NITI Aayog

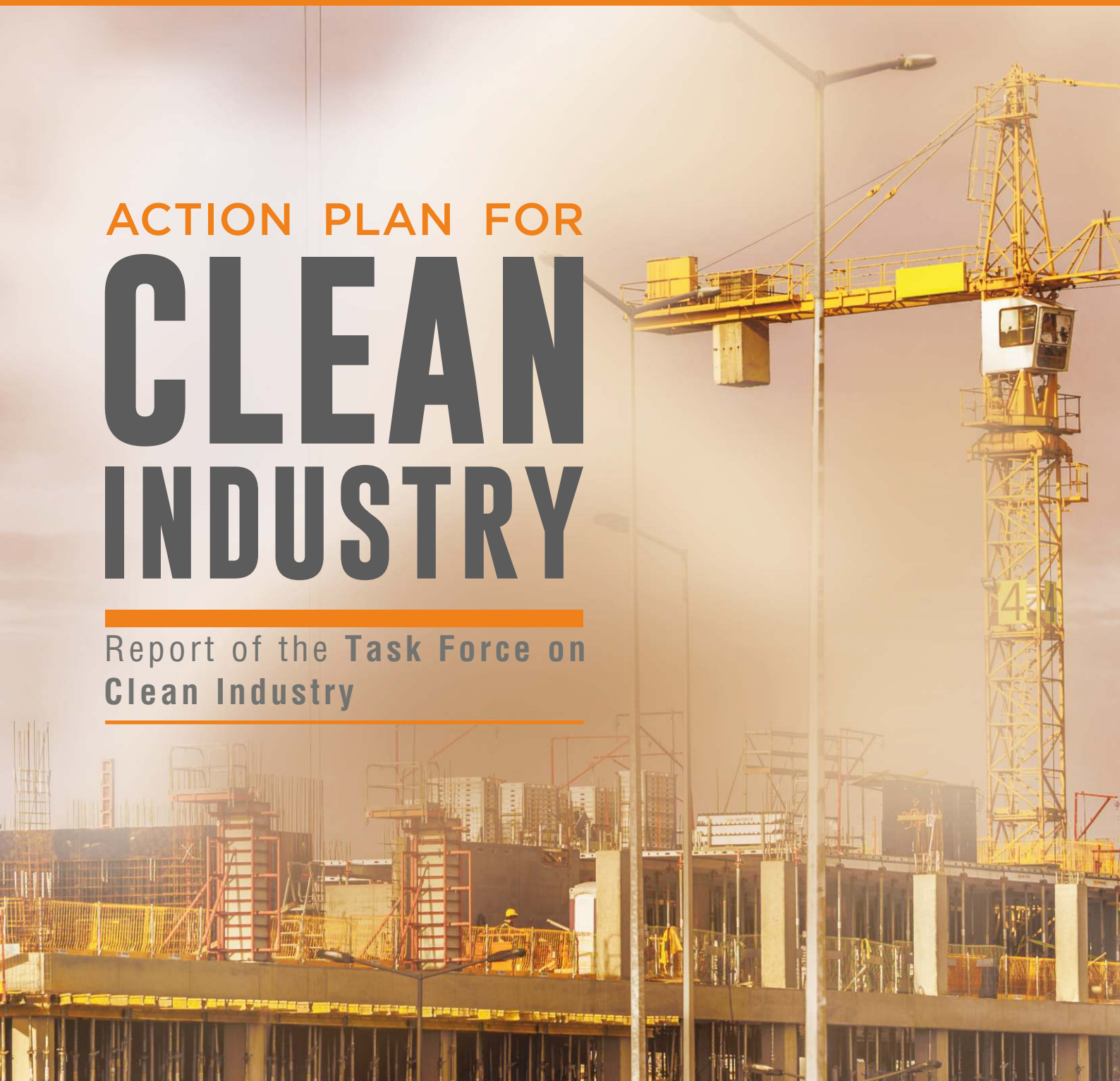
Confederation of Indian Industry

'Cleaner Air-Better Life Initiative'

ACTION PLAN FOR

CLEAN INDUSTRY

Report of the **Task Force on Clean Industry**



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FOREWORD

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MESSAGE

Formulation of appropriate strategies for maintaining a clean, green and healthy environment is a priority in NITI Aayog. We are all aware that air pollution is a major threat to a healthy environment. For controlling air pollution, NITI Aayog has been working closely with Confederation of Indian Industry (CII) and other stakeholders. On the World Environment Day (5th June, 2017), NITI Aayog and CII organized the first meeting of their joint initiative "Cleaner Air Better Life" with an objective to address the issue of air pollution in the country with active participation of the Government agencies, the industries and other stakeholders.

Subsequently, four Task Forces were constituted in NITI Aayog with experts as members to recommend suitable interventions for Clean Fuel, Clean Transport, Clean Industry and Biomass Management. Reports of the Task Forces on Clean Fuel, Clean Transport and Biomass Management have already been finalized and placed in the public domain (website of NITI Aayog). These reports and also the report of the Task Force on Clean Industry contain useful recommendations for controlling air pollution.

I congratulate CII team for their excellent work on the "Cleaner Air Better Life" initiative. I would also like to congratulate the Convener of the Task Force on Clean Industry for showing great leadership while undertaking extensive consultations with the stakeholders and coming up with specific recommendations. I would also like to place on record appreciation for Mr. Yaduvendra Mathur, Mr. Jitendra Kumar and other officers of the NRE Vertical, NITI Aayog for providing necessary support and relevant inputs to the Task Force.

(Amitabh Kant)

Place- New Delhi
Dated- 04/11/2019

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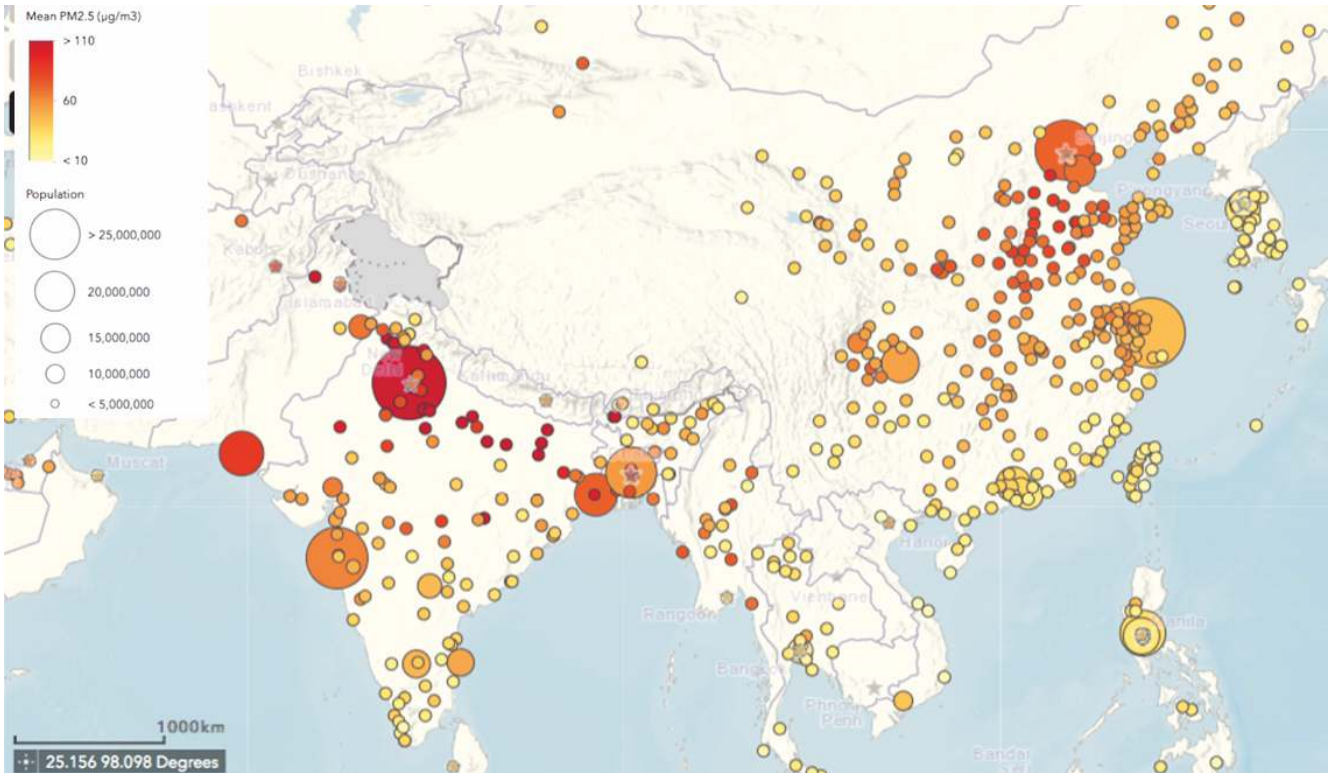
1. BACKGROUND

Air pollution in Delhi has surged to crisis level in recent years and has become a major concern for public health. As shown in Figure 1, air pollution crisis in Delhi National Capital Territory (NCT) and surrounding region has become a crisis because of the large population exposed to its health impacts. The recorded mean concentration of PM_{10} in Delhi was 292 µg/m^3 in 2016 to which more than 25 million inhabitants were exposed (compared to 104 µg/m^3 in Mumbai with 21 million inhabitants exposed or 92 µg/m^3 in Beijing with 20 million inhabitants exposed) (WHO, 2018).

With the aim of involving diverse stakeholders to improve air quality in the airshed, the Confederation of Indian Industry (CII) partnered with the National Institution for Transforming India (NITI Aayog) under the Cleaner Air Better Life Initiative in November 2016. The first meeting of the initiative took place on 05 June

Figure 1. Exposure to Air Pollution in Regions of Asia as per Measured Data in the Year 2016



Source: WHO (2018)

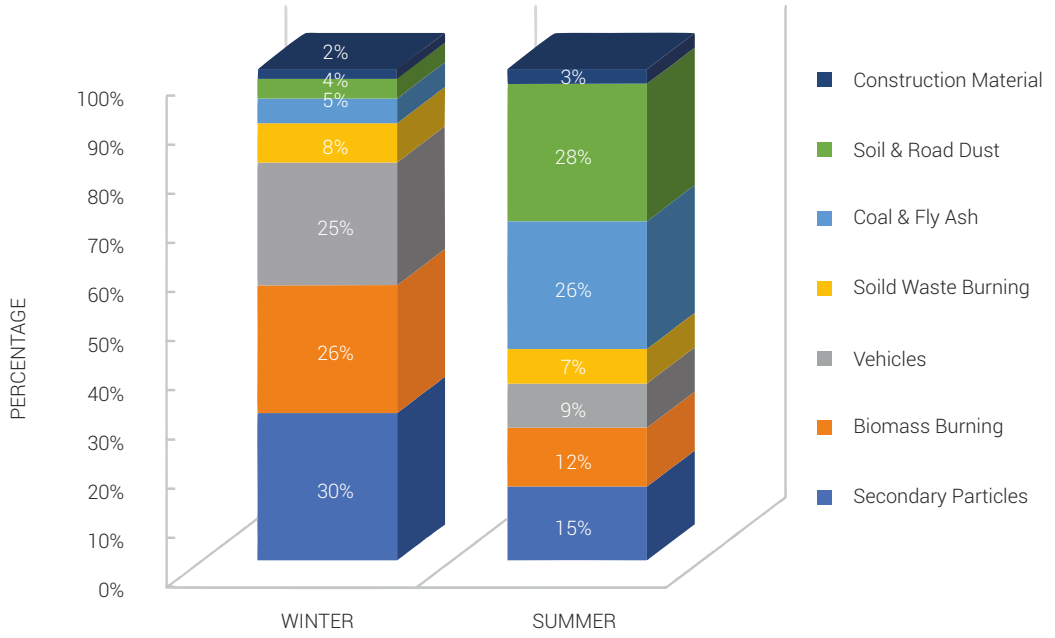
2017. Subsequently, four task forces were constituted by NITI Aayog to formulate appropriate strategies for addressing the sources of air pollution. These task forces were on: Biomass Management, Clean Fuel, Clean Transportation and Clean Industry. Of these, the task forces on Biomass Management, Clean Fuel and Clean Transportation have submitted their reports which are now in the public domain[1].

The report of this task force on clean industry addresses sources of air pollution whose contribution is significant but have received somewhat less attention such as fugitive dust from construction and roads, fly ash from coal use (both, in thermal power plants and other establishments), and stack emissions from thermal power plants.

A comprehensive source apportionment study for Delhi (Sharma and Dikshit 2016) was carried out in 2013-14 and the results in terms of contribution (percentage) of different sources to $PM_{2.5}$ (for winter and summer) and gas phase emissions (SOx and NOx) are shown in Figure 2 and Figure 3.

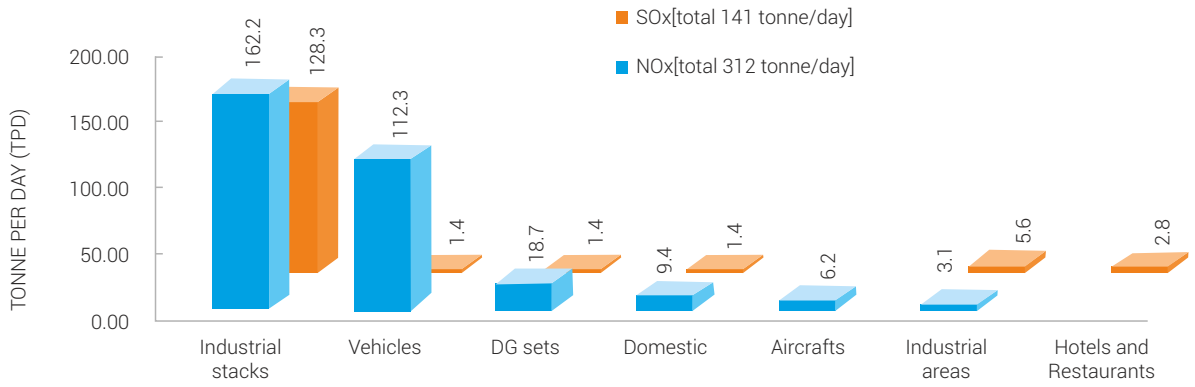
[1]Available at www.niti.gov.in/documents/reports

Figure 2. Contribution of Identified Sources to $PM_{2.5}$ in Delhi



Source: Sharma and Dikshit (2016)

Figure 3. Contribution of Identified Sources to SOx and NOx Emissions in Delhi



Source: Sharma and Dikshit (2016)

2. INCLUSIVE APPROACH OF TASK FORCE

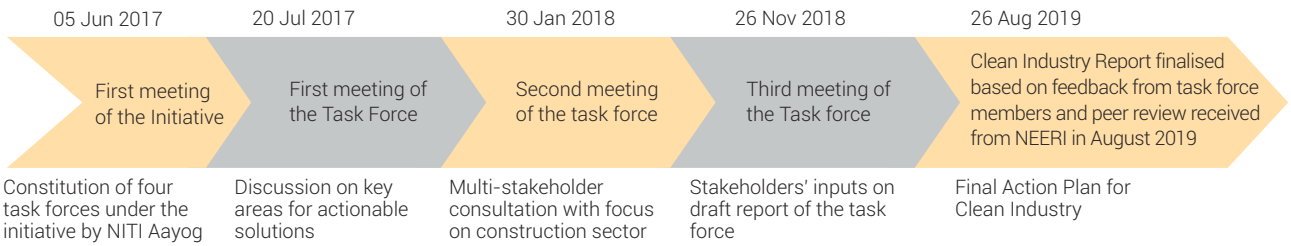
The task force attempts to bring together: government agencies, industry, research organisations and thinks tanks to design workable solutions addressing air pollution in NCR airshed[2]. The objectives of the Cleaner Air Better Life initiative are shown in Box 1.

Box 1. Objectives of Cleaner Air Better Life Initiative

Developing an integrated approach that brings together policy makers, industry and academia	Building consensus amongst stakeholders on the options for improving air quality in NCR	Catalysing voluntary commitments from stakeholders towards reducing air pollution	Promoting adherence to existing polices and advocating better policies

Addressing air pollution in an airshed needs a comprehensive strategy and coordinated action in the entire region, involving multiple sectors and agencies. Evolution of the task force's activities since its constitution and stakeholders involved are shown in Figure 4.

Figure 4. Inclusive Approach Followed by the Task Force on Clean Industry



Stakeholders Consulted:[3]

Government: Ministry of Environment Forest and Climate Change; Central Pollution Control Board; State Pollution Control Boards in NCR; Urban Local bodies in NCR.

Industry: ACC; Ambuja; Cummins; CLP India; Federation of Hotels and Restaurant Association of India; Indian Green Business Council; IL&FS; Nabha Power Limited (L&T); Tata Power; Supertech; Syntron Industries

Research institutes: Central Buildings Research Institute; Central Road Research Institute; The Energy and Resources Institute

[2]Air-shed is a common area where prevalent meteorological and geographical conditions limit dispersion of pollutants, therefore requiring a comprehensive strategy for the entire area.
[3]Refer to Annex. 11 for detailed list of stakeholders consulted

3. SOURCES OF INDUSTRIAL POLLUTION IN DELHI NCR

The Task Force considers three key air pollutants, (1) road/soil dust (2) fly ash (3) secondary particles. An analysis of source apportionment study (Sharma and Dikshit, 2016) indicates that dust and fly ash, together, contribute 19% (in winter) to 53% (in summer) of the total $PM_{2.5}$ load in Delhi while the secondary pollutants contribute 15% (in summer) to 30% (in winter) throughout the year (See Table 1). The relatively large contribution from road/soil dust and fly ash in summer is because of dry weather conditions and high wind speeds including occasional dust storms which make dust and fly ash particles airborne.

Coal or lignite based thermal power plants are significant point sources (industries in the vicinity of Delhi and with a stack height of more than 20 metres) for both, fly ash and SO_2/NO_X gas emissions. SO_2/NO_X gas emissions contribute to secondary particulate matter, formed in the atmosphere by the chemical transformation of their precursors, i.e. SO_2 and NOx. These secondary particles contribute to particulate matter in Delhi consistently throughout the year (25% PM_{10}, 30% $PM_{2.5}$ in winter, and 10% PM_{10}, 15% $PM_{2.5}$ in summer).

The updated source apportionment for Delhi NCR, ARAI-TERI (2018), is available at the time of finalising this report. The broad findings of new source apportionment are found to be consistent with the earlier study, Sharma & Dikshit (2016), which is the scientific basis for designing this action plan. As expected, the contribution of Industrial sources of air pollution is found to be higher in NCR towns compared to Delhi due to presence of Industry in proximity (ARAI-TERI 2018). Further, the Task Force on Clean Industry only focuses on the major contributors and highly distributed sources such as crematoriums and bakeries are not covered in this study.

Table 1. Contribution of Sources to Particulate Matter in Different Seasons

Percentage contribution to Particulate matter	Summer		Winter	
	$PM_{2.5}$ [%]	PM_{10} [%]	$PM_{2.5}$ [%]	PM_{10} [%]
Fly ash/coal dust	26	37	05	12
Road/soil dust	27	26	14	04
Secondary particles	15	10	30	25

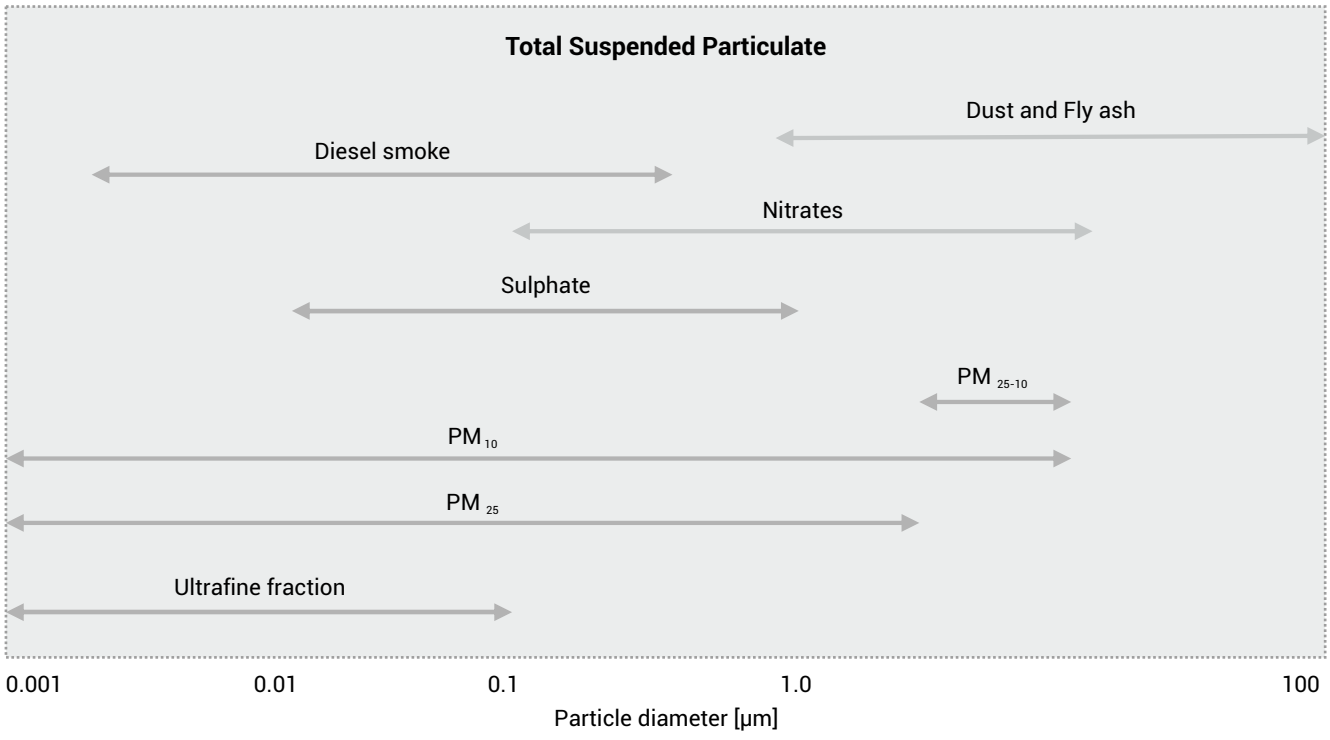
Source: Sharma and Dikshit (2016)

Thermal power plants are the single largest contributor of SOx: 90% of SOx emission load in Delhi. They also contribute to 52% of the total NOx emissions in Delhi, followed by vehicular emissions at 36%.

The most significant contribution to SO_2 emissions is from industrial point sources (coal/lignite based thermal power plants) located in NCR region. These sources contribute about 90% of the total SO_2 emissions load in the city (~141 t/d) and are the single largest contributor of SOx (Sharma and Dikshit, 2016). Nearly 52% of the total NOx emissions in Delhi (~312 t/d) are attributed to the same source, followed by vehicular emissions (occurring at ground level) contributing to 36% NOx loading. Two other significant contributors to NOx emissions are DG sets (6%) and aircrafts (2%) (Sharma and Dikshit, 2016).

Secondary particles (from conversion of SO_2 and NO_x gases to particulate) and direct emissions from diesel engines (soot) are most critical in terms of health impact due to their ultrafine size (< 0.1 µm particle size). Figure 5 shows the typical size range of particles (WHO 2006; Ghosal et al 1995; and Chatterjee 2010) associated with different sources. It is evident from the Figure 5 that SOx emissions and PM emissions from diesel engines or generators contribute significantly to $PM_{2.5}$ as well as PM_{10} while NOx, fly ash and dust emissions may contribute to PM_{10} more compared to $PM_{2.5}$.

Figure 5. Typical Size Range of Airborne Particles Including Health-Related Ultrafine Fractions, $PM_{2.5}$, PM_{10} and Major Constituents Considered by this Task Force



Source: WHO (2006); Ghosal et al (1995); and Chatterjee (2010)

In order to prepare a source-specific plan of action, different industrial activities contributing to these (dust, ash, and secondary particles) emissions are broadly classified as-

1. Fugitive Particulate Matter (PM) Emissions: Emissions originating from spatially distributed sources and wide array of activities as opposed to specific discharge point such as exhausts and stacks. Dust emissions from construction (buildings and infrastructure), utilities operations in NCR towns (waste management, roads and highways, water, telecom), material transportation, fly ash emissions from concrete batching etc.

2. Energy-related Emissions: Emissions originating from energy conversion and consumption in industry subsectors. In Delhi NCR, these include: SOx, NOx and PM emissions from thermal power plants within 300 km of Delhi, PM emissions from brick kilns in NCR, PM and NOx emissions from diesel generators' use in buildings and industry subsectors such as telecom, IT, real estate, hospitality and healthcare in NCR.

