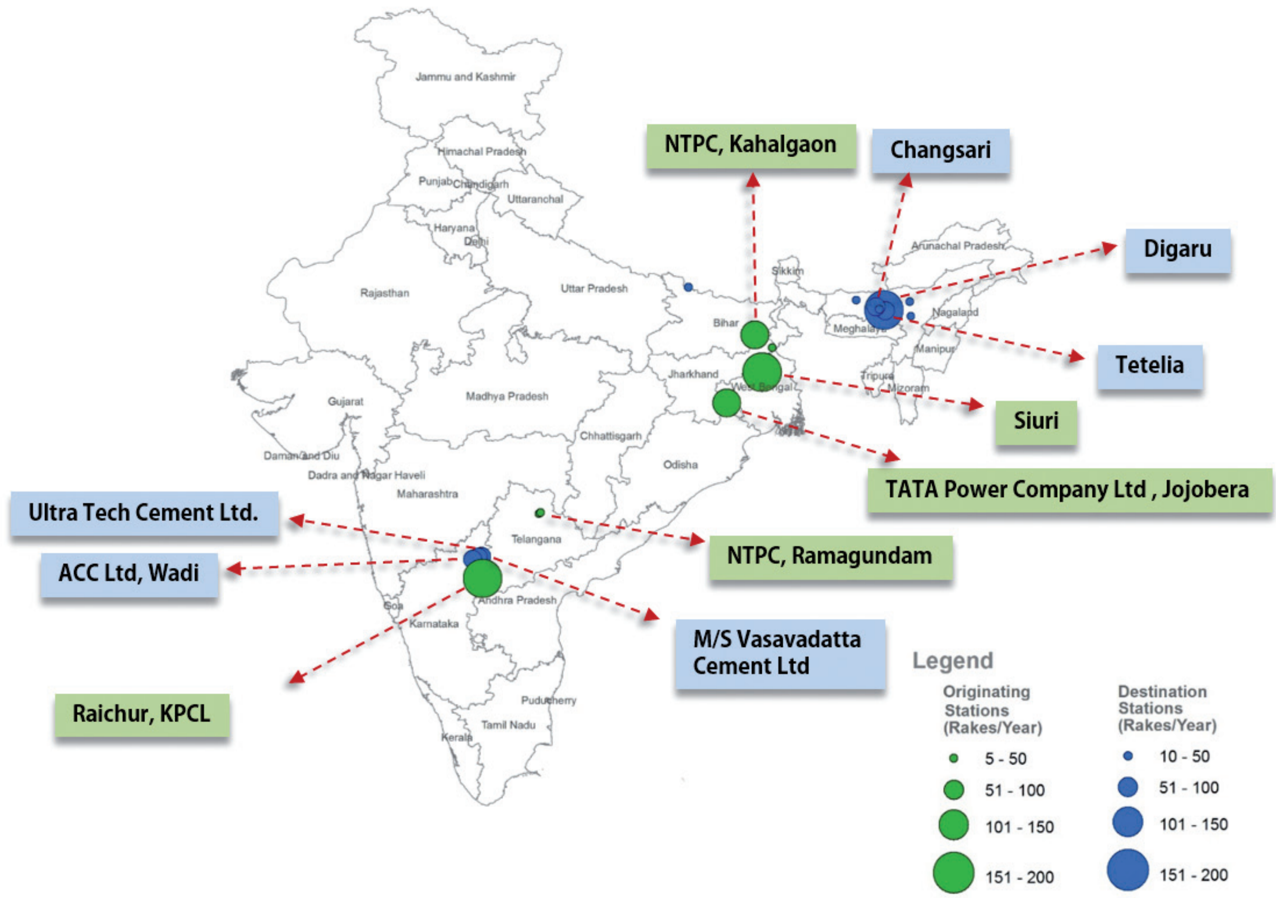


Figure 12 : Major Origin and Destination Nodes for Transporting Fly Ash through Railways
Source: Centre for Railway Information Systems, Ministry of Railways (2016-17) & TERI Analysis

Rake Composition

As per the CPCB guidelines, specially designed railway wagons should be used for transporting fly ash by rail, but as of now, most of the fly ash is being transported in BCN wagons (see Figure 13), which are mainly used for transporting cement. Around 67% of the total fly ash is transported in BCN wagons, where it is first bagged and then loaded into the wagons. Specialized fly-ash wagons are being used on only few circuits such as Raichur and Ramagundam. Cement manufacturers in these circuits have procured BCCW and BCFC wagons, which are being used to transport fly ash from thermal power plants located in Raichur and Ramagundam (see Figures 14 and 15). These are top-loading and bottom-discharge wagons. Around 31% of the total fly ash is being transported in BCCW wagons, followed by BCFC wagons which contribute to merely 1.4%.

Another type of wagon, which is still under the trial phase for transporting fly ash, is the BTAP wagon (see Figure 16). This wagon is used to transport alumina powder. Trials for bulk transportation of fly ash have been undertaken by NTPC in BTAP wagons, but commercial operation of such wagons is still awaited. These are top-loading wagons and have the option for both bottom- and side-discharge.

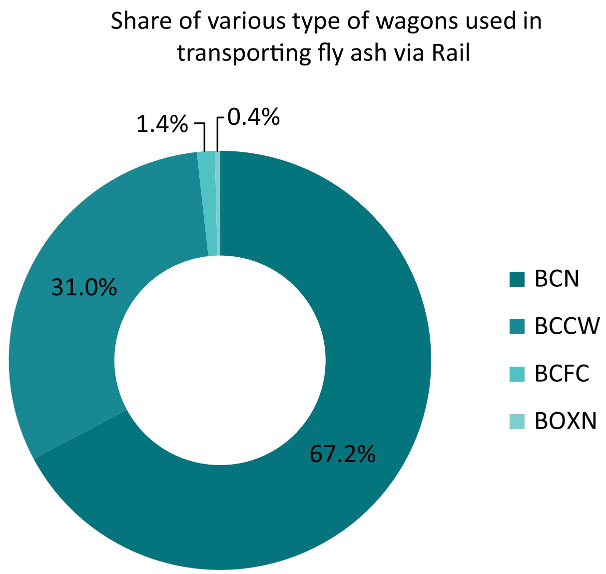


Figure 13: Various type of Wagons used in transporting fly ash via Rail
Source: Centre for Railway Information Systems, Ministry of Railways (2016-17)

Figure 15: BCCW wagons for bulk transport of Cement/Fly Ash
Source: Texmaco Rail & Engineering[2]

Figure 14: Covered Car "BCCW" wagon for bulk transport of Cement/Fly Ash
Source : Texmaco Rail & Engineering [1]

Figure 16: BTAP Wagon
Source: Texmaco Rail & Engineering[3]

[1] *https://www.texmaco.in/webfiles/product.php?product_cat_id=3*
[2]*http://www.touaxtexmaco.com/content/bccw-cement-wagon*
[3]*http://www.touaxtexmaco.com/type/tank-wagons*

Fly-Ash Transport in Cement Industry

As mentioned earlier also, cement industry is the largest consumer of fly ash in the country (see Figure 9). Fly ash can either be blended with cement at the time of production (Portland Pozzolana Cement [PPC]) or added as an admixture while mixing concrete. This is done because of fly ash's pozzolanic behaviour. Pozzolanic materials are those substances which are not cementitious in nature but contain certain chemical constituents. These materials, once combined with lime and water at ordinary temperature, can develop cementitious properties. Pozzolana cement is obtained by blending a mixture of clinkers, up to 35% of pozzolana (for ex-fly ash), and the stipulated quantity of gypsum. The strength of pozzolana is comparable to Ordinary Portland Cement (OPC) and the concrete produced using fly ash has shown a better performance and resistance towards corrosion and chemical attack.

