CAPITAL GAINS

CLEAN AIR ACTION IN DELHI-NCR: WHAT NEXT?

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Editor: Akshat Jain

Design: Ajit Bajaj

Cover photo: Vikas Choudhary

Layout: Kirpal Singh

Production: Rakesh Shrivastava and Gundhar Das

This report was made possible because of:

Bloomberg Philanthropies

The opinions expressed do not necessarily reflect the views of the supporters and funders, nor should they be attributed to them.

Citation: Anumita Roychowdhury et al 2021. *Capital Gains: Clean Air Action in Delhi-NCR: What next?,* Centre for Science and Environment, New Delhi

Published by
Centre for Science and Environment
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CONTENTS

Clean air in Delhi-NCR: Action so far. What next?

After years of battling air pollution, the time has come to assess what has worked, what has not, and what more is needed to clean the air of Delhi and the National Capital Region (NCR). It took a pandemic induced lockdown to once again experience the joys of clean air and blue skies. But lockdowns are not the answer. For post-pandemic transformational changes it is necessary to draw lessons from what it takes to push durable long-term action.

The experience of Delhi and NCR has been unique. Pressure applied by the combined forces of judiciary, executive, civil society, and media has kept this region ahead of others. Empowered public opinion has enabled early adoption of several important local measures as well as catalysed national emissions regulations. This presents a learning curve for other cities and regions—those implementing clean air action plans under the National Clean Air Programme (NCAP) and those with populations of over a million receiving funds for their urban local bodies under the recommendations of the 15th Finance Commission to control air pollution.

Even though the battle against pollution is two decades old in this region, the last five years have proved to be an inflexion point. This period witnessed the generation of more robust scientific information on air pollution, the maturing of several actions initiated over the past decades, and opening up of new policy opportunities to enable the attention this public health crisis deserves.

We have come a long way since the first phase of action began in the late nineties when air pollution was barely understood or talked about. Change was driven by firm support from the Supreme Court in the ongoing public interest litigation on air pollution in NCR and the need to develop strategies for urgent relief from the choking haze of pollution. Public campaigns stoked public conversation. The Environment Pollution (Prevention and Control) Authority (EPCA), that was appointed under the direction of the Supreme Court and set up under Section 5 of the Environment Protection Act 1986, brought scientific thinking and focus to the judicial process providing direction, countering resistance, and pushing implementation.

Twenty years of clean air action in Delhi strategically targeted diesel, coal, other dirty fuels and inefficient combustion to reduce toxic emissions across sectors. The focus was to cut gross pollution from dirty diesel in transport, and coal in power plants and industry. That defined specific actions like shifting of big industries, moving diesel powered public transport and local commercial transport to compressed natural gas (CNG), improving emissions standards, restricting heavy-duty trucks, phasing out old vehicles, banning petcoke and furnace oil. and promoting cleaner fuels in industry, gradual closure of coal power plants, etc.

But the scope and scale of action was asymmetrical across the NCR. Sub-regions of the other three states in NCR—Haryana, Uttar Pradesh, and Rajasthan—were neither prepared to align with the actions in Delhi nor did they have stronger ambitions based on locally appropriate solutions. Nonetheless, this became the first ever experiment in the country to govern air quality at a regional scale with the co-operation of multiple state governments. This is creating the template for harmonized action with inter-state accountability. Getting this right is important for the rest of the country.

The air quality gains from early action were mixed in Delhi. The pollution stabilized initially. But this could not be sustained as the change was overwhelmed by urban growth, motorization, and mushrooming of small industrial units and waste dumps. A bigger load of pollution was being added than the city could remove.

Despite national policies becoming more progressive and comprehensive during the last decade, with emissions regulations becoming stronger for power plants, vehicles, and waste streams, on-ground change was slow. Local institutional mechanisms and systems were not adequately geared up to bridge the gap between policy and implementation. This made frequent judicial intervention necessary.

Navigating the system to force action was a challenge. Nearly all decisions taken and measures proposed faced pushback and derailment. Either the industry resisted the changes or the government was not convinced. The battle in the courts became more protracted and time consuming. But judicial intervention did help to counter pushback so several multi-sector measures could get going. Those impatient with change need to understand this dimension to know why the change was not faster despite judicial support.

Initially, the focus was on issue specific strategies to ensure follow through and implementation. This changed in 2015 when the Supreme Court directed framing of a more comprehensive multi-sector action plan in addition to the Graded Response Action Plan (GRAP) for emergency response during smog episodes. The focus shifted to more composite NCR-wide multi-sector action with time-bound responsibilities as well as emergency measures to respond to the smog episodes during winter. By this time, public conversation had become stronger and sharper in the city and the region. This was further aided by the emergence of new science of pollution source assessment. In 2015, the first source apportionment and inventory study came from the Indian Institute of Technology, Kanpur (IIT Kanpur). The scientific evidence on pollution sources and their relative role was clearer. While this helped to give a bigger push to the ongoing strategies it also helped to frame a more comprehensive approach.

The urgency of change was also driven by mounting evidence on the health crisis. Studies from Chittaranjan National Cancer Research Institute showed every third child in Delhi had weak lungs. Studies from doctors of Vallabhbhai Patel Chest Institute showed children in polluted areas growing up with smaller lungs than those growing up in cleaner environments. State level global burden of disease indicated that health risk from air pollution was among the top three risk factors in the region. This provoked anger and a strong judicial response.

Supreme Court directives during 2016 and 2017 led to the notifications of two seminal plans in the region—Comprehensive Action Plan (CAP) to combat air pollution in Delhi-NCR was issued under Section 3 and Section 5 of the Environment Protection (EP) Act 1986 in 2018 and the Graded Response Action Plan was notified in January 2017 for emergency response. This paved the way for multi-sector strategy across the NCR to move action on vehicles, transport, industries, power plants, and waste. This also led to the implementation of first ever emergency measures that

included temporary closure of industry, brick kilns and stone crushers, stopping of trucks and construction, and odd and even scheme to reduce vehicle numbers during smog episodes.

Within this comprehensive planning approach, specific strategies had to be pursued for real world change. Solutions in each sector were getting more complex in design and scope and support from target groups was becoming more difficult to enlist. Implementing agencies were having a harder time enforcing and institutionalizing change. This called for knowledge building, systemic approach, and improvement in methods of delivery. Nearly each action needed a protracted courtroom battle.

It is this story that other cities and regions need to understand. What it takes to move action and make a difference and what more is needed to get scale, speed, and ambition for change. This is the story of change since 2015, the turning point for second-generation action.

This insight is also important for the next generation of action in Delhi and NCR. In October 2020 a Commission for air quality management in the NCR and adjoining areas was formed for air quality management in the region. This seeks to enhance the role and responsibility of the executive in the matter of air pollution control. The Commission is an executive body that consists of key ministries and state governments with central political oversight.

The real challenge at this juncture is to build ambition and scale of action to push even more difficult and inconvenient solutions to cut particulate pollution by at least 60 per cent. At the same time, it is necessary to ensure that gains made so far are not lost. This review by the Centre for Science and Environment (CSE) aims to build the conversation and propel action around solutions.

Highlights

The next big transition in the region requires access to clean fuel and technology in all sectors; mobility transition to prevent lock in of pollution in the commuting infrastructure; circular economy for resource recovery from waste and to prevent its burning; and addressing the special challenges of an informal economy. At the same time, we need to push for better data and science in the sector. A lot of these measures have been included in the clean air action plans for NCR that are under implementation. While there has been some progress, further refinement has to be made based on the experience and outcome so far. It is therefore important to understand the status of action in each of these sectors to figure out what must happen next. Here is an outline of the sector-wise progress so far, with current gaps and next steps.

Air quality assessment

This region is now better equipped to understand air quality as more granular real time data is available after the expansion of the air quality monitoring network. While Delhi has a dense network, rest of the NCR has also seen some improvement. The available longer term data shows that particulate matter less than 2.5 micron ($PM_{2.5}$)—the more harmful fraction of total particulates and the target of current action—has stabilized and is showing a declining trend. Delhi has seen it drop by almost a quarter. But even after this drop, Delhi has to reduce the three-year running annual average of $PM_{2.5}$ by yet another 60 per cent. This has to guide the level of ambition during this new decade. This report brings out the nature of change in use of diesel and coal and other measures in the city that have contributed to this decline.

Rationalize and expand network of real time monitoring stations in NCR: Delhi has seen significant progress in the expansion of real time monitoring network and has 40 monitoring stations. These now need strong quality control for quality data. However, air quality monitoring is still very limited in the rest of NCR. The network needs to be expanded to improve real time monitoring of regulated parameters across all land uses and pollution hotspots.

Adopt satellite-based monitoring to complement ground-based air quality monitoring: This will address gaps in data in the larger region, including rural and peri-urban areas, to capture the airshed profile and the impact of agricultural burning and other fires. Central Pollution Control Board (CPCB) has already tied up with technical institutions like IIT Delhi to develop satellite-based assessment. This will have to be taken forward.

Explore application of sensor-based monitoring in areas without regulatory monitors: This is expected to be a cost effective strategy compared to the regulatory monitors along with being more efficient in mapping local exposures. But this will require an appropriate protocol for certification of sensors, calibration, operations and maintenance, and quality assurance for credible data. This can be utilized for exposure monitoring and informing local area plans and action. Some cities in NCR like Gurugram have already taken steps in this direction. This will have to be well informed. Currently, Bureau of Indian Standards has set a process to develop a certification process for the sensors. This will have to be expedited quickly.

Pollution forecasting technique may be further strengthened: Adoption of GRAP for emergency response, especially during winter, has been possible due to the System of Air Quality and Weather Forecasting and Research (SAFAR). There is now capability in the region to do pollution forecasting, daily reporting of air quality data based on National Air Quality Index (NAQI), and to inform implementation of emergency measures during smog episodes under GRAP. This system may be further developed for planning advance action during smog episodes.

Public information system and dissemination: The Central Pollution Control Board, as per the National Air Quality Index (a system of grading air quality daily based on its severity that was adopted in 2015), has developed a daily information system to communicate the severity of pollution with colour coded grading. This is publicly accessible. This can be further developed for more targeted communication and wider dissemination through state boards.