3.1 Fugitive Particulate Matter (PM) Emissions

Air pollutants originating from spatially distributed sources and wide array of activities as opposed to specific discharge point such as exhausts and stacks are called fugitive emissions. Fugitive emissions have the potential for much greater ground-level impact since they are discharged and dispersed close to the ground (IFC, 2007). The two main types of fugitive emissions are Particulate Matter (PM) and Volatile Organic Compounds (VOCs)[4]. As control strategies (See Annex. 5) for addressing various fugitive emissions are the same, the more comprehensive and umbrella term: "fugitive emissions" is used in many places in the following text while addressing the fugitive dust or particulate matter emissions.

Road/soil dust, coal dust and fly ash emissions or so-called fugitive particulate matter emission originate from various economic activities in NCR towns and peri-urban areas. These particles travel up to several kilometres before settling down and at the same time, they get re-suspended in the air due to vehicular movement and resulting winds. An exhaustive list of various sources of these emissions in the city is presented in Table A5-2 (See Annex. 5). Sources include various anthropogenic activities: building constructions ranging from small building renovations to area development projects, urban infrastructure projects, operations of city-wide utilities (solid waste, electricity, roads, and water) and resuspension due to vehicular movement. Although dust storms occur frequently during pre-monsoon season in Ganga Basin in North India (Dey et al., 2004), these sources are outside the purview of this report. Only local phenomena contributing to generation and suspension of dust or particulate matter in Delhi's air are considered here.

3.1.1 Building Construction

Rampant construction activities across NCR towns and rapidly expanding urban sprawl contribute to fugitive dust emissions. These activities are either greenfield or brownfield, accompanying huge amounts of construction and demolition (C&D) waste produced every day. It is estimated that 5000 tonnes of construction and demolition debris[5] is generated in Delhi NCT every day (IL&FS, 2018). This is projected to grow rapidly in future with the high growth in residential and commercial floorspace projected for the next decade[6]. Demolition activities contribute to the dust emissions not only during the demolition of structures but also during the improper transportation and disposal of construction debris. As per the Construction and Demolition (C&D) Waste Management Rules (MoEFCC, 2016a), no government authority, contractor, builder or person can store the construction and

[4]VOCs are secondary aerosols which are important component of fugitive PM emissions and associated control strategies. VOCs have not been covered under the latest source apportionment study available for Delhi (Sharma & Dikshit, 2016) and It is speculated that significant amount of VOCs are added to Delhi's air every day due to unregulated activities which are prevalent in industrial clusters and small enterprises throughout the city
[5]90% of this is estimated to be generated from demolitions activities whereas 10% from new constructions activities
[6]70% of the total floorspace by 2030 is yet to be constructed

> Demolition activities contribute to the dust emissions not only during the demolition of structures but also during the improper transportation and disposal of construction debris.

demolitions waste outside the areas demarcated by officers of concerned authority or corporation (NGT, 2014). Those generating C&D waste beyond this threshold will pay a waste management fee to local authorities for processing or disposal of their waste whereas the generators who salvage, process and recycle (preferably in-situ) their waste will be incentivised. Local authorities are supposed to track the C&D waste generated in their jurisdiction and maintain an active database which is used for establishing and reporting the yearly generation trends. The 2016 rules also emphasise the need for maintaining a sustained system of information, education and communication by the local authority in collaboration with expert institutions and civil society. As per the rules, procurement of materials made from C&D waste should be mandatory for a certain percentage (10-20%) in municipal and government contracts. In addition, the use of recycled products from C&D Waste needs to be incentivised in construction activities as well as in non-structural concrete, paving blocks, lower layers for road pavements including the colony and village roads (MoEFCC, 2016a).

> Construction activities in the city including infrastructure projects rely on allied construction industry such as brick kilns, RMC batching plants and stone crushers for supply of raw and processed materials.

3.1.2 Urban Infrastructure and Utilities

Besides building construction, large infrastructure projects (e.g. metro, roads, bridges, flyovers) contributes to dust and fly ash emissions. Handling of materials, i.e. transportation and storage (both onsite and offsite) during construction, renovation and demolition phases of different projects is a major focus area of the interventions required for dust control and management in construction/infrastructure industry. Other control options for infrastructure projects are similar to building construction, such as, paving the access roads, providing vehicle wash down facilities at site, and installing wind breakers.

Re-entrainment of dust from vehicular movement on roads (paved or unpaved) is the largest source of dust emissions in Delhi (See Annex 1 on emission inventory for Delhi). Key factors which aggravate dust generation and re-suspension include: poorly maintained road stretches, frequent digging of roads/pavements by public utilities, illegal dumping of construction debris beside roads, dust emanating from exposed surfaces in the proximity and improper (not conforming to guidelines for load conditions and containing dust) transportation of materials, and improper road/street designs. Day-to-day maintenance activities of urban utilities such as waste management, energy supply, water, sewage and roads contribute to dust generation due to frequent digging of roads and nearby surfaces. These emissions can be avoided though properly designed infrastructure, organisational behaviour change (among civic agencies and public utilities) and strict management practices. Identification of poorly maintained road stretches can be undertaken immediately by the concerned agencies in order to implement the mitigation measures on priority basis.

3.1.3 Allied Construction Industry

All construction activities in the city including infrastructure projects rely on allied industrial activities for supply of raw and processed materials. Allied construction industry is concentrated in the periphery of Delhi NCT or so-called peri-urban areas. These include mainly three allied sectors-

1. Ready-Mix Concrete (RMC) batching plants
2. Stone crushers
3. Brick kilns

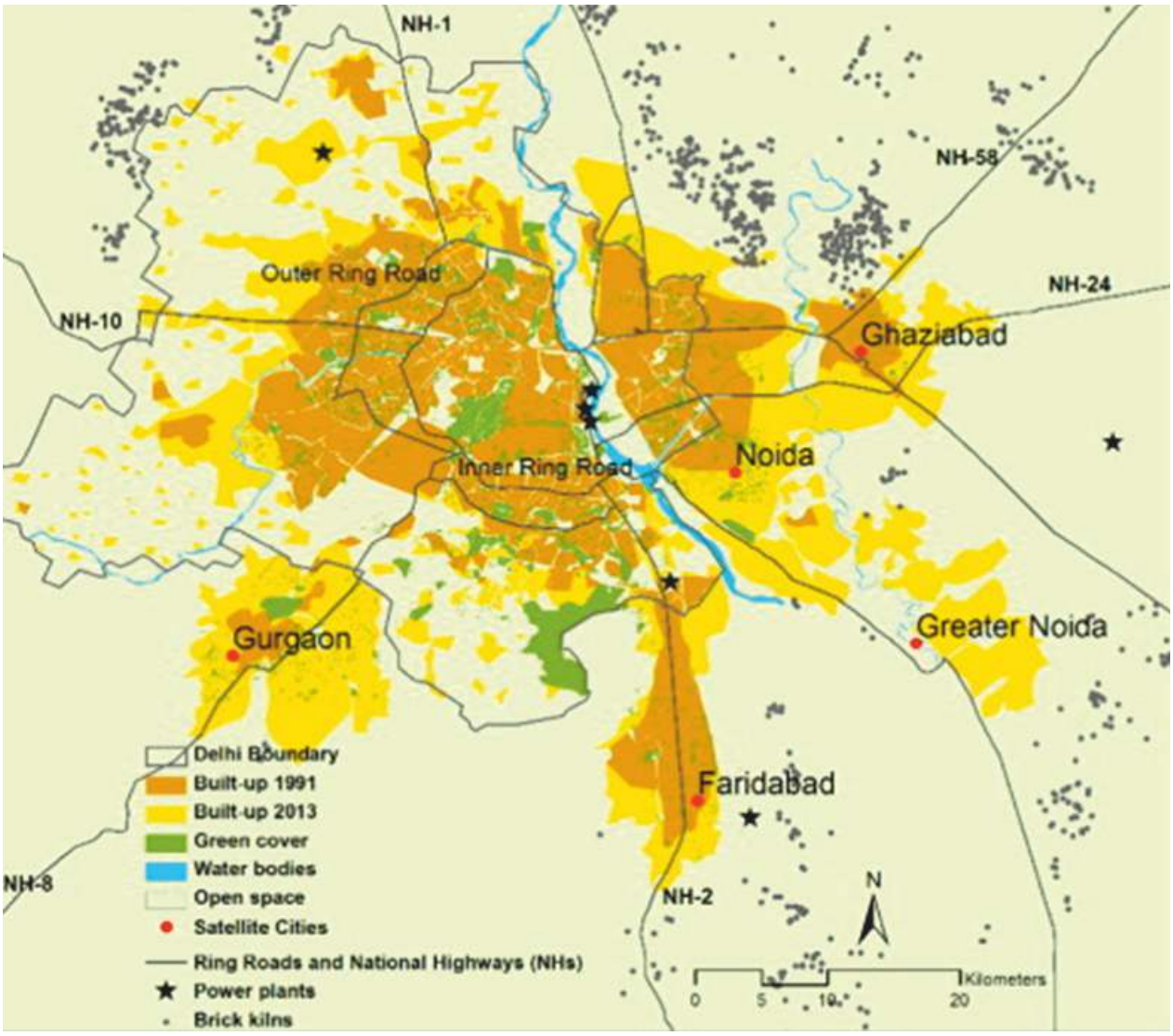
Ready-Mix Concrete (RMC) Batching Plants

Rampant construction activities in the city require huge amounts of concrete: a mix of sand, coarse aggregates, cement and water. For small construction projects, mixing is undertaken at site (in-situ) whereas large construction projects are dependent on RMC sourced from concrete batching plants. Concrete batching plants can be located either onsite or offsite. The concrete supplied from on-site batching would involve trucks carrying different raw materials such sand, aggregates, cement etc. to the site while sourcing concrete from an off-site RMC plant avoids transportation of material and associated emissions within the control area. Concrete from RMC plant is transported to site in wet form in enclosed containers.

Besides air quality benefit, RMC also provides opportunity for use of pozzolans like fly ash and ground slag in concrete while maintaining strict quality control (BIS 2016). As per National Building Code of India, preference may be given to use of RMC, if the RMC manufacturing plant is nearby. However, due to lack of monitoring and good practices, a large amount of fly ash

generation is expected from the RMC batching activities (Sharma and Dikshit, 2016). It is estimated that there are a few hundred concrete batching plants operating in NCR region (Sharma and Dikshit, 2016). The pozzolan cement used in the preparation of RMC contains 35% of fly ash (Sharma and Dikshit, 2016), main cause of fugitive emissions in the process. Although it is advisable that RMC is utilised for construction projects in order to curb dust emissions at site and promote utilisation of fly ash, it is crucial that stringent control measures are followed at RMC batching plants. These control measures are detailed in the Annex 5.

Figure 6. Brick Kiln Units Located in the NCR, Represented by Black Dots on the Map



Source: Goel and Guttikunda (2015)

> Due to more efficient burning in zigzag kilns, SPM and unburnt carbon emissions are reduced drastically by **60-75%**.

Stone Crushers

Aggregates for concrete are sourced from stone crushers located in NCR or outside the region. These plants crush stones to coarse aggregates to be used as part of concrete in the construction projects. It is also possible to use Recycled Concrete Aggregates (RCAs) sourced from C&D waste processing plants and there is a huge potential to replace the virgin materials used in construction projects and avoid the transportation of materials into the city. As noted by members during the second meeting of the task force, illegal mining of virgin materials for building and construction is the key factor affecting uptake of sustainable building materials despite their clear economic and environmental advantages.

Brick Kilns

Emissions from brick kiln industry is another major area requiring attention. Fly ash from brick kilns operating in NCR contributes to the air pollution in Delhi (Sharma and Dikshit, 2016). As per 2014-15 data, there were about 2,080 brick kilns in Delhi-NCR, predominantly located in North Western and South Eastern peripherals of the city as depicted in Figure 6 (Goel and Guttikunda 2015). Majority of these brick kilns are based on old technology: Fixed Chimney Bull Trench Kiln (FCBTK), having chimneys emitting pollutants continuously during the manufacturing season (January to June) every year. Many of them do not have gravity settling chambers which purify the effluent gas from the stacks.

Latest environmental standards propose a shift from FCBTK type to zigzag type. Zigzag brick settings allow sufficient time for heating of fuel to reach ignition temperatures and result into near-complete combustion of fuel (Kamyotra 2017). Due to more efficient burning in zigzag kilns, SPM and unburnt carbon emissions are reduced drastically[7] by 60-75% (EPCA 2017; CCAC 2018). Zigzag design also reduces the specific energy consumption in kilns by almost 20% due to proper hot air circulation. As a co-benefit, the number of good quality bricks in the process are increased by up to 25% (EPCA 2017; Kamyotra 2017). High draft Zig-Zag technology was first developed by the Central Building Research Institute (CSIR-CBRI), Roorkee in 1987-88 to overcome the pollution from brick kilns. The license of the technology has been transferred by CBRI to three agencies for implementation in brick kiln all over India. But the technology has received renewed focus due to concerns about air pollution from existing brick kilns. Also, in recent years, some of the brick makers have modified the brick setting and practices and have successfully operated the kiln with natural draught (Greentech-Enzen 2012).

Despite the significant advantages and very high return on investment, zigzag kilns have not been an attractive proposition for small scale brick kiln industry. The capital expenditure for both types of kilns: FCBTK and zigzag is found to be same, i.e. INR 40-50 lakh for a brick kiln with a production capacity of 30,000-40,000 bricks per day (Kamyotra 2017) but shift to new brick kiln setting requires dismantling the existing kiln structure and laying the bricks again in the zigzag setting. International experience in moving towards zigzag technology shows that imparting awareness and training to brick makers is extremely important. Specific training programmes are required to educate brick makers on shortcomings of existing technologies/practices and their impact on revenue, climate, agriculture and health (CCAC 2018) vis-à-vis various benefits of cleaner technology/practices such as fuel saving, improved occupational health, better product quality, increased revenues, and compliance to environmental regulation. Also, the role of cleaner brick firing practices, including practical training for fire master on zig-zag kiln firing practices (CCAC 2018) is very important for ensuring lower emissions in the long

[7]As per observations by Central Pollution Control Board: SPM emissions decline from 517-1375 mg/Nm3 in FCBTK natural draft kiln setting to 155 mg/ Nm3 in zigzag natural draft kiln setting whereas the black carbon emission decline from 1.18 mg/ kg-fired brick in FCBTK natural draft kiln setting to 0.22 mg/ kg-fired brick in zigzag natural draft kiln setting.

term once the right infrastructure is in place. After a prolonged consultation with the brick kiln industry in NCR, the CPCB has issued directives to all bricks kilns in 22 NCR districts: Uttar Pradesh (7 districts), Haryana (13 districts) and Rajasthan (2 districts). These directives stipulate conversion of all brick kilns in NCR to zig-zag technology by October 2018; units based on the old technology will not be allowed to operate beyond July 2018 (CPCB 2018). As per the latest information, 35% of the brick kilns (1835 out of total 5240 units in 2018) in NCR lying in neighbouring states of Haryana, Rajasthan, Uttar Pradesh have converted to zig-zag technology while rest of the units; which haven't switched to new technology; are not allowed to operate (EPCA 2018).

3.2 Energy-related Emissions

Energy related emissions originate from diverse industrial subsectors and are related to-

- Use of DG set in various subsectors such as Telecom, IT, hospitality, real-estate, construction etc
- Gaseous (SOx and NOx) and particulate matter emissions from Coal-based thermal power generation units within 300 km of Delhi
- Use of coal and wood for firing tandoors in hotel and restaurant industry

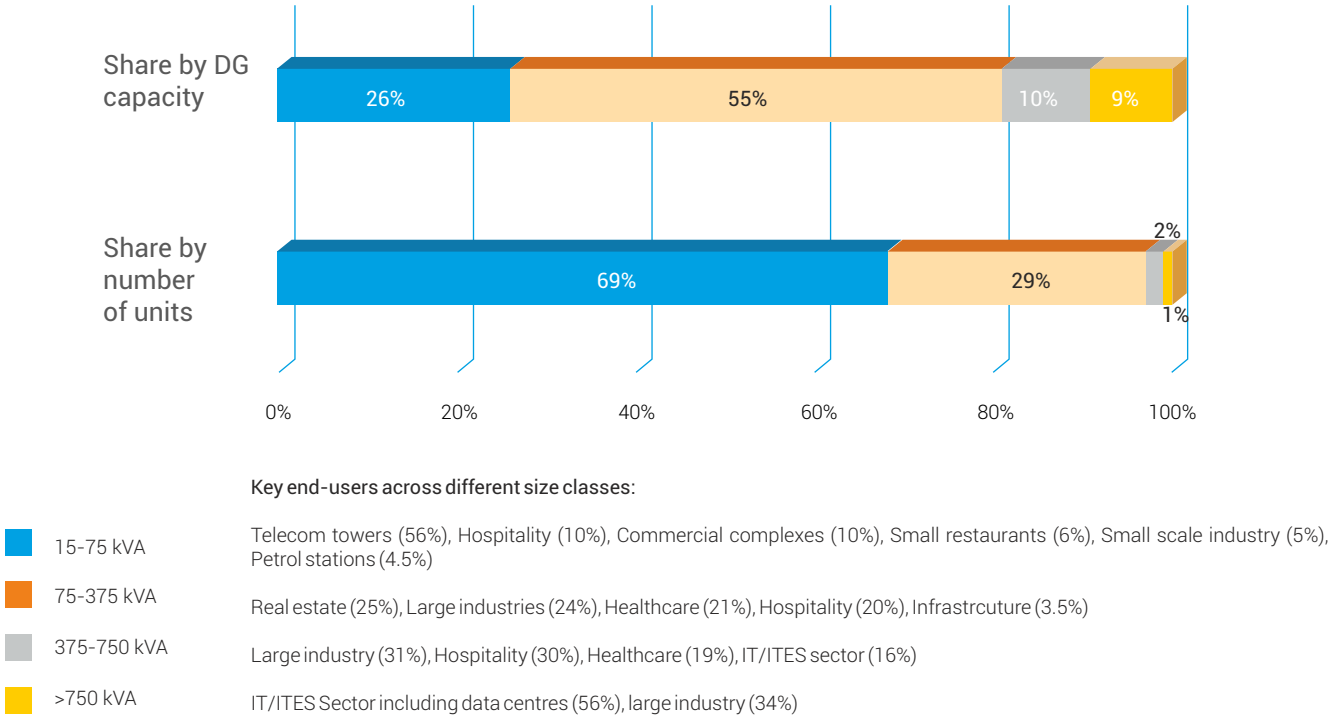
> Diesel generators contribute significantly to NOx emission in Delhi and their contribution to NOx within Delhi NCT is observed to be 6%.

3.2.1 Use of Diesel Generators in Buildings & Industry Subsectors

Diesel generators are used for maintaining reliable supply of power in various commercial and industrial activities where 24x7 power supply is critical. They also serve as source of primary power in locations where modern energy infrastructure is missing. DG sets are preferred option for power back up during outages despite very high cost of electricity per unit: INR 16 per unit from DG set compared to INR 3.5 per unit from coal power plant. Roughly about 85-90 % of DG set demand in India is for backup power whereas their demand for primary power is significantly lower: less than 15% (Oswal 2017). Major end-use sectors of DG sets are telecom towers, hotels, commercial complexes, hospitals, data centres, infrastructure (metro and road) and large industry such as power plants for black start.

Diesel generators contribute significantly to NOx emission in Delhi and their contribution to NOx within Delhi NCT is observed to be 6% (Sharma and Dikshit, 2016). It is expected that this contribution is higher for Delhi NCR as power outages are more frequent in peri-urban and satellite towns of Delhi. Various studies

Figure 7. Market Segmentation of DG Sets by Size Classes Including Major End-Users Across Size Classes



Source: Adapted from Oswal (2017)

SOx and NOx emissions from thermal power plants are eventually transformed into secondary pollutants and contribute to ultrafine PM range.

highlight that contribution of DG sets can be as high as 16% in case of satellite towns of Delhi and exposure to PM2.5 increases significantly within the residential areas in event of power outages (SCAPHRI 2015; CSE 2018).

Although, Delhi NCR specific market data is not available to our best knowledge, national level market report (Oswal 2017) indicates that these high horsepower DG sets (> 750 kVA) are merely 1% of total number of DG units and 9% of total DG capacity installed in India as shown in the Figure 7. It is found that large stock of existing DG sets, which are not covered under in-use emission norms need to be addressed on priority basis for clean air action in Delhi. Although improved reliability of power can lower the usage of DG sets for predominant backup application and resulting emissions, the usage of DG sets cannot be ruled out in case of power contingencies. As per the Graded response action plan (GRAP) for Delhi NCR, the DG sets were banned in Delhi for a period from 18 October 2017-28 February 2018 due to air quality slipping to very poor level (DPCC 2017, NCTD 2017). While this ban was executed in Delhi alone, it is not a permanent solution to address emissions from diesel generators. Hence, policy emphasis may be laid out at a national level on using proven options for control of emissions from DG set, which would ensure smooth running of economic activities.

Emission Norms for DG sets

Under the Environment (Protection) (Third Amendment) Rules, 2013, environmental standards exist in India for new generator sets with capacity up to 800 kW and specify emission limits for three different size classes: up to 19 kW, 19-75 kW and 75-800 kW (MOEFCC 2013). Emission limits for NOx + HC, CO and PM apply for type approval and conformity of production. On the contrary, in-use environmental standards apply to generators with capacity above 800 kW or 0.8 MW (or 1000 kVA), as applicable to diesel engines for application in power plants generator set applications and other requirements, under the Environment (Protection) Third Amendment Rules 2002. It is observed that under the current regulatory regime for control of in-use emissions which is applicable only to high horsepower capacity segment, load conditions are not mentioned during the periodic emission testing of DG sets. DG sets are installed to fulfil part load in building application and in-use emission standards can be improved by considering actual load conditions for testing of existing DG sets.

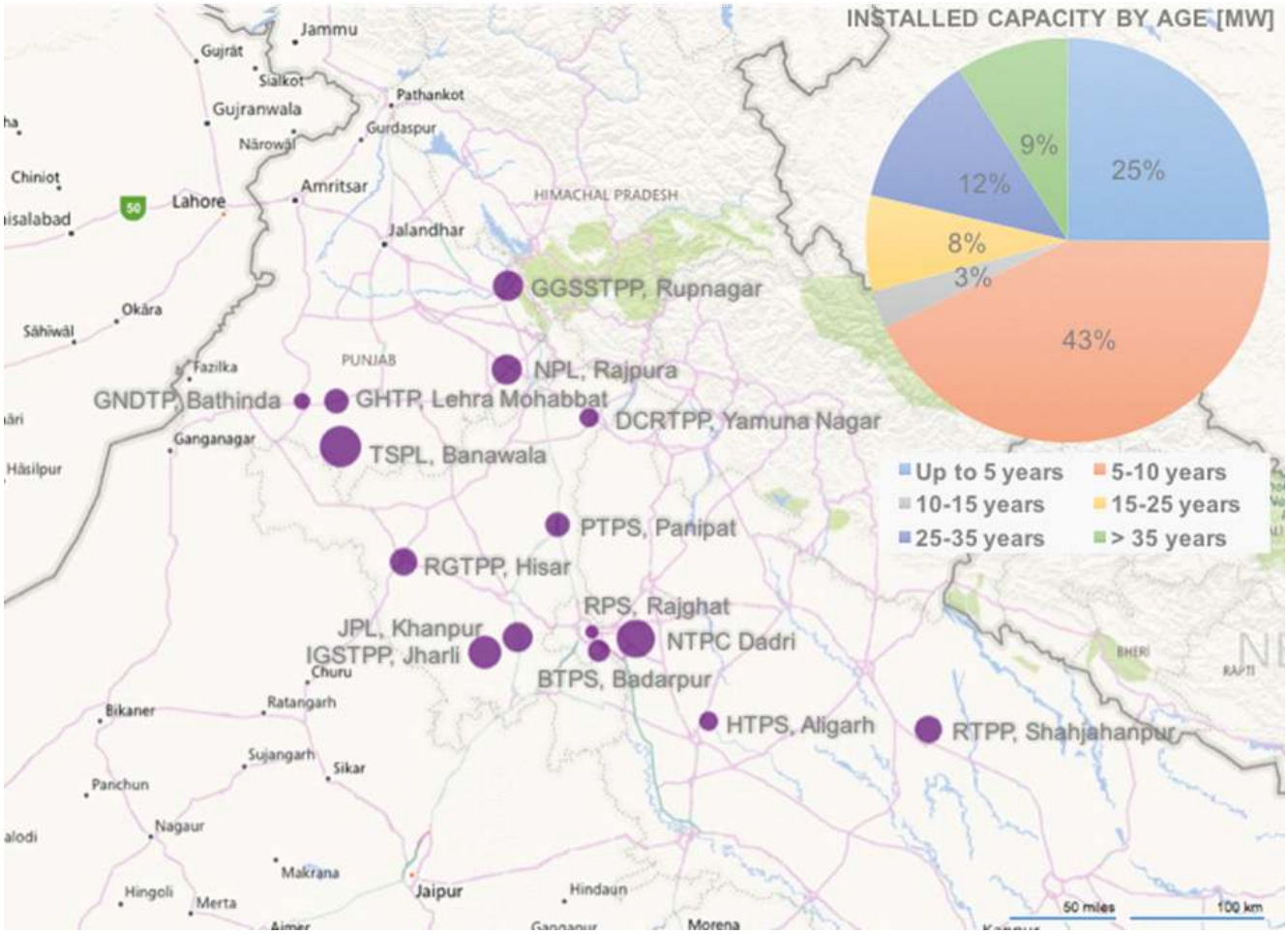
Currently the discussions for further reduction of emissions through next level norms for DG sets are underway. India needs to adopt stringent norms with global references to derive long term benefits of change rather than regular small step changes. The introduction of one universal norm instead of split by application, usage or territory is thus essential for ease of enforcement through good governance.