With nearly 280 million tonnes of cement production in 2016–17 (Ministry of Commerce and Industry 2017), the Indian cement industry is the second-largest in the world. While cement production has increased steadily, its composition in terms of OPC and PPC has changed significantly (see Figure 17). In the period prior to 1986, the use of PPC in cement production was significant, for instance, in 1983, PPC constituted 80% of the total cement produced. PPC production came down to less than 20% in 1990 and remained at this level for almost a decade. The downslide was a fallout of the Central Public Works Department's (CPWD) circular banning the use of PPC[4]. The ban was subsequently rolled back in 2004 and PPC production increased to more than 50% of the total cement production in 2006.

Table 9 gives the breakup of the cement produced from 2000–01 to 2007–08, along with PPC production.

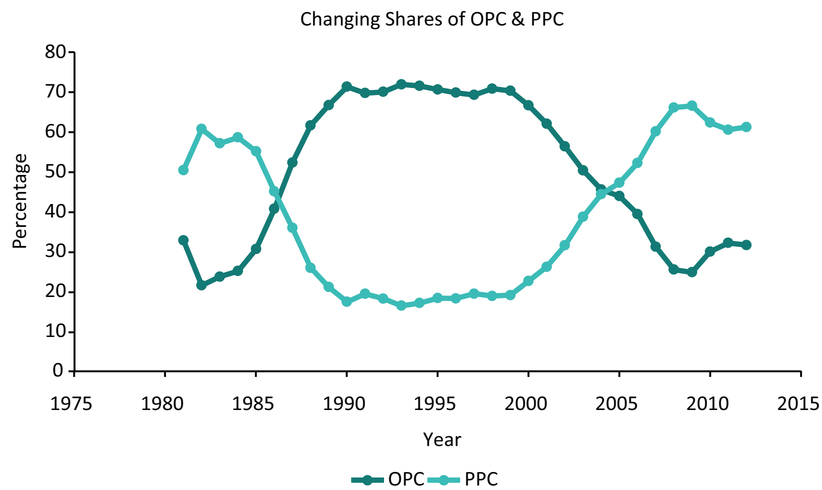


Figure 17: Share of PPC cement and OPC cement in total cement production
Source: Cement Manufacturers Association (CMA)

Table 9: PPC's share in the total cement production

Year	Cement Production (Million Tonnes)	PPC Production (Million Tonnes)	% of Total Production
2000-01	93.6	24.5	26.2
2001-02	102.4	32.3	31.5
2002-03	111.4	43.1	38.7
2003-04	117.5	52.1	44.4
2004-05	127.6	60.2	47.2
2005-06	141.8	74.0	52.2
2006-07	155.7	93.6	60.1

[4]*See https://www.downtoearth.org.in/news/cpwd-no-fly-ash-zone-11910*

Table 9: PPC's share in the total cement production

Year	Cement Production (Million Tonnes)	PPC Production (Million Tonnes)	% of Total Production
2007-08	168.3	111.2	66.1
2008-09	181.6	120.8	66.5
2009-10	160.8	100.2	62.3
2010-11	216.3	102.4	60.5
2011-12	230.3	110.1	61.2
2012-13	235.1	-	-
2013-14	256.0	-	-
2014-15	276.9	-	-
2015-16	283.5	-	-
2016-17	280.0	-	-

Source: Cement Manufacturers Association (CMA)

Due to the unavailability of data, the updated figures for PPC's share in recent years have not been presented here, but as per the discussion with stakeholders, PPC's share in cement production at present is likely to be somewhere around 65%. Considering the 280 million tonnes of cement production in 2016–17, PPC production can be pegged at around 182 million tonnes. At a rough estimate of 20% of fly-ash blending in producing PPC-grade cement, the total amount of fly ash used in 2016–17 by the cement industry to produce 182 million tonnes of PPC would be about 36.4 million tonnes, which is close to the total fly-ash consumption by the cement industry in the same year (see Table 4). Hence, the share of PPC production (65%) seems more or less accurate for 2016-17. In the coming years, with the Indian economy doing well, the per capita consumption of cement is also likely to increase, putting more pressure on cement production. Hence, there is a clear possibility that PPC production will increase, and so will the demand for fly ash. Therefore, the cement industry is expected to remain the single-biggest consumer of fly ash in the coming years.

Figure 18 shows the distribution of cement plants[5] as well as thermal power plants[6] in India. Cement plants, the largest consumers of fly ash, are generally located close to limestone deposits, which is the basic raw material for cement production. In India, there are several such clusters of cement plants around large limestone deposits.

Many cement manufacturers have established split-grinding units close to the consumption centres, where the clinker brought from the mother plant are passed through the grinding stage, bagged, and dispatched to the market. Some of the cement manufacturers have established split-grinding units close to TPS, so that fly ash can be utilized without entailing a high transportation cost. The proximity of these cement plants has been calculated by plotting a 100-km buffer from the TPS. As Figure 18 shows, of the 242 cement plants plotted on the map (actual numbers might vary slightly due to the unavailability of a few plant locations), 172 cement plants were located within a distance range of 100 km from TPS. Further, if we increase this buffer up to 300 km (see Figure 19), this number increases from 172 to 225, which means that a total of 53 cement plants are located within a distance range of 100–300 km from TPS. This indicates that around 71% of the total cement plants are located within a 100-km buffer of thermal power plants, and around 22% of cement plants are located within a buffer of 100–300 km.

A few cement plants are also located in isolated places. It is clear from Figure 19 that the spatial distribution of cement-manufacturing units follows the spatial patterns of fly-ash producers, i.e. TPSs, for example, the cement plants located near the Singrauli, Anpara, and Vindhyachal cluster of power plants and the cement plants located near Kahalgaon, Farakka, Mejia, and Kolaghat.

[5] 242 Cement Plants as provided by Cement Manufacturers Association

[6] 142 Thermal Power Plants as mentioned in CEA Report, 2016-17

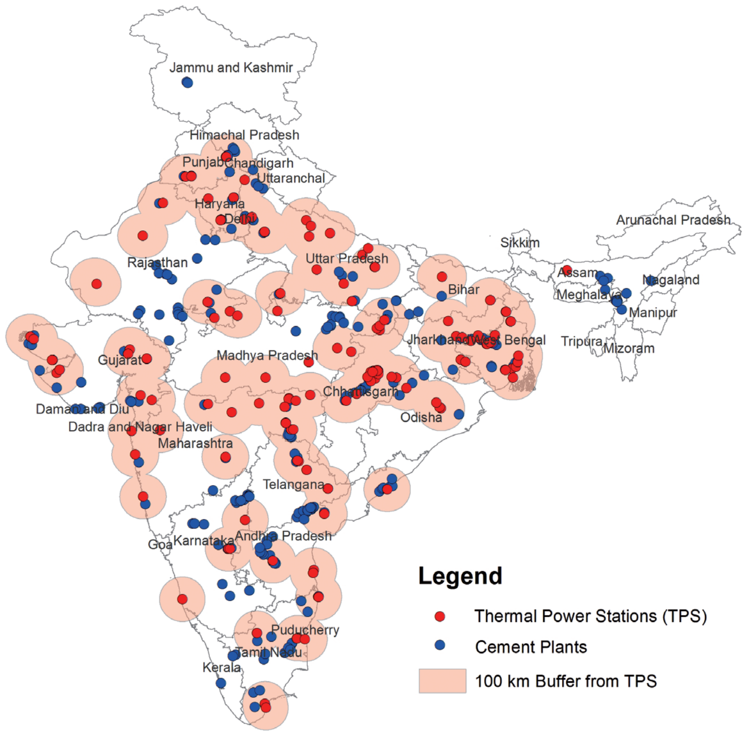


Figure 18: Spatial distribution of Cement plants in India along with the Thermal Power Plants (Buffer Range – 100 km)
Source: Report on Fly Ash Generation, Central Electricity Authority (2016-17) & Cement Manufacturers Association