Improve pollution source assessment in the region: Over the last five years we have seen progress in multiple source apportionment and emission inventory studies in NCR. While these are indicative of the magnitude and nature of the problem and can ramp up action, a more granular view and more advanced assessment can bring greater precision in decision making. However, future studies may be further refined for better source characterization, estimation of emissions, assessment of regional influence, and impact of secondary pollutants, among others. More innovative approaches and methods of source assessment, including real time source apportionment, have to be adopted to provide more dynamic inputs for policy action. There is a nascent beginning of real time source apportionment initiative. This may be taken forward.

Adopt standardized protocol for analysing real time data to compute annual and daily trends in air quality for reporting compliance with clean air targets of national ambient clean air standards: CSE's assessment of the current practice of air quality trend reporting in India has shown that even today CPCB depends on only the manual monitors under the National Ambient Air Quality Programme to report changes in long term trends. Only for daily reporting it uses data from the real time monitors. There is no established protocol for using the real time data for longer term trend reporting. There is also no protocol for addressing data gaps or missing data with data substitution methods or identification of primary and collocated monitors as the global air quality regulators do. This requires immediate intervention as not only Delhi and NCR but other non-attainment cities under the NCAP will have to begin reporting air quality trends to establish compliance against the NCAP target of 20–30 per cent reduction by 2024. Under the NCAP programme it is the real time monitoring network that is being expanded. This investment will go to waste without a proper protocol for its usability.

Industrial pollution

Mitigation action in the industrial sector shows divergent trends in Delhi and NCR. Delhi has seen more progress but that is partly because a lot of industries could shift out of Delhi to neighbouring NCR while continuing to pollute in the common airshed. Delhi has also taken more active steps to scale up access to piped natural gas in its industrial areas and taken the more ambitious decision of banning coal and other dirty fuels including petcoke and furnace oil. But Delhi continues to face the challenge of regulating and monitoring large numbers of informal small scale units outside the designated industrial areas. Enforcement of clean fuel notification in this sector has remained a challenge.

CSE's review of industrial clusters in the NCR has shown that this region requires diverse strategies to control pollution in the industrial areas. This includes improving stack emissions and access to clean fuels, control of fugitive emissions from material handling and movement of heavy duty trucks, and reduction in open burning of industrial waste.

It is very clear from the regional assessment that NCR needs a massive clean fuel transition to clean up emissions from large numbers of small and medium scale units that are often incapable of installing expensive pollution control equipment. This region cannot meet the clean air benchmark with large scale usage of coal in industries. The last five years have seen evidence based action since the EPCA-CSE study on industrial fuels exposed large scale use of dirty petcoke and furnace oil with high sulphur content and largely without pollution control equipment. That study catalysed the ban on dirty petcoke and furnace oil as combustion fuels in all four states of NCR and the notification of first ever sulphur dioxide (SO_2) and nitrogen oxide (NO) standards for industries.

Going forward, clean fuel strategy will have to be combined with stringent compliance with the emissions regulations while further tightening them. Simultaneously, stringent action needs to be taken on fugitive emissions and pollution from open burning of industrial waste. Moreover, the decentralized small scale high polluters like brick kilns will require special attention. EPCA intervention has led to about 50 per cent of brick kilns in the NCR to convert to improved zig zag technology. It is this comprehensive approach towards controlling stack emissions and fugitive emissions along with clean fuel transition that can reduce industrial emissions. But this requires some urgent steps based on the lessons learnt.

Delhi requires stringent enforcement of approved fuel notification: Even though Delhi has adopted one of the most progressive clean fuel policies, its implementation remains a challenge as entry and illegal use of dirty fuels in informal industry clusters has continued. This will have to be regulated and monitored at the entry level. This will additionally require a siting policy to reorganize the informal sector and control illegal units. It should be made mandatory for all industrial units to display the details of the consent obtained on the premises.

Delhi and NCR need to further expand piped natural gas network and improve gas pressure for quality supply to all industrial units: While sizeable shift to piped natural gas has been achieved in the industrial areas in Delhi, there are concerns around the quality of gas supply in terms of consistent pressure of the gas, etc. This makes further strengthening of the gas infrastructure and and its expansion a necessity. There is also a need for a time-bound plan to expand piped natural gas infrastructure in industrial clusters of NCR and ensure connectivity with all legal units to replace coal. Respective state governments have already integrated this strategy in their larger industrial development policies for the states. This may be further developed for the respective sub-regions of the NCR.

Rationalize natural gas pricing to make it competitive vis a vis coal in Delhi and NCR: CSE review shows that state governments along with the Union government need to harmonize taxes on natural gas within the NCR and also bring it within the GST to lower the overall tax burden on gas. Currently, coal is under GST with lower tax burden. But natural gas is outside the orbit of GST and attracts state value added tax and this has a cascading effect on the final price in NCR. State taxes on natural gas also vary within the NCR with lowest tax in Delhi to highest in Uttar Pradesh. This will have to be addressed immediately. Otherwise, NCR will find it difficult to meet clean air target if coal remains the dominant industrial fuel and that too in small units that are incapable of installing pollution control equipment. Coal import allowed under open general licensing and recent permission for commercial coal mining will bring more cheap and low quality coal in the sector. Immediate steps are needed to bring natural gas within the five per cent GST slab.

Tighten the emissions standards for industrial boilers: The CSE review has also shown widespread use of small, inefficient and highly polluting small industrial boilers. More than 70 per cent of the boilers in NCR are below two tonne per hour and mostly do not have pollution control equipment. Monitoring these numerous small units for compliance is a challenge. Moreover, the norms for boilers are so weak that even compliance is meaningless. The Ministry of Environment, Forest and Climate Change (MoEFCC) needs to finalize the ongoing revision and notify more stringent emissions standards urgently.

Adopt centralized common boiler policy to replace numerous small boilers in the small and medium scale industries across NCR: The problem of small boilers needs more fundamental intervention. Respective state governments need to adopt a common boiler policy for targeted industry areas as much as feasible to replace the numerous small boilers that are extremely inefficient, polluting, and difficult to monitor. Centralized common boilers can serve different units and these can be fitted with pollution control equipment. After EPCA raised this issue with respective state governments, their state pollution control boards agreed to assess this strategy. This will have to be taken forward.

Ensure implementation of SO_2 and NO_x emissions standards notified by MoEFCC on 29 January 2018 for 16 categories of industries as applicable: To address the problem of high sulphur fuels like furnace oil, the Supreme Court had directed the notification of SO_2 and NO_x emissions standards in 34 groups of industries. Out of these, the MoEFCC has notified these standards for 16 categories. But the implementation is still uncertain given the unpreparedness of the industrial sectors. This needs urgent monitoring and time-bound implementation.

Assess the scope of using intermediary fuels to lower emissions: Till the time full transition to gas and electricity as industrial fuel becomes possible, it may be useful to assess the use of intermediary fuels like agro-residue for industrial combustion. In fact, the special drive under GRAP measures that leads to temporary closure of industries using dirty fuels during smog episodes has been one of the catalysts to kindle interest in intermediary fuels. Moreover, the prospect of meeting the SO_2 and NO_x standards has given an extra push to use pellets of biomass as that minimizes such emissions. Even though full emissions profiling of these fuels is still awaited, this is expected to have some benefits. This also has an added co-benefit of absorbing the biomass waste in the region, especially the crop residue that is otherwise burnt.

Promote smart monitoring of industrial stacks emissions with continuous emissions monitoring system and with strong quality control: While the process of installing CEMS in big industries has begun in the region, its quality control and active leveraging for compliance is not ensured. CEMS has to be installed and operated properly for credible and accessible data. The emissions data should be available in the public domain for transparency.

Implement industrial waste management plan to prevent open dumping and burning: The first alarm about large scale burning of industrial waste was raised by EPCA after its field survey in Mundka and Bawana areas where non-usable plastic and rubber waste from the recycling plants was found dumped for open burning. Industrial associations, municipal agencies, and waste disposal agencies were directed to enter into agreements for safe collection and disposal of this waste. Subsequently, CSE carried out more surveys in NCR and found this to be a large scale problem. Waste collection and disposal plans will have to be made mandatory. Implementing agencies, industry associations, and waste disposal agencies will have to be made accountable.

Implement hyper local hotspot action plans for each industry cluster in NCR to control fugitive emissions: Each industry cluster in NCR needs an action plan to control fugitive emissions from material handling and heavy-duty vehicle fleet movement on poorly constructed or unpaved roads in industrial areas. This requires time-bound implementation. EPCA had started this exercise in 13 hotspots in Delhi in 2018 to identify the local sources of pollution for more hyper local action and tracked change over time. This will have to be carried forward.

Mandate all industrial units to prominently display details of the Consent to Operate within their premises to prevent illegal operations: This is urgently needed to stop illegal operations of industries in all land-uses. Both state pollution control boards and the municipal agencies will have to be made responsible for this.

Implement siting plan for industrial units outside the industrial zones for regulations and monitoring: There are large numbers of illegal units operating

outside the industrial areas that do not come under the radar of the SPCBs. A siting plan for such illegal industrial units needs to be prepared for their identification and relocation in designated industrial areas. If they can't be relocated, they should be closed or the areas in which they are located should be designated as industrial areas. These unidentified industries can ruin the entire effort being made in all directions for pollution control.

Dispersed industrial sources like brick kilns in the common airshed need to move to improved kiln technology urgently: Brick kilns are widely dispersed in the NCR. The threat of temporary closure of operations under GRAP during winter had spurred a large number of brick kilns to file an affidavit to EPCA promising to adopt cleaner zig zag kiln technologies. This has led to a conversion of about 50 per cent of the kilns. This is an unfinished agenda and will have to be taken up with zero tolerance.

Power plants

There is a difference in approaches that address coal based power plants in Delhi and NCR. Delhi was able to stop coal power generation completely. The last one to go was the Badarpur power plant which was shut in 2018 after a protracted battle. This also required intervention from EPCA to ensure supply of natural gas at controlled pricing for the new gas based Pragati power plant in Bawana. It is not yet possible to shut coal based power plants in NCR. CPCB has identified eleven coal based power plants that are within 300 km of Delhi and are part of the common airshed. These plants will require stringent time-bound action to meet the 2015 emissions standards. Even though the deadline for meeting the standards was advanced for NCR to 2019, that has also been missed. CSE has carried out a plant-by-plant assessment judging their preparedness to meet the new standards. The progress based on this will have to be monitored diligently.