3.2.2 Coal-based Thermal Power Plants

There are fifteen existing coal-based thermal power stations in NCR and its vicinity which contribute to loading of SOx and NOx emissions in the city. Source apportionment study for Delhi establishes that power plants are largest sources of SOx and NOx emissions which are blown over the NCR region by prevalent North Western and South Eastern winds (Sharma and Dikshit, 2016). These emissions are eventually transformed into secondary pollutants and contribute to ultrafine PM range as given in the Figure 5. All thermal power stations within a radial distance of 300 km from Delhi are mapped in the Annex 8 along with details of individual units. These installed generation capacities (total

16,465 MW) are also mapped in Figure 8 below. Size of the bubble in Figure 8 indicates unit's installed capacity. Out of 15 existing coal-based power stations, two located in Delhi: BTPC Badarpur and RPS Rajghat face closure. Closure report for RPS Rajghat was submitted by its operator IPGCL to Govt. of NCT of Delhi (GNCTD) and decision of GNCTD is pending in this regard (CEA 2018). Units 1, 2 and 3 at BTPC Badarpur are going to be phased out by June 2018 (CEA 2018) whereas units 4 and 5 face closure due to unviability of flue gas desulphurisation for control of SOx emissions (NRPC 2017). All in all, there are total 56 coal-based thermal units in the region out of which 15 are in the process of being phased out and face closure in the near future due to unavailability of space for Flue Gas Desulphurisation (FGD) as described below. A total installed capacity of 3525 MW or 24 units are above the age of 25 years as highlighted in the Figure 8.

Figure 8. Map Showing Existing Coal-Based Power Stations within 300 km of Delhi



Source: CII-CESD (2018) analysis

Emission Control at Coal Thermal Power Plants

Government of India acknowledged the health hazards from the coal based thermal power plants and informed of certain steps in 2013 which included formulation of new emission standards. Other proposed steps included (GoI, 2013): use of beneficiated coal with ash content below 34%, emphasis on cleaner coal technologies such as supercritical and Circulating Fluidised Bed Combustion (CFBC) while granting environmental clearances to TPPs, pollution control systems on case to case basis (on the basis of ambient air quality and sensitivity of the area) and directive to TPPs for 100% utilisation of fly ash.

The new emission standards were notified for the first time in December 2015 with December 2017 as a deadline to meet these standards. New emission standards included standards for SOx and NOx emission which were previously non-existent in the country including more stringent standards for PM. All power plants in the country were supposed to meet the new emissions limits (as given in the Table 2) by December 2017 which in turn would have helped to improve the ambient air quality. Ministry of Power (MoP) constituted a committee under chairmanship of Central Electricity Authority (CEA) in September 2016 to prepare action plan for power plants to meet new emission norms.

CEA (2016)[8] estimated that FGD units are required for nearly 151 existing units (90 GW) and 73 new units under construction (72 GW) to meet the new norms whereas 430 units smaller than 500 MW in capacity (including few older 500 MW units) face space constraint for installation of FGD systems. Nearly, 302 existing units in the country would require modification in combustion processes (low NOx burners) to meet the targets of 600 mg/Nm^3. Denitrification systems such as Selective Catalytic Reduction (SCR) systems are required for 279 existing units (120 GW) and 73 upcoming units (72 GW) to meet the targets of 300 mg/Nm^3 and 100 mg/Nm^3 (CEA, 2016). The globally available SCR units are not proven for Indian coal with high ash content (~40%) and demonstration projects would be required for SCR system in India. MoP raised concerns of various power plant in country for compliance with new emission norms. It informed the

Table 2. Emission Norms for Power Plants as Amended by Government of India in December 2015

Installation Date	Before 31.12.2003	01.01.2003 - 31.12.2016	After 01.01.2017
	Emissions limits [mg/ Nm^3]:		
Particulate matter	100	50	30
Sulphur Dioxide (SO_2)	<500 MW: 600		100
	>500 MW: 200		
Oxides of Nitrogen (NO_x)	600	300	100

Source: MoEFCC, 2015

[8]As of 31 Mar 2016, installed capacity of coal based thermal power was 185 GW with 75 GW additional capacity under construction

Ministry of Environment Forest and Climate Change (MoEFCC) that retrofitting additional fields in ESP units or replacement in existing units will require complete shut down for 4-6 months, and asked for 30-36 months required for arranging funds and implementing FGD in phased manner to avoid any grid contingencies. Following this, the MoEFCC undertook multiple consultations with stakeholders including MoP, CEA and NTPC in 2017. It was decided that action plan prepared by MoP for compliance in 7 years (up to 2024) was too long and should be implemented by 2022 considering the health impact on general public. Based on the revised action plan by MoP and prioritisation by MoEFCC for plants close to urban areas, new directions were issued to all coal-based thermal power plants by MoEFCC and CPCB in December 2017. According to these directions, the unit-wise phased plan for installation of emission control devices is given in Annex 8 along with mapping of all TPP units in NCR and surrounding region.

The revised unit-wise phase out schedule for installation of FGD in power plant located in the Northern regions, as shown in Annex 8, spans from year 2019 to year 2022. All power plants in this region are supposed to retrofit FDG by 2019 in order to meet SOX standards except RTPP, Shahjahanpur (Uttar Pradesh) which is supposed to meet the timeline for FGD installation in 2021. As recommended by MoP, same timelines apply for meeting NOx standards as well (MoEFCC 2017) whereas immediate upgradation of ESP is planned in most of these plants. MoEFCC directions prescribe immediate measures such as installation of low-NOx burners, providing Over Fire Air (OVA) etc. and achieving progressive reduction to comply to NOx emission limit in the stipulated year. As highlighted in the Figure A7-1 (See Annex 7), it is technically feasible to achieve emission reductions on par with combustion emission control options by modifying the combustion process and implementing a combination of in-situ abatement options such as low-NOx burners, OVA and flue gas recirculation. In addition to 15 old TPP units (1935 MW) which face closure, additional 8 TPP units (1380 MW) face closure by 2022 as FGD installation is not viable in these TPP units due to space constraint (MoEFCC 2017, NRPC 2017).

Coal and lignite used in these TPPs gives rise to fly ash and safe utilisation of fly ash is essential, making sure that ash does not become airborne (CEA, 2017b).

More research and development will be required in future to utilise the bottom ash for value added products besides its application for road construction, mine filling and filling low lying areas.

According to the latest notification, MoEFCC (2016b), construction agencies (public or private) within 300 km of the location of TPP are mandated to use products based on fly ash[9] . For first 100 km, 100% cost of fly ash transportation is borne by TPP whereas beyond 100 km, the cost of transportation is equally shared by TPP and user. Since July 2016, all coal/ lignite TPPs are required to update information about the stock of ash on their website and update it every month (MoEFCC, 2016b). All thermal power plants in India are required to have a system in place for 100% management of fly ash in four years from the date of commissioning. The information on ash utilisation for power plant in NCR region is captured in Annex 8. The management and control options for fly ash are already covered under Annex 5.

Roughly, 20% of the total ash which gets generated during combustion at TPP is bottom ash: coarse ash that gets collected at the bottom of boiler. It has been highlighted by task force members that there is limited availability of viable options for utilising the bottom ash from TPPs. As per member inputs, at least one global technology player claims to have used the bottom ash and fly ash in a ratio of 3:1 but the technology is yet to be tested for Indian ash. More research and development will be required in future to utilise bottom ash for value added products besides its application for road construction, mine filling and filling low lying areas.

Existing Policy for Utilisation of Biomass in Thermal Power Plants

Surplus biomass is available in abundance in NW India. A detailed list of state-wise biomass potential in India is provided in Annex 10, which is based on the data from National Biomass Atlas. Ministry of Power (MoP), through its policy and advisory issued in November 2017 has urged all utilities and power plants[10] in the country to utilise 5-10% blend of biomass pellets through co-firing along with coal. The advisory issued by MoP notes that biomass co-firing is a proven technology and is recognised by UNFCC as a carbon neutral technology for mitigation of carbon emissions from coal-based power plants (MoP 2017a). It is estimated from the open sources of data that nearly 230 plants across the globe, majority of which are located in European and American countries, utilise biomass for co-firing with coal. NTPC's Dadri plant has successfully demonstrated 7% co-firing with biomass pellets and the advisory suggests that 5-10% co-firing with biomass pellets can be replicated[11] in- all coal fired TPP units (fluidised bed or pulverised coal units) having bowl mills, vertical roller mills, or beater mills (except those having ball and tube mills[12]) (MoP 2017a; MoP 2017b). The policy advises public/ private utilities to undertake technical feasibility, especially for safety aspects, prior to biomass co-firing.

Existing policy notes that paddy-straw that remain unutilised and burnt in the North West India has potential to generate about 6000-8000 MW or 45,000 million units (m-kWh) electricity annually (MoP 2017b). The policy also highlights the decentralised

[9]MoEFCC has established threshold for minimum fly ash content in order for construction materials to be classified as fly ash products such as 50% of raw material for fly ash blocks/ tiles/ bricks; 15% of the raw material for cement etc.

[10]fluidised bed or pulverised coal units having bowl mills

[11]0.25-0.3 million tonne of biomass pellets are required for 7% blending in a 1,000 MW coal-based plant

[12]Co-firing biomass pellets is deemed to be unfit for TPP units having ball and tube type mills due to higher risk of fire hazards (MoP 2017b)

infrastructure for biomass conversion (bales to pellets) as an opportunity for generating employment. Following institutional arrangements, are recommended in the policy-

1. Central Electricity Authority (CEA) will develop and issue specification for pellets, and additionally, it will provide technical assistance to public and private utilities for blending biomass pellets with coal.
2. Responsibility of devising suitable mechanism lies with the appropriate commission: The State Electricity Regulatory Commissions (SERCs) in respective states.

Existing policy suggests that appropriate commission (SERC) will determine the compensation to power utilities[13] for any incremental cost on account of using biomass pellets e.g. cost of pellets, increase in auxiliary power consumption, and plant heat rate. It also mentions explicitly that any increase in cost of generation will not be taken into account for merit order dispatch.

3.3.3. Hotel and Restaurant Industry

Hotel and restaurants among other eateries utilise tandoor (traditional North Indian oven made of clay) for cooking which are fired with solid fuels such as wood, coal and charcoal. Large hotels and restaurants mainly utilise charcoal as opposed to wood and coal. It is estimated that there are roughly 9000 tandoors (Sharma and Dikshit, 2016) in the city which contribute to fly ash. This figure is based on the conservative estimate that 25% of enterprises use tandoor for cooking. Delhi is known for its street food. Due to large number of unregistered enterprises, the actual number of eateries using tandoors is expected to be much higher.

The key reason for emission from these tandoors is not simply the usage of polluting fuels but also the inappropriate tandoor design which is not optimised for efficient burning. The community/commercial tandoors in India are unregulated with no standards, guidelines or labelling for either efficiency or emissions.

The cleaner options for tandoors include gas, electricity, and solid biofuels. Clean fuel options need to be promoted across the eateries in Delhi NCR. Biomass is a low sulphur option compared to coal (See Annex 9) and appropriately designed tandoor for solid biofuels can ensure significantly lower emissions compared to conventional tandoors in use today. CSIR-NEERI has developed a clean tandoor based on biomass pellets. Improved combustion chamber design for better air-fuel contact and heat transfer, reduced emissions as a result of improved burning, higher thermal efficiency are some of the proposed features of this efficient tandoor. The tandoor is under fabrication, testing and performance optimisation. It is reported to be available for INR 20,000-30,000 per unit based on the capacity and automatic pellet feeder option.

[13]Except plants whose tariff has already been determined under the Section 62 of Electricity Act.

4. RECOMMENDED ACTION PLAN FOR CLEAN INDUSTRY

Fugitive emissions (Dust, ash and VOCs) are generated from wide array of activities spatially distributed in the city as opposed to energy related emissions (PM, SOx and NOx) from specific discharge points, that is, exhausts or stacks. Therefore, two different sets of strategies are required for tackling these two broad categories of sources. Two sets of actions recommended for addressing these emissions at source are outlined below. A summary of recommended actions, along with the timelines and priorities, is presented in the Table 3.

4.1 Prevention and Control of Fugitive PM Emissions

Based on the discussions during task force meetings and review of best practices in India and internationally, a detailed guide on best practices and technologies for prevention and control of fugitive emissions (dust and ash) is prepared as part of this study. This guide is enclosed as Annex 5 along with the specific examples of prevention and control measures. These comprehensive measures are further summarised in the Box A5-1 (See Annex 5).

A comprehensive strategy is accordingly recommended to address particulate matter emissions from concerned subsectors. It encompasses prevention and control of fugitive emissions (dust and ash) across-

1. Construction activities at site (i.e. buildings and infrastructure projects)
2. Operation of various utilities (waste management, power, road/highways, water, electricity and gas) within NCR cities and towns
3. Allied construction industry (brick kilns, concrete batching plants, stone crusher etc.) predominantly located beyond Delhi NCT in the NCR region.

4.1.1 Promotion and Adoption of Clean Construction Practices

Organisational behaviour in NCR must shift in favour of cleaner construction practices. Civic agencies and construction industry need to proactively ensure implementation of appropriate measures for prevention and control of air pollution during construction and maintenance of infrastructure. A comprehensive strategy, involving multi-stakeholders is crucial in addressing these. Wide scale adoption of clean construction practices requires not only stringent enforcement, but also appropriate incentives or disincentives as recommended below.

a. Mandatory Contractual Obligations on Clean Construction for all Individuals/Organisations

Contractually binding obligations for clean construction need to be specified for individuals or organisations under the mechanism of 'building permits/approvals' by local bodies/authorities and 'environmental clearances' by Ministry of Environment Forest and Climate Change. To mitigate the impact of widely dispersed construction activities across the city, these contractually binding obligations need to apply to all scales of construction projects as listed in the Table A3-1 (See Annex 3). Comprehensive measures listed in the Box A5-1 are usually applied in combination to achieve desired control and it should be up to the individual/organisation to choose appropriate mitigation measures as per the site and local conditions.

It is advised that, under these obligations, project proponents of- (1) buildings with BUA >20,000 m^2 and (2) all urban infrastructure projects need to conduct feasibility for using following in their projects and accordingly source the materials.

1. Conduct technical feasibility of using sustainable building/construction materials. The guidelines set forth in 'Part 11: Approach to Sustainability' of the 'National building code of India' (BIS 2016) can be used as a reference for this.
2. Mandatory use of multi-utility service ducts/corridors, along with ITC enabled platform for inter-agency coordination, in all infrastructure, township and area development/redevelopment projects
3. Technical feasibility of using prefabricated or modular construction elements in the infrastructure projects.

b. Linking of Green Incentives to Clean Construction Practices

Currently there are multiple incentives which are conferred to projects which are provisionally rated to be green by buildings rating systems such as GRIHA, IGBC, LEEDS etc. (See Annex 4.). It is recommended that following incentives can be reconsidered by local bodies/authorities/ state and union government ministries for construction projects only when it is demonstrated through obligatory contracts requirements and project feasibility reports that projects will follow clean construction practices in order to achieve the mitigation of ambient air quality impacts during the construction and end-of-life phase. These incentives include-

I. 10-20% reduction on permit fees by urban local bodies
ii. Additional Floor Area Ratio (FAR) of 5-10% for building projects
iii. Fast track environmental clearance by MoEFCC
iv. 100 % exemption of building scrutiny fee for projects by local bodies/authorities
v. Financial assistance offered to MSME sector projects at concessional rates from Small Industries Development Bank of India
vi. Capital subsidies on total fixed capital investment of the project, if any

c. Mandatory Funds Allocation for Ambient Air Quality Management Under Corporate Environmentally Responsibilities (CER) in Cities not complying to Ambient Air Quality Standards

It is recommended that for cities/towns which are non-compliant to National Ambient Air Quality Standards (102 cities as per CPCB in 2018), CER funds are spent for air quality improvement in the airshed. Fund allocation can be made towards the following and can be expanded based on specific requirements of the city/town.

i. Infrastructure with local bodies for random checks (mobile monitoring devices or PEMS) in the air shed

ii. Real-time monitoring of air pollution hotspot in the airshed

iii. Piloting and demonstrating technologies for ambient air quality improvement

iv. Developing capacities and resource base of urban local bodies

Also, it is suggested that for a city figuring as non-compliant in any particular year, 40% of the CER funds may be diverted toward indicative activities as listed above, based on the local requirements. The proportionate funding for the consecutive years, if the city is able to meet the standards again, can be lowered by 10%.

d. Strengthened Building Code and Building Byelaws for Ambient Air Quality

Buildings in India are governed by National Building code (NBC) and Energy Conservation Buildings Code (ECBC) (See Annex 4). It is recommended that unified building code is adopted at national level for addressing various aspects of building and promoting adherence to code across all commercial and urban residential buildings. More importantly, the building code needs to be strengthened in order to address the environmental footprint of 'construction' and 'end-of-life' phase of buildings. Environmental footprint during construction phase (fugitive dust emissions and diesel emissions from DG sets and construction equipment) receive a relatively little focus in existing building codes and their primary focus is use-phase of the building (building energy, structural integrity, water conservation, indoor air quality). Although the use-phase contributes to majority of environmental footprint of the building over its life cycle due to significant energy consumption over building's life, construction and demolition (end-of-life stage) activities take major toll on ambient air quality of local environment. Proposed unified code needs to have separate provisions and guidelines for ambient air quality management. Construction and demolition/end-of-life phases of building need to be considered for minimising environmental footprint of building. These provisions can further be adapted by local bodies into building byelaws as per their specific conditions. These specific conditions may include the carrying capacity of the local environment, population densities in in receptor area and ambient air quality conditions of the airshed. Specific action points under this recommendation include-

i. Mandatory provisions under the National Building Code for ambient air quality management during construction and end-of-life phase of buildings in accordance with specific criteria for population density in receptor area and ambient air quality data.

Measures in the proposed building code need to percolate down to the level of Buildings Bye Laws so that they could be implemented by concerned Local body and authority in their area of jurisdiction.

ii. Mandatory provisions for ambient air quality management at construction sites in the Urban Building Byelaws of all NCR cities/towns

iii. Unification of building codes: In order to ease adherence to building code, it is recommended that unified codes are adopted by bringing together all concerns related to buildings such as building structure, fire safety, building energy, ambient and indoor air quality, water conservation etc.

As pointed out by task force members, local bodies need the required resources and equipment in order to stringently enforce the environmental compliance in NCR.

e. Developing Capacity of Urban Local Bodies for Monitoring and Enforcement

Capacity of urban local bodies in NCR towns need to be developed for ensuring clean construction in their respective jurisdiction areas. Environmental concerns for construction projects above 20,000 m^2 are now integrated with the building permits/approvals (Annex 3). Therefore, the onus of ensuring clean construction lies with the local bodies. As pointed out by task force members, local bodies need the required resources and equipment in order to stringently enforce the environmental compliance in NCR. State legislation should allow ULBs in NCR region to collect fees for making their operations feasible. It is suggested that local bodies can monitor local sources of air pollution by using affordable infrastructure, such as-

I. Mobile monitoring devices for random checks such as Portable Emission Measurement Systems (PEMS)

ii. Low cost sensors for monitoring key pollutants such as PM, SOx and Nox.

f. Strengthened Monitoring and Penalties for Individuals/Organisations

It is recommended that monitoring for air pollution is strengthened and individuals/organisations are penalised for not complying to Ambient Air Quality Standards. As below, two levels of monitoring and enforcement mechanism is recommended.

i. Tier-1 monitoring and enforcement at local level

Random checks need to be conducted by local bodies at local hotspots of air pollution such as construction hotspots, poorly maintained road stretches, landfills etc. Individuals/organisations/utilities who own/service the building and any other infrastructure in NCR cities and towns may be penalised 5-10% of the project cost for not being able to comply with the ambient air quality standard.

ii. Tier-2 monitoring and enforcement at state level

Real-time monitoring needs to be strengthened by concerned SPCBs assisted by EPCA and CPCB. It is recommended that competent authority (CPCB) notifies under the Air (Prevention and Control of Pollution) Act, 1981 that the civic agencies (local bodies, authorities, landowning agencies etc) may be penalised for non-compliance in their area. Such sources include-

- Construction/demolition of urban infrastructure/ buildings
- Maintenance of urban infrastructure
- Operations of public/private utilities

In addition to penalties for individuals/organisations as suggested earlier, civic or landowning agencies may be penalised based on the direct correlation of estimated health impact from air pollution and cost to society. The proposed notification under the Air (Prevention and Control of Pollution) Act, 1981 may suggest an appropriate mechanism for attributing social and environmental cost to these activities.

4.1.2 Sustainable Supply Chains for Construction Materials

Policies promoting circular economy, that is utilisation of waste streams (such as fly ash, C&D waste, road dust and surplus farm biomass) for sustainable buildings materials will be crucial for addressing air pollution in NCR. Several products from fly ash and C&D waste

including finished and semi-finished products, are summarised in Box A5-2 (See Annex. 5). Using these as construction material or feeding them back into city's materials flows eliminates or significantly lowers the life cycle emissions from construction activities. Procurement of sustainable construction materials is advised under the two categories, material manufactured using-

- Finished or semi-finished products from waste streams such as C&D waste, fly ash, recycled waste aggregates, or agricultural waste
- Clean manufacturing practices, e.g. bricks manufactured in zigzag-type kilns or aggregates from stone crushers with proper dust suppression equipment

a. Fiscal incentives for Sustainable Building Materials

As per the inputs from task force members, key barriers for adoption of sustainable building materials (despite clear economic and environmental benefit) arise from sourcing of virgin materials from illegal mining (such as aggregates, sand etc.) Therefore, fiscal or tax incentives are crucial to promote sustainable bulling materials. GST can provide a level playing field for sustainable building materials and favorable taxation is recommended for all sustainable building materials.

b. Sustainable Public Procurement

It is recommended that sustainable public procurement is made mandatory for all government tenders in Delhi NCR and targets are set for public agencies to fulfil stipulated part of their total requirement from recycled products and products with lower environmental footprint. City Development authorities in NCR such as Delhi Development Authority (DDA), Haryana Urban Development Authority (HUDA), Ghaziabad Development Authority (GDA), New Okhla Industrial Development Authority (NOIDA) etc. including public utilities such as DMRC, NHAI, CPWD, PWD (Delhi, Haryana, Rajasthan and Uttar Pradesh) etc. have been identified as key public agencies which govern most of the urban infrastructure development projects. Key enablers would be-

- Building capacity of Small-Medium Enterprises (SMEs) for remanufacturing and clean production technologies
- Sectoral guidelines and best practices for setting up and operating allied construction plants: Zigzag-type brick kilns, ready-mix concrete batching plants and stone crushers
- Promotion of existing rating systems for construction/building materials (e.g. GRIHA, IGBC and USGBC certified products/materials)

c. Sustainable Supply Chains for Construction Materials

Initiatives can be taken by all large construction industry/ infrastructure companies (to begin with) in NCR for sustainable supply chain procurement and disclosure as part of their corporate social and environmental responsibilities. Following independent reporting frameworks/platforms can be used by industry to report progress on sustainable supply chains and procurement-

i. Global Reporting Initiative (GRI)

ii. Sustainability Report

iii. U.N. Global Compact

iv. SDG reporting

v. Dow Jones Sustainability Index

Coal Thermal Power Plants with latest emission controls are most economical choice for enhanced biomass co-firing.