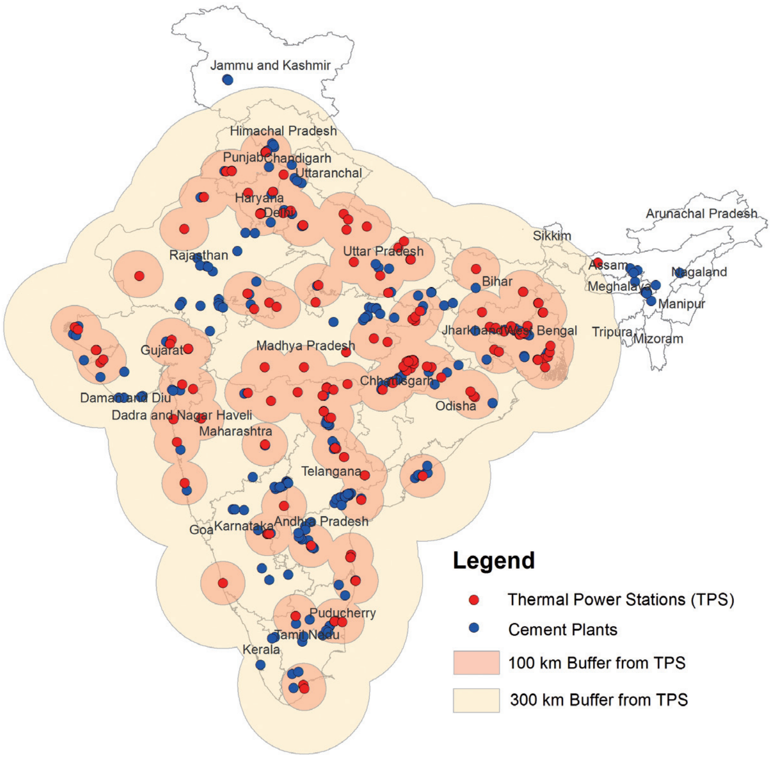


Figure 19: Spatial distribution of Cement plants in India along with the Thermal Power Plants (Buffer Range – 300 km)
Source: Report on Fly Ash Generation, CEA (2016–17), and CMA

Opportunity of Fly-Ash Transport by Rail

As discussed earlier also, the cement industry is likely to be the main consumer of fly ash in the coming years. Therefore, the report focusses on the possibilities of transporting fly ash by rail from power plants to cement plants. Presently, almost all fly-ash transportation happens by road. The modal share of railways in transporting fly ash was only 2.3% in 2016–17. Thermal power plants generally construct silos for intermediate storage of fly ash, from where it is transported to cement plants either by bulkers or rail. Discussions with the stakeholders from ACC Cement, NTPC, and the CMA revealed that the major reasons for the use of road transport are lower capital investment and complete control over the transportation chain. These companies have purchased road tankers and given them on labour contract to agencies for provision of driver and other manpower. They have also made capital investment at both ends for the development of loading and unloading facilities as well as the creation of silos for storage. Some of these companies have entered into long-term agreements with power plants for the supply of fly ash (Nanduri, 2008). As the movement of fly ash in road tankers is expensive and unsuitable for large quantities, several cement manufacturers have also located clinker-grinding units close to the power plant.

To understand if it is feasible to transport fly ash by rail, it is important to relate the patterns of fly-ash production with the consumption centres, and also understand the logistical requirements to move fly ash in bulk quantities. Figure 7 shows that because coal-based power plants are spread across the country, fly-ash generation is not evenly distributed. Because of geographical advantage, large coal-based plants are located in regions of Uttar Pradesh, Jharkhand, Chhattisgarh, and West Bengal. Other concentrations can be observed in Telangana and the Telangana–Maharashtra border in the Wardha Valley Coalfield. Some major power plants are also located in Gujarat, Odisha, Bihar, and Andhra Pradesh. For a better understanding these thermal power plants can be divided into the following clusters throughout the country:

Cluster 1: Five coal-based power plants with large capacities are located in a cluster known as the Singrauli region at the border of Uttar Pradesh and Madhya Pradesh. These power plants are Obra, Rihand, Singrauli, Anpara, and Vindhyachal. They have a combined fly-ash generation of around 20 million tonnes per year. In the same region, power plants with slightly lower capacities are also located at Tanda, Panki, Unchahar, and Parichha.

Cluster 2: In Bihar and West Bengal, the major power plants are Kahalgaon, Farakka, Mejia, and Kolaghat. The power plants at Kahalgaon and Farakka alone produce around 8 million tonnes of fly ash per year.

Cluster 3: In Chhattisgarh, the major power plants are NTPC Sipat and Korba. Few other state-owned and private sector plants like Jindal Thermal Power Plant and others are also located in the same cluster. These power plants produce around 15 million tonnes of fly ash per year.

Cluster 4: In the Telangana, Andhra Pradesh, Karnataka, and Maharashtra cluster, large coal-based power plants are Ramagundam, Kothagudem, Vijayawada, Simhadri, Rayalaseema, Raichur, Chandrapur, and Tirora. The power plants at Ramagundam, Vijayawada, and Raichur produce more than 10 million tonnes of fly ash per year.

Cluster 5: In the Gujarat and Rajasthan cluster, Wanakbori, Ukai, Kota, JSW Barmer, and Suratgarh are the major power plants which produce significant quantities of fly ash in the western part of India.

Cluster 6: In the Delhi, Punjab, and Haryana cluster, power plants located at Dadri, Jhajjar, and Hissar produce significant quantities of fly ash.

Two case studies from the aforementioned clusters have been selected and presented here to further understand the various aspects involved in transporting fly ash by rail and road.

Case Study I

Ramagundam Region

The southern region consisting of states like Telangana, Andhra Pradesh, and Karnataka houses major power plants like Ramagundam, Vijayawada, and Raichur, which produce more than 10 million tonnes of fly ash per year. In 2007, a concerted effort was made by Railways, NTPC, and cement plants to transport fly ash by rail mode. Kesoram Cement Company, Raghavapuram, a subsidiary of Vasavadatta Cements, Sedam, entered into an agreement with NTPC, Ramagundam, to take away fly ash from NTPC silos by road tankers to Raghavapuram siding, and from there, to Vasavadatta siding at Sedam by railway wagons, covering a distance of 377 km (see Figure 20). A pilot study conducted by South Central Railway for this arrangement showed benefits for all the parties involved. While cement plants benefitted from the cheaper transport cost, Indian Railways was successful in capturing and generating revenue by capturing the traffic, which would have otherwise been transported by road.

Prior to this agreement, the entire quantity of fly ash was transported by road though bulker trucks. Transporting fly ash through road would cost cement plants around Rs 1,225 per tonne, but after the introduction of rail movement, this cost was reduced to Rs 363 per tonne in the distance slab of 377 km (Nanduri, 2008). The railway wagons were initially provided by the South Central Railway by way of in-house modification of the existing surplus tank wagons (see Figure 21) on the condition that these wagons would be used only until the cement plants procure their own specialized wagons. Also, loading and unloading facilities were created at both sidings. About 210 surplus four-wheeler tank wagons were deployed by the South Central Railway for moving fly ash between Raghavapuram siding and Sedam (Nanduri, 2008). The wagons used to transport fly ash were only provided as a temporary solution, as Railways did not have many surplus wagons for modification. In the long term, Indian Railways/cement companies/power corporations will have to consider the option of investing in pneumatic hopper-type wagons.