Delhi has to procure clean power: Delhi may have closed down all coal power plants but it now has to ensure that it procures only clean or cleaner electricity from plants that are meeting the standards or are close to meeting the standards. Currently, Delhi is procuring electricity from some of the dirtier power plants in the country. Delhi has to take the lead to create bottom up pressure by obtaining electricity from plants meeting the new emissions standards.

Delhi must ensure remediation of fly ash ponds: Delhi has to ensure that the legacy fly ash dumps are reclaimed and the land is put to sustainable use, including for solar power generation. This process has started. This will have to be taken forward.

Delhi has to strengthen distribution and transmission network for reliable electricity and eliminate diesel generator sets: Existing infrastructure to supply electricity must be strengthened to prevent power cuts and ensure supply of reliable electricity so that dependance on diesel generator sets can be reduced. DISCOM reforms have to be accelerated to enable this quickly.

While ensuring that only natural gas based power plants operate in Delhi, ensure access to affordable natural gas: Power stations like Pragati 1 should have reliable access to affordable natural gas. Till date these stations are forced to operate below capacity due to high price of natural gas.

In NCR implement new emissions standards before 2022 for coal power plants: The 2015 emissions standards that were advanced for NCR to 2019 will have to be met by 2022. Plants are in varying stages of progress. This will have to be tracked with due diligence. Attempts to dilute the norms will have to be stopped. Each power plant needs to submit a progress report on compliance with the new standards. This should be available in the public domain. Currently, eleven power plants are meeting particulate standards and most of them are on track to meet the NO_x standards. But most plants are lagging behind with regard to SO_2 control. This will require special attention.

Retrofitting old power stations should be decided expeditiously based on techno-economic analysis: Retrofitting old plants should be carried out only if it is cost-effective to retrofit pollution control equipment. Till the time these plants are decommissioned they may also run only on biomass/co-fire biomass as an intermediate strategy to replace coal. This can reduce particulate emissions to some extent and nearly eliminate SO_2 emissions.

Direct the states of Haryana, Uttar Pradesh and Punjab to implement first-run approach to put the more capable plants in the merit order: To incentivize implementation of the new norms, preferential scheduling of electricity from cleaner power stations has to be adopted. Along with renewable energy or must-run plants, a new category of clean coal power plants need to be included as first-run or priority-run plants. Those coal-based thermal power plants which are headed towards meeting the new environmental norms by 2022 need to be given priority for electricity procurement and should be made to run at full load. Others should be kept at the bottom of the merit order dispatch. Decision on old units at PSPCL Ropar, Panipat TPS (HPGCL), NCTPP Dadri – Stage 1, and Guru Hargobind TPS (GHTP Lehra Mohabbat) must be expedited.

Revise the penalty for non-compliance with the 2022 deadlines for strong deterrence: A deterrence mechanism which includes drastic punitive measures such as levying of fines or closing down non-complying plants is neither effective nor practical. Preferential scheduling on the other hand could serve as an incentive to stations which are advanced in the direction to meet new norms.

Vehicle technology and fuel quality

Action to improve vehicle technology and to contain dieselization of car segment has been hotly contested over two decades. This had its origin in decisions to control toxic diesel emissions from diesel run public transport and commercial vehicles as well as heavy duty diesel trucks. This action, which was strongly supported by the Supreme Court, replaced diesel public transport fleet and local commercial fleet with CNG. The ambit of this was expanded to the NCR region as well at the end of the last decade. Diverse strategies were adopted to control emissions from trucks, including construction of two bypass expressways to divert truck traffic, imposition of environment compensation charge (ECC) on each truck entry, and restriction on entry of ten-year-old trucks into Delhi. At the same time, environment pollution charge has been imposed on diesel cars with more than 2000 cc engines and air ambience cess on each litre of diesel fuel sold in Delhi. National Green Tribunal (NGT) has also banned ten-year-old diesel vehicles. Tightening of action on diesel vehicles and constant pressure from the Court also contributed to the national level

decision to move directly from Bharat Stage IV (BS IV) emissions standards in 2017 to BS VI emissions standards and equivalent clean fuels in 2020.

This development was further facilitated by the affidavit that the Ministry of Petroleum and Natural Gas (MoPNG) had submitted to the Supreme Court committing to nation-wide introduction of 10 ppm sulphur fuels and its early introduction in Delhi and NCR. This catalysed the decision to simultaneously introduce BS VI compliant vehicles by 2020. Additionally, during this time, CSE had also reviewed the European Euro VI emissions regulations that were further reformed following the emissions fraud episodes of diesel gate globally. This demanded early alignment of Indian BS VI regulations with the European reform packages to ensure adoption of requirements related to the real world emissions monitoring. This matter was discussed in the Supreme Court following the EPCA report on the matter. Despite initial resistance from the automobile industry to the test procedures related to real world emissions regulations, the industry finally committed to it. In view of all these developments, the next steps in the region are the implementation of more advanced on-road emissions management systems to maximize emissions gains from the new technology and from phasing out of older technologies. Series of directives have come from the Supreme Court on this matter that need implementation.

Strengthen periodic auditing of Pollution Under Control (PUC) centres and calibration of equipment and third-party checks: PUC centres have to be reformed for authentic and reliable testing of on-road vehicles and upgraded to test BS VI compliant vehicles. Ongoing linkage of PUC centres with NIC VAHAN server needs to be accelerated to eliminate manual intervention in PUC testing as quickly as possible. It has to be ensured that all vehicles obtain valid PUC certificates which are linked with annual vehicle insurance. Visibly polluting vehicles should be penalized. All transport departments need to roll out periodic audit and inspection of the PUC centres to prevent fraudulent practices. Simultaneously, remote auditing system needs to be developed based on the centralized database.

Vehicle labelling or sticker programme to identify old and polluting vehicles: Hologram based stickers indicating the fuel and vintage of vehicles should be used as directed by the Supreme Court for Delhi and NCR. This is needed to enable easy recognition of types of vehicles for implementation of emergency action to restrict polluting vehicles, if needed, or to ensure all mandated old vehicles have been phased out. While Delhi government has begun the implementation process, the rest of the NCR has yet to take this forward.

Upgrade PUC system to adopt checklist for inspection of advanced emissions control systems in BS VI vehicles to prevent tampering: Learning from global experience it is necessary to put in place a strong surveillance system to ensure that advanced emissions control systems in diesel vehicles, including catalysed particulate filter and selective catalytic reducing system (SCR) for NO_x control, are not tampered with. As operation and maintenance of these systems adds to the operational cost of the vehicles, it creates an incentive for tampering. The PUC centres will have to be equipped with the ability to conduct basic physical checks to catch such tampering. Otherwise, there can be uncontrolled emissions even after making huge investments in BS VI technology.

Coordinate with oil companies to ensure easy availability of autograde urea for diesel vehicles fitted with SCR system for NO_x control: Work with oil companies to build supply network for autograde urea solution for the SCR system in BS VI vehicles.Also ensure adequate network for supply and dispensation of certified autograde urea is in place across Delhi and NCR for the big diesel vehicle owners.

Integrate on-board diagnostic (OBD) system fitted in new vehicles with vehicle inspection: Since 2013 new vehicles have to be fitted with OBD—a self-monitoring system in vehicles that tracks all anomalies including emissions and alerts the driver through a malfunctioning light on the dash board. This requires detailed scanning of OBD in a workshop to rectify any problem. As per the advisory issued by the Ministry of Road Transport and Highways (MoRTH), PUC centres have to check for the malfunctioning indicator light (MIL) on dash boards of vehicles. If the light is found on, vehicles are to be sent back for testing in authorized workshops. Now it is important to take another step forward to equip PUC centres to check if the OBD is functioning properly or if it has been disabled. If OBD is not working it will be difficult to catch several anomalies or cases of tampering with the emissions control systems.

Modern centralized vehicle inspection centres: Yet another development in the region is the development of a state-of-the-art centralized annual fitness and road worthiness test centre for commercial vehicles in Juljuli. This centre and the one in Burai should also be modernized to cater to larger commercial fleets for more thorough fitness checks. This also has the scope to advance emission testing in these vehicles and minimize corruption. State governments have to ensure that all commercial vehicles go to these advanced centres.

Remote sensing or on-road emissions screening of vehicles: A noteworthy development in Delhi during the last five years is the move to introduce a more advanced on-road emissions screening system with the help of remote sensing devices. The pilot scheme on remote sensing of vehicles was implemented by International Centre for Automotive Technology (ICAT). Based on this pilot and EPCA's review, the Supreme Court has already directed MoRTH to amend the rules under the Motor Vehicle Act to enable nation-wide implementation. The Delhi government has also been directed to implement this programme. Delhi and the key cities of NCR may devise a plan to implement this strategy which is more appropriate for the new generation of vehicle technologies for which PUC will not suffice anymore.

Action on freight traffic to cut down toxic diesel emissions: One of the most protracted battles started in 2001 when the Supreme Court issued directives to make truck traffic bypass Delhi. A CSE survey conducted in 2015 at 13 key entry points in Delhi showed that a much larger number of trucks enter Delhi than is shown by the estimates available from various municipalities. It also emerged that the municipal toll was lower than the toll rate of some of the bypass roads around Delhi and that created an added incentive for the truckers to transit through Delhi. After EPCA shared this evidence with the Supreme Court, environment compensation charge was imposed on each truck entry daily and restrictions were placed on entry of non-destined trucks and 10-year-old trucks into Delhi. To stop corruption, RFID system

was installed at the entry points for electronic monitoring and cashless collection of ECC. This has made real time tracking of truck entry possible. A dedicated fund has been created from the ECC collection that is now available for air pollution control in Delhi. In the next phase this will have to be scaled up to all the 127 entry points in Delhi with strong monitoring to prevent leakages.