4.2 Mitigation of Energy-related Emissions

4.2.1 Prioritising Clean Fuels and Technologies

Efforts need to be made for Fuel Switch in diesel generators, brick kilns and thermal power plants. As recommended in the CII-NITI Aayog's Clean Fuel Report, prioritisation of clean power is required in NCR region and other dense urban areas suffering from severely degraded air quality. Gas-based capacities are under-utilised in NCR region. They can meet 50% of Delhi's power demand whereas they only cater to 20% of the demand presently (CII-NITI, 2018b). Nationally, gas-based generation suffers a huge economic loss and average plant load factor for gas-based generation is about 23% due to unviability of natural gas (CII-NITI, 2018b).

The dispatch of power from generation sources is governed by merit dispatch order principle, where generators of cheap power are prioritised over others, except renewable power plants[14] which are treated as must-run power plants. Prioritisation of clean power would require more comprehensive and conducive fiscal policies for clean power. CII-NITI Aayog Clean Fuel Report (2018) recommends priority dispatch of clean power requiring amendment to Indian Grid Electricity Code (2010) and other short-medium term actions (CII-NITI 2018b). Similarly, in the areas with availability of natural gas, use of fuel injection kits for existing DG sets, gas-based generators, and other clean fuel-based equipment need to be mandated by the competent authority.

Thermal power plants are main source of SOx emissions in the NCR region. Coal power units, in NCR and beyond, need to comply with the latest environment norms by 2019 and 2022 respectively. Environmental standards are key instrument for cleaning thermal power and certain control technologies have been prescribed to power generators in order to meet these standards.

Coal TPPs with latest emission controls are the most economical choice for enhanced biomass co-firing. Power industry can make a leapfrog from 5-10% utilisation of biomass (Refer Section 3.2.2) to higher co-firing (See Annex 9: Business case: leapfrogging to 50% biomass co-firing in existing thermal power plants). As

[14]excluding biomass power and cogeneration plants

mapped in Figure 9, biomass potential from surplus biomass in Punjab, Haryana and Western U.P. can fulfil the demand for 50% biomass co-firing in thermal power units within 300 km of Delhi. New conversion technologies need to be utilised for enhancing co-firing in existing TPPs. As detailed out in Annex 9, multiple benefits of using enhanced soil biofuel from biomass include-

1. Enhanced fuel characteristics (energy density or caloric value) similar to coal
2. Low-sulphur biomass as feedstock implies reduction in SOx emissions and operational cost of SOx control
3. Better handling and storage characteristics compared to conventional pellets or straw bales
4. Avoided cost of coal transportation from pitheads or ports

Due to significantly lower sulphur content in biomass compared to coal, biomass as a feedstock is also an opportunity to cost-effectively reduce SOx emissions from coal-based thermal power plants (See Box A9-1, Annex 9). It is a carbon neutral energy resource for greening the coal power. Advanced biomass co-firing in existing thermal power plants would require clear policy signals and dedicated policy support to power generators from Ministry of Power, Government of India.

Source: CII-CESD (2018) analysis based on MNRE-IISc (2004); MoA (2014) and Kumar et al (2015)

> Task force recommends that power dispatch from thermal power plants is prioritised based on the cleanliness of power so that those using clean technologies are incentivised over the rest.

a. Priority Status to Clean Generation

As discussed, the dispatch of power from generation sources is governed by merit order dispatch principle, where generators of cheap power are prioritised over the rest, except renewable power plants which are treated as must-run power plants. Task force recommends that power dispatch from thermal power plants is prioritised based on the cleanliness of power so that those using clean technologies are incentivised over the rest. Accordingly, it is recommended that priority for clean power is provided in the merit dispatch for-

- Gas-based thermal power generation units
- Coal-based thermal power generation units which use advanced emission control technology for meeting emission levels of PM, SOx and NOx as prescribed in the latest emission norms

Prioritising clean power will entail following short-term and long-term actions-

i. Notification to Northern Region Load Dispatch Centre (NRLDC) to provide priority to clean power in merit dispatch order. (Short-term)

ii. Amendment to the Indian Grid Electricity Code (2010) giving priority to cleaner sources of power generation (Long-term)

Additionally, the cleaner power producers are to be allocated with the quantity of coal that can ensure the plant to operate at full load. This is important, because, even if a plant is high on merit order, without coal, it won't be able to operate, defeating the purpose. Specific interventions needed for this purpose are-

iii. Inter-ministerial Sub Group constituted by the Infrastructure Constraints Review Committee, headed by Joint Secretary (Coal), to release a guideline to Rail and Coal India to prioritise the allocation and transportation of coal to the cleaner power producers based on priority dispatch order requirement.

iv. Central Electricity Authority (CEA) may release an advisory to Railways and Coal India for prioritising the coal supply to the cleaner power producing TPPs to meet the priority dispatch order requirement.

v. Scheme for Harnessing and Allocating Koyala (Coal) Transparently in India (SHAKTI); can be amended to incorporate the prioritisation of coal allocation to the greener power producers to meet the priority dispatch order requirement.

b. Incentives for Co-firing Biomass in Existing Coal Power Units:

Power generators need to be incentivised for burning low-sulphur biomass which is also a renewable source of energy. Incentives may include- renewable energy certificates (RECs), tax benefits and priority dispatch based on the proportionate power generated from co-firing biomass. Existing policy from Ministry of Power recommends co-firing up to 5-10% biomass in existing coal thermal power units. Key Enablers for this would be the guidance document for biomass co-firing in existing coal-based power plants which is awaited from Central Electricity Authority (CEA) as per the existing policy of Ministry of Power.

c. Leapfrogging to Advanced Biomass Co-firing in Coal Power Plants in North West Region:

Leapfrogging to advanced biomass co-firing (more than 10% biomass) requires a long-term and comprehensive policy for promotion of biomass co-firing in thermal power plants. Commercial feasibility of enhanced co-firing is still being evaluated at this stage. However, in long term, this could potentially unlock a cost-effective strategy for greening the coal power and simultaneous reduction of emissions from stubble burning in North West region.

Department of Science and Technology (DST) is currently piloting torrefaction of rice-straw in Punjab in partnership with a Swedish agency. Torrefied biomass, once piloted and proved in existing coal power stations in region, can pave way for large scale utilisation of Biomass (up to 50% without significant cost to retrofit technology).

d. Fuel Switch for Diesel Generators and Hotels/Restaurants industry:

Diesel engines are utilised in hospitality, healthcare, real estate, IT and telecom sectors. As discussed in the Clean Fuel Report, fuel injection kits or gas-powered generator are commercially feasible option in places with availability of gas, a clean fuel (CII-NITI 2018b). Central Pollution Control Board or Concerned State Pollution Control Board may issue a directive mandating the use of gas kit at all such locations. Similar to suggestion for DG use, gas or electricity-based tandoors may be mandated at locations where electricity and Piped Natural Gas (PNG) infrastructure is available. Availability of natural gas and physical infrastructure, benchmarking of available clean fuel options (gas, electricity, solid-biofuels for tandoors) and clean fuel pricing and taxation strategy are key enablers for adoption of clean fuel options in these sectors.

4.2.2 Adoption of Best Available Technology for Emission Control

Available abatement technologies or end-of-pipe solutions need to be promoted across industry subsectors. It is found that commercially proven options are available for addressing emissions from DG sets (See Annex 6 and Annex 7), but they are not being utilised due to absence of in-use emission standards for > 1000 kVA DGs, lack of proper inspection and monitoring system for DG sets and lack of capacity with the regulatory agencies for implementing DG set in-use emission standards.

Available options need to be promoted equally by public and private agencies through a combination of appropriate policies, voluntary commitments, environmental regulation, and emission standards. Diesel generators, a major component of non-road engines, is an identified source of health-related ultrafine PM fractions and NOx emissions. Retrofit solutions for existing DG sets can only thrive in presence of strictly enforced in-use environmental standards for all DG sets.

Apart from comprehensive coverage of emission norms for all DG sets, guidelines and minimum requirements (e.g. technical life) for the end-of-pipe retrofit products need to be formulated by the regulator. Due to inherent technological challenges as discussed in Annex 6, it needs to be ensured that retrofit devices perform up to certain level for a minimum number of years (as prescribed by regulator). Innovative retrofit technologies can only thrive in presence of strict in-use emission standards for DG sets and recommended actions include- (1) Notification of appropriate environmental standards and guidelines covering all DG sets and retrofit products; (2) Certification of all retrofit devices by CPCB recognised laboratories in line with the independent type approvals and conformity of production requirements for NG and LNG kits (See Annex 6). As highlighted earlier, India needs to adopt stringent emission norms for DG sets by considering global benchmarks to derive long term benefits from imminent transition. Adoption of suggested actions can pave way for the most advanced regulations in the country.

a. Strict In-use Emission Norms for all Diesel Generators

To ensure uptake of best available technology for emission control in DG sets, regulation should also include specification of minimum requirements for DG retrofit device e.g. control efficiency and life of device. Key enablers for this action are certification of available retrofit options in the market by CPCB certified laboratories; and benchmarking studies for control efficiency, life and cost.

b. Extend and Adopt a Strengthened Pollution-Under-Control System to Non-Road Diesel Engines

Monitoring of in-use emissions from DG sets can be initiated in line with the recommendations of Task force for Clean Transportation. It recommends a strengthened real-time Pollution-under-control (PUC) regime involving innovative and cost-effective monitoring/compliance measures such as random checks using portable emission measurement system (PEMS), standardised software, crowdsourcing of compliance (citizen helpline for reporting visibly polluting diesel equipment). Cost effective strategies for monitoring existing DG sets include-

- Random checks for DGs and other non-road diesel engines by using PEMS
- Citizen helpline to report visibly polluting DG sets or other non-road equipment

Table 3. Summary of Actions Recommended by the Task Force on Clean Industry

Action Area	Recommended actions	Priority	Timeline	Implementation	Supplementary Notes
Promotion and Adoption of Clean Construction Practices	Mandatory contractual obligations on clean construction for all individuals or organisations Additional mandatory conditions to (1) buildings with BUA >20,000 m^2 and (2) all urban infrastructure projects for- • Technical feasibility for sourcing smart and sustainable materials/infrastructure • Mandatory use of multi-utility service ducts/corridors, along with ICT enabled platform for inter-agency coordination • Technical feasibility of using prefabricated or modular construction elements	High	Immediate	Urban local bodies & Ministry of Environment Forest and Climate Change	1. Refer to Annex 5 for guidelines on comprehensive measures and Table A5-1 (Annex 5) for overview of these. 2. Refer to Part 11: National building code (BIS 2016) and guidelines in Annex 5 for sourcing sustainable materials.
	Linking of green incentives to Clean Construction Practices: incentives conferred to projects which are provisionally rated as green by building rating systems such as GRIHA, LEEDS, IGBC etc)	Low	Immediate	Urban local bodies, Development authorities & State Governments in NCR; Ministry of Environment Forest and Climate Change	List of incentives provided in Section 4.1.1 (b).
	Mandatory funds allocation for ambient air quality management under CER in cities not complying to Ambient Air Quality Standards	High	Long term	Ministry of Environment Forest and Climate Change	Indicative set of activities and suggested allocation in Section 4.1.1 (C).

Action Area	Recommended actions	Priority	Timeline	Implementation	Supplementary Notes
	Strengthened Building Code and Building Byelaws for addressing ambient air quality during 'construction & end-of-life' phase of projects- I. Mandatory provisions under the National Building Code for ambient air quality management during construction and end-of-life phase of buildings/infrastructure in accordance with specific criteria for population density in receptor area and ambient air quality data. ii. Mandatory provisions for ambient air quality management during construction and end-of-life phase of buildings/ infrastructure in the 'Unified Building Byelaws' for NCT Delhi and building byelaws of other NCR cities/towns iii. Unification of building codes (NBC and ECBC)	High	I. Immediate ii. Immediate iii. Long term	I. Bureau of Indian Standards, Ministry of Consumer Affairs, Food and Public Distribution ii. Development authorities & ULBs in NCR iii. Bureau of Indian Standards, Ministry of Consumer Affairs, Food and Public Distribution; Bureau of Energy Efficiency, Ministry of Power	Refer to Annex 4 for review of building codes.
	Developing capacity of urban local bodies for monitoring and enforcement: Monitoring local sources using portable emission monitoring devices and low-cost sensors	High	Long term	Ministry of Housing and Urban Affairs; Ministry of Environment Forest and Climate Change	List of incentives provided in Section 4.1.1 (b).
	Strengthened Monitoring and Penalties for Individuals/Organisations- I. Penalties by ULBs worth 5-10% of the project cost to individuals/organisations ii. Penalties by SPCBs in NCR to local bodies/authorities in lieu of the estimated cost of damage	High	Immediate	Central Pollution Control Board; State Pollution Control Boards and Urban local bodies in NCR	Refer Section 4.1.1 (f) for more details.

Action Area	Recommended actions	Priority	Timeline	Implementation	Supplementary Notes
Sustainable Supply Chains for Construction Materials	Fiscal incentives for Sustainable Building Materials	High	Immediate	GST Council, Ministry of Finance	Refer to Box A5-2 under Annex 5 for different waste streams which can be utilised for sustainable building/ construction materials
	Mandatory sustainable public procurement for construction/building materials in all government projects/tenders in NCR	High	Immediate	Ministry of Housing and Urban Affairs and public agencies such as DMRC, NHAI & CPWD; State Governments in NCR and its agencies; local bodies/developm-ent authorities in NCR	Refer to Part 11: National building code (BIS 2016) and guidelines in Annex 5 for sourcing sustainable materials.
	Sustainable supply chains for building materials: third-party verification or independent reporting frameworks/ platforms to be used by large construction/infrastructure companies in NCR to report progress on sustainable supply chains and procurement	High	Immediate	Large construction and infrastructure companies in NCR	List of reporting frameworks/platforms is available in the section 4.1.2 (c).
Prioritising Clean Fuels and Technologies	Priority status to cleaner generation- (1) Gas-based thermal power units & (2) coal-based thermal power units with advanced emission controls for SOx, NOx and PM, in order to incentivise/disincentivise clean power:	High	Immediate	Ministry of Power; Central Electricity Regulatory Commission; and Ministry of Coal	

Action Area	Recommended actions	Priority	Timeline	Implementation	Supplementary Notes
	i. Notification to Northern Region Load Dispatch Centre (NRLDC) to provide priority to clean power in merit dispatch order. (Short-term) ii. Amendment to the Indian Grid Electricity Code (2010) giving priority to cleaner sources of power generation (Long-term) iii. Inter-ministerial Sub Group constituted by the Infrastructure Constraints Review Committee, headed by Joint Secretary (Coal), to release a guideline to Rail and Coal India to prioritise the allocation and transportation of coal to the cleaner power producers based on priority dispatch order requirement (immediate) iv. Central Electricity Authority (CEA) may release an advisory to Railways and Coal India for prioritising the coal supply to the cleaner power producing TPPs to meet the priority dispatch order requirement (immediate) v. Scheme for Harnessing and Allocating Koyala **(Coal)** Transparently in India **(SHAKTI)**; can be amended to incorporate the prioritisation of coal allocation to the greener power producers to meet the priority dispatch order requirement (immediate)				
	Incentives for biomass co-firing in existing coal power units	High	Immediate	Ministry of Power; Central Electricity Regulatory Commission & State Electricity Regulatory Commissions in North Western States	Refer to Section 3.2.2 for existing policy from Ministry of Power

Action Area	Recommended actions	Priority	Timeline	Implementation	Supplementary Notes
	Leapfrogging to advanced (up to 50%) biomass co-firing in coal power plants in North West region	High	Long-term	Ministry of Power	Refer to Annex 9 for business case on leapfrogging to 50% Biomass Co-firing in Existing Thermal Power Plants
	Fuel switch in diesel generators, hotels & restaurants	High	Immediate	Central Pollution Control Board; State Pollution Control Boards and Urban local bodies in NCR	Refer to Section 3.2.1 and Annex 6 on existing regulation and control options for DG sets
Adoption of Best Available technology and Emission Standards	Strict in-use emission norms for all diesel generators along with minimum performance requirements (for instance life and efficiency) for retrofit devices	High	Immediate	Central Pollution Control Board	Refer to Section 3.2.1 and Annex 6 on existing regulation and control options for DG sets
	Adoption of a strengthened Pollution-under-control system to non-road diesel engines	High	Medium-term	Central Pollution Control Board; State Pollution Control Boards and Urban local bodies in NCR	Refer to Section 3.2.1 and Annex 6 on existing regulation and control options for DG sets

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ANNEXURE 1

Emission Inventory for Delhi

	Emissions [tonne/ day]				
Sources	PM10	PM2.5	NOx	SO2	CO
Industrial Stack	13.7	6.6	161.8	128.8	11.6
Vehicle	12.9	11.6	113.4	1.2	322.4
Road Dust	79.6	22.2	0.0	0.0	0.0
Hotels/Restaurants	3.5	1.8	1.1	2.7	6.2
Domestic	7.4	6.9	7.7	1.2	25.4
Aircraft	0.1	0.1	5.4	0.4	4.1
Industries Area	1.6	1.4	1.9	5.6	0.2
DG Set	1.4	1.2	19.6	1.3	4.2
MSW Burning	2.0	1.8	0.7	0.1	10.3
Cremation	0.3	0.3	0.1	0.0	2.1
Construction/Demolition	5.2	1.3	0.0	0.0	0.0
Concrete Batching	14.4	3.6	0.0	0.0	0.0
Agricultural Soil Dust	1.4	0.0	0.0	0.0	0.0
Medical Incinerators	0.0	0.0	0.1	0.3	0.0

Source: Sharma and Dikshit (2016)

ANNEXURE 2

Dust Control Regulation for Construction

Construction activities happening rampantly and in an unregulated manner are main causes of concern in Delhi NCR (NGT, 2015). The National Green Tribunal (NGT) issued guidelines for dust control in Delhi NCR in the years 2014 and 2015 covering construction activities and road/soil dust. In January 2018, the Ministry of Environment Forest and Climate Change (MoEFCC) issued the Environment (Protection) Amendment Rules, 2018 which apply to cities and towns where level of PM10/PM2.5 exceeds the limits prescribed in the National Ambient Air Quality Standards. Overview of these directions, along with guidelines by Central Pollution Control Board (CPCB) in December 2017, is enclosed in subsequent boxes (Box A2-1, Box A2-2, Box A2-3). It is worth noting that multiple violations have been reported by public and private agencies alike in NCR such as Delhi Development Authority (DDA), Delhi Jal Board (DJB), Delhi Metro Rail Corporation (DMRC), National Highway Authority of India (NHAI), NBCC, Public works Department (PWD), Central Public Works Department (CPWD), and Tata Power Delhi Distribution Limited (TPDDL) (NGT 2016; GNCTD 2016; GoI 2018). There is an urgent need for organisational behaviour changes across public and private organisations working in NCR.

Box A2-1 National Green Tribunal Directions in 2014 and 2015

Construction	1.	It is the responsibility of every builder, contractor or owner (NGT, 2014) to cover the construction materials and install wind breakers on all sides of plot or area so dust does not get dispersed during the construction activity or storage of materials.
	2.	Use of wet-jet in grinding/cutting operation is compulsory as per NGT guidelines (NGT, 2015)
	3.	Storage of construction material on the roads or streets is prohibited (NGT, 2015).
	4.	Every builder and owner is mandated to use tarpaulin on the scaffolding around the building or area of construction (NGT, 2015)
	5.	During the transportation of construction material, proper coverage precautions are required. The vehicles or trucks carrying the construction materials like cement, sand and allied materials are required by NGT to be fully covered.
	6.	After the unloading operation, the vehicles need to be properly cleaned before they are permitted to ply on the road
	7.	Vehicles not complying to these directions are not permitted to enter NCR Delhi (NGT, 2014)
	8.	NGT demands strict vigilance of the stone crushers by all concerned State Pollution Control Boards (SPCBs) and Environment Departments of State
	9.	All builders, building commercial or residential complexes, covered under the EIA notification 2006, are mandated to provide green belt cover around the constructed buildings. Compliance is to be ensured by respective authorities before issuing the occupancy certificate.

Road/soil dust	1. Executive engineer of each PWD in NCR is personally responsible for compliance of NGT guidelines for construction and demolition activities which equally applies to construction of roads and highways and is required to report to chief engineer every week. 2. The city corporations/ councils (MCDs, NMDC, DCB, MCG etc.) and development authorities (DDA, HUDA, NOIDA, Greater Noida Authority etc.) including the state departments are expected to make efforts of increasing the tree-cover in NCR by planting the right kind of plants/trees species depending on the soil quality and other natural settings. 3. During the maintenance of roads, it is required from DDA, PWDs and other concerned agencies that coal-tar, bitumen or asphalt mix is brought in molten condition without the fire to melt these materials on the open road. 4. All the concerned utilities or service providers are required to formulate comprehensive waste management plans for C&D waste generated within their jurisdiction. Plan should cover segregation, storage, collection, reuse, recycling, transportation, and disposal of this waste.

Source: Adapted from NGT (2014; 2015)

Box A2-2. Environment (Protection) Amendment Rules (2018) for Dust Mitigation in Construction and Demolition Activities

Mandatory Implementation of Dust Mitigation in projects requiring Environmental Clearance	Mandatory Implementation of Dust Mitigation Measures for all Construction and Demolition Activities
1. No building or infrastructure project requiring Environmental Clearance shall be implemented without approved Environmental Management Plan inclusive of dust mitigation measures. 2. Roads leading to or at construction sites must be paved and blacktopped (i.e. metallic roads). 3. No excavation of soil shall be carried out without adequate dust mitigation measures in place. 4. No loose soil or sand or Construction & Demolition Waste or any other construction material that causes dust shall be left uncovered. 5. Wind-breaker of appropriate height i.e. one third of the building height and maximum up to 10 meters shall be provided. 6. Water sprinkling system shall be put in place. 7. Dust mitigation measures shall be displayed prominently at the construction site for easy public viewing.	1. Grinding and cutting of building materials in open area shall be prohibited. 2. Construction material and waste should be stored only within earmarked area and road side storage of construction material and waste shall be prohibited. 3. No uncovered vehicles carrying construction material and waste shall be permitted. 4. Construction and Demolition Waste processing and disposal site shall be identified and required dust mitigation measures be notified at the site.