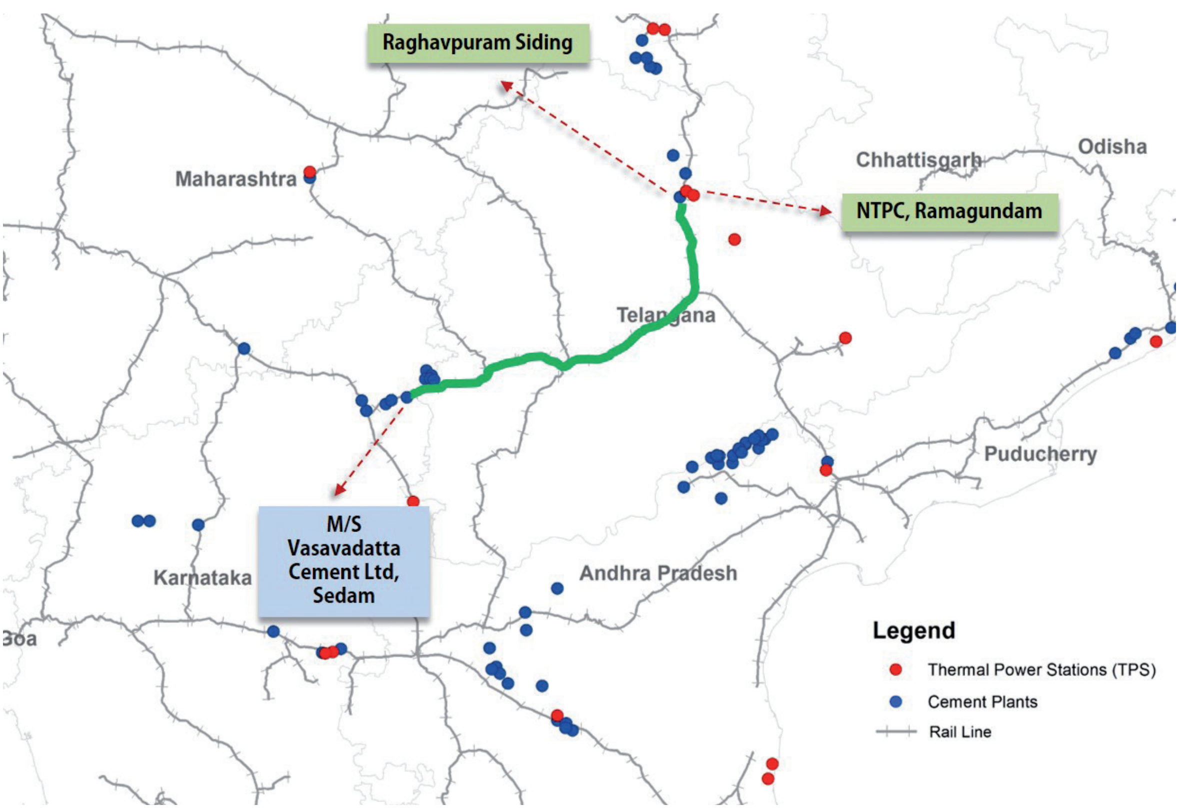


Figure 20: Map showing the rail connectivity of fly-ash transportation from Raghavapuram siding to Vasavadatta Cements, Sedam
Source: Report on Fly Ash Generation, CEA (2016–17), CMA, and TERI analysis

Figure 21: Railway wagons before and after modification
Source: Report on fly-ash utilization by cement industry (Nanduri, 2008)

Figure 22: Fly-ash loading at NTPC, Ramagundam
Source: The Hindu [7]

The pilot study has also pointed out the benefits, specifically to railways, by fly-ash transportation from the Raichur Thermal Power Station to Vasavadatta Cements, Sedam (see Figure 23).

As mentioned in the pilot study report, benefits to railways on both the aforementioned routes have been listed in Tables 10 and 11 for a better understanding.

[7] *See https://www.thehindu.com/news/cities/Hyderabad/high-demand-for-ntpc-fly-ash/article23282313.ece.*

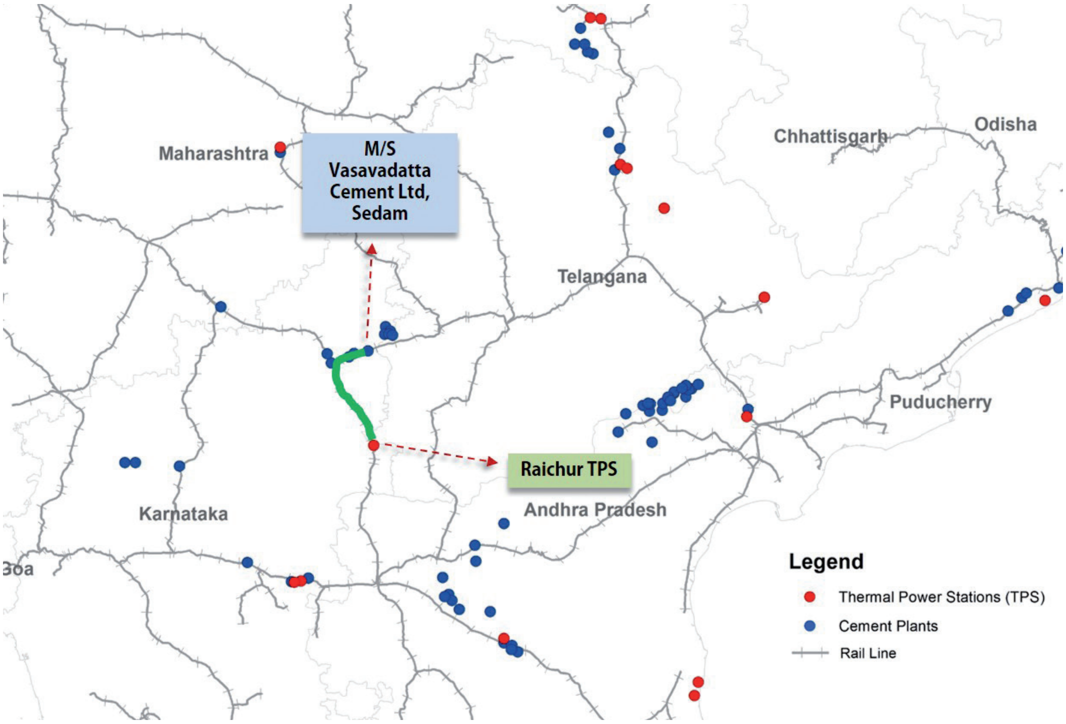


Figure 23: Map showing rail connectivity of fly-ash transportation from the Raichur Thermal Power Station to Vasavadatta Cements, Sedam
Source: Report on Fly Ash Generation, CEA (2016–17), CMA, and TERI analysis

Table10: Cost of moving fly ash from Raghavapuram to Sedam by rail (2007–08)

Particulars	Details
No. of wagons per rake	40
No. of rakes to be loaded	180
Average quantity per rake (metric tonnes)	2,400
Total quantity to be moved (metric tonnes)	4,32,000
Wagon days per year	14,600
Cost of moving fly ash	
Distance	377 km
NTKM per year	23,40,49,140
Tare tonne km per year	5,23,03,140
Total GTKM	28,63,52,280
Line-haul cost in 2005–06 per 1000 GTKM in Rs	195
Operational cost in Rs	5,58,38,695
Total distributed costs as derived ratio in Rs	8,93,41,911
Benefit to Railways	
Revenue per tonne km in Rs	363
Total revenue in Rs	15,68,16,000
Surplus per year in Rs	6,74,74,089
Surplus after 15% freight concession	43,951,689

Source: Report on fly-ash utilization by cement industry (Nanduri, 2008)

Table11: Cost of moving fly ash from Raichur to Sedam by rail (2007–08)

Particulars	Details
No. of wagons used	200
No of wagons per rake	40
No. of rakes to be loaded	365
Average quantity per rake	2,400
Total quantity to be moved	8,76,000
Wagon days per year	73,000
Cost of moving fly ash	
Distance	150 km
GTKM per year	18,88,32,750
Tare tonne km per year	0
Total GTKM	18,88,32,750
Line-haul cost in 2005–06 per 1000 GTKM	195
Operational cost in Rs	3,68,22,386
Total distributed costs as derived ratio in Rs	5,89,15,818
Benefit to Railways	
Revenue per tonne km	140
Total revenue in Rs	15,68,16,000
Surplus per year in Rs	9,79,00,182
Surplus after 15% freight concession	74,377,782

Source: Report on fly-ash utilization by cement industry (Nanduri, 2008)

Case Study II

Singrauli Region

Geographically spread across the Singrauli district of Madhya Pradesh and Sonebhadra district of Uttar Pradesh, the Singrauli region is known as the power capital of India. Several coal-based thermal power plants are located in this region with the installed capacity of more than 20,000 MW of power generation. Table 12 shows the details of the power plants in this region.