NCR cities will also require a well thought out strategy to address heavy duty traffic by rationalizing movement patterns, routes and logistic infrastructure, spacing of warehouses/wholesale marts, entry points, and timing. Truck rest areas/parks along national and state highways will have to be provided to prevent entry of trucks into cities during day time or peak hours. Wherever possible, local trucks can shift to LNG/CNG. Even targeted electrification of the commercial fleet is possible. Off-peak passenger travel times should be used to move freight. Entry of heavy vehicles into cities during the day should continue to be restricted. National permits must not be misused for local operations. Fitness and road worthiness of trucks and compliance to set standards has to be ensured. Weigh in motion bridges have to be installed at all entry points to control overloading.

Expand compressed natural gas programme in NCR: The Supreme Court has already directed expansion of CNG programme in the NCR and requisite infrastructure is being laid out. This will have to be done quickly to remove diesel commercial vehicles, including diesel autos, from the region. This will require harmonization of state taxes on CNG across NCR to keep it affordable and prevent distortions in the market.

Scale up H-CNG programme: The pilot scheme carried out by the IOC R&D Centre in Delhi has demonstrated that mixing hydrogen with CNG (up to 18 per cent) while fuelling vehicles can improve emissions appreciably. All emissions parameters improve compared to standard CNG except NO_x which remains the same. This strategy based on in-situ hydrogen reforming at the CNG centre for pre-mixing is important to further clean up the BS VI compliant CNG buses. This programme will have to be scaled up.

Scrappage policy for old vehicles: Following the directives from the National Green Tribunal, Delhi has initiated a massive phase out programme for old vehicles and end-of-life vehicles. Ten-year-old diesel vehicles and 15-year-old petrol vehicles are not allowed in Delhi. But this will also require infrastructure for safe scrapping and disposal and for material recovery. Delhi has already adopted scrappage policy and started the process of setting up proper infrastructure. Similar policies are needed in the NCR to ensure that end-of-life vehicles are not dumped in a way damaging to the environment and reusable resources are recovered. This will also require integration of informal recyclers and proper support for infrastructure to prevent harming of environment from unsafe disposal.

Installation of vapour recovery systems in refuelling outlets to reduce benzene and VOC emissions in cities: Considerable effort has been made in Delhi to comply with the directives by installing vapour recovery systems in fuel outlets that reduce benzene and VOC emissions. Additionally, NGT has given direction for installation of Stage I and Stage II vapour recovery systems in all new retail outlets with capacity 300 KL MS per month in cities with population more than one lakh. CPCB has

issued direction for installation of Stage I and Stage II vapour recovery systems in all retail outlets. This needs to be implemented across entire NCR. High VOC emissions are harmful and extremely toxic.

Electric vehicles

To curb vehicular pollution and toxic exposure in Delhi and NCR, it is proposed that a mandate for electrification of targeted vehicle segments is implemented in a time-bound manner for sizeable shift to zero emissions vehicles and e-mobility.

Delhi to implement its notified policy on electric vehicles in a time-bound manner: Delhi has already notified its policy to achieve 25 per cent electrification of new fleet by 2024 and detailed out the enabling strategies. Each milestone will require time-bound implementation to meet the target. Key elements of the policy like targeted electrification of different vehicle segments, setting up charging infrastructure, and reform of taxation to cross subsidize the programme will also require time-bound implementation. Each element will require rigorous tracking to ensure progress.

In Delhi, the current cap on auto-rickshaw numbers and registration may be relaxed in a phased manner with all new replacements and additions to be of e-rickshaws. The policy target in Delhi is to make 50 per cent of all new city buses (including DTC and cluster services) e-buses. All government owned cars and leased/hired cars for government uses are targeted to be replaced with e-cars. All new metro feeder buses are to be deployed as e-buses. Delhi EV policy also targets to convert all delivery fleet (aggregators like Zomato, Swiggy, Amazon, etc.) by 31 March 2025.

Other state governments in the NCR need to implement a comprehensive electric vehicle policy: Some of these states are working on state level policy but their regions within NCR will require special focus. This will require a timeline and mandate for vehicle segment-wise electrification; provision of infrastructure for charging and amendment of building byelaws and design code with dedicated metering system to integrate changes for vehicle charging; and incentive structures and charging enabled parking areas. A policy for safe disposal of batteries as per the Waste Management Rules 2016 issued by MoEFCC should also be implemented. Incentives/schemes such as road tax rebate, concession on charges, credit on transition to EV, etc. should be made available to IPT owners to ease transition from ICE vehicles to EV.

While all NCR states need to adopt electric vehicle policy for the NCR sub-regions, a specific mandate with targets may be notified for public transport and para transit. NCR cities like Gurugram, Faridabad, Noida, and Gaziabad that have dedicated bus services or are planning to introduce such services need to set a target for electric bus procurement. Keeping in view that para transit is the dominant form of public transport in smaller towns of NCR, a targeted electrification of this segment is needed. This target should be combined with a complete phase out of diesel autos from the region. All state governments need to frame their respective plans indicating the target and timeline for these vehicle segments. Supportive action in terms of incentives, tax measures and charging infrastructure may be planned and implemented accordingly. Financing strategy for electric vehicles, addressing barriers to charging, appropriate electricity tariff, and registration process will have to be streamlined.

Transport and mobility

It is clear that vehicular pollution in Delhi and NCR cannot be addressed if overall traffic volume is not controlled, vehicle miles travelled are not reduced, and vehicle restraint measures are not scaled up across the region. This will require well-integrated public transport options, accessible streets for walkers and cyclists, and very efficient last mile connectivity based on feeder services and intermediate public transport. This will have to be supported by restraint and demand management measures, transit oriented development, and compact urban form for redevelopment and new development.

The region is locked in car centric development and any hard measures to develop public transport, walking and cycling infrastructure, or any car restraint measure, face resistance from the car owning minority. This sector will require transformative changes to meet the overall target of at least 80 per cent public transport ridership by 2025 in Delhi and across the urban NCR. This will require different approaches for big cities and smaller towns.

Delhi bus service reforms to be accelerated: CSE review has shown how bus ridership in Delhi has declined steadily since 2014 and bus procurement has been considerably delayed in Delhi and needs to be accelerated. While bus numbers fall woefully short of the court mandated 10,000–11,000 buses, there is also a huge service deficit. However, reforms have started to rationalize the routes and improve tracking of services, along with increasing use of electronic ticketing systems and public information system. But after the massive disruption caused by the pandemic, there is need for a bailout and recovery package for the buses to not only recover from pandemic but also to overcome the legacy challenge. Reliable bus service with adequate frequency has to be ensured—at least 10 minutes headway, accessible within 200 meters of all neighbourhoods. Bus priority lanes have to established, along with monitoring of all service level benchmarks. Bus service will also have to be well integrated and aligned with other services.

NCR cities need to ensure time-bound augmentation of city bus services: Most NCR cities barring Gurugram and Noida do not have dedicated city bus services. This requires an immediate plan for intra-city services in cities and an implementation strategy. This will have to be guided by the service level benchmark of Ministry of Housing and Urban Affairs to decide fleet size and network for adequate city penetration**.** Transit infrastructure like depots, terminals, bus queue shelters, etc. needs to be built in a phase-wise manner. GPS, Public Information System (PIS), etc. should be put to use to manage the services, locate buses, and also to make buses more attractive to commuters. Electronic Ticketing Machines should be used for ticketing purposes where possible.

Speed up multi-modal integration (MMI): Delhi is already implementing multi-modal integration of 69 metro stations for convenient interchange, easy transfers and improved last mile connectivity. When EPCA was monitoring this, about 69 metro stations were selected for this implementation and work on 14 had started. This needs to be scaled up for the entire network. It has been estimated that after the complete implementation of the metro network, 80 per cent of Delhiites will be living within 400 meters of some metro station. Therefore, multi-modal integration with convenient access can increase usage of public transport appreciably.

Reorganization and augmentation of intermediate public transport in Delhi and NCR: There is a strong role for autos and taxis to play in this region for efficient connectivity. Ride sharing and hailing are now widely available and there is a system for their deployment. There is now considerable focus on the augmentation and deployment strategy for autos to meet the travel demand and provide last mile connectivity that buses and metro cannot provide. But auto rickshaw numbers were frozen in Delhi in the late nineties to control pollution when these were two-stroke powered and were running on diesel. Even though the cap has been raised a bit its waiver is being discussed. This is an opportunity to link their augmentation with electrification to make them zero emissions. E-rickshaw service will also have to be integrated with this strategy.

In NCR a detailed strategy is needed for augmentation of IPT and auto services. This service is more appropriate for smaller towns and cities that cannot have metro or a big bus programme given the lower volume of travel demand and short travel distances. High frequency and low occupancy services of these vehicles will be more appropriate for these towns and smaller cities. They will require rationalized route networks for connecting residential areas to important nodes (transport nodes, shopping areas, or other areas with high footfall), well planned dedicated parking and pick-up and drop-off points for IPT, and well organized shared IPT/autos with specific routes, fares and carrying capacity, and clean fuels. GPS should be installed in autos for monitoring and enforcing safety standards. This will require planned electrification and complete ban on diesel autos in the entire NCR.

Build adequate street network that is walkable, cyclable, and provides safe mobility for all road users: The clean air action plan for Delhi-NCR has provided for an extensive network for walking and cycling. All major arterial and sub-arterial roads should be redesigned to have dedicated/protected space for walking and cycling. Earmark street vending activities with respect to complete street principles and universal accessibility. For street design, refer to Design Standards of Indian Road Congress (IRC): 103-2012, or improved draft IRC code on road design, or any other adopted standards and good practices. Street Design Guidelines document in Delhi, published by UTTIPEC, needs to be mandated. Delhi has started the process of redesigning roads. This will require zone-wise network plans for implementation. Similar approach is needed in NCR towns. There is some progress in Noida and Gurugram. But this will require massive scale of operations. Only a few corridor based approaches will not suffice.

Scale up pedestrianization in high footfall areas to create low emissions zones: Delhi has to stay on course with its policy of pedestrianization of key commercial streets and areas. This has already been implemented in Ajmal Khan Road in Karol Bagh and in Chandni Chowk. About 21 streets have been identified for this purpose. But there are reports that pedestrianization of Ajmal Khan Road is being rolled back after successful implementation. Municipalities will have to be made accountable and penalized for such violation and deviation from the programme. Other NCR cities and towns need to create a comprehensive list of high footfall areas and streets for planned pedestrianization, to restrict movement of vehicles, to and increase connectivity with electric vehicles. This is needed to create low emissions zones in the city.