Source: Adapted from MoEFCC (2018)

Box A2-3. Central Pollution Control Board Guidelines for Dust Control (2017)

Transportation of construction, and C&D waste materials	1. Transportation routes to be identified for avoiding sensitive receptors 2. Proper covering of materials 3. No overloading of vehicles to avoid overflow of materials 4. Transportation to be generally during night, transport permit to include details on material type, quantity and transfer points 5. Location of all temporary/intermediate C&D storage sites to be placed in public domain 6. Dampening of dust by water spray or wind breakers at all temporary/intermediate C&D storage sites 7. All construction material loading/ unloading activities at on-site or off site to ensure dust suppression using location, water spraying and proper cover 8. Road surfaces to be maintained well to avoid spillage from transport vehicles 9. Regular sweeping of roads to avoid resuspension of dust on roads
Storage of construction and C&D waste materials	1. Off-site: Prohibition from storing/ dumping material on metalled roads 2. On-site: a. location of sites should be such that dispersal of dust is minimum during handling b. Contractor/ builder to synchronise availability of material with its utilisation so that storage period is minimum c. Site of demolition to be cordoned off and adequate measures to prevent dust beyond site limits d. Reducing dust particles in air by storing the fine materials such as sand, gravel and cement in demarcated area with cover (cement bags in enclosed areas, loose cement to be stored in silos)
Dust control measures at site- Construction/ demolition/ renovation	1. Raise barricade along the perimeter depending on the nature of adjoining area (alternate to wet suppression) 2. Mount dust barrier sheet on scaffolding around the construction/ construction building- particularly side facing residential building 3. Selective mechanisation of handling material/ waste helps in better management and reduction of dust generation at site

Additional measures mentioned in CPCB guidelines	1.	Operations of equipment / machineries include transporting (conveyor belt) crushing / hammering etc. deployed at site generate dust - these areas need to be bounded (enclosed) and use of water sprinklers to suppress dust emissions
	2.	DG sets to be well maintained to ensure low emissions
	3.	The transport vehicles engaged be well maintained (PUC compliance)
	4.	Routes of transport vehicles within construction site be damped by water (preferably treated waste water) sprinklers
	5.	Dry sweeping of work areas to be prohibited
	6.	For construction activities, simultaneous development of green buffer would assist in arresting dispersal of dust (preferably shrubs & trees that have low uptake of water)
	7.	All builders / contractors engaged in construction & demolition activities to submit an undertaking to the concerned government department on measures adopted to control dust
	8.	Sale of construction material from road sides to be prohibited
	9.	Dumping (unloading) and storage of construction material for use in ongoing projects on public road sides is prohibited
	10.	Construction projects to be encouraged to utilize products manufactured from C&D waste processing– this step improves organised collection of C&D wastes, stops indiscriminate dumping of C&D wastes thereby reducing dust load escaping into the atmosphere during dry weather
	11.	Inclusion of condition(s) by concerned agencies for adoption of dust mitigation measures in approvals / permits / consent provisions / environmental clearances for construction projects

Source: Adapted from CPCB (2017)

ANNEXURE 3

Building Permits and Environmental Clearance

Besides existing regulation discussed above, provisions in buildings byelaws and codes check environmental pollution over the course of construction. A risk-based classification is used by Delhi Development Authority (DDA) for approval of building plans in Delhi. Different types of approvals and environmental clearances for building projects are summarised in Table A3-1. Model building Bye-Laws by the Ministry of Housing and Urban Affairs (MoUD 2016) stipulate specific conditions to be met for environmental safeguard before and during the course of building construction. These conditions now apply to building projects with total built up area (BUA) between 5,000-50,000 square metre which do not require separate environmental clearances from Expert Appraisal Committee (EAC) of the Ministry of Environment (MoEFCC) or the State Expert Appraisal Committees (SEACs). MoEFCC has integrated the environmental concerns into building plan approval process, empowering the concerned local body or development authority to approve and certify compliance of stipulated requirements (MoUD 2016, DDA 2016). Depending on the size of project, specific conditions require project proponents plan mitigation measures. As per the Unified Building Byelaws notified by DDA on March 2016 and subsequent notification by MoEFCC in 2018, project proponents under all categories of building projects need to meet stipulated environmental conditions (DDA 2016; MoEFCC 2018b). As per the latest notification, these environmental conditions for all building categories with BUA above 20,000 m^2 include-

1. Roads leading to or at construction sites must be paved and blacktopped (i.e. metallic roads). No uncovered vehicles carrying construction material and waste shall be permitted.
2. No excavation of soil shall be carried out without adequate dust mitigation measures in place. Water sprinkling system shall be put in place. Unpaved surfaces and loose soil shall be adequately sprinkled with water to suppress dust.
3. No loose soil or sand or Construction & Demolition Waste or any other construction material that causes dust shall be left uncovered. Construction material and waste should be stored only within earmarked area and road side storage of construction material and waste shall be prohibited.
4. Wind-breaker of appropriate height i.e. 1/3rd of the building height and maximum up to 10 meters shall be provided.
5. C&D waste processing and disposal site shall be identified and required dust mitigation measures be notified at the site.
6. Grinding and cutting of building materials in open area shall be prohibited. Wet jet shall be provided for grinding and stone cutting.
7. Dust, smoke and other air pollution prevention measures shall be provided for the building as well as the site.
8. Dust mitigation measures shall be displayed prominently at the construction site for easy public viewing.
9. Exhaust pipe of the DG set, if installed, must be, at least 10 metres away from the building, or else an exhaust pipe must be provided at least 3 metres above the building.
10. A minimum of one tree for every 80 sqm of land to be planted and maintained, with preference to native species. Wherever the existing trees need to be cut, compensatory plantation in the ratio of 1:3 (i.e. planting of three trees for every one tree that is cut) to be done with the obligation to provide continued maintenance for such plantations.

Additionally, use of fly ash bricks as per the latest Fly ash notification by MoEFCC is mandatory for all construction projects with BAU >20,000 m^2 (DDA 2016). According to latest amendment by MoEFCC, all construction agencies within a radius of 300 km from thermal power plants (TPPs) need to utilise fly ash products (MoEFCC 2016b). In addition, the state authorities have been asked by MoEFCC to amend the building byelaws of the cities (with population ≥1 million) to ensure mandatory use of fly ash-based bricks. Further, the use of fly ash in infrastructure projects is emphasised in the latest notification. Concerned authorities are advised to link the payment to contractor with certification of supply of fly ash or fly ash based products. Cost of fly ash transportation to the user is to be borne by TPPs within a distance of 100 km and shared equally between them for transportation between 100 km to 300 km.

All construction projects with BAU > 20,000 m^2 also need to prepare and implement an Environment Management Plan (EMP) for addressing environmental concerns (DDA 2016). EMP ensures that mitigation measures specified in EIA (or stipulated as environmental conditions to be met for buildings permission by local authority), are actually complied with during implementation of projects. It covers the mitigation measures and monitoring undertaken by project proponent at the site and nearby receptors. EMP applies to all environment infrastructure which is kept operational through administration of Environment Monitoring Committee with defined functions and responsibility.

Table A3-1. Overview of the Building Approvals and Environmental Clearance

Type of approval	Building categories	Built up area (BAU)	Approval Process
Risk-based fast track procedure for building approvals by local bodies/ authorities	Very-low risk residential buildings	≤ 105 m^2 height < 15 m	• Owner gives an undertaking for intimation of construction start & completion to the concerned authority or local body along with building permit fee[1] • Approval in accordance with the 'General Building Requirements' of building byelaws and 'Development Control Regulation' by the development authority
	Low risk residential buildings	105-500 m^2 height < 15 m	• Qualified engineer/architect provides building permit upon submitting permit fees to local body or owner can apply for sanction from local body • Permit from local body is provided within 10 days
	Moderate risk residential buildings	> 500 m^2 height < 15 m	• Qualified engineer/architect to submit building plans for approval from local body along with requisite documents and fees • Permit from local body is provided within 20 days.
	High risk residential buildings	≥ 3000 m^2 height > 15 m	• Mandatory clearance from Delhi Fire Service • Qualified engineer/architect submits building plans for approval from local body along with requisite documents and fees • Permit from local body is provided within 30 days
Building projects not requiring Environmental clearances	Category 'A' building projects	5,000-20,000 m^2	• Local bodies to ensure compliance of the stipulated conditions to address environmental concerns
	Category 'B' building projects	20,000-50,000 m^2	
	Category 'C' building projects	50,000-1,50,000 m^2	• Local bodies to ensure compliance of the stipulated conditions to address environmental concerns • Mandatory Environment Management Plan (EMP)
Building projects requiring Environmental clearances	Townships & area development projects	> 1,50,000 m^2	• Mandatory conditions for environmental safeguard • Mandatory Environment Impact Assessment (EIA) & Environment Management Plan (EMP) • Development of green belt around the site

Source: DDA (2016), MoEFCC (2018b)

[1]Buildings permit fee levied in Delhi NCT varies from Rs.1500-5000 per m^2 depending on localities.

All major infrastructure and building projects with built up area more than 1,50,000 square metre require Environmental Impact Assessment (EIA) for environmental clearance and approvals. EIA addresses the impact of project on the environment by drawing up an Environmental Management Plan (EMP) and integrating it with the any measures proposed by the government (See Annex 2 and Annex 3). From May 2018 onward, project proponents are also required to submit a plan for Corporate Environment Responsibility (CER) along with the EIA report as specified by the MoEFCC in May 2018. CER is only required in greenfield or brownfield projects where the pollution load is expected to increase. Cost of CER is in addition to the cost of control measures envisaged under EIA/EMP. The actual fund allocation under CER will be decided in the EAC, SEAC or District-level Expert Appraisal Committee (DEAC). The maximum percentage of CER, as prescribed by MoEFCC is 0.25%-2% for greenfield projects and 0.125%-1% for brownfield projects depending on the capital investment (MoEFCC 2018a). EAC based on appraisal, can suggest the activities to be carried out under CER, restricted to the affected area around the project.

It is mandatory for project proponents to submit half-yearly compliance reports with respect to the stipulated terms and conditions of the environmental clearance granted to them. Specific motoring reports may also be required from the project proponents as part of any specific environmental conditions mentioned in the EC letter. These reports are public documents and the latest compliance/monitoring reports are uploaded at MoEFCC website.

ANNEXURE 4

Buildings Codes and Green Buildings' Rating Systems

There are two different building codes which govern the residential and commercial buildings in India-

1. National Building Code (NBC) of India by Bureau of Indian Standards (BIS) under the Ministry of Consumer Affairs, Government of India
2. Energy Conservation Building Code (ECBC) by Bureau of Energy Efficiency (BEE), a statutory body under the Ministry of Power, Government of India.

The National Building Code (NBC) is a model code for adoption by all agencies involved in building construction. The focus of NBC is primarily the structural integrity, material sustainability, fire safety, facility/asset management and building services. Energy Conservation Building Code (ECBC) is a building energy code. It deals primarily with the energy efficiency of the building envelope and building energy services such as lighting, thermal comfort and water heating. Literature review of NBC indicates that there are two ways in which ambient air quality concerns are addressed under the NBC and these are briefly described below.

1. Sourcing of buildings materials with low embodied energies
2. Construction practices and environmental management

National Building Code of India (2016) notes that construction in busy localities of cities need special considerations and meticulous planning due to restricted space, adjoining structures, underground utilities, traffic restrictions, noise and environmental pollution and other specific site constraints (BIS 2016).

To address the environmental footprint of construction, considering the whole lifecycle of building materials is crucial. Lifecycle also encompasses the extraction of virgin materials, allied construction activities for manufacturing of building materials and transportation of materials to the site which contribute to total embodied energy of building material. NBC recommends minimising environmental footprint of building construction by considering construction materials with low embodied energies. Embodied energy of recycled materials from C&D waste, fly ash and agricultural waste are typically in the range of 1-5 GJ/ tonne compared to high embodied energy (5-50 GJ/ tonne) for cement, steel, glass etc (BIS 2016). In addition to environmental footprint during the construction phase, there are other frequently used building materials like reconstituted wood products, paints, glues, paints, carpets and upholstery, which may release gases/fumes commonly classified as volatile organic compounds (VOCs) from the chemical composition used, even long after installation (BIS 2016).

NBC (2016) also stresses the role of contractual obligations towards sustainable construction. It notes that use of materials and technologies deployed at site may impact the environment, especially the ambient air quality. Such scenarios include (BIS 2016)-

- Use of inefficient construction equipment/ technologies
- Suboptimal use of equipment/technologies and suboptimal transportation of materials
- Processing of materials such as cutting, mixing, and fabrication.

As per the building code, such materials and technologies need to be identified and procedures need to be planned accordingly to mitigate their impact (BIS 2016). Contracts determine obligations of individuals and organisations. Therefore, contracts shall make it obligatory on the part of suppliers of materials and equipment/services to follow sustainable processes and practices. Contractually binding obligations ensure system-wide responsibilities so that necessary mitigation resources may be budgeted within the project scope (BIS 2016). Responsibilities for sustainability practices during construction may be clearly assigned, explicitly assigning liabilities (including contingencies for risks known as well as management reserves towards unknown risks) that may accrue on account of lapses (BIS 2016).

Building code also specifies the requirement for ambient air quality monitoring depending on the project size, location and type of activities. SPM, SO2, NOx and CO need to be monitored twice a week at representative locations at site and study area adopting a schedule of 24 hours. The monitoring locations need to be considered on the basis of predominant wind directions, land use patterns and height of proposed stacks. At least one monitoring locations needs to be at maximum pollution deposition area due to proposed deposition of stacks of generators. The number of air quality monitoring locations should be at least five including at least one at project site (BIS 2016).

In addition to buildings codes, there are independent building rating systems which are voluntarily adopted by owner or developers. These rating systems assess how green the buildings are and have their own set of requirements for doing so. Prevalent rating systems in India include-

1 Green Rating for Integrated Habitat Assessment (GRIHA)

2 Indian Green Building Council (IGBC)

3 Leadership in Energy and Environmental Design (LEED)

These rating systems focus on various aspects of building systems, mainly-

1. Energy efficiency of building envelope and associated energy services
2. Sustainability of building architecture and design
3. Sustainability of building materials and resource efficiency
4. Quality of indoor environment
5. Water efficiency and conservation

A comparison of different rating systems and their focus on management of ambient air quality is provided in the Table A4-1. Although use of sustainable building materials is covered well under all rating systems, footprint of construction activities on the ambient air quality is not emphasised enough. It is observed that the focus of existing rating systems is dominantly the post-construction use or operational phase of the building system.

Table A4-1. A Comparison of Focus on Ambient Air Quality Management During Construction Across Different Building Rating Systems in India

Building Rating Systems	Specific Criteria Linked to Ambient Air Quality Improvement	Remarks
GRIHA (Maximum 104 points)	1. Reduce air pollution during construction as per GRIHA clauses **(Mandatory- 2 points)** 2. Proper stabilization of soil & topsoil laying for vegetative growth **(Mandatory- 1 point; Optional- 4 points)** 3. Preserve and protect landscape during construction **(Mandatory- 1 point)** 4. Consolidation of utility corridors **(Optional- 1 point)** 5. Utilization of fly ash in building structure **(Optional- 6 points)** 6. Reduce volume, weight, and construction time by adopting efficient technologies such as pre-cast **(Optional- 4 points)** 7. Reduction in waste during construction **(Optional- 1 point)**	• GRIHA requires provision in the contract document that the contractor will undertake the responsibility to prevent air pollution • It also requires a narrative explaining the air pollution preventive measures (site photographs showing different stages of construction along with preventive measures to support the claim).
IGBC (Maximum 100 points)	1. Indoor air quality management during construction' **(Optional- 1 point)** 2. Preservation or transplantation of trees **(Optional- 1 point)** 3. Natural topography or vegetation **(Optional- 2 points)** 4. Sustainable building materials **(Optional- 8 points)** 5. Handling of waste materials during construction **(Optional- 1 point)** 6. Use of certified green building materials, products & equipment **(Optional- 5 points)**	• Ambient air quality is partially addressed under the 'Indoor air quality management during construction' • Credit for air quality management is not eligible for exemplary performance
USGBC/LEED (Maximum 149 points)	1. Construction indoor air quality management plan **(1 point)** 2. Building life-cycle impact reduction **(5 points)** 3. Environment product declarations **(2 points)** 4. Building product disclosure and optimization: sourcing of raw materials **(2 point)** 5. C&D waste management planning **(2 points)** 6. On-site restoration using native or adapted vegetation **(2 points)**	• Ambient air quality is partially addressed under the 'Construction indoor air quality management plan

Source: GRIHA (2010), IGBC (2016), USGBC (2018)

ANNEXURE 5

Best Practices Guide: Prevention and Control Measures for Fugitive Emissions

Introduction

Depending on the nature of source and local conditions, technological and management options are available for keeping fugitive PM emissions under check or eliminating them altogether. Particularly, the dust suppression techniques can be broadly classified into- the dry suppression and the wet suppression. Wet suppression requires water to neutralise the dust. Fresh water is a scarce resource and wet suppression can only be applied in areas with sufficient availability of treated water. Prevention of dust generation at the first place and dry suppression techniques are therefore preferable to wet suppression as they do not require water to suppress dust. Having said that, wet suppression is the only practical choice for many activities/sources generating dust e.g. unpaved roads and large stockpiles. Different options for control of dust are outlined and briefly described in the following text along with their advantages and limitations in Delhi-NCR's context. These control options are broadly classified as- (1) Smart construction materials, (2) Modern multi-service utility corridors, (3) Surface improvements, (4) Site/plant layout and design (5) Wet suppression and chemical stabilisation, (6) Best management practices for control of emissions, and (7) Best available technology for dust suppression. Dust prevention combines those techniques and management practices which eliminate dust generation. These options need to be considered at the early stages of the project, i.e. the planning and design stages.

Box A5-1 Comprehensive Measures for Prevention and Control of Fugitive Emissions in Delhi NCR

S.N.	Category	Measures
1	Smart and Sustainable Construction Materials	Prefabricated, pre-casted and modular construction elements
		Building materials with low-embodied energy: finished or semi-finished products from waste streams including C&D waste, fly ash, road dust and rice straw
2	Multi-utility service corridors/ducts with ITC enabled system for inter-agency coordination	Multi-utility service corridors/ducts
		ITC enabled system for inter-agency coordination for minimal disturbance during utility maintenance operations
3	Surface improvements	Revegetation on road edges using industrial techniques (geo-textiles, hydro-seeing etc)
		Flexible/open grid paving and gravelling on exposed surfaces around roads/sites
		Vegetation drives in abandoned fly ash pounds (decorative and aromatic plants)
4	Site or plant layout and design features	Tree-lines for dust/ash interception at existing fly ash ponds or various other sites/plants
		wheel-wash facilities for transportation vehicles
		Optimal location of plants/sites with respect to transportation of construction materials
		Paved access roads at sites/plants
		Hoods and other enclosures around conveyers and hoppers
		Conveyers or chutes with adjustable height
		Hopper load systems with a good match for truck sizes

S.N.	Category	Measures
5	Wet suppression	Simple wet suppression techniques including gravity and mechanical sprinklers which are relatively inefficient and require more water (treated water)
		More efficient techniques including dry fog suppression system (covering relatively larger area for the same amount of water), chemically-aided wet suppression (more efficient agglomeration of particles) or combinations of these
6	Best management practices	Monitoring and housekeeping for all potential leakages points of dust/ash (Refer Annex 5)
		Best practices for handling materials at site/storage facilities/plants (Refer Annex 5)
		Best practices for transportation e.g. load size limitations, speed limits etc. (Refer Annex 5)
		Planning and optimising transportation of construction materials
7	Dust/ash Suppression Systems	Construction equipment with dust suppression technology: cyclone separators, bag filters, ESP etc. for capturing dust/ash
		Vacuum cleaning of roads/streets with 'segregation and binding' of dust into fine aggregates

Source: CII-CESD (2019) analysis

A 5.1 Smart and Sustainable Construction Materials

Smart construction and building materials eliminate fugitive dust emissions during the construction phase at site and are therefore one of the most effective strategies for dust control. Smart construction materials include pre-fabricated modular construction materials, recycled building materials, flexible pavements and advanced road construction materials such as recycled plastics and geopolymer concrete.

Smart and pre-fabricated modular constructions reduce pollution at the construction site caused by transportation and handling of raw material. Fugitive dust emissions can be controlled more effectively in industrial environments where these modular units are fabricated. Pre-fabricated modular constructions are already common in urban infrastructure projects. These modules (precast/prefabricated/partially prefabricated concrete elements) are used in construction in the form of building elements which are assembled at site and made monolithic by pouring in-situ concrete. They break the structural elements down into smaller segments resulting in ease and economy in construction (BIS 2016).

Recycling C&D waste ensures that waste materials feed back into the material flows in the city and are utilised in new construction projects. Re-utilisation of C&D waste is expected to curb illegal dumping of C&D waste and dust generation as a result. Currently, the installed C&D processing plants can process the C&D waste at 2500 tonne per day (GNCTD 2018a) and can handle 50% of the C&D waste generated within NCT Delhi. Enhancement in capacities of C&D waste recycling plants is required in Delhi NCT and other NCR towns where such infrastructure is non-existing. The Burari plant by IL&FS was set up under the Public-private partnership (PPP) model and recycles 2000 tonne C&D waste per day into construction-grade aggregates (with recycling rate of 95%). These aggregates are further converted into products such as RMC, cement bricks, hollow bricks, pavement blocks, kerb stones, concrete bricks and manufactured sand, thereby reducing the consumption of virgin materials such as fresh stones and sand, and mitigating pollution arising in the processes of quarrying and mining (IL&FS 2018).

Similar to C&D waste, fly ash is another major waste stream which can feed back into the material flows to the city. Low cost fly ash based permeable concrete provides hard surface (for moving heavy vehicles etc.) and can seep water. It also has the added advantage of significantly lower cost as compared to the conventional bitumen roads. 100% recycled materials can be promoted for urban infrastructure projects and civic authorities can be mandated to source 100% recycled materials. The various commercially established products and applications of fly ash are summarised in Box A5-2.

NTPC has recently demonstrated use of fly ash from its coal thermal power plant in Dadri (NCR Delhi) for road construction (NTPC 2017). This specific use case demonstrates use of fly ash in the form of high strength geopolymer concrete (meeting IRC specifications for road construction) and it was implemented by NTPC Energy Technology Research Alliance (NETRA) and CSIR laboratory- Central Buildings Research Institute (CBRI). Geopolymer concrete is typically made up of waste products such as fly ash, granulated blast furnace slag (GGBS), fine/coarse aggregates and catalytic liquid system (BIS 2016). As per NTPC, geopolymer road does not need water curing as required by cement concrete road and paves the way for bulk fly ash utilization. NTPC is now inviting expression of interest from Indian firms and contractors for building geopolymer concrete based roads at NTPC projects or stations across India (NTPC 2018d).

Box A5-2. Finished & Semi-Finished Recycled Products from Different Waste Streams

C&D Waste	1. Recycled Concrete Aggregates (RCA) 2. Ready Mix Concrete (RMC) 3. Cement bricks 4. Hollow bricks 5. Pavement blocks 6. Kerb stones 7. Concrete bricks 8. Manufactured sand
Road/street Dust	1. Road paving blocks using road dust as fine aggregate 2. Road paving bricks using road dust as fine aggregate 3. Road paving tiles using road dust as fine aggregate
Fly Ash	1. Light-weight Aggregates (LWAs) 2. Geopolymer concrete 3. Clay-fly ash bricks, blocks, tiles, roofing tiles (manual 60% fly ash; mechanised 85% fly ash) 4. Fly ash-lime-gypsum-cement bricks and blocks (50% fly ash) 5. Fly ash bricks (90% fly ash) 6. Manufacturing of Cement 7. Part substitution of cement in concretes including RMC, SCC, high strength & structural concretes (up to 50% fly ash) 8. Construction of roads, embankments & bridges including pavement interlocking block, kerb stones etc. 9. Stowing in underground mines, backfilling of open cast mines 10. Construction of haul roads & other construction / development activities in mine sector 11. Construction of dams & water management structures
Rice straw	1. Straw-bales for building insulation in alternate building designs 2. Eco-panels made from rice-straw for building indoors

Source: CBRI (2018), CFARM (2018); IL&FS (2018), BIS (2016), NTPC (2017, 2018d) and other stakeholder inputs

Recycled concrete aggregate (RCA) is the primary product of C&D waste recycling plant which is further processed into products as shown in box A5-2. The production of concrete for buildings and roads in India is governed by BIS (IS 456, IS 1343) and IRC codes (IRC 112) respectively (CPWD 2014). All these codes further conform to BIS code: IS 383 for use of aggregates in concrete. This standard has been revised for use of RCA in concrete in the year 2016. As per the revised specifications (IS 383, 2016), maximum allowable RCA content in concrete is-

a. Plain cement concrete (PCC): ≤ 25% coarse & fine RCAs

b. Reinforced cement concrete (RCC): ≤ 20% coarse & fine RCAs

c. Lean concrete: 100% RCAs for non-load bearing structures using lean concrete

As per the National Building Code of India, recycled aggregates may be used in concrete for bulk fills, bank protection, base/fills of drainage structures, pavements, sidewalks, kerbs and gutters etc. (BIS 2016). Up to 30% of the natural coarse aggregate can be replaced by the coarse recycled aggregate, in fresh concrete. This percentage can be further increased up to 50% for pavements and other areas which are under pure compression (BIS 2016).

In addition to above standards and codes, there are specific mandates for utilisation of C&D waste in new projects in Delhi. The Government of National Capital Territory of Delhi (GNCTD) has issued advisory to all its Departments for a mandatory clause in their tenders requiring use of 2% and 10% of recycled C&D waste products in building and road projects respectively (GNCTD, 2018b). It also categorically mentions that C&D waste should be reutilised in-situ for all big redevelopment projects of government worth more than INR 500 Crores. GNCTD notice also advises 500 tonne per day processing units to be set up across the city with one such unit by a major government stakeholder. A similar notice was also issued by Central government agencies: Ministry of Urban and Housing Affairs (MoHUA) and Central Public Works Department (CPWD) in March 2016.

A 5.2 Modern Multi Utility Service Corridors

Multiple agencies and departments are involved in maintaining the utility lines (gas, sewage, fresh water, electricity, telecommunications etc.) along the roads. Actions of different departments or utilities are not synchronised, and this leads to dust generation on roads which is further suspended in the air due to vehicular movement. Modern utility corridors are essential for curbing emissions from day-to-day activities of utilities across the city.