Table 12: TPS in Singrauli Region

S. no.	Name of TPS	Capacity (MW)
1	NTPC Vindhyachal	4,760
2	NTPC Singrauli	2,000
3	Hindalco Renusagar	750
4	Sasan Ultra Mega Power Project	3,960
5	Anpara	2,630
6	Hindalco Mahan	1,200
7	Essar Power	1,200
8	NTPC Rihand	3,000
9	Obra	1,194
	Total	20,694

Source: Report on Fly Ash Generation, CEA (2016–17)

Power plants in the Singrauli region generate around 25 to 30 million tonnes of fly ash per year. However, the ash-utilization levels of these power plants have been considerably low over the years. As per the CEA report (2016–17), NTPC Vindhyachal, Obra, and Rihand had utilization levels of 23.5%, 27.6%, and 15.5%, respectively, whereas NTPC Singrauli and Anpara had utilization levels of only 9.2% and 0.4%, respectively.

The location of fly-ash generation contributes significantly to its gainful utilization. Although there are many coal-based thermal power plants in the Singrauli region, the remote location of these plants from the ash-consumption belt restricts the utilization of ash generated in the region. The nearest cities from the Singrauli region are Rewa and Varanasi, which are located at a distance of 225 km and 250 km, respectively. Providing fly ash to the cement industries of the Rewa–Satna–Katni region is a major way of ash utilization for the power plants of the Singrauli region. The total peak demand of fly ash from these cement plants is around 25,000 tonnes per day, whereas the Singrauli region generates more than 70,000 tonnes of fly ash every day (Narayan & Mangla, 2016). Therefore, a large quantity of fly ash remains unutilized and is being disposed of in ash dykes.

Fly ash is being provided to the cement industries of the Rewa–Satna–Katni region through closed bulkers and

Figure 24: Pneumatic unloading facility for bulker trucks at Prism Cement, Satna
Source: Fly Ash Utilization 2018 – Conference [8]

Figure 25: Mechanized fly-ash unloading by truck tippler at Prism Cement, Satna
Source: Fly Ash Utilization 2018—Conference[9]

trucks. Although power plants and cement plants have the facility of pneumatic loading and unloading through road bulkers and trucks (see Figures 24 and 25), some modifications are required in order to develop loading and unloading facilities for the rail mode.

As far as specialized wagons are concerned, trials of modified BTAP wagons for transporting fly ash are going on. Once approved, it will help in transporting fly ash by rail in an environmentally safe manner. Railway freight charges are less than 50% of the cost of fly-ash transportation by road (Narayan & Mangla, 2016). Hence, fly-ash transportation by rail will not only encourage the cement plants of Rewa–Satna–Katni to take more fly ash from TPS, but will also encourage the bulk movement of fly ash to distant consumers in an economic manner.

Estimation of Costs and Benefits of Fly-Ash Transportation

The transportation cost of any commodity plays a significant role in the marketability of the product. The transportation cost usually varies according to the type of mode used and distance travelled. At present, freight charges for transporting fly ash through bulkers and trucks range between Rs 800 per tonne and Rs 1,200 per tonne, (Narayan & Mangla, 2016), which is significantly

[8]*See http://flyash2018.missionenergy.org/presentations/Prism%20Cement.pdf.*
[9]*See http://flyash2018.missionenergy.org/presentations/Prism%20Cement.pdf.*

high when compared to transportation charges through the rail mode. Indian Railways has classified fly ash as Class-120 material for full rake load, and as per the current rates, railway freight charges for transporting fly ash to a distance of 301–350 km (since most of the cement plants of the Rewa–Satna–Katni region are within 250–350 km of power plants) shall be in the range of Rs 393 per tonne to Rs 419 per tonne. High freight charges, which at present are borne by users, can limit the substantial utilization of fly ash. The analysis presented in this section is restricted to fly-ash movement between the cement plants located in the Rewa–Satna region and the thermal power plants located in the Singrauli region (see Figure 26).

Demand Assessment

Only cement plants with rail connectivity have been selected to estimate the fly-ash demand since these are the potential buyers to whom fly ash can be transported by rail, provided they have the required infrastructure in place for unloading the fly ash from rail. Table 13 lists selected cement plants. The average annual capacity utilization for previous years has been used to project the current PPC production in these plants. It is assumed that on an average, the quantity of fly ash required to produce PPC is 30% of the total PPC production.

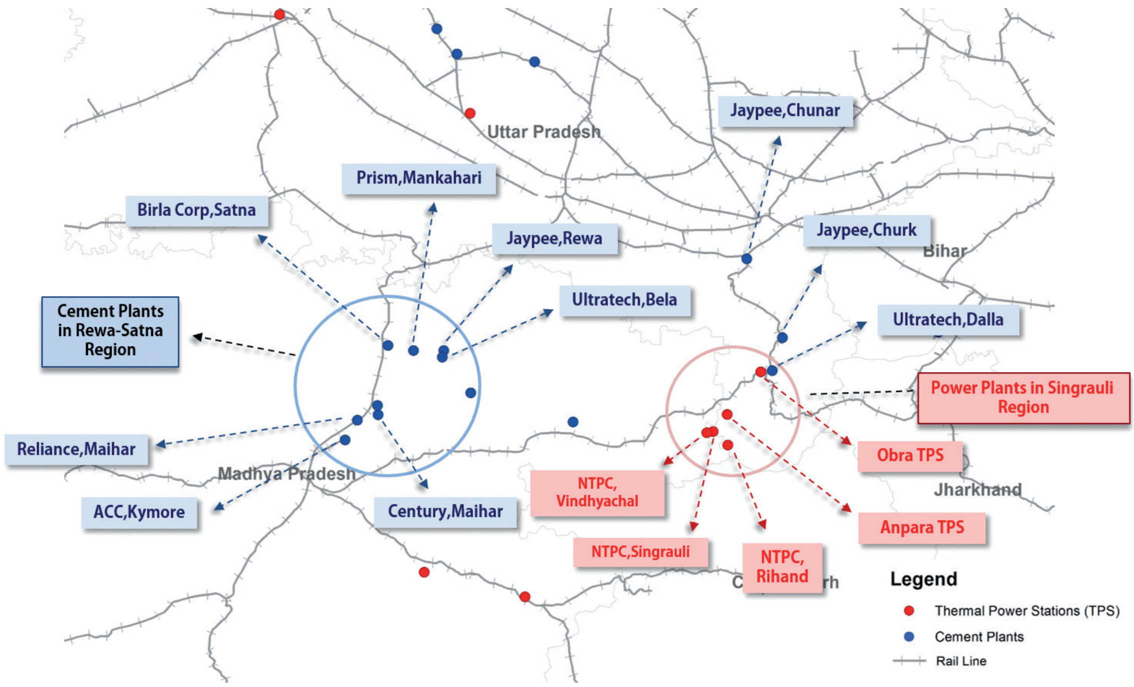


Figure 26: Map showing the location of TPS in the Singrauli region and cement plants in the Rewa–Satna region
Source: Report on Fly Ash Generation, CEA (2016–17), CMA, and TERI analysis