Implement city-wide Comprehensive Parking Policy and Parking Area Management Plans (PAMP): Parking policy as a demand management and vehicle restraint measure was first taken on board by the Supreme Court in 2006 following the recommendations from EPCA. But it has been difficult to get the government to accept the restraint principle. This required consistent engagement and knowledge building. Over the past decade CSE has carried out several assessments of the parking challenges and strategy in Delhi to highlight how this can be designed as a demand management and vehicle restraint measure. In 2019, Delhi was the first city to notify parking rules as a demand management and restraint measure. Based on this and under the directive of the Supreme Court, three pilot projects were implemented in representative land use areas—Lajpat Nagar, Kamala Nagar, and Krishna Nagar. Based on the outcome, in August 2020, the Supreme Court further directed Delhi government as well as the NCR governments to implement the parking area management plans city-wide and NCR-wide. This will have to be expedited immediately.

The rules have asked for PAMPs zone/ward wise to physically identify, demarcate, and delimit on-street and off-street parking based on local area assessment. This has to ensure no parks and green spaces are converted into parking and all streets have at least one lane that remains free of encroachment all the time for free flow of traffic, especially emergency vehicles. It asks for strict fines for illegal parking of vehicles in non-designated areas and variable parking fees as per the location and time duration in all commercial and mixed use areas. In areas where both on-street and off-street parking is available, on-street parking charge should be higher than off-street parking charges to maximize use of multi-level car parks. This opens up the possibility of residential parking permits. This will also require commuter information system on availability of parking spaces in off street parking facilities and identification of streets for parking/night time parking of commercial vehicles.

If this is implemented on an area wide basis and across all municipal wards the parking supply as well as parking demand can be restrained. Implementation faces challenge as there is still resistance to parking charges. This will require strong executive action as well as public support.

Solid waste management and the need for circular economy

Open burning of waste is a serious source of toxic exposure in the region. This remains a challenge despite the series of central rules and regulations that were announced in 2016 with regard to all waste streams—municipal solid waste, plastics, electronic waste, construction and demolition waste, etc. These rules require amendment of municipal byelaws in states and investment in infrastructure for waste management and governance.

Delhi has amended its byelaws but it is yet to implement them. All three municipalities will have to scale up infrastructure for decentralized waste segregation, recycling, and composting. This will have to be implemented in each municipal ward with clear milestones to prevent accumulation of waste in the open. This will require systemic reforms. In addition, implementing a comprehensive communication strategy to engage with the individual and institutional waste generators using appropriate IEC tools is the need of the hour. Waste management has to be seen as a shared responsibility and not a challenge to be dealt with technologies alone.

Other NCR cities and sub-regions will require similar systemic reforms. Some of them like Gurugram have started to amend their laws and reform the systems. But all cities need zero landfill policy to minimize disposal of waste in landfills. This

requires a segregated collection system for material recovery from waste for recycling. Dependency on waste to energy plants for energy recovery has to be cut down as without segregation these end up burning mixed waste causing enormous pollution. Waste to energy plants have to be the last resort and that too with a good siting policy to keep them away from habitation including low income neighbourhoods.

Horticulture waste will require composting in all public parks, housing societies, official buildings, schools, etc. Municipalities should provide subsidies to households/ DDA flats/gated societies for adoption of composting/biomethanation technologies for wet waste management at source. Horticultural waste (garden waste) generated in residential and commercial areas and public parks should be segregated and composted in gardens or parks, wherever it is feasible. Waste management is a low hanging fruit but the devil is in the details.

Construction and demolition (C&D) waste

Construction and demolition waste is a special problem in Delhi and NCR given high level of urban construction. Even though Delhi and several other prominent cities of NCR including Gurugram and Noida have started addressing this issue, the attention is not adequate and requires stringent milestones to be set. One of the big hurdles that had to be overcome to push this agenda in the last decade is to get the recycled aggregate from C&D waste legally accepted as a building material. EPCA took the lead to get Bureau of Indian Standars (BIS) to change the rules to allow this. CSE has since then carried out extensive review of C&D waste management in the region.

Delhi and states in NCR have adopted state-wide C&D rules and regulations. Action in Delhi is comparatively more scaled up while substantive action on the ground is sporadic in NCR and limited to a few prominent cities around Delhi including Gurugram, Noida, and Gaziabad. This requires NCR-wide action.

Implement on-site management and segregation of C&D waste: Reduce generation of waste and maximize on-site reuse or recycling and not just collection and transportation to city's recycling facilities.

Implement public information system on collection system: Level of awareness regarding C&D waste rules and services and facilities provided by the urban local bodies (ULBs) is extremely poor among the public and even construction agencies. ULBs need strong public outreach.

Collection and transportation services: Delhi does not offer an affordable on-call C&D waste transportation service to the public like many other cities in the country. There is a very poor public database of empanelled transporters that people can engage to properly dispose of their C&D waste.

Uptake of recycled products: Currently, recycling plant operators have a monopoly over the manufacturing and sale of products made from recycled C&D waste. The plants prefer large scale orders from government agencies. This has limited public access to these materials and also stunted product innovation and development.

Reduce GST rates on recycled products: Products from recycled C&D waste are charged 18 per cent GST, while same products from conventional material are charged only five per cent GST. This is perverse and hinders development of a true self-sustaining circular economy.

Demolition management: Construction and demolition are not well understood separately for policy making. Cities do not issue independent demolition permits nor do they have guidelines to ensure maximum resource recovery and minimum C&D waste generation during the demolition process. Demolition work in the city is dominated by the informal sector with negligible regulation and oversight. This requires separate management of demolition agencies.

Informal sector: There exists a vibrant informal system of salvaging, recycling, reusing, and reselling of building elements and material from demolished buildings. Demolishers salvage valuables like doors, windows, iron, bathroom fittings, and electrical equipment. Interface between formal and informal will have to be strengthened for more cost effective scaling up of operations.

Dust control in construction sites: A Supreme Court order dated 16 December 2015 had directed the Delhi government to ensure measures to mitigate dust pollution on construction sites. A concise checklist for inspection of construction sites has been adopted. This requires stringent implementation. Control measures have to be taken for fugitive emissions from material handling and conveying and screening operations through water sprinkling, curtains, barriers and dust suppression units. Penalties should also be enhanced. It should be obligatory on part of the developers to provide evidence of debris disposal at designated sites. Recycling of construction material has to be promoted. Provisions of central regulations for construction and demolition waste need enforcement. Municipal bodies, PWD, CPWD, DSIIDC, DTTDC, and road owning agencies will have to address this.

Eliminate solid fuels for household cooking

It has been well established by multiple source inventory and apportionment studies that solid fuels for household cooking and in open eateries are sources of enormous exposure. The committee report on air pollution and health released by the Union Health Ministry in 2015 had estimated that household pollution can contribute upto 30 per cent of outdoor air pollution. Action on household use of solid fuels has not been part of the Supreme Court led action. This was addressed through other mechanisms. It started with the kerosene free scheme of Delhi government around 2012–13 that led to distribution of LGP to poor households in Delhi. Subsequently, this further expanded under the central government scheme of Ujjwala and Pahal in the larger NCR. Even though officially there is 100 percent coverage of households, the problem persists among low income groups and migrant populations. The bigger challenge is to ensure refill and reliable access to LPG, especially in the rural areas that arepart of the common airshed.

The new affordable housing typologies including rental and dormitories in cities need to be equipped with clean cooking systems for the migrant and floating population to use. More strategic intervention is needed to eliminate solid fuel in NCR. Moreover, it has to be strictly ensured that all open eateries have access to LPG and electricity. This should be linked with their commercial license. Delhi has banned use of dirty fuels in eateries except charcoal in tandoors but with some pollution control effort.

Crop fires

The episode that keeps the public conversation on air pollution alive in the region is the swathe of smoke plume from burning crop residues after harvests in the neigh-

bouring states of Haryana, Uttar Pradesh, and Punjab that contribute to winter smog episodes. Over the last few years the central government, along with the state governments, has developed several plans to control this. But it is a daunting challenge to coordinate with millions of farmers to scale up the solutions.

The plans include in-situ mulching and composting of straw and ex-situ value addition by making other products with straw. For in-situ measures, sufficient numbers of stubble management machines need to be procured and made available for use in the states. it has to be ensured that all small and marginal farmers who cannot buy these machines have access to them through panchayats or other community run centres. Farmers have to be provided assistance for smart straw management. Rental/operational cost rates need to be fixed in such a manner that the cost is minimal for small and marginal farmers. While some progress has been reported a lot more needs to be done.

For ex-situ measures, a strong policy needs to be framed to promote enterprise in the region to absorb the straw as a raw material and create value for the farmers. Some important steps have been taken in this direction in terms of power generation, agro residue based fuel, production of bio-CNG and ethanol, etc. These will require scaling up, along with proper infrastructural support for bailing the straw and collecting and transporting it.

Longer term solutions will emerge only with changes in cropping patterns to reduce acreage under paddy by promoting other locally appropriate crops and reforming the support price structure accordingly. Some reduction in acreage in paddy area has already been reported.

Institutional mechanism and capacity building

A new ordinance was passed in October 2020 to form a commission for air quality management in NCR and adjoining areas. This replaces all other committees and authorities that were set up under judicial and administrative orders. It seeks to limit the role of the judiciary and creates a centralized framework for air quality management in the region. This also seeks to enhance the role and responsibility of the executive in the matter of air pollution control. The ordinance asks for a consolidated approach towards monitoring, elimination of pollution sources, and enforcement. The commission will have the power to coordinate with relevant state and central governments on the multi-sector plans including industry, power plants, agriculture, transport, residential, and construction.

It is not clear how the state governments in the region will exercise power to take decisions on mitigation and set higher level of ambition. As the commission now takes the agenda forward, it would be of interest to know how the executive can push more difficult and complex solutions, speed up sector reforms and investments, and ensure an effective compliance and deterrence framework. This move brings urgent and much deserved attention to the public health crisis. This institutional arrangement is only useful if it succeeds in implementing tougher solutions to clean up the air.