Separate utilities corridors and demarcations are required across NCR (on the lines of ongoing project under smart cities) so that only relevant utility lines are disturbed during renovation work and dust generation is minimum. Table A5-1 shows ongoing smart city projects (above INR 100 Crore) under the category of utility works. 13 out of total 17 cities have opted for multi-utility ducts, trenches or tunnels. This indicates significant interest among cities for implementing common utility corridors. But it must be noted that all projects under smart cities are area-based development and do not cover the entire city. As clear from Table A5-1, cost for project varies from INR few crores to INR few hundred crores per kilometre depending on the type and number of utility lines. It will therefore be a good idea for NCR towns to learn from implementation of smart cities projects and accordingly implement a cost-effective model after assimilating the learnings from ongoing projects.

Advanced Information and Communications Technology (ICT) system can be deployed at common utility corridors to ensure inter-departmental or inter-agency coordination. ICT system ensures that information is shared with all the relevant departments or agencies whenever a particular activity is undertaken. It can be seen in Table A5-1 that few cities have opted for advanced ICT systems to integrate utility operations. ICT system may include advanced metering infrastructure for urban utilities such as water and energy.

The only operation utility corridor in the country is a 1.25 km long underground utility tunnel (Figure A5-1) at Connaught Circle, New Delhi developed as part NDMC's city redevelopment plan.

Figure A5-1. Common Utility Tunnel in Connaught Place, New Delhi

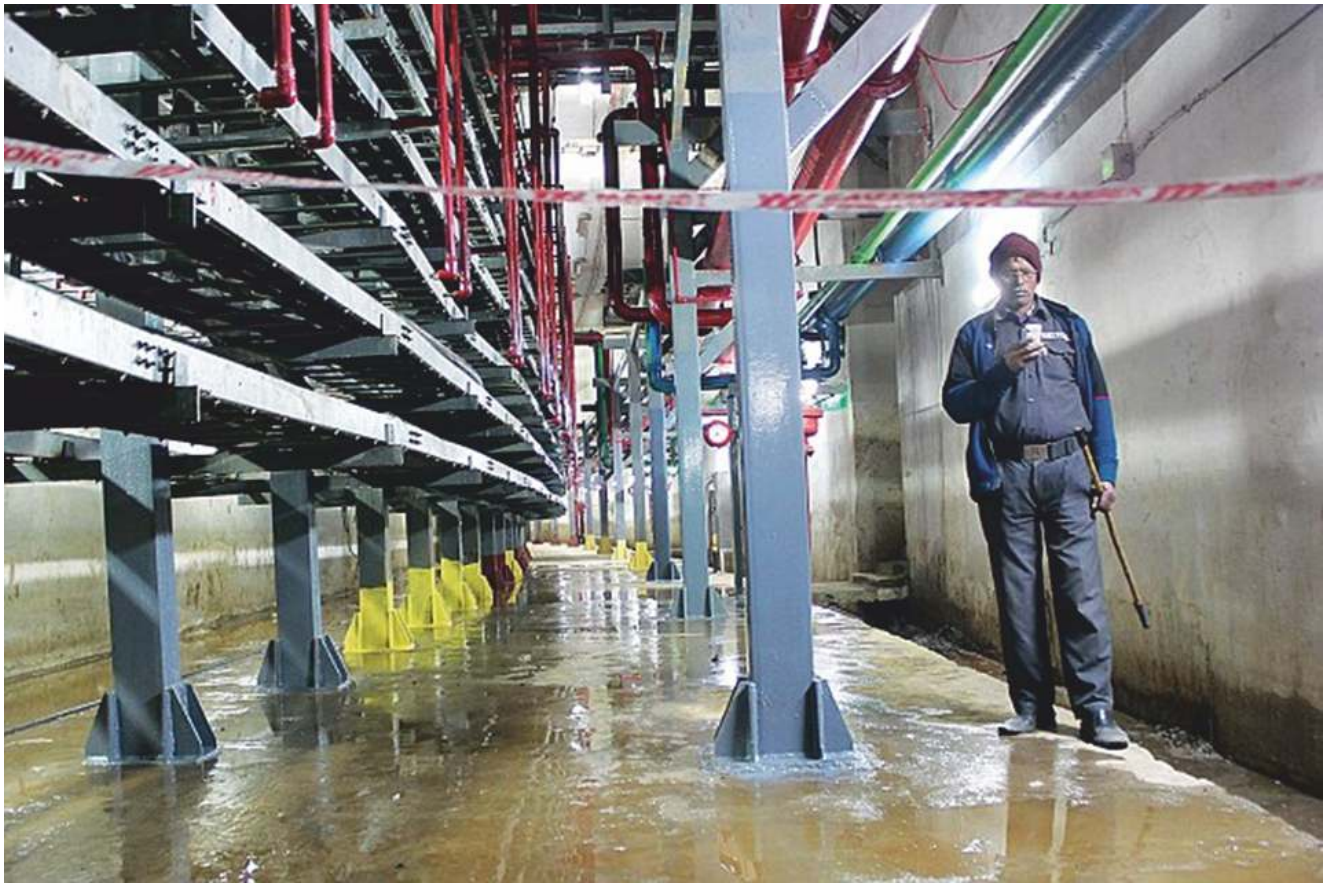


Image source: Mail Today (2016)

Table A5-1. Smart City Projects Worth INR 100 Crore and Above Being Implemented Under Utility Works as per the Smart City Proposals

S. No.	City	Project details in the smart city proposal	Cost [INR, Crore]
1.	Agartala	Utility Trench	333.95
2.	Ahmedabad	Utility Network (Water, sewerage, drainage, roads, street lighting etc.)	385.00
3.	Belagavi	City Gas Distribution (CGD)	150.00
4.	Bhopal	Miscellaneous (Landscaping, Flyovers to approach site, Development of public utilities)	627.00
5.	Dharamshala	Underground cabling	111.00
6.	Faridabad	Underground cabling	276.00
7.	Jalandhar	Water, Waste Water, Power and Utility Ducting	262.51
8.	Kanpur	Utility Duct (Electricity, Water, Sewer, OFC, Telecom, PNG)	147.15
9.	Kohima	Multi services utility duct	112.99
10.	NDMC	Sensor based Common Service Utility Duct	150.00
11.	Port Blair	Service core trench	175.00
12.	Shivamogga	Underground ducting	264.00
13.	Thanjavur	Underground utility trunk - 27 km	108.17
14.	Tumakuru	Underground Ducting	196.00
15.	Udaipur	Drains, Relaying road & utility duct	148.00
16.	Vadodara	Multi utility duct	122.50
17.	Varanasi	Underground wiring to reduce unwanted clutter on the streets through and implementation of smart metering	431.96

Source: Information extracted from smart cities project database (GoI, 2018)

A 5.3 Surface Improvement

Surface improvement includes various techniques like revegetation, gravelling or flexible pavements on exposed surfaces. Revegetation can be implemented by developing green covers around road stretches. To ensure efficient implementation of revegetation wide scale, industrial techniques such as hydro-seeding, geo-textiles can be used to stabilise road sides and edges. Green covers are one of the most effective ways to control dust from exposed surfaces and permanently addresses the fugitive dust emissions along roads, highways and streets where dust control is very important from the perspective of exposure on the roads and road safety.

Different paving options including flexible pavements, gravelling, open grid or grass pavers etc. can be considered for exposed surfaces. An important consideration for paving materials is their durability so as to minimise the repairs and disturbances to paved surface.

Surface improvements are also crucial for curbing the fly ash emissions discussed in Section 3.2.2. The most effective and permanent control method is growing vegetation in the fly ash pond. Nutrient rich soil is normally required for growing grass and plants in fly ash. As fly ash is laden with toxic metals, growing fruits and medicinal plants is not advisable. Only the flowering or decorative plants can be grown in the fly ash pond, supplemented by nutrients/soil.

A 5.4 Site or Plant Layout and Design

Design strategies are important for curbing air pollution during construction phase of various projects (buildings or infrastructure). Transportation and handling of materials is a major source of dust at the project site during the construction phase. Therefore, minimising travel distances through appropriate plant/site layout and design is an important strategy for preventing fugitive dust emissions. One of the most common practices at the construction site is to prepare an unpaved road for transportation of construction materials to and from the site. This leads to majority of fugitive dust emissions during construction phase. Paving the access roads at construction sites is an important strategy for control of PM emissions. Other design approaches that can be integrated into layout and design include- concrete bunding and using natural features of the land or local topography. To ensure effectiveness, bund walls need to be at least one third higher the stockpile height.

Wind breakers can also be built at the site using horticulture cloth supported on poles, or by planting trees, that provide green cover around the site (considering prevailing wind conditions). Besides control of dust from road, green covers are also very effective for containing dust originating at construction sites. It is estimated that a single row of trees may bring about a 25 percent reduction in airborne particulates and complete dust interception can be achieved by a 30-metre belt of trees (ASCI 2010). Growing dense green-covers around the fly ash ponds prevents blowing of ash by wind to the surrounding area. It should be noted that certain species of trees may be chosen for their pollution abatement qualities including dust trapping. To avoid reliance on a single species, a combination of trees, shrubs, grass should be grown (MoUD 2014). Choice of tree is important and evergreen trees are a preferred choice for an effective windbreaker (BIS 2016). The building code GRIHA (GRIHA 2018) provides a reference list of native or naturalised species of flora which can be grown in accordance with different agro-climatic zones (climatic conditions and soil types) prevalent in India.

A comprehensive set of design measures for construction sites including waste management facilities and allied construction industry include-

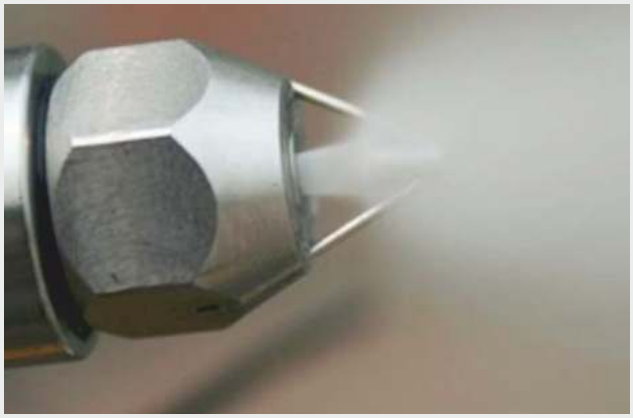
1. Optimal location of plants/sites with respect to transportation of various finished/semi-finished construction/demolition materials
2. Paving the access road for transportation of construction/demolition materials to and from the site/plant
3. Integrating natural features into the building layout and design e.g. tree lines around site/plant. Consideration should be paid to the prevailing wind conditions and tree species.
4. Enclosures around conveyers and hoppers (hoods and other enclosures) for transferring fine materials. In absence of enclosures, wet suppression using water sprinklers is required and might not be suitable for all materials and processes.
5. Use of adjustable conveyors that can be raised and lowered in order to minimise drop heights and avoid spillage of materials
6. Hopper load systems should be designed to ensure a good match with truck size and should be fully enclosed on the sides

A 5.5 Wet Suppression and Chemical Stabilisation of Particulate Matter

Wet suppression involves applying water onto road surfaces, material stockpiles, transportation vehicles and other vulnerable locations for supressing dust. Wet suppression techniques can be broadly classified into three types- (1) Simple wet suppression using gravity or mechanical sprinklers, (2) Dry fog suppression (3) Chemical stabilisation of particulate matter during wet suppression.

Figure A5-2. Wet Suppression on Road Using Water Tanker and Mechanical Sprinkler

Figure A5-3. Dust Suppression Nozzle Used in Dry Fog Systems for Suppression of Airborne Particles



Source: manufacturer's website

Simple wet suppression can be achieved by using gravity or mechanical sprinklers as shown in the Figure A5-2. Applications include paved/unpaved road, pavement, exposed surfaces and unused material/waste stockpiles, landfills, wet jet in grinding/cutting operations and wash down facilities for transportation vehicles. Water sprays/ sprinklers are also used at conveyors and other transfer points in allied construction industry and waste management facilities, depending on the process and materials. Before using wet suppression technique, assessment of dust suppression water demand and supply is important in the locality. Water demand depends on the surface area for treatment, and rate and frequency of application required at the location. Application rates are in turn based on inputs such as local meteorological forecasts and traffic volumes in case of application on the roads. Water conservation strategies are important to reduce water footprint of dust suppression activities.

Dry fog suppression systems can be used to enhance water use efficiency of wet suppression. Dry suppression nozzles as shown in the Figure A5-3 can be designed for suppressing PM of particular size range. Dry fog suppression is also utilised to cover large control areas as opposed to simple mechanical means which are attached to diesel operated vehicles for providing coverage to large areas. High frequency applications by mechanical means or simple wet suppression, therefore need to be carefully planned considering the emissions from diesel vehicles. Application of dry suppression technique has limited utility for suppression of fugitive PM due to wide range of ultrafine particles suspended in urban airshed. This would otherwise require custom designed dry suppression nozzles for ultrafine PM ranges and might be practically impossible to implement[2]. Additionally, wet particles are hydrophobic (water repellent) and resist agglomeration of finer particles in air. Both of these techniques are therefore not effective for supressing fugitive PM unless targeted surfaces are fully covered with water and are ineffective for controlling air borne PM. Also, local climatic conditions (high temperature and dry weather) render the wet suppression ineffective as water evaporates quickly from surfaces under high temperature conditions.

Chemical stabilisation of particulate matter during wet suppression ensures much higher control efficacy, which can be further enhanced in combination with dry fog suppression. This can significantly reduce requirement of water and are more effective than wet suppression or dry fog suppression systems used in isolation. In this technique, control agents are added to water for facilitating binding of particulate matter through particle agglomeration. Chemical stabilisation also has an added advantage of improving visibility and safety conditions on the road. Calcium chloride ($CaCl_2$), Magnesium chloride ($MgCl_2$) and Organic Polymer-plus-Binders (OPBs) are common dust suppressants used traditionally around the world but are not advisable due to corrosion of vehicle parts and environmental impacts caused by run off from the road after excessive application. A new family of chemical stabilisers have been developed that consist of long-chain hydrocarbons which are biodegradable and have no reported environmental impact. This solution has been developed indigenously by Syntron Industries in India in collaboration with the Central Institute for Mining and Fuel Research (CIMFR). These stabilisers have only been used for dust control in the mining industry so far and there is a huge potential to use them in urban environment. Additives not only lower the water surface tension to create the smaller droplets of water, they also produce interfacial tension between particles. This permits dust to penetrate the surface of water droplets and form agglomerates, making the suppression more effective with less moisture requirement.

[2]Dry fog suppression system was recently tried by Delhi government and DPCC at Anand Vihar in the form of fog guns but it had limited or very little impact for control of PM (HT, 2017) due to possible reasons explained in text but no documented data or information on the same is available in the public domain

In an example provided under the Box A5-3, three different applications of chemically assisted wet suppression technique are described: (A) road dust, (B) material stockpiles and (3) airborne PM, based on the inputs provided by the solution provider. Interventions below can achieve PM suppression with control efficiency of 90-95% as opposed to simple suppression with water which is resource intensive and can only achieve a control efficiency up to 20%. Key considerations for application (time, rate and frequency) of chemical stabilisers include: local meteorology, traffic volumes on the road, aggregate or unpaved road (binder content is higher for gravelled roads). Application can be optimised based on the experience in the city environment. Evidence for control efficacy of these agents can be established in NCR through pilots and demonstrations.

Box A5-3. Example of a Proposed Pilot for Chemically Assisted Wet Suppression of Particulate Matter in NCR Under Three Different Conditions

Based on interview[3] with one of the solution providers three applications of chemical additives are suggested for pilots in city environment to suppress fugitive PM-

A. Application on the roads with vehicular movement

Chemical stabilisation can be used for wet suppression during road maintenance and for application on unpaved roads/surfaces. Recommended mixing ratio is 1 kg compound for 2500 litres of water. One litre of water and additive can cover up to 3-4 m^2 and 1.5-2.5 m^2 area for mechanical and manual gravity spray pattern respectively. Cost of chemicals is estimated to be INR 0.39 per m^2. To begin with, solution provider recommends three applications in a 24 hour period.

B. Application on loose materials with no movement

Potential applications under this category could include- inactive fly ash ponds, illegal dumps of C&D waste, landfills and stockpiles of loose and fine materials including construction materials at project sites or plant locations. Recommended mixing ratio for these applications is higher: 1 kg compound for 50 litres of water. Application rate for this category is recommended at 3-4 litres of water and additive per square metre. The suppressant is applied using a mechanical sprayer to which water is pumped from a stationary water tank at the site. Recommended frequency of application is once per month, costing up to INR 20 per m^2.

C. Control of airborne PM in pollution hotspots

In addition to above applications, the technique can be adapted for PM control in specific areas which suffer from critically polluted air due to rampant construction activities, rapid vehicular movement on roads, illegal dumping/burning of waste etc. Mixing ration of 1 kg chemical for 10,000-15,000 litres of water is suggested for this application. The dry fog suppression system with high jet pump is recommended for this category to cover wide areas for suppression of fugitive dust and PM. Recommended application rate is once in 24 hours with midnight being the most suitable time for its application.

[3]conducted on 24 April 2018, New Delhi

A 5.6 Best Management Practices

Role of management options and best practices is extremely important for PM suppression. Adopting best practices requires a fundamental shift in behaviour of organisations/industry. Ensuring best practices therefore would require sensitisation of stakeholders in NCR region and high level of inter-departmental coordination.

1. Best practices for moving sources: material transportation-
    a. Restricting transportation vehicles to specified roads and time of the day
    b. Speed limits for vehicles in designated areas (say, up to 10-15 km/ hour)
    c. Load size limitations for avoiding material spillages
    d. Proper covering of transportation vehicles e.g. with tarpaulin/bins
    e. Monitoring traffic for transportation vehicles carrying construction and demolition material

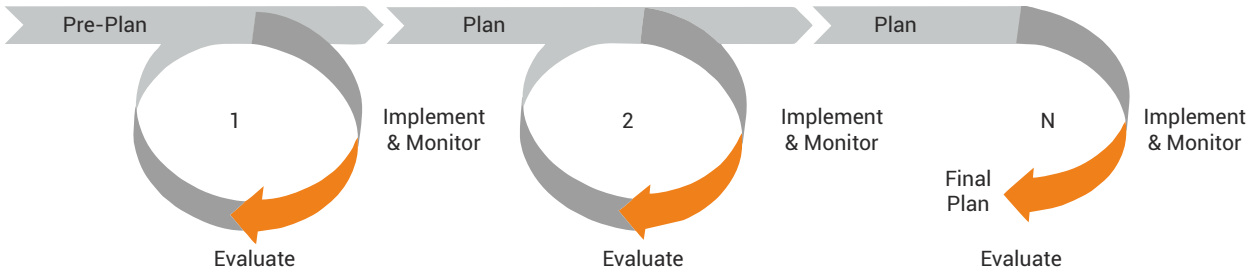
2. Best practices for stationary sources: sites, plants and storage facilities-
    a. Limitation on stockpiles' size: height & slope. For instance, flat and shallow stockpile is preferred over tall conical stockpiles in order to reduce wind entrainment.
    b. Wind breakers, shelter belts or temporary screening at construction site
    c. Location of wind breakers from stockpile is critical (at a least distance which is equal to the height of pile)
    d. Proper cover (tarpaulin/ bins) for fine materials such as sand, gypsum & cement
    e. Maintaining minimum drop heights for equipment transferring materials to/ from stockpiles
    f. Regular clean-up of spillages and covering of potential spillage areas
    g. Regular maintenance of hydraulic grabs to ensure complete closure
    h. Operating plants/facility at times when meteorological conditions are not conducive to producing large dust plumes (for plants which do not run 24x7)
    i. ITC enabled systems and protocols for inter-departmental and inter-agency coordination among utility operators to ensure minimal dust generation during regular maintenance operations
    j. In-situ utilisation of excavated soil at construction projects

Box A5-4. Suggested Air Quality Monitoring and Implementation Framework

Control measures need to be designed considering features of local area and accordingly implemented across urban settlements in the NCR region. Availability of treated water is one of the deciding factors for achieving dust control via wet suppression. Road traffic conditions, such as traffic volumes and time of day are important for deciding the best time of the day for application of chemical aided wet suppression. Dust control is crucial in construction hot spots which are in close proximity to sensitive receptors such as schools, hospitals and residential areas. Low-cost sensor-based monitoring can be used in such areas which are critical from the perspective of exposure and would require monitoring in order to design suitable local interventions.

Figure below illustrates variables and parameters related to sources of air pollution, local area, environment and control measures. Optimising these using available information is crucial for achieving desired reductions in air pollution. Instead of applying arbitrary control measures in an ad-hoc manner and temporarily suspending activities, evidence needs to be generated continuously though action and it needs to feed into management and planning processes. This requires a comprehensive management and control programme involving multiple stakeholders. Control strategies need to be improved though an iterative process as shown below and standard operating procedures (SOPs) need to be established based on tested efficacy of control measures under local conditions.

Framework for Continuous Improvement of Management and Control Strategies at Local Level Through Evidence



CONTROL VARIABLES

- Location of key sources e.g. construction hotspots, identified highway/road stretches
- Location of sensitive receptors e.g. hospitals, schools and residential areas
- Local meteorological factors e.g. predominant wind directions
- Frequency and time of activities
- Availability of treated water at site

CONTROL STRATEGY

- Type of control measure (e.g. wet or dry suppression)
- Rate & frequency of application
- Best time of day for application
- Control efficiency
- Capital cost of equipment/ infrastrcuture
- Operational cost: fuel, chemicals, and maintenance of infrastructure

key parameters for devising air quality management strategies vis-s-vis area specific control variables

Source: CII-CESD (2018) analysis

At the evaluation stage, the tested efficiency of control measures under given conditions can be established with the help of a transparent monitoring and data ecosystem. This not only helps choosing or discarding options based on concrete evidence, it also scientifically ascertains and helps understanding why specific control measure failed under given conditions and how it can be improved in the next planning stage by adjusting few variables or discarded particular measure due to unsuitability in certain location.

Monitoring and robust data ecosystem is essential for controlling dust emissions. Testing efficacy of control options would require regular inspection, sampling and monitoring of sites with high generation of dust and other fine particulate matter emissions, for instance, the construction hotspots, landfills, stone crushers etc. Monitoring of SPM and PM using low cost infrastructure can be mandated at such sites. Emphasis should be on continuous improvement of management practices and control strategies based on these findings as illustrated by Figure 9. Random monitoring of different sources responsible for fugitive emissions, as in listed table A4.2, is prescribed, along with the online monitoring by industry, utilities and civic agencies along key locations in NCR cities. Online monitoring for SPM, PM and local meteorological conditions can be set up voluntarily by public and private agencies across region and would supplement the existing monitoring capabilities.

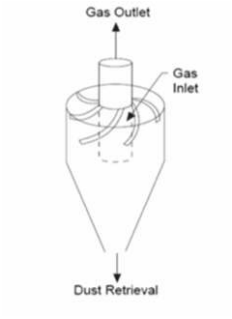
A 5.7 Best Available Technology for Dust Suppression

Dust can be collected from hard surfaces, such as roads, streets and pavements, by mechanised/vacuum sweeping but it is ineffective compared to other options discussed above due to inherent problems with municipal solid waste management system in NCR. As of now, a fraction of road dust is being collected by mechanical sweepers employed by local bodies and PWD (Government of Delhi). Dust is predominantly collected by manual sweeping of the roads or streets by sanitation workers of municipality. Sweeping the roads itself generates a lot of dust. Besides this, segregation does not take place at source in Delhi NCR. Unless collected dust and other fine particulate matter are bound using an agent and disposed using scientific methods, mechanised or vacuum cleaning is not advisable for addressing air pollution. It could in turn lead to higher ultrafine PM emissions from diesel engines if emissions from these vehicles are not monitored and controlled properly.

With the initiative of Department of Environment (GNCTD), Central Building Research Institute (CBRI) has carried out investigation on the utilization of road dust, also called silt, for development of building components. Various value-added building components like road paving blocks, bricks and tiles have been developed using road dust as fine aggregate and this option may reduce burden of road dust on Delhi's airshed.

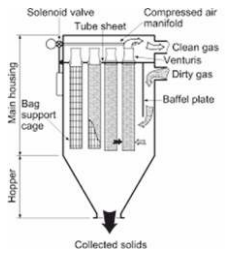
Containment of particulate matter and other air emission such as VOCs is especially relevant for construction and small-scale industry in Delhi NCT and other NCR towns. Some of these air emissions can be contained at the source using mechanical extraction and collection. Depending on the intensity and scale of these processes, extracted air can be routed to one of the emission control devices (for containment of PM): (1) Cyclone separator, (2) Bag/ fabric filter, (3) Electrostatic precipitator, and (4) Wet scrubber. The relative advantages and disadvantages which might help the user choosing the right emission control device are summarised in the Box A5-5.