Table 13: Cement plants selected to estimate the annual fly-ash demand

	Cement plant	Location	Estimated annual fly-ash demand (in million tonnes)
1	ACC, Kymore	Katni, MP	0.518
2	UltraTech, Dalla	Sonebhadra, UP	0.117
3	UltraTech, Bela	Rewa,MP	0.434
4	Jaypee, Chunar GU	Mirzapur	0.487
5	Jaypee, Churk GU	Mirzapur	0.012

Table 13: Cement plants selected to estimate the annual fly-ash demand

	Cement plant	Location	Estimated annual fly-ash demand (in million tonnes)
6	Jaypee, Rewa	Rewa,MP	0.603
7	Reliance, Maihar	Satna, MP	1.015
8	Century, Maihar	Satna, MP	0.451
9	Birla Corp, Satna	Satna, MP	0.416
10	Prism, Mankahari	Satna, MP	1.337
Total			**5.39**

Source: TERI analysis

Fly-Ash Availability

As discussed earlier also, cement plants located in the Rewa–Satna region are the major consumers of fly ash available at power plants in the Singrauli region. Assuming that all the fly-ash demand has to be met through the fly ash available in the Singrauli region, fly-ash availability has been calculated by selecting major fly-ash-producing plants in the region. Table 14 represents the availability of fly ash in major TPS in the Singrauli region.

Estimation of Transport Cost

Transportation costs for moving fly ash from the Singrauli region to cement plants in the Rewa–Satna region by both rail and road modes have been estimated. The cost for road transport has been estimated based on literature review as well as through primary survey with trucking companies operating in the region. Similarly, the rail transport cost has been taken from the Freight Operations Information System (FOIS). The FOIS provides per tonne line-haul costs based on different distance slabs. In addition to this cost, Railways also charge a development fee of 5% and busy-season surcharge of 15% on the base fare.

At present, rail transport is not being used because of the lack of appropriate wagons and loading/unloading infrastructure. The loading infrastructure available at these power plants is suitable for loading fly ash into trucks but not into trains. The cost of loading and unloading has not been considered separately for cost estimations, as fly ash is loaded directly into bulker trucks from silos and unloaded in a similar manner at cement plants. The estimated costs for both road and rail have been shown in Table 15 and Table 16, respectively.

Based on the tariff rates discussed earlier, estimated annual transport cost incurred on account of rail-based movement of fly ash has been arrived at in Table 16.

Table 14: Fly-ash availability in major TPS in the Singrauli region

S. no.	Name of TPS	Capacity (MW)	Fly-ash generation (million tonnes)	Fly-ash utilization (million tonnes)	Total unutilized fly ash (million tonnes)
1	NTPC Vindhyachal	4,760	7.63	1.79	5.84
2	NTPC Singrauli	2,000	3.67	0.33	3.34
3	Anpara	2,630	7.17	0.03	7.14
4	NTPC Rihand	3,000	4.85	0.75	4.1
5	Obra	1,194	1.38	0.38	1
Total			**24.7**	**3.28**	**21.42**

Source: Report on Fly Ash Generation, CEA (2016–17)

Table 15: Annual estimated costs for transporting fly ash from the Singrauli region to cement plants by road

S. no.	Cement plant	Location	Distance by road (km)	Estimated annual fly-ash demand (in million tonnes)	Estimated annual transport cost by road (Rs million)
1	ACC, Kymore	Katni, MP	324	0.52	517.70
2	UltraTech, Dalla	Sonebhadra, UP	109	0.12	46.92
3	UltraTech, Bela	Rewa, MP	216	0.43	434.20
4	Jaypee, Chunar GU*	Mirzapur, UP	186	0.49	487.20
5	Jaypee, Churk GU*	Mirzapur, UP	123	0.01	4.68
6	Jaypee, Rewa	Rewa, MP	213	0.60	603.20
7	Reliance, Maihar	Satna, MP	285	1.02	1,015.00
8	Century, Maihar	Satna, MP	285	0.45	451.25
9	Birla Corp, Satna	Satna, MP	260	0.42	416.00
10	Prism, Mankahari	Satna, MP	255	1.34	1,336.50
Total				**5.39**	**5,312.65**

*Grinding unit

Source: TERI analysis

Table 16: Annual estimated costs for transporting fly ash from the Singrauli region to cement plants by rail

S. no.	Cement plant	Location	Distance by rail (km)	Estimated annual fly-ash demand (in million tonnes)	Estimated annual transport cost by rail (Rs million)
1	ACC, Kymore	Katni, MP	308	0.52	244.02
2	UltraTech, Dalla	Sonebhadra, UP	75	0.12	23.96
3	UltraTech, Bela	Rewa, MP	480	0.43	302.88
4	Jaypee, Chunar GU*	Mirzapur, UP	175	0.49	135.99
5	Jaypee, Churk GU*	Mirzapur, UP	91	0.01	2.39
6	Jaypee, Rewa	Rewa, MP	480	0.60	420.77
7	Reliance, Maihar	Satna, MP	313	1.02	478.43
8	Century, Maihar	Satna, MP	330	0.45	227.05
9	Birla Corp, Satna	Satna, MP	415	0.42	249.60
10	Prism, Mankahari	Satna, MP	437	1.34	845.20
Total				**5.39**	**2,930.29**

*Grinding unit

Source: TERI analysis

Comparison of Transport Cost and Estimated Savings

The analysis presented in this section tries to estimate the cost savings cement companies will make if suitable infrastructure for loading and unloading of fly ash for railway rakes is available at supplier and user ends respectively. Considering the availability of such infrastructure, the relative costs for transporting fly ash by both rail and road modes have been estimated and compared (see Figure 27).

It is evident from Figure 27 that road freight charges are much higher than the rail freight cost for moving fly ash between the Singrauli and Rewa–Satna regions. Table 17 shows the estimation of savings for cement companies, if the mode of transport is shifted to rail.

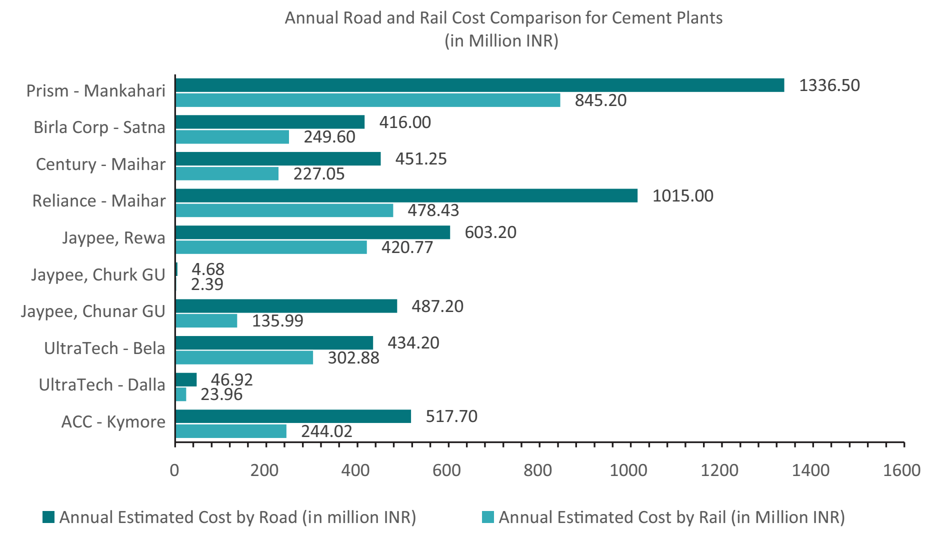


Figure 27: Annual Rail and Road Cost Comparisons for Cement Plants
Source: TERI Analysis