However, the experience of the last five years has shown that while concerned departments in sub-regions of the NCR have started to make progress in their respective sectors, more aligned action is needed to address the gaps in the system and harmonize the ambition level. This will require strengthening of the institutions, capacity building, technical skill building for new generation measures, and empowerment for decision making and enforcement.

Don't lose the gains: Pushback and dilution need to be fought

This review has shown that policies and regulations alone cannot drive ambition in decision making and action on air pollution. Pressure points like judicial directives and public campaigns are very important. But this also creates asymmetry in progress. Each action has to be carefully negotiated in the face of resistance which delays progress and impact. It is also possible that the government cannot work in support of difficult decisions if larger public support cannot be built. This will have to be addressed going forward. After decades of action all soft measures are over. New action is more complex in design, expensive to implement, and demands tougher behavioural change. Therefore, growing awareness about air pollution, and illnesses caused by it, have to work for new generation action.

At the same time, it is necessary to ensure that what has been achieved already is not rolled back and not diluted. There are signs of that happening already. Even before the norms for power plants are implemented there is already demand for their dilution. Pressure is being exerted by calciners and the steel industry for dilution of the ban on petcoke import. There is delay and prevarication on implementation of parking rules and parking management area plans in Delhi and NCR. Pricing of parking mandated as car restraint measure is being resisted. The pedestrianization of Ajmal Khan Road is falling apart. There are fears that even truck rules may slacken. In fact, expansion of the RFID system for collection of environment compensation from incoming trucks has slowed down.

Dilution and slowdown are not an option anymore. What has been achieved cannot be lost while raising the level of ambition, scale, and speed of action.

SECTION 1

Air quality targets and assessment

The big target

Future action in Delhi-NCR will have to be guided by the reduction targets for particulate pollution and other pollutants to be able to meet the national ambient air quality standards. The long term trend shows that Delhi has already bent the pollution curve. The annual level of particulate matter, especially $PM_{2.5}$ that is more harmful and the key target of action now, is declining every year. The rolling three-year averages, a firmer indicator of change, have reduced by about a quarter since 2014–15.

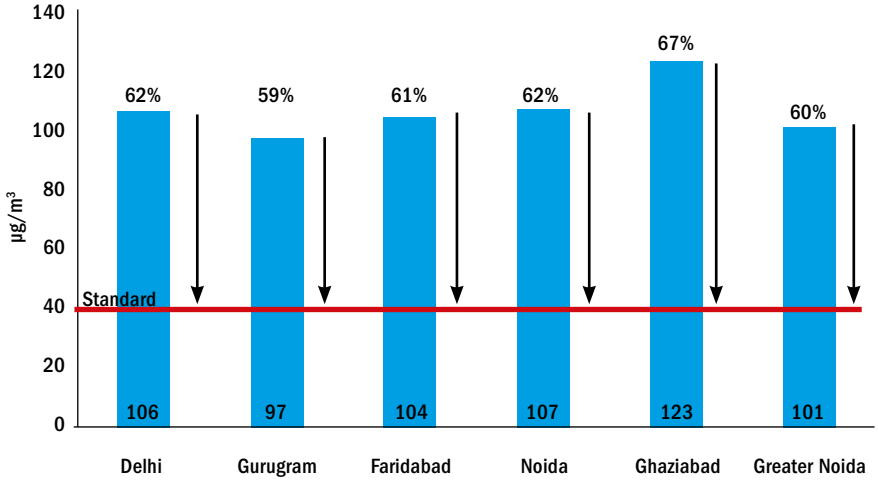
However, even after that decline, Delhi needs more than 60 per cent cut in annual $PM_{2.5}$ concentration to meet the national ambient air quality standards. This has to define the level of ambition and scale and speed of change across the region.

Similar challenges prevail in the big cities of NCR that are also within the immediate vicinity of Delhi. While Gurugram needs 59 per cent reduction, Ghaziabad needs 67 per cent reduction. The range for Faridabad, Noida, Greater Noida, and Faridabad varies between 60 and 62 per cent. The reduction targets in other smaller towns in the wider NCR including Bhiwadi, Alwar, Meerut, Bahadurgarh, Karnal, Rohtak, Panipat, etc.vary between 16 to over 64 per cent (see *Graph 1: Reduction targets for annual $PM_{2.5}$ concentration in six major cities of NCR* and *Graph 2: Reduction targets for annual $PM_{2.5}$ concentration in towns of larger NCR*).

This needs a special rider to put the year 2020 into perspective. Due to the extraordinary situation arising from the COVID-19 pandemic, the levels this year have been substantially low. But with the reopening of the economy the temporary gain was lost due to retaliatory emissions.

Air quality trend analysis is based on data from various government agencies that are available in the public domain. Most granular data (15-minute averages) has been sourced from the CPCB's official online portal Central Control Room for Air Quality Management - All India.[1] This portal analyses data recorded by 79 air quality monitoring stations, or 100 per cent of the current NCR network, under the Continuous Ambient Air Quality Monitoring System (CAAQMS) of CPCB. Farm stubble fire data has been sourced from SAFAR. Weather data has been sourced from the Palam weather station of Indian Meteorological Department (IMD).

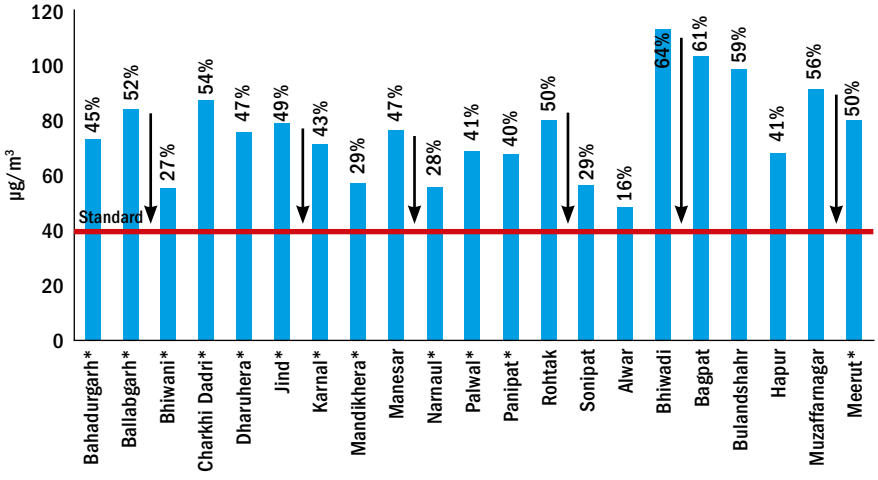
Graph 1: Reduction targets for annual $PM_{2.5}$ concentration in six major cities of NCR



Note: Mean of 3-yr average of all CAAQM stations that have been working in the city since 2018. Data upto 31 Dec 2020.

Source: CSE analysis based on CPCB data

Graph 2: Reduction targets for annual $PM_{2.5}$ concentration in towns of larger NCR



Note: Mean of 3-yr average of all CAAQM stations that have been working in the city since 2018. Data upto 31 Dec 2020.

* Based on 2-year-data

Source: CSE analysis based on CPCB data

Common airshed

The ongoing public interest litigation on air pollution in Delhi-NCR is the first ever instance of regional approach to air pollution mitigation. This is the first ever experiment with devising a common action plan for a region that includes sub-regions of four different state governments. Even though bottom up action in all four states is asymmetrical, this is an opportunity to harmonize action to reduce regional influence on local action in the common airshed. Importance of this approach

has been further reinforced by the studies that have established the movement of pollution between administrative boundaries in the region. Even satellite imaging of pollution underscores the regional build-up of pollution across the region.

In 2018, the NCR-wide study by TERI and ARAI reported that the contribution of NCR to Delhi's particulate pollution can be in the range of 23–24 per cent for $PM_{2.5}$ and 26 per cent for PM_{10}. At the same time, Delhi also contributes to the pollution level of NCR towns. Noida which is downwind from Delhi receives 28 per cent of its pollution from Delhi during summer and 40 per cent of it during winter. Panipat that is upwind from Delhi receives only one per cent of its pollution from Delhi.

This reinforces the fact that multi-sector action has to be equally stringent across the region to minimize regional influence on local air pollution in cities and towns. This is an important lesson to learn for other regions of the country. This approach needs to be explored and strengthened to develop an appropriate regional template.

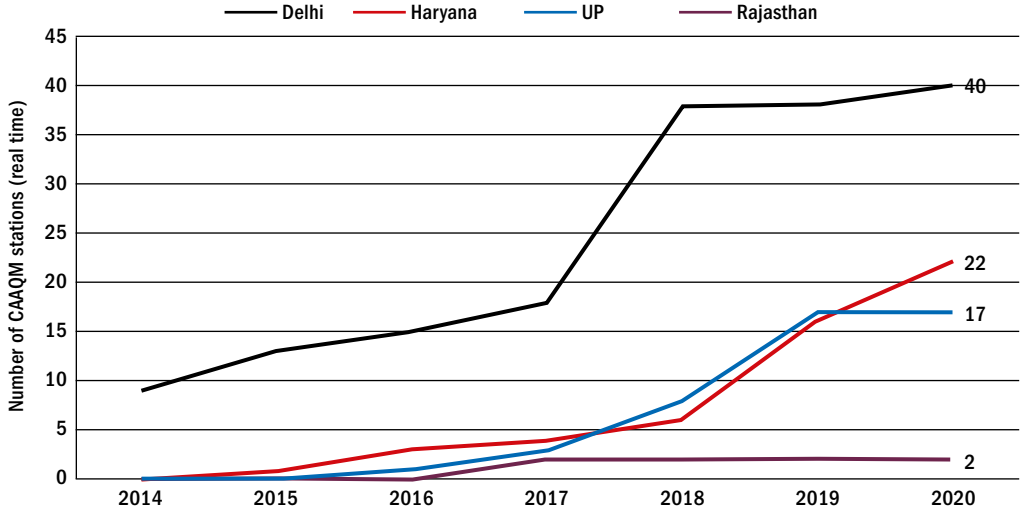
Improvement in air quality monitoring

Post 2015, Delhi and NCR have witnessed a dramatic expansion in air quality monitoring. India had a total of 235 CAAQM stations as of 15 October 2020 and Delhi-NCR accounted for over one-third of this network. NCR represents about two per cent of total geographical area and four per cent of total population of India.