Box A5-5 Proven Technologies for Containment of Particulate Matter Emissions



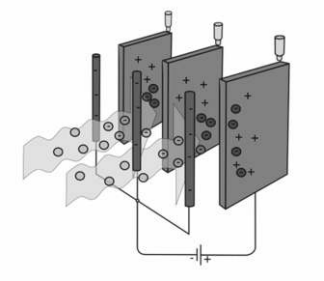
Cyclone separator (~70% collection efficiency)

- Low cost
- No moving parts
- Relatively lower efficiency
- Wide temperature/pressure applications
- Low space requirement
- Dry operation
- Efficient operation requires high pressure drops



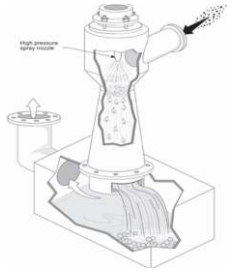
Bag/ fabric filters (~95% collection efficiency)

- Higher efficiency with use
- Up to 99.9% collection efficiency
- High collection of coarse and fine PM
- Multiple configurations and wide capacity rang
- Limited to temperatures below 290^{o}C
- Maintenance against corrosion
- Lower efficiency after cleaning filters



Electrostatic precipitators (ESP) (60-90% collection efficiency)

- High capital and low operational cost
- Dry and wet types
- Multiple fields
- High efficiencies achievable
- very low pressure drop
- Minimal maintenance (non-corrosive materials)
- Large space requirement
- Sensitive to fluctuations in gas flow



Wet scrubbers (40-99% collection efficiency)

- Moderate pressure drop
- Can handle corrosive and acidic gases/mists
- Limited to gas inlet temperatures < 50-85^{o}C
- Relatively low capital cost
- Small space requirement
- Wet collection

Source: EPA (2008)

Table A5-2 Example of Prevention and Control Options for Various Sources of Fugitive PM Emissions in NCR

S. No.	Key Sources	Description of Sources	Area of intervention	Prevention and control options
1	**Building construction**	a. Township or area development projects b. Large building construction projects for which environmental clearance is required including commercial/public buildings and residential complexes c. Building construction projects including renovation of existing buildings where environmental clearances are not required	• Construction hotspots in NCR region • Material handling during construction and demolition	• Best practices for dust preventions and minimisation during material handling at site • Chemically assisted wet suppression methods • Site layout and design e.g. Integrating natural features in design for dust prevention and minimisation of travel distances through proper site layout • Green covers and wind screens • Paving the access road
2	**Urban infrastructure projects**	Urban infrastructure projects including construction of roads, flyovers, intersections, bridges, footpaths, lighting poles etc.	• Large infrastructure projects e.g. DMRC • Construction and demolition of roads/highways, pavements, bridges, flyovers etc.	• Best practices for dust preventions and minimisation during material handling at site • Chemically assisted wet suppression methods • Re-vegetation on exposed surfaces, paving the access road and other surface improvements
3	**Utility operations**	Utility operations across the city involving digging on/along the roads. Utilities include electricity, gas, water, roads, municipal solid waste etc.	• Day-to-day activities carried out by utilities such as NHAI, PWD, IGL, BSES, DJB and urban local bodies • Inter-departmental coordination among different agencies/departments	• Modern multi-utility service corridors along roads with a provision for inter-departmental coordination
4	**Demolition**	Various demolition activities across the city including buildings demolition	• Demolition of buildings • Demolition of roads, bridges, pavements etc. in city	• 100% recycling of C&D waste • Best practices for dust preventions and minimisation (during storage, transportation and use at site) • Chemically assisted wet suppression methods

S. No.	Key Sources	Description of Sources	Area of intervention	Prevention and control options
5	Material Transportation	Transportation of materials	• Transportation of construction materials • Transportation of C&D waste	• Speed limits in designated areas • Best practices for vehicle loading and transfer of materials • Wash down facilities at sites/plants
6	Vehicular movement on roads	Resuspension of dust due to vehicular movement on paved/ unpaved roads, especially due to poorly maintained road/ highway stretches	• Roads and highways, especially poorly maintained road stretches in NCR • Repair/maintenance of roads/ highways stretches	• Chemically assisted wet suppression using mechanical/gravity/fog suppression spray systems • Monitoring and management of road traffic, especially for heavy-duty vehicles: speed limits on designated roads • Re-vegetation on exposed surfaces along roads, paving roads and other surface improvements • Mechanised sweeping with proper disposal of collected dust from paved roads
7	Soil and other exposed surfaces	Wind erosion from exposed surfaces and loose soil	Unpaved roads and exposed surfaces along roads/highways	• Surface improvement: paving, gravelling, re-vegetation on exposed surfaces etc. • Chemically assisted wet suppression using mechanical/gravity/fog suppression spray systems
8	Waste handling and disposal	Collection and handling of Construction and Demolition (C&D) waste, Municipal Solid waste (MSW), and fly ash Landfills and fly ash pond in NCR	• MSW collection from streets/roads • Management of landfills, fly ash ponds and illegal dumping sites in NCR • Waste handling units (C&D waste and MSW)	• Plant design and layout • Best practices for dust preventions and minimisation during waste handling • Chemically assisted wet suppression
9	Allied construction industry	a. Bricks kilns (fly ash) b. Stone crushers c. Ready mix concrete (RMC) batching plants	• Material handling • Improved Kiln designs • Fuel switch at these plants	• Plant design and layout • Best practices for preventions and minimisation of dust/fly ash • Chemically assisted wet suppression

Source: CII-CESD (2018) analysis

ANNEXURE 6

Best Available Technologies for Diesel Generators

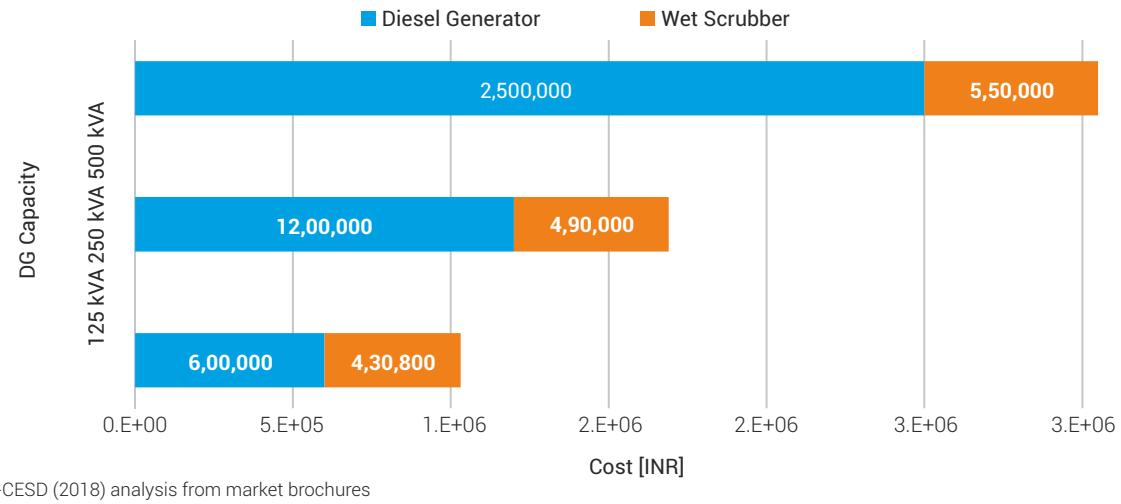
Available options in the market can be classified as-

1. End-of-Pipe Retrofit
2. Fuel Substitution in Diesel Generators
3. Energy Storage

A 6.1 End-of-Pipe Retrofit Technologies

Emission control devices for DGs work on the same principle as in the diesel engines. Emission control methods for these are broadly classified as- wet scrubbers, diesel particulate filters (DPF), continuous regenerative trap (CRT). Low-cost retrofit options at approximately 10% of the DG's capex are available in the market with a minimum collection efficiency of 70%, although the auxiliary energy consumption is observed to be significant. Hospitality sector in India utilises wet scrubbers in order to keep the PM emissions from DG sets under check. The Figure A6-1 below gives a comparison of wet scrubber options for three different size classes available with an equipment vendor in Delhi. Three key components of wet scrubber: stainless steel ducting, water cooler and venture scrubber constitute about 8%, 27% and 65% of the total cost respectively. As evident from Figure A6-1, wet scrubber is cost-effective retrofit option for mid to high capacity segments. For a 500-kVA diesel generator, wet scrubber constitutes about 18% of the total capex. Although options are available in the Indian market, they need to be benchmarked to understand their relative advantages/disadvantages (collection efficiency, back pressure impact, energy requirement etc.) for different capacity segments.

Figure A6-1. Cost of Indigenous Wet Scrubber of Different Capacities Available Commercially in the Indian Market



Source: CII-CESD (2018) analysis from market brochures

In addition to the above said technologies for retrofit options for DGs, on-road original equipment manufacturers (OEMs) currently have experience on other low cost proven solutions like Diesel Oxidation Catalyst (DOC) and Partial Flow Filters (PFF). The technology has capability to reduce PM between 30-60% depending on the organic fraction of diesel particulates: soluble organic fractions (SOF) or insoluble organic fractions (IOF) observed at the engine outlet conditions. The DOC on its own can be used as a retrofit solution having the ability to oxidize CO, HC and SOF (PM). When combined with downstream PFF, the Partial Oxidation Catalyst (POC) architecture can reduce PM close to 50-60%.[4] The key driver for this technology to perform is engine exhaust temperature. One should maintain temperature higher than 250^{o}C at minimum 50% duty cycle on periodic basis to aid the passive soot oxidation. PFF traps soot within and on the walls, converting trapped carbon to form CO_2 up on reaction with incoming NO_2 (from DOC). This technology has been in practice in commercial vehicles in India and China since the introduction of BS-IV and NS-IV norms respectively. As per the inputs received from stakeholders, the product quality and reliability has been good with the right level of integration measures. The product cost of this solution is around INR 30-100 thousand depending on the product requirement. The industry experience of this technology has been on electronic architecture which would be able to react if there are any choking or plugging issues. For DG retrofit, the engines currently in the field are primarily based on mechanical architecture. These engines have their own set of limitations in terms how they would be able to react if technologies are deployed downstream. Backpressure, vibration, noise and durability should be well understood before this could be mass deployed.

Furthermore, several indigenously designed end-of-pipe retrofit devices that capture PM and that turn it into useful products (such as ink, paint) are currently under development in India. These options are currently being piloted at sites for large corporates, real estate players, oil and gas companies, etc. in Delhi NCR and other metropolitan areas; but are yet to be certified by CPCB approved laboratories. Such devices are able to capture significant amount of particulate matter emissions from diesel generators based on age and condition of the generator. The cost of such retrofit options is fractional as compared to the capital expenditure on diesel generator and varies with capacity (12-16% of the DG capex). The devices work by cooling the exhaust in most optimized manner to cause rapid agglomeration of soot particles. Capturing of soot particles is realised by slowly passing the exhaust gases through contours and meshes while interacting with solution, that traps the soot. The solution ensures continuous cleaning of the meshes and contours in real time, collecting soot at the bottom of collection bin.

A 6.2 Fuel Substitution

Dual fuel injection kits are readily available for existing DG sets (CII-NITI 2018b). Gas injection kits may be mandated by competent authority to existing DG sets in areas with availability of CNG and piped natural gas (PNG) infrastructure. Additionally, efforts maybe ramped up to improve availability of cleaner fuels in commercial segment. Recommendations for the same have been made in CII-NITI Aayog task force report on Clean Fuel (CII-NITI 2018b). Existing and new DGs in commercial sector: 82%, 65-70% and 56% of the low, med-high and high-horsepower capacity segments

[4]Data based on certified commercial products by ARAI India & MIC China for light duty vehicles.

respectively (contribution of different sectors as shown in Figure 6) can be prioritised for retrofit in this regard. All major manufacturers have gas-based DGs or multi-fuel injection models available in the market. Similar to gas, other clean fuel options such as liquid bio-fuels and bio-CNG can also be explored in Delhi NCR based on the availability of bio-fuels and by promoting waste-to-energy.

A 6.3 Energy Storage

Using electric batteries/ invertors for energy storage can partially address the emissions from diesel generators in urban areas. Inverters or battery storage can only fulfil the energy requirements for small appliances: lighting, fan etc. Standalone electric storage is therefore a long-term measure currently available in market and can fulfil the energy requirements for energy intensive applications such as air conditioning for thermal comfort.

Thermal energy storage is a separate set of solutions available to fulfil the needs for thermal comfort in the buildings in case of power outages. In addition to providing back up power during power contingencies, TES enables businesses to manage peak electricity demand by storing electricity as thermal energy during non-peak hours and utilising it during peak hours[5]. This is especially relevant in case of the commercial and industrial users of electricity for whom time of day tariffs are applicable. While invertor backs up small appliances such as lights, TV and computer; TES backs up the installed cooling system. TES options available in the market today utilise- (1) Chilled water, (2) Ice storage[6], (3) Phase changing material (PCM), and (4) Molten salt energy storage. Most thermal energy storage systems are partial storage systems. This implies that thermal storage capacity accounts for about 30% of the total cooling required. This reduces the required floor space to about 0.25% of the conditioned space (Bijli Bachao 2015). TES is commercially established in India and is utilised as a demand side management (DSM) tool by Tata Power. Tata power offers its commercial and industrial consumers incentives for using TES and launched the first of its kind TES incentive programme under its DSM Initiative in 2014 (AICHE 2014; IIFL 2014). It not only helps large consumers meet their peak cooling demand cost-effectively but also enables the utility to manage peak power. TES has been widely adopted in cities, including Delhi. It is reported that installed capacity of TES is about 12 MW in major metropolitans such as Bangalore, New Delhi and Chennai (Calmac 2015). This constitutes only a fraction of peak power demand in Delhi which was all time high at 6934 MW on 08 June 2018 (6% higher from the previous year). As per the information available for the year 2015, that is peak power of 5925 MW (BSES 2015), installed capacity of TES was just 0.2% of the total peak power.

From discussion above it is clear that energy storage has huge potential to solve energy management challenges but also to address air quality to the extent DG set are used in commercial and large residential complexes for thermal comfort. It is proposed that integrated solutions/services, combining electric and thermal energy storage, can be provided by utilities/DISCOMs, energy service companies (ESCOs) etc. with the focus on energy management as well as air quality.

[5]Time of Day (TOD) tariffs are applicable to industrial and commercial users with differentiated tariff structures for peak and non-peak hours
[6]latent heat of fusion of water is used to store energy, with the help of charging fluids/anti-freeze agents added to water

> "Industry experts agree that incremental cost of emission control is comparatively low and is speculated to be INR 5/ bag for cement industry and INR 0.50-0.60/ unit for the power industry".

ANNEXURE 7

Emission Control in Coal Thermal Power Plants

An overview of different emission control technologies available to TPPs is presented in the Figure A7-1 listing two types of technologies: (1) in-situ abatemnt technologies and (2) post-combustion abatement technologies. In-situ abatement technologies involve plant modifications in order to ensure more efficient burning of fuel and include change in boiler deisgn, e.g. Fluidised Bed Combustion (FBC), limestone injection, Over Fire Air (OFA), low-NOx burners, flue gas recirculation. Post-combustion abatement technologies include Flue Gas Desulphurisation (FGD); selective catalytic/non-catalytic process for NOx reduction; and PM control options (ESP, bag filter and wet scrubber). High upfront capital requirement has been a major impediment for installation of emission control systems in addition to other factors described below. It has been established that health benefit far overweighs these investments in clean technology (CSTEP 2018). Industry experts agree that Incremental cost of emission control is comparatively low and is speculated to be INR 5/ bag for cement industry and INR 0.50-0.60/ unit for the power industry.

Figure A7-1. Available Technologies for Control of SOx, NOx and PM Emissions in Coal-Based Thermal Power Plants with Respective Control Efficiencies

	In-situ abatement			Post-combustion abatement		
SO_2 Control Technologies	Fluidised Bed Combustion (FBC)	Circulating FBC	90-95%	Flue Gas Desulphurisation (FGD)	Seawater FGD (Seawater-based)	≤ 90%
		Bubbling FBC	70-90%		Semi-dry FGD (Lime-based)	≤ 94%
		Dry Sorbent Injection	55-60%		Wet FGD (Limestone-based)	≤ 98%
NO_x Control Technologies		Low-NOx Burner	30-40%		Selective Catalytic Reduction (SCR)	80-95%
		Over Fire Air	20-50%			
		Flue Gas Recirculation	20-50%		Selective Non-Catalytic Reduction (SNCR)	30-50% 50-70-% (FBC)
PM Control Technologies					Electrostatic Precipitator (ESP)	96.5%
					Fabric Filter	99.6%
					Wet Scrubber	98.5%

Source: Adapted from CSTEP (2018), Tata Power (2017), CPCB (2012), IFC (2008) and Word Bank (1998)

ANNEXURE 8

Coal Thermal Power Plant Units within 300 km of Delhi

S. No	Thermal Power Station	State	Plant operator & owner	Installed Capacity [MW]	Technology	Unit number	Installed Capacity [MW]	Year of commissioning	Phase out date	MOEFCC Directions (December 2017)			Fly ash utilisation
										FGD upgradation	NOx upgradation	ESP upgradation	
1	BTPS Badarpur, New Delhi	Delhi	NTPC	720	Subcritical	1	95	1973	Jul-2018	...	...	...	100%
						2	95	1974	Jul-2018	...	...	...	
						3	110	1975	Jul-2018	...	...	...	
						4*	210	1978	Jul-2018	...	...	...	
						5*	210	1981	Jul-2018	...	...	...	
2	Rajghat TPS, Delhi		IPGCL	135	Subcritical	1	67.5	1989	Closure report submitted	...	...	...	N.A.
						2	67.5	1990		...	...	...	
3	NTPC Dadri, Dist. Gautam Budh Nagar	Uttar Pradesh	NTPC	1820	Subcritical	1	210	1991	...	Dec-2019	Dec-2019	Immediate	100%
						2	210	1992	...	Dec-2019	Dec-2019	Immediate	
						3	210	1993	...	Dec-2019	Dec-2019	Immediate	
						4	210	1994	...	Dec-2019	Dec-2019	Immediate	
						5	490	2010	...	Dec-2019	Dec-2019	Immediate	
						6	490	2010	...	Dec-2019	Dec-2019	Immediate	
4	Harduaganj Thermal Power Station (HTPS), Harduaganj, Aligarh		UPRVUNL	610	Subcritical	7*	110	1978	Dec-2022	...	...	...	
						8	250	2012	...	Dec-2019	Dec-2019	Immediate	
						9	250	2013	...	Dec-2019	Dec-2019	Immediate	
5	Rosa Thermal Power Plant (RTPP), Shahjahanpur		RPSCL; Reliance Power	1200	Subcritical	1	300	2010	...	Dec-2021	Dec-2022	...	71%
						2	300	2010	...	Dec-2021	Dec-2022	Dec-2021	
						3	300	2011	...	Oct-2021	Dec-2022	Dec-2021	
						4	300	2012	...	Oct-2021	Dec-2022	...	
6	Panipat Thermal Power Station (PTPS), Panipat	Haryana	HPGCL	920	Subcritical	1	110	1979	Closed	...	...	...	100%
						2	110	1980	Closed	...	...	...	
						3	110	1985	Closed	...	...	...	
						4	110	1987	Closed	...	...	...	
						5*	210	1989	Dec-2018	...	...	...	
						6	210	2001	...	Dec-2019	Dec-2019	...	
						7	250	2004	...	Dec-2019	Dec-2019	Dec-2019	
						8	250	2005	...	Dec-2019	Dec-2019	Dec-2019	
7	Rajiv Gandhi Thermal Power Project (RGTPP), Khedar, Hisar		HPGCL	1200	Subcritical	1	600	2010	...	Dec-2019	Dec-2019	Dec-2019	92%
						2	600	2011	...	Dec-2019	Dec-2019	Dec-2019	

[7]APC is 50% NTPC, 25% HPGCL and 25% IPGCL

S.No	Thermal Power Station	State	Plant operator & owner	Installed Capacity [MW]	Technology	Unit number	Installed Capacity [MW]	Year of commissioning	Phase out date	MOEFCC Directions (December 2017)			Fly ash utilisation
										FGD upgradation	NOx upgradation	ESP upgradation	
8	Indira Gandhi Super Thermal Power Project (IGSTPP), Jharli, Dist. Jhajjar	Haryana	Aravalli Power Corporation (APC)[7]	1500	Subcritical	1	500	2010	...	Dec-2019	Dec-2019	Dec-2019	76%
						2	500	2011	...	Dec-2019	Dec-2019	Dec-2019	
						3	500	2013	...	Dec-2019	Dec-2019	Dec-2019	
9	Jhajjar Power Plant (JPP), Khanpur, Dist. Jhajjar		Jhajjar Power, CLP India	1320	Supercritical	1	660	2012	...	Jan-2019	Dec-2019	Immediate	80%
						2	660	2012	...	Jan-2019	Dec-2019	Immediate	
10	Deenbandhu Chhotu Ram Thermal Power Plant (DCRTPP), Yamuna Nagar		HPGCL	600	Subcritical	1	300	2008	...	Dec-2019	Dec-2019	Dec-2019	
						2	300	2008	...	Dec-2019	Dec-2019	Dec-2019	
11	Guru Gobind Singh Super Thermal Power Plant (GGSSTPP), Roopnagar	Punjab	PSPCL	1260	Subcritical	1	210	1984	Dec-2017	...	...	...	167%
						2	210	1985	Dec-2017	...	...	...	
						3	210	1988	Dec-2022	...	...	...	
						4	210	1989	Dec-2022	...	...	...	
						5*	210	1992	Dec-2022	...	...	...	
						6*	210	1993	Dec-2022	...	...	...	
12	Guru Hargobind Singh Thermal Power Station (GHTP), Lehra Mohabbat		PSPCL	920	subcritical	1	210	1999	...	Dec-2019	Dec-2019	Dec-2019	100%
						2	210	1999	...	Dec-2019	Dec-2019	Dec-2019	
						3	250	2008	...	Dec-2019	Dec-2019	Dec-2019	
						4	250	1010	...	Dec-2019	Dec-2019	Dec-2019	
13	Guru Nanak Dev Thermal Plant (GNDTP), Bathinda		PSPCL	440	subcritical	1	110	1974	Dec-2017	...	...	...	100%
						2	110	1975	Dec-2017	...	...	...	
						3*	110	1978	Dec-2017	...	...	...	
						4*	110	1979	Dec-2017	...	...	...	
14	Rajpura Thermal Power Plant (RTPP), Patiala		NPL, L&T	1400	Supercritical	1	700	2013	...	Dec-2019	Dec-2019	Immediate	
						2	700	2014	...	Dec-2019	Dec-2019	Immediate	
15	Talwandi Sabo Power (TSP), Mansa		TSPL (Vedanta)	1980	Supercritical	1	660	2014	...	Dec-2019	Dec-2019	Immediate	
						2	660	2015	...	Dec-2019	Dec-2019	Immediate	
						3	660	2016	...	Dec-2019	Dec-2019	Immediate	

Source: Operators' websites (APCPL 2018, CLP 2018, HPGCL 2018, IPGCL 2018, L&T 2018, NTPC 2018a, NTPC 2018b, PSPCL 2018, Reliance Power 2018, TSPL 2018, UPRVUNL 2018); NRPC (2017); MoEFCC (2017); and CEA (2018)

Notes:

1. MoEFCC (2017) prescribes immediate measures such as installation of low-NOx burners, providing Over Fire Air (OVA) etc. and achieve progressive reduction to comply to NOx emission limit in the stipulated year.
2. Thermal power plant units, marked with asterisk (*) in the table, face the space constraints for installing FGD system and are required to be phased out by 2022.
3. Near-term additional capacity of 2.12 GW is expected in this region. There is a provision of 1320 MW (2x660 MW) under stage –II of HTPS, Harduaganj, including 800 MW capacity high efficiency supercritical thermal power unit is planned by way of simultaneous phasing out of old and less efficient units (unit 1 to 4) at PTPS, Panipat.

ANNEXURE 9

Business Case: Leapfrogging to 50% Biomass Co-firing in Existing Thermal Power Plants

Besides air pollution emanating from large thermal power plants in NW India, a huge quantity of surplus biomass is currently burnt in open fields by farmers as its extraction is not an economically attractive value proposition to farmers. Open burning of surplus biomass is responsible for large scale impact on regional air quality in North India and this issue has been the focus of the CII-NITI Aayog task force report on biomass management. The report (CII-NITI 2018a) suggest a multipronged strategy for managing paddy straw in North West region, including use of biomass in the field for enhancing crop productivity and outside the field for waste-to-energy applications.