Table 17: Comparison of road and rail costs as well as respective savings

S. no.	Cement plant	Location	Distance by road (km)	Distance by rail (km)	Annual cost by road (Rs million)	Annual estimated rail cost (Rs million)	Cost savings if shifted to rail (Rs million)
1	ACC, Kymore	Katni, MP	324	308	517.70	244.02	273.68
2	UltraTech, Dalla	Sonebhadra, UP	109	75	46.92	23.96	22.96
3	UltraTech, Bela	Rewa, MP	216	480	434.20	302.88	131.32
4	Jaypee, Chunar GU*	Mirzapur	186	175	487.20	135.99	351.21
5	Jaypee, Churk GU*	Mirzapur	123	91	4.68	2.39	2.29
6	Jaypee, Rewa	Rewa, MP	213	480	603.20	420.77	182.43
7	Reliance, Maihar	Satna, MP	285	313	1,015.00	478.43	536.57

Table 17: Comparison of road and rail costs as well as respective savings							
S. no.	**Cement plant**	**Location**	**Distance by road (km)**	**Distance by rail (km)**	**Annual cost by road (Rs million)**	**Annual estimated rail cost (Rs million)**	**Cost savings if shifted to rail (Rs million)**
8	Century, Maihar	Satna, MP	285	330	451.25	227.05	224.20
9	Birla Corp, Satna	Satna, MP	260	415	416.00	249.60	166.40
10	Prism, Mankahari	Satna, MP	255	437	1,336.50	845.20	491.30
				Total	**5,312.65**	**2,930.29**	**2,382.36**
*Grinding unit							
Source: TERI analysis							

Estimation of Transport Emissions

For the same estimated distances between the two regions, CO_2 emissions from both the modes have been estimated. Table 18 shows assumptions made regarding the same.

Based on the aforementioned assumptions, CO_2 emissions caused by transporting fly ash from the Singrauli region to each of the selected cement plants have been calculated for both rail and road. Figure 28 shows that fly-ash transportation by road causes a much higher amount of CO_2 emissions when compared to rail transport for the same distance.

Table 18: Assumptions made for calculating savings in CO_2 emissions			
For diesel trucks		**For rail**	
Mileage[10]	3.59 km/ltr	Rail emissions in kg CO_2 per tonne km[11]	0.00996
Diesel density[12]	0.84 kg/ltr		
Fly-ash carrying capacity [13]	30 tonnes		
Kg CO_2 per km[14]	0.7375		

Savings in CO_2 emissions, if the existing movement by road shifts to rail, has also been estimated. Table 19 shows the savings in CO_2 emissions for fly-ash transportation to each of the selected cement plants.

In brief, the annual cost and CO_2 savings can be summarized as the following:

- Shifting of traffic from road to rail will save the 10 cement companies an annual transportation cost of INR 2382.36 million.
- Shifting of traffic from road to rail will save 13795.83 tonnes of CO_2 emissions annually.

The fact that power plants and cement plants can be observed in clusters can be considered an advantage for transporting fly ash by rail, as this will encourage the bulk movement of fly ash. Given the fact that the demand for PPC is likely to increase in the coming years and bulk transport by road has its own limitation, the situation should favour fly-ash transportation by rail. But

[10]Report on India Specific Road Transport Emission Factors (WRI, 2015)
[11]See http://www.indianrailways.gov.in/railwayboard/uploads/directorate/traffic_comm/Rates-Letters/2017/6_%20Arun%20Kumar_MPPL_Carbon%20Footprint%20in%20Railway.pdf
[12]Report on India Specific Road Transport Emission Factors (WRI,2015)
[13]Primary survey
[14]Report on India Specific Road Transport Emission Factors (WRI, 2015)

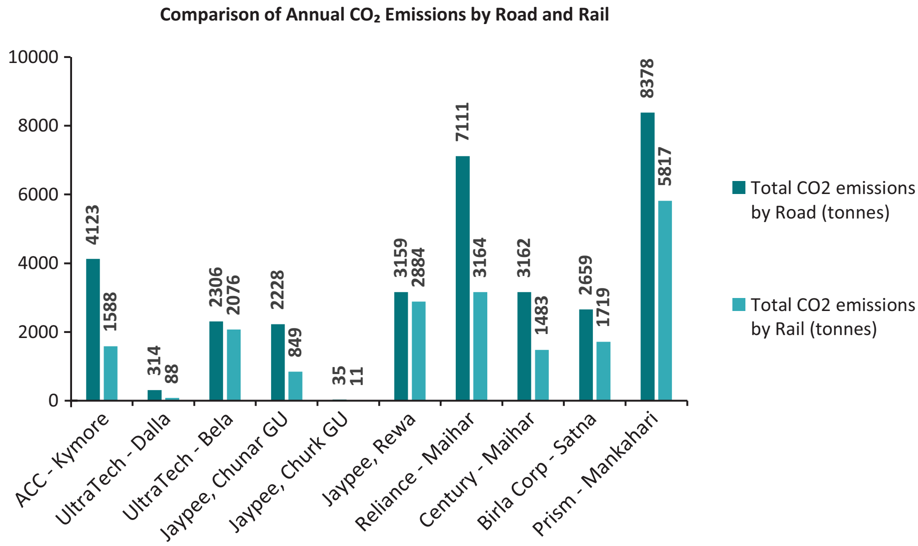


Figure 28: Comparison of Annual CO_2 Emissions
Source: TERI Analysis

Table 19 : Savings in CO_2 Emissions

S.No.	Cement Plant	Location	Annual on Road CO_2 emissions (in tonnes)	Annual Rail CO_2 emissions (in tonnes)	Annual CO_2 emissions saved if shifted to Rail (in tonnes)
			(1)	(2)	(3)= (1-2)
1	ACC - Kymore	Katni, MP	4,123	1,588	2,535.34
2	UltraTech - Dalla	Sonebhadra, UP	314	88	226.69
3	UltraTech - Bela	Rewa,MP	2,306	2,076	229.78
4	Jaypee, Chunar GU*	Mirzapur, UP	2,228	849	1,378.53
5	Jaypee, Churk GU*	Mirzapur, UP	35	11	24.77
6	Jaypee, Rewa	Rewa, MP	3,159	2,884	274.73
7	Reliance - Maihar	Satna, MP	7,111	3,164	3,947.10
8	Century - Maihar	Satna, MP	3,162	1,483	1,678.40
9	Birla Corp - Satna	Satna, MP	2,659	1,719	939.44
10	Prism - Mankahari	Satna, MP	8,378	5,817	2,561.04
			33,475	**19,679**	**13,795.83**

**Grinding Unit; Source: TERI Analysis*

as with any other mode of transport, movement by rail is also the function of a combination of factors, which include modal suitability, ease of transport, and distance. Therefore, to make a considerable modal shift from roadways to railways, loading and unloading facilities for rail, possibility of multiple rake use (for example, fly ash in one direction and cement in another), and economic feasibility of different routes for transporting fly ash will also have to be looked into/studied by each of the cement plants and TSPs considered under the analysis.

Issues

As per discussion with the various stakeholders from the industry, the following issues have been identified which are most probably responsible for the low modal share of railways in fly-ash transport.