In the entire Delhi-NCR, manual stations increased from 20 to 40 and real time monitoring stations increased from 14 to 81 between 2015 and 2020. Of the 81 CAAQM stations in NCR that generate continuous real time data, 40 are in Delhi while 22 are in Haryana, 17 in Uttar Pradesh and two in Rajasthan (see *Graph 3: Growth of CAAQM station network in NCR*).

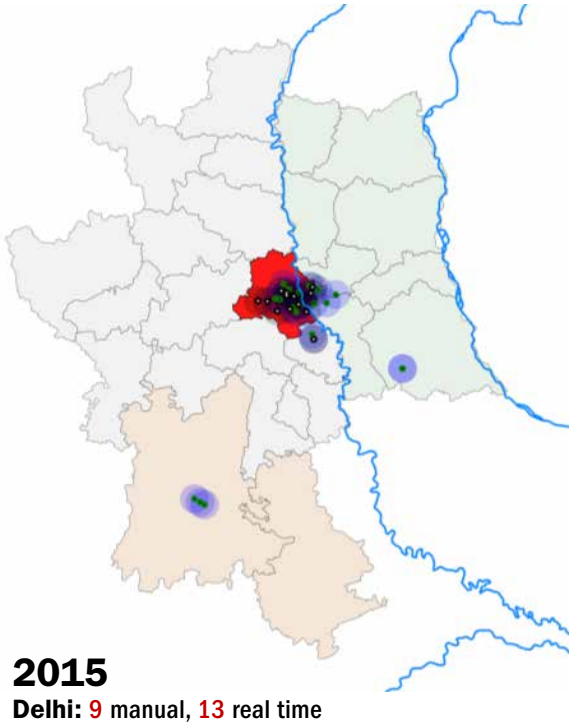
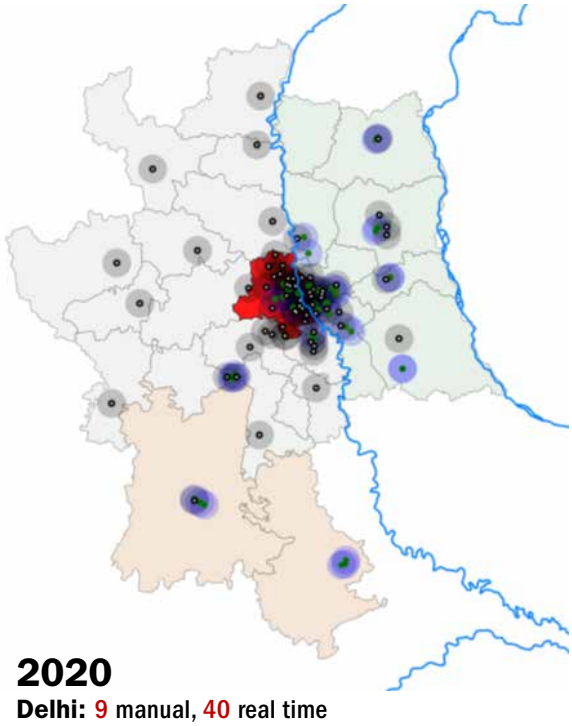
Most stations in Delhi (20) were added in 2018, while 2019 saw substantial addition in Haryana (10 stations) and Uttar Pradesh (9 stations). Rajasthan set up one station each in Alwar and Bhiwadi in 2017. Bharatpur in Rajasthan and Shamli in UP are the only two districts in NCR that have no CAAQM stations (see *Map 1: Locations of manual and real time monitors in Delhi and NCR*).

Graph 3: Growth of CAAQM station network in NCR



Source: CSE analysis of CPCB data

Map 1: Locations of manual and real time monitors in Delhi and NCR

Air quality monitoring network in Delhi-NCR in 2015	Air quality monitoring network in Delhi-NCR in 2020
	
2015 **Delhi:** 9 manual, 13 real time **Haryana:** 2 manual, 1 real time **UP:** 6 manual, 0 real time **Rajasthan:** 3 manual, 0 real time	**2020** **Delhi:** 9 manual, 40 real time **Haryana:** 2 manual, 22 real time **UP:** 20 manual, 17 real time **Rajasthan:** 9 manual, 2 real time

Note: Map is not to scale
Source: CSE analysis based on CPCB data

Dense monitoring network in Delhi

Air quality monitoring network of Delhi has significantly expanded since 2015. There were nine air quality monitoring stations in Delhi at the end of 2014. Four more were added in 2015, two in 2016, and another three in 2017. In 2018, DPCC added 20 more stations expanding the network to 38 CAAQM stations. No new stations have been added since. Of the total CAAQM stations in Delhi, CPCB and IMD own seven each while DPCC owns the rest. Two more stations were added to the network by Indian Institute of Tropical Meteorology (IITM), Pune in the latter half of 2020.

Data availability for each station varies. Data availability was patchy for the 2015–17 period. It is especially very poor among stations owned by IMD (complete archival data for 2015 and 2016 is missing for CAAQM stations at PUSA and Lodi Road, quarterly data for IGI Airport is consistently below the 75 per cent threshold). Data from CPCB owned stations is relatively better but didn't meet the 75 per cent quarterly threshold for most of 2015–17. DPCC stations have been the best performers but they too fall short of the 75 per cent threshold in a few quarters.

Data availability has significantly improved since 2018, with most stations meeting 75 per cent threshold for all quarters. A notable exception to this is the IMD station at Burari Crossing that has not reported any valid 24hr $PM_{2.5}$ average in 2020. Overall, it is noted that IMD stations have higher volume of missing data compared to stations of CPCB and DPCC.

Expanding monitoring network in NCR cities

Gurugram: First CAAQM station in Gurugram became operational at the HSPCB office at Vikas Sadan in early 2016. A second station, owned by IMD, was added in Gwal Pahari at the end of 2017. Two more stations were added in early 2020 by HSPCB. Data availability is generally over 75 per cent in most quarters for each station. Overall, it is noted that IMD station at Gwal Pahari has higher volume of missing data compared to other stations of HSPCB.

Faridabad: First CAAQM station in Faridabad became operational at Sector 16A in early 2015. Three more stations were added in early 2020 by HSPCB. Data availability is generally over 75 per cent in most quarters for the station at Sector 16A. The new stations at New Industrial Area and Sector 11 have had significantly lesser than 75 per cent data in the second and third quarters of 2020. The station at Sector 30 meets the 75 per cent quarterly threshold.

Noida: First CAAQM station in Noida, setup by IMD, became operational at Sector 62 at the end of 2016. UPSPCB set up a station in Sector 125 in late 2017. Two more stations were added by UPPCB in mid 2019. Data availability is generally over 75 per cent in most quarters for UPPCB stations. Most of the 2017 data is missing for the IMD station but availability improved since 2018 and that station has since met the 75 per cent quarterly threshold.

Ghaziabad: First CAAQM station in Ghaziabad, set up by UPSPCB, became operational at Varundhara in late 2017. Three more stations were added by UPSPCB in early 2019. Data availability is over 75 per cent in most quarters for all stations.

Outer NCR—Haryana: Rohtak got a CAAQM station in early 2016 but most of the data for 2016 and 2017 is missing. Sonipat and Manesar got CAAQM stations at the end of 2018. At the start of 2019 every district headquarter in Haryana got a CAAQM station. Of those, 10 were located in NCR, namely at Ballabgarh, Dharuhera, Bahadurgarh, Bhiwani, Jind, Karnal, Mandikhera, Narnaul, Palwal, and Panipat. Another CAAQM station was added in Charkhi Dadri in early 2020. Data availability in most stations is over 75 per cent in most quarters since 2019. Data availability in Mandikhera and Narnaul dropped below the 75 per cent threshold in the third quarter of 2019, while Bahadurgarh and Charkhi Dadri have less than 75 per cent data for all three quarters of 2020.

Outer NCR—UP: Bagpat, Bulandshahr, Hapur, Greater Noida, and Muzaffarnagar each got a CAAQM station in 2018. Greater Noida got its second CAAQM station and Meerut got three CAAQM stations in 2019. AQM stations in Bulandshahr, Greater Noida, and Meerut (Ganganagar and Pallavpuram) have over 75 per cent data availability in all quarters since they became operational. Data availability for CAAQM stations at Hapur and Muzaffarnagar is significantly below the 75 per cent threshold for multiple quarters in 2019 but it has improved in 2020. Data availability for CAAQM stations at Bagpat and Jai Bhim Nagar (Meerut) was significantly below 75 per cent in 2020.

Outer NCR—Rajasthan: Cities of Alwar and Bhiwadi each got a CAAQM station in late 2017. Data availability from these stations meets the 75 per cent threshold for all quarters since mid 2018. Bharatpur has no CAAQM station.

The next challenge in the sector is to improve monitoring in the larger NCR and to consider more innovative strategies including satellite based assessment and more economical sensor based monitoring with good quality control to cover areas that are still not monitored.

Trends in $PM_{2.5}$

Delhi

Out of the 40 CAAQM stations in Delhi, only 13 stations have been operational since 2015. Of these 13 stations, those located at PUSA and Lodhi Road have significant data gaps till 2017 that cannot be addressed with the data substitution method of USEPA. Therefore, to assess the long-term trend in Delhi's $PM_{2.5}$ concentration, stations located at Anand Vihar, CRRI Mathura Road, IGI Airport, IHBAS, ITO, Mandir Marg, NSIT Dwarka, North Campus DU, Punjabi Bagh, RK Puram, and Shadipur have been considered.

Delhi's average $PM_{2.5}$ concentration has reduced (see *Graph 4: Trend in three-year annual average $PM_{2.5}$ concentration in Delhi based on mean of 11 CAAQM stations*) but Delhi still needs to reduce $PM_{2.5}$ levels by more than 60 per cent to meet the annual NAAQS for $PM_{2.5}$.