A large part of this biomass, especially paddy straw is burnt in fields along with the standing stubble. The practice of stubble burning is not only limited to paddy straw. Significant number of fire incidents are reported this year for burning of wheat straw in April-May across the country, especially in the North-Western region (NASA, 2018). It has, in fact, been estimated that more than 80% of paddy straw (18.4 million tonnes) and almost 50% wheat straw (8.5 million tonnes) produced in the state of Punjab is being burnt in fields (Sidhu and Beri, 2005; kumar et al, 2015). As mapped in Figure 9, a huge amount of surplus biomass is available across North Western states which presents a lost opportunity for improving environmental performance of coal power plants in the region as farm waste is a carbon neutral source of energy. It is estimated that total biomass power potential from surplus biomass in Punjab, Haryana and Uttar Pradesh can fulfil the demand for 50% biomass co-firing in power plants located in a radial distance of 300 km from Delhi. Total 6.375 GWe biomass potential against 50 million tonne surplus biomass in a year is estimated in these three states whereas total installed capacity of active TPP units as mapped in Figure 8 is 14.53 GW. Out of this, 13.15 GW is planned to continue operations after installation of advanced emission controls for SOx, NOx and PM whereas an additional capacity of 2.12 GW is planned to be expanded in near future at two of the existing locations (PTPC Panipat and HTPS, Harduaganj).

Pelletisation is simple densification of biomass involving- shredding, hammering, drying and densification. Final product is compressed biomass in 6:1 ratio compared to original biomass (in the form of bales). Pelletisation enables biomass to be easily transported to the end-users. The surplus biomass needs to be baled in order to be transported cost-effectively to biomass conversion units. Extraction and collection of biomass into bales at the farm requires employing- (1) chopper/shredder or superSMS (attached to combine harvesters for chopping standing stubble), (2) rakers (for collecting straw) and (3) balers (for baling the raked straw). Farmers can offer fields for clearing to the Farmer Producer Organisations (FPOs) or private collection agencies engaged by businesses. To prevent the incidents of stubble burning, Government of India formulated a special scheme on air pollution in 2018 (GoI 2018). The central government scheme subsidises the farm equipment required by farmers in this region for chopping the standing stubble and mulching/collection of surplus biomass/ crop-residues. Under this scheme individual farmers and farmer groups (farmer producer organisations, farmer co-operatives etc.) can avail a capital subsidy of 50% and 80% respectively towards farm equipment for crop-residue management. There are two proven technologies available for energy densification of biomass so that it could be utilised in industry boilers- (1) pelletisation/briquetting of biomass (2) torrefaction of biomass. Surplus biomass is picked from fields and baled for transportation to biomass conversion units where it undergoes physical transformation to more suitable energy carriers. Transformation of biomass bales to two different energy carriers is highlighted in the Figure A9-1.

Co-firing biomass is competitive for plants located in North Western States due to their proximity to origin of surplus biomass from agricultural activities. Major challenge highlighted by various experts and stakeholder in the utilisation of surplus biomass for power generation are- (1) high operational cost of dedicated bio-power plants and (2) the low calorific value of biomass feedstock available for co-firing, especially the paddy-straw 80% of which is currently burnt by farmers in NW India. Based on the inputs provided by solution providers, it is estimated that an equivalent of 18% of the total capital required for setting up dedicated bio-power plants need to be pumped every year in the form of operational subsidies to make the plant operations viable (CII-NITI 2018a). Although, the capital expenditure for torrefaction is much higher, the operational cost is lower compared to pelletisation, mainly because modern torrefaction reactors have been designed to utilise the waste heat (in the form of torrefaction gas) and it is near net zero energy process.

Torrefaction is a thermochemical process involving heating of biomass in the absence of air at 200 to 300° C temperature (Acharya et al 2012). As the volatilisation of biomass takes place in this temperature range, 30% mass of the original biomass is reduced. Torrefaction is near net zero energy process where 10% energy released in the form of a combustible gas (torrefaction gas) is re-utilised in the process for pre-drying the biomass feedstock. In the pre-drying step, free water is evaporated from biomass at a constant temperature of 100 ° C using the torrefaction gas (DTI 2012). Global experience shows us that efficiency of co-firing biomass in large coal-based thermal power plants is much higher than utilising the same biomass in the dedicated bio-power plant with 100% energy supply from biomass (IEA 2013, IEA 2017). Also, incremental investment required for co-fired plants are lower than dedicated bio-power plants which are designed for 100% firing of biomass. As per International Energy Agency, the capacity of biomass co-fired power plants in OECD countries already exceeds the dedicated biomass power plants (IEA 2017). Various benefits of torrefied biomass over traditional biomass pellets are highlighted in Box 4.

TPP units in the region are located far away from pitheads and ports. This leads to very high cost of raw material transportation to these plants. Landed price of domestic and imported coal at TPP in Punjab is as high as INR 4500/ tonne and INR 9000/ tonne[8]. Clean energy cess is charged on coal purchase for power consumption and it has increased eightfold from INR 50/ tonne to INR 400/ tonne presently. It is estimated that the most recent hike in the Clean energy cess from INR 200 per tonne to INR 400 per tonne in 2016 has increased power tariffs by 10-12 paisa / unit (BCG-CII 2017). Also, the freight charges for coal are among the highest in the world. It constitutes about 20-30% of total landed cost of coal for TPPs and rail freight has increased by ~50% over the last 5 years (BCG-CII 2017).

Based on simple energy-mass balance of torrefaction process (i.e. 10% energy reduction and 30%mass reduction), the energy density of biomass increases by ~1.3 in the process. This implies that torrefied paddy straw[9] (GCV=4500 Kcal/kg) nearly exceeds the energy density of domestic bituminous coal used in power plants (~ 4000 Kcal/ kg). Torrefied biomass therefore overcomes challenges of the low energy value associated with traditional paddy straw pellets. Based on estimated capital and operational cost for a typical 200 thousand tonne biomass torrefaction unit[10], the cost comparison of torrefied biomass, biomass pellets including domestic and imported coal based on their energy value is presented in Figure A9-2. Although the capital cost of torrefaction is as much as 3 times higher than traditional pellets, it is cost effective mainly due to high energy value of finished product and near net zero energy process[11].

[8]Based on consultations with power generators in the region

[9]Similarly, the energy value of torrefied wheat straw is estimated to be 4886 Kcal/ kg

[10]The capex for torrefaction unit is INR 207.5 Crore (14% for collection infrastructure) and opex is estimated to be INR 39 Crore out of which 38% is operational expenditure towards biomass collection. The reminder opex is mainly for procurement of the biomass feedstock.

[11]The opex for wheat straw torrefied biomass and pellets is comparatively higher due to higher market value of wheat straw compared to paddy

Box A9-1. Favourable Properties of Torrefied Biomass over Traditional Biomass Pellets

Torrefied biomass has greater bulk density and is more homogenous compared to biomass pellets/ briquettes. Torrefied biomass has combustion characteristics similar to coal and it also looks exactly like coal (is therefore termed as bio-coal alternately) but offers significant environmental advantages over coal and traditional solid bio-fuels due to its improved fuel characteristics such as high energy density, low moisture content, near-zero sulphur content. Additionally, it has water repelling properties which address the storage issues inherent with farm waste. Standard pellet press is utilised to compact the torrefied biomass. Energy requirement for grinding and compacting biomass feedstock reduces significantly (~80%) as a result of torrefaction of biomass. Salient features of bio-coal vis-à-vis coal and conventional solid biofuels are described as below.

- **Enhanced Fuel characteristics**

Due to partial thermal decomposition in torrefaction reactor, energy density of torrefied biomass is higher than conventional solid biofuels i.e. pellets/briquettes (25-30% higher energy density than conventional biomass pellets) (IEA 2013) and is found to be comparable to high grade coal. In a typical torrefaction process, the energy content of biomass is reduced by 10% whereas the mass is reduced by nearly 70% (Acharya et al, 2012). Net effect of this energy conversion is energy densification of torrefied biomass by nearly 1.3 times the original biomass. Also, the moisture content in torrefied coal is lower compared to conventional pellets and briquettes. Torrefaction additionally improves the grindability of biomass rendering it more suitable to co-firing (Rokni et al 2017). Due to these favourable characteristics, up to 50% co-firing with torrefied biomass is possible in thermal power plants.

- **Improved emission characteristics**

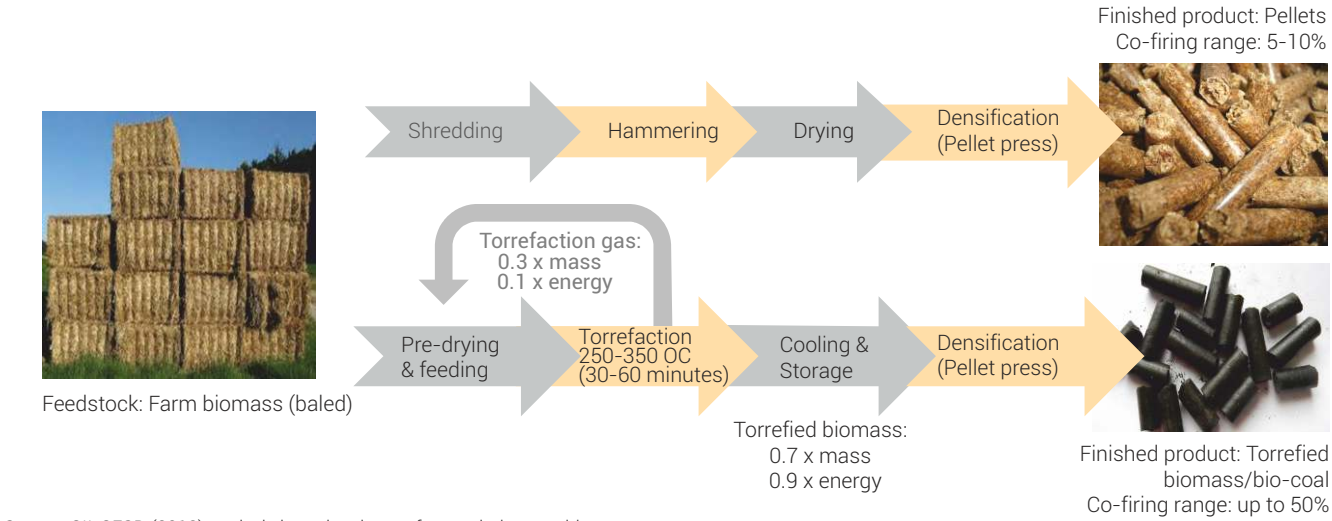
SOx emissions from power plants occur as a result of high sulphur content of coal. Co-firing biomass in general leads to beneficial synergies for SO_2, NOx and HCl emissions depending on the characteristics of individual biomass. Torrefaction process additionally reduces the sulphur (30-80%) and chloride (20-70%) content[12] of the biomass (Rokni et al 2017). An addition to the evident effect of co-firing low-sulphur biomass feedstock with high-sulphur coal, SOx emissions further reduce due to high alkali metal content of biomass that can capture the gas-phase SO_2 heterogeneously in the ash (Rokni et al 2017). Sum effect of all these in turn leads to lower operating cost (lime stone for FGD units) at thermal power plants.

- **Better handling and storage characteristics**

Material characteristics of biomass improve significantly in the torrefaction process. Torrefied coal particles are hydrophobic in nature (i.e. they repel water) compared to biomass pellets/bales which are hydrophilic (Thrän et al 2016). Therefore, unlike straw bales, they are far less prone to degradation from longer storage periods and weather conditions. It is observed that in case of torrefied coal, energy content remains stable even after longer storage periods. Transport and material handling is less expensive and torrefied biomass had longer storage life without fuel degradation.

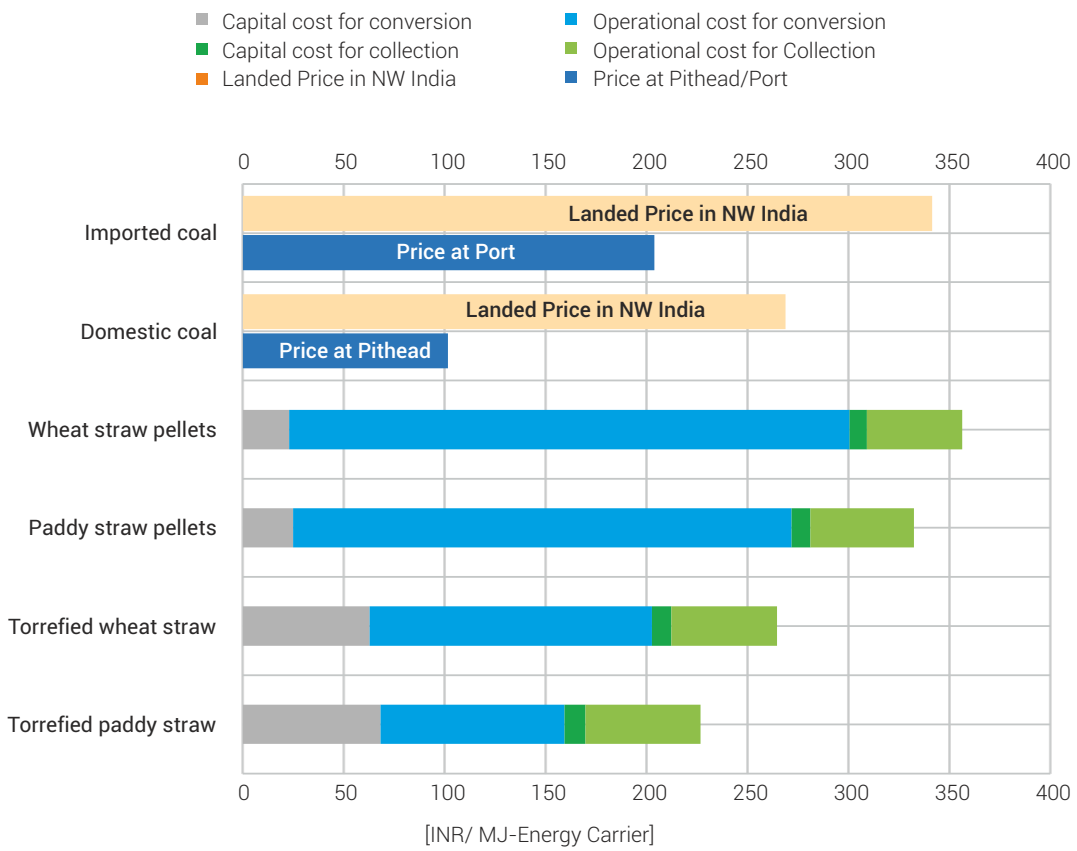
[12]The release of chloride in low-temperature torrefaction reactor is less problematic than inside high-temperature boilers.

Figure A9-1. Pelletisation and Torrefaction Processes Enabling Densification of Biomass for Co-Firing in Existing Power Plants



Source: CII-CESD (2018) analysis based on inputs from solution providers

Figure A9-2. Cost Comparison of Different Energy Carriers for Co-Firing in Thermal Power Plants Based on Their Inherent Energy Value



Source: CII-CESD (2018) analysis based on secondary information and consultation with solution providers

Notes on keys assumptions:

1. Cost of feedstock or farm biomass is assumed to be: INR 1200 / tonne-paddy straw and INR 2000/ tonne-wheat straw. This forms a key component of operational expenditure of biomass conversion units.
2. Capex includes capital cost of collection equipment, torrefaction and densification units
3. Opex includes recurring cost of feedstock, fuel, labour and maintenance
4. Landed price for coal at TPP located in Punjab is used for above calculations: INR 4500/ tonne for domestic coal and INR 9000/ tonne for imported coal. The price of domestic and imported coal in the spot market was found to be INR 1700/ tonne and INR 5376/ tonne respectively. (ET 2017; OGI 2018)
5. Thermal coal with Gross calorific value (GCV) ranging 3400-4600 k Cal/ kg constitutes about 69% of India's domestic coal supply (Coal India, 2018) whereas calorific value (GCV) for imported coal is assumed to be 6300 kCal/ kg.
6. Calorific value of biomass feedstock: paddy straw and wheat straw is assumed to be 3500 and 4000 Kcal/kg respectively

India can leapfrog from 5-10% biomass co-firing to up to 50% biomass co-firing by using proven technology which is commercially established. For this, surplus biomass needs to be seen an opportunity rather than a burden. Opportunity for power generators to utilise low-sulphur biomass feedstock enhancing environmental performance and image of coal power needs to be tapped by a set of more comprehensive policies promoting biomass in existing TPPs. There are multiple benefits of co-firing biomass in existing TPPS units in NW region including-

1. Improved environmental performance and image of TPPs units as biomass is a renewable and carbon-neutral source of energy. Additionally, compared to bituminous coal from domestic sources and high-Sulphur imported coal, torrefied biomass is low-Sulphur fuel. Also, it is established that co-firing leads to positive synergies for NOx reduction in TPPs.
2. It reduced power generators' supply risks associated with the imported coal. Reduced operational cost of compliance to SOx and NOx standards, especially in the case of FDG units for SOx control.
3. India is second largest importer of coal after China and imported about 200 million tonne coal in 2016 (World Coal Association, 2018). Reduced dependence on imported coal is important for national energy security and reducing government's import bill.
4. There are significant costs and emissions involved in transporting the coal from pithead and ports in case of domestic and imported coal respectively. Emission reduction from avoided transportation of domestic and imported coal from pitheads and ports respectively to TPP units in NW India.
5. Coal prices are bound to increase in future whereas in case of torrefied biomass the cost of conversion is only going to come down in future. Investment in torrefied coal technology therefore presents significant opportunities for power generators to reduce the cost of fuel supply.
6. Utilisation of biomass by power producers will result in reduced instances of stubble burning in NW India through utilisation of surplus biomass and associated air quality/health benefits in the region. It will also lead to significant job opportunities in rural NW.

ANNEXURE 10

Biomass Potential Across India's State

Table A9-1. Biomass Generation, Surplus and Biomass-to-Power Potential Across India's States

State	Biomass Generation [million tonne/year]	Biomass Surplus [million tonne/year]	Potential [MWe]
Punjab	50.85	24.84	3172.20
Maharashtra	47.62	14.79	1983.70
Uttar Pradesh	60.32	13.74	1746.20
Haryana	29.03	11.34	1456.90
Madhya Pradesh	33.34	10.33	1373.30
Gujarat	29.00	9.09	1224.80
Karnataka	34.17	9.03	1195.70
Tamil Nadu	22.51	8.90	1160.00
Rajasthan	29.85	8.65	1126.70
Kerala	11.64	6.35	864.40
Andhra Pradesh and Telangana	43.89	6.96	863.30
Bihar	25.76	5.15	641.10
West Bengal	35.99	4.30	529.30
Orissa	20.07	3.68	429.30
Assam	11.44	2.35	283.90
Chhattisgarh	11.27	2.13	248.50
Himachal Pradesh	2.90	1.03	132.60
Jharkhand	3.64	0.89	106.70
Uttaranchal	2.90	0.64	80.90
Jammu & Kashmir	1.59	0.28	37.10
Goa	0.67	0.16	20.90
Manipur	0.91	0.11	14.30
Meghalaya	0.51	0.09	11.30
Nagaland	0.49	0.09	10.00
Arunachal Pradesh	0.40	0.07	9.20
Tripura	0.04	0.02	2.94
Sikkim	0.15	0.02	2.29
Mizoram	0.06	0.01	1.12

Source: Adapted from MNRE-IISc (2004), MoA (2014) and Kumar et al 2015

ANNEXURE 11

List of Stakeholders Consulted

S.N.	Category	Name	Organisation
1	Government & Regulators	Jitendra Kumar	NITI Aayog
2		Sanjay Kumar	NITI Aayog
3		L Gopinath	NITI Aayog
4		Harendra Kharkwal	Ministry of Environment Forest & Climate Change
5		S K Paliwal	Central Pollution Control Board
6		Nazimuddin	Central Pollution Control Board
7		R K Ratra	Punjab Pollution Control Board
8		Vivek Kumar Tripathi	South Delhi Municipal Corporation
9		Vikas Gautam	South Delhi Municipal Corporation
10		Sandeep Kumar	South Delhi Municipal Corporation
11		Shashi B Kumar	South Delhi Municipal Corporation
12		Izhar Ahmed	North Delhi Municipal Corporation
13		R.K Mehta	North Delhi Municipal Corporation
14		BirenderPahil	Municipal Corporation, Faridabad
15		ChanderDutt Sharma	Municipal Corporation, Faridabad
16		Dinesh Yadav	National Highways Authority of India
17	Scientific Bodies	Mukesh Sharma	Indian Institute of Technology, Kanpur
18		N. Gopalakrishnan	CSIR- Central Building Research Institute
19		Anuradha Shukla	CSIR- Central Road Research Institute
20		SoumitraMaiti	CSIR- Central Building Research Institute
21		Neeraj Jain	CSIR- Central Building Research Institute
22	Civil Society	R Suresh	The Energy Research Institute
23	Industry	Sandeep Shrivastava	Ambuja Cement
24		Taruna Saxena	Tata Power
25		K N Rao	ACC Cement
26		Asha Sharma	Shvaas Consulting
27		Gaurav Bhatiani	IL&FS
28		Shantanu Satapathy	CLP India
29		Devendra Mahajan	Supertech
30		Shrenik M Trivedi	Syntron Industries
31		Ajay Kumar	Syntron Industries
32		Anant J Talaulicar	Cummins India
33		Sandeep Sinha	Cummins India
34		Ashish Aggarwal	Cummins India
35		Harsh Doshi	Cummins India
36		Khagender Kumar	Cummins India
37	Confederation of Indian Industry	Seema Arora	Confederation of Indian Industry
38		Sachin Joshi	Confederation of Indian Industry
39		Kamal Sharma	Confederation of Indian Industry
40		Mohit Sharma	Confederation of Indian Industry
41		Priyanka Yadav	Confederation of Indian Industry
42		Punit Agarwal	Indian Green Building Council

Confederation of Indian Industry

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering industry, Government, and civil society, through advisory and consultative processes.

CII is a non-government, not-for-profit, industry-led and industry-managed organization, playing a proactive role in India's development process. Founded in 1895, India's premier business association has more than 9100 members, from the private as well as public sectors, including SMEs and MNCs, and an indirect membership of over 300,000 enterprises from 291 national and regional sectoral industry bodies.

CII charts change by working closely with Government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness and business opportunities for industry through a range of specialized services and strategic global linkages. It also provides a platform for consensus-building and networking on key issues.

Extending its agenda beyond business, CII assists industry to identify and execute corporate citizenship programmes. Partnerships with civil society organizations carry forward corporate initiatives for integrated and inclusive development across diverse domains including affirmative action, healthcare, education, livelihood, diversity management, skill development, empowerment of women, and water, to name a few.

India is now set to become a US$ 5 trillion economy in the next five years and Indian industry will remain the principal growth engine for achieving this target. With the theme for 2019-20 as 'Competitiveness of India Inc - India@75: Forging Ahead', CII will focus on five priority areas which would enable the country to stay on a solid growth track. These are - employment generation, rural-urban connect, energy security, environmental sustainability and governance.

With 68 offices, including 9 Centres of Excellence, in India, and 11 overseas offices in Australia, China, Egypt, France, Germany, Indonesia, Singapore, South Africa, UAE, UK, and USA, as well as institutional partnerships with 394 counterpart organizations in 133 countries, CII serves as a reference point for Indian industry and the international business community.

CII-ITC Centre of Excellence for Sustainable Development

CII-ITC Centre of Excellence for Sustainable Development is a not-for-profit, industry-led institution that helps business become sustainable organisations. It is on a mission to catalyse innovative ideas and solutions, in India, and globally, to enable business, and its stakeholders, in sustainable value creation. It's knowledge, action and recognition activities enable companies to be future ready, improve footprints profiles, and advocate policymakers and legislators to improve standards of sustainable business through domestic and global policy interventions.

CESD leverages its role of all-inclusive ecosystem player, partnering industry, government, and civil society. It has been a pioneer of environment management systems, biodiversity mapping, sustainability reporting, integrated reporting, and social & natural capital valuation in India, thus upgrading business in India to sustainable competitiveness.

With three locations in India, CESD operates across the country and has also been active in parts of South and South East Asia, Middle East, and Africa. It has held institutional partnerships and memberships of the United Nations Global Compact, Global Reporting Initiative, International Integrated Reporting Council, Carbon Disclosure Project, development agencies of Canada, the USA, the UK, and Germany.

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