Issues with Indian Railways

a) Lack of Initiatives by Railways

At present, there seems to be a lack of substantial push from the railways to encourage fly-ash transportation in bulk. The Secunderabad division of the South Central Railways made a successful attempt back in 2007, when a collaborative effort was made by NTPC, cement plants, and Railways to transport fly ash in bulk between cement plants and NTPC Ramagundam which benefitted all the stakeholders. But apart from this, no such case studies were found which focused on prioritizing fly ash as a rail commodity or encouraged its movement by rail. Therefore, in order to increase the fly-ash traffic by rail, there's need for such inter-agency collaborations where all the parties can sit and discuss the hurdles involved in moving fly ash by rail and arrive at a win-win situation.

b) Absence of Specialized Wagons

The wagons available to transport fly ash are not environment-friendly. As per the CPCB notification, specially designed railway wagons should be used for transportation by rail. But as of now, 67% of the fly-ash movement has been carried out in BCN wagons, which are mainly used for transporting bagged cement. Being an environmentally sensitive material, fly ash should be transported in pneumatic hopper-type wagons. But such wagons are only being used in a few regions and are mostly privately owned. Although trials for bulk transportation of fly ash in BTAP wagons has been conducted successfully by NTPC in association with Indian Railways and Texmaco (the wagon-manufacturing company), (NTPC Limited, 2017) approval for its commercial run is still under process.

c) Non-Incentive Tariff Structure

At present, fly ash is being charged under class-120. Apart from the base tariff, Railways charges a development fee of 5% and busy-season charges of 15%. Demurrage charges are also levied for the detention of wagons after the expiry of free time. Also, fly ash has lower density than cement. Since fly ash is being mostly transported in the same wagons used to transport cement, the tonnage of fly ash in full rake load, as compared to cement, is less. The tonnage of fly ash in bulk cement wagon reduces from 65 tonnes (cement) to 47 tonnes. (Nanduri, 2008) And since Railways charges for the full rake load, the customer has to pay the same freight for less quantity. All these issues call for a revised tariff structure if Railways has to compete with road transport in case of fly-ash transportation.

d) Concession on Party-Owned Wagons

Railways provide freight subsidy if the wagon is owned by the party itself under the 'Liberalized Wagon Investment Scheme'. The freight subsidy provided by IR in such cases is 15% for a period of 20 years. The life of the wagon is 35 years. Cement manufacturers, however, want freight subsidy for the complete serviceable life of the wagons which are owned by the party.

Issues with NTPC

a) Lack of Rake Availability

Rake availability has been a major issue at times with regard to fly-ash transportation. Since BCN wagons are majorly used for transporting cement, priority is given to keeping BCN wagons available for cement transportation; hence, there's shortage of these wagons, especially for fly-ash transportation, for most part of the year. Moreover, transporting fly ash in BCN wagons is not an environment-friendly option, since fly-ash bags need to be manually loaded into and unloaded from such wagons, which causes dust emission. As discussed earlier also, pneumatic hopper-type wagons are best suited in such cases, as they minimize the chance of fly ash getting airborne, but such wagons are not available as of now.

b) Commercial Reasons and Infrastructure Issues

Specially designed infrastructure is needed to transport fly ash in an environmentally sound manner at both the user and supplier end. Thermal power plants should have loading infrastructure and cement plants should have unloading infrastructure in order to put a complete logistic chain in place. An investment of 80 to 90 crore is required to develop a loading and unloading infrastructure. At present, it's up to the power plants and cement plants or end users to develop the loading/ unloading infrastructure, but cement companies are hesitant to develop such infrastructure all by themselves, as it needs a huge investment.

Issues with Cement Plants

- Although cement plants have developed infrastructure facilities for loading and unloading fly ash through trucks and bulkers, most of them do not have the rake-handling facility to unload fly ash at their end. Hence, there is a glaring lack of rake-unloading facilities at most of the cement plants.
- As of now, the rate of fly ash sold by power plants is mostly market-driven: lower where the demand is less and higher where the demand is more. There is a general understanding among cement manufacturers that power plants should get into a long-term agreement with cement plants to ensure regular supply of fly ash, and there should be some assurance regarding the tariff structure to be followed over the agreed period.
- As discussed earlier also, various industry experts agree that Railways should provide dedicated wagons for transporting fly ash and bring down the existing tariffs in order to incentivize cement plants to shift to railways.

Recommendations

a) Inter-Agency Collaboration

There is a clear lack of inter-agency collaboration when it comes to resolving issues related to fly-ash transportation. Railways should take the lead in bringing all the stakeholders, such as power plants and cement plants, together so as to devise a strategic action plan to increase fly-ash transportation by rail in an environmentally safe manner, which shall be beneficial to all the stakeholders, that is, TSP, cement plants, as well as Railways. The case studies like that in the Ramagundam region should be replicated at other places as well. The fact that the thermal power plants and cement plants are located in clusters should be considered as an advantage for moving fly ash in bulk by rail.

b) Acquisition of Specialized Wagons

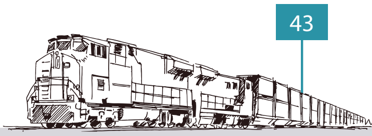
At present, the use of specially designed wagons such as the BCFC and BCCW wagons, is only restricted to transporting fly ash between cement plants in the Wadi region and power stations at Ramagundam and Raichur. These rakes are either owned by cement manufacturers or are taken on lease from leasing companies. Presently, Indian Railways has only two BCFC rakes available for bulk transportation of fly ash and cement (RDSO, 2013-14). BTAP wagons, which were earlier used to carry alumina, are also now allowed to carry fly ash. The Ministry of Railways, vide its circular dated 20 January 2017, has fixed the permissible carrying capacity of fly ash in BTAP wagons to 60.36 tonnes[15] .

Using such high-capacity wagons will not only help in transporting fly ash in an efficient and environment-friendly manner, but will also help in reducing the loading and unloading time at both ends. While the BCFC and BCCW wagons are already in use, trials for BTAP wagons are going on. NTPC has successfully conducted trials for bulk transportation of fly ash in BTAP wagons from its Rihand Power Station to the cement plants in the Satna region. Therefore, planned investment should be made on the design and acquisition of specialized wagons for transporting fly ash.

c) Development of Terminal Infrastructure

Lack of the required infrastructure facilities for loading fly ash at power plants and unloading at cement plants is another factor discouraging the movement of fly ash by rail. Power plants should develop the facility for loading fly ash from silos into rail wagons and cement plants should install suitable unloading facilities such as compressors and pneumatic pipelines to unload fly

[15]See http://www.indianrailways.gov.in/railwayboard/uploads/directorate/traffic_comm/Freight_Rate_2016/Corri_RC_03_2016_200117.PDF



ash from rail wagons into ash-storage silos. Although in case of BTAP rakes, fly ash can be directly unloaded into bulkers through a mobile compressor system from BTAP wagons at the railway siding itself. At present, only a few power plants in the country have developed the loading facilities for handling rakes, such as the NTPC plants located at Ramagundam and Rihand, and Adani Power Plant in Tirora. The creation of such infrastructure would encourage the bulk movement of fly ash between TPS and cement plants. On the one hand, cement plants will benefit from savings in transportation cost (considering the significant gap between rail and road tariffs), whereas thermal power plants will benefit from the increased utilization of fly ash, which will subsequently save them a significant amount of capital spent on the creation and maintenance of ash ponds for unutilized fly ash. (On an average, thermal power plants spend Rs 96 per tonne to store fly ash in ponds and 1,000 ltr of water per tonne is wasted in doing so[16])

d) Freight Subsidy

There's a need to reduce or revise the tariff structure for fly-ash transportation if Railways has to compete with road transport. The reason is the low density of fly ash because of which only 45 to 50 tonnes can be loaded into a wagon, which can otherwise (ex-cement) load up to 60 tonnes. Also, demurrage charges should be revised for fly-ash loading and unloading, as it generally takes more than the stipulated hours to manually load and unload a full rake of fly ash.

e) Rebate in Wagon Investment

Railways should consider giving a suitable rebate to the investors interested in investing in their own wagons for transporting fly ash. Under the 'Liberalized Wagon Investment Scheme', Railways provide 15% concession on freight for a period of 20 years. Since the lifespan of a wagon is 35 years, increasing the concession period to cover the entire lifespan of wagons would further incentivize users to procure their own wagons and shift towards railways, especially for fly-ash transportation.

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[16]*See https://timesofindia.indiatimes.com/city/nagpur/Not-using-fly-ash-fully-will-be-disastrous-for-environment/articleshow/55516458.cms*

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