35 CAAQM stations in Delhi have over 2.5 years of data for the 2018–20 period. That allows for computing indicative three-year averages for these stations with limited use of data substitution. Anand Vihar has the highest indicative three-year average of 128 µg/m^3 while Lodhi Road and Sri Aurobindo Marg stations have the lowest at 78 µg/m^3. The mean of these 35 stations works out to be 100 µg/m^3. That is only marginally (less than two per cent) lower than the mean of 11 stations used in creating the long-term trend.

East Arjun Nagar CAAQM station does not have a $PM_{2.5}$ monitor, Burari Crossing CAAQM station has not been working since the beginningof 2020, while Alipur station started only in November 2018 and was offline for the whole of first quarter of 2019.

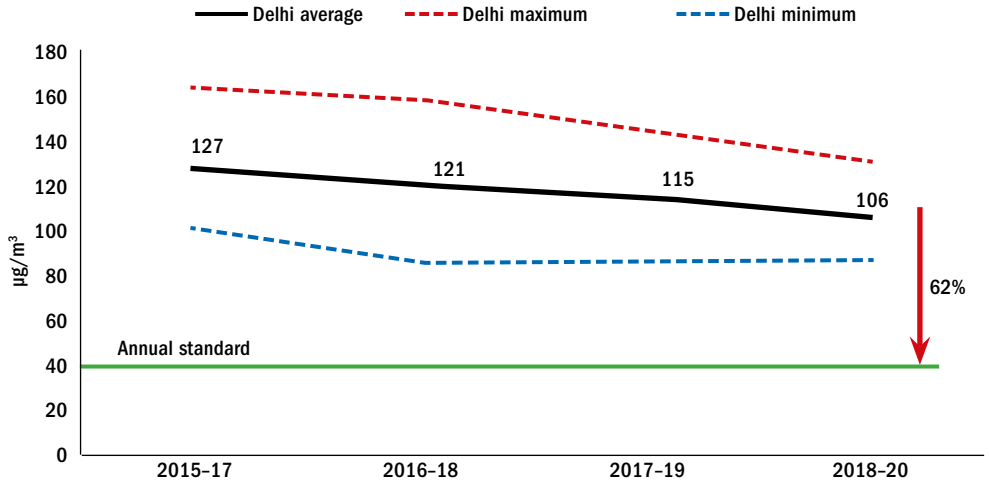
Method of assessment

CPCB has adopted a protocol for real time monitoring in CAAQM stations but there is no protocol for use of the real time data in terms of selection of primary and collocated monitors, ways to address data gaps and missing data with data substitution methods, etc. Therefore, CSE has adopted the USEPA method to address data gaps and analyse trends.

For establishing long-term trends in $PM_{2.5}$, 11 stations have been selected that have the most continuous data since 2015 and their spatial averaging has been done using the USEPA method of long term trend analysis in which $PM_{2.5}$ values are shown as the composite averages among the trend sites in each area. Data from exceptional events is included.

These trends are based on sites having an adequate record of monitoring data during the trend period. Year-on-year comparison is based on three-year averages which help to even out the unusual events during any one year. Three-year averages for each station were computed using CPCB's real time data with USEPA methodology. Data substitution has been applied to quarters with less than 75 per cent data with the median value of the combined data from that quarter for all three years as per the substitution test of USEPA. For instance, the 2018–20 data set of every station lacks data for the fourth quarter (Oct–Dec) of 2020. Therefore, while computing the three-year average for 2018–20, the data that is still not fully available for the fourth quarter of 2020 was substituted with the median value observed in the combined dataset of the fourth quarters of 2018 and 2019.

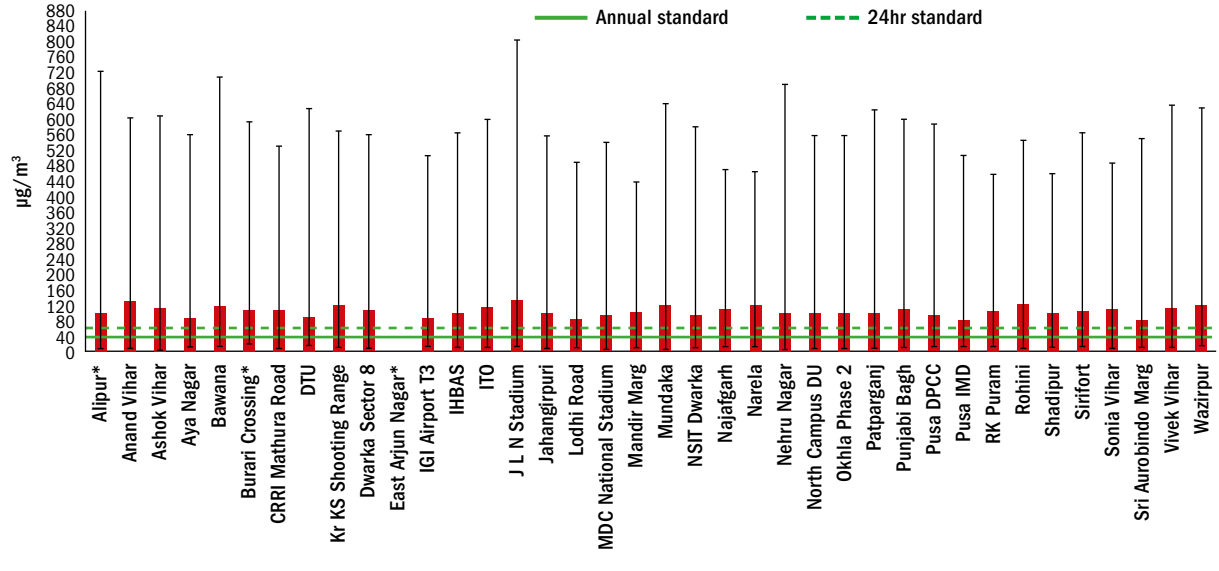
Graph 4: Trend in three-year annual average $PM_{2.5}$ concentration in Delhi based on mean of 11 CAAQM stations



Note: Data from following CAAQM stations from where continuous data is available: Anand Vihar, CRRI Mathura Road, IGI Airport, IHBAS, ITO, Mandir Marg, NSIT Dwarka, North Campus DU, Punjabi Bagh, RK Puram, and Shadipur. Data up till 31 Dec 2020. Three-year averages are calculated using USEPA methodology and data completeness requirement, with median value substitution for missing data.
Source: CSE analysis of CPCB's realtime data

Even though there is a downward trend in annual average level in Delhi, short-term peaks can be very high, especially during winter. The maximum values reached varied between 806µg/m³ at JLN Stadium and 438 µg/m³ at Mandir Marg. The cleanest day for all stations was recorded during the monsoon of 2020. Cleanest 24-hr average varied between 17 µg/m³ (DTU) and 6 µg/m³ (Ashok Vihar) (see *Graph 5: Maximum, minimum and average $PM_{2.5}$ concentration at each CAAQM station of Delhi from 2018–20*).

Graph 5: Maximum, minimum and average $PM_{2.5}$ concentration at each CAAQM station of Delhi from 2018–20



* Stations have less than two years of data.

Source: CSE analysis of CPCB's real time data using USEPA methodology

Central NCR cities

Long-term annual trends in cities surrounding Delhi—Gurugram, Faridabad, Noida, Ghaziabad—are not going up but are still significantly high and require significant reduction of 63 per cent to meet the national ambient air quality standards for $PM_{2.5}$.

Aggregate trend of these four cities shows three-year averages declined by 17 per cent between 2016–18 and 2018–20 (see *Graph 6: Trend in three-year average $PM_{2.5}$ concentration in central NCR cities*). The mean three-year averages of these four cities are identical to the mean three-year average of 11 stations of Delhi. Cities in Haryana are relatively cleaner than cities in UP.

The trend in Gurugram is based on the CAAQM station at Vikas Sadan. Three-year average declined 32 per cent between 2016–18 and 2018–20. The city needs to further reduce 59 per cent from 97µg/m³ recorded in 2018–20 to meet NAAQS.

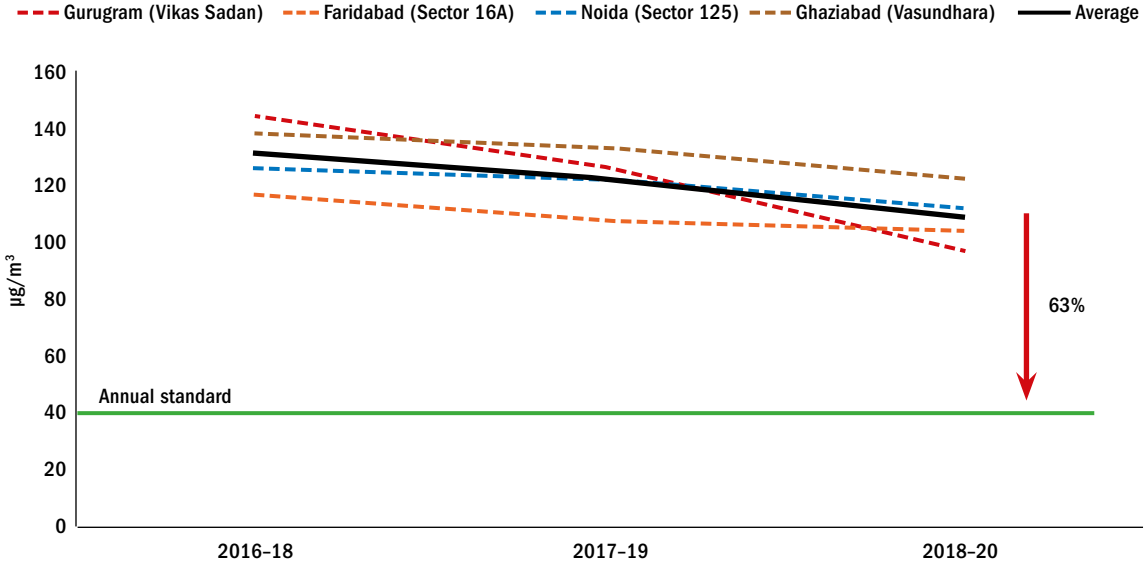
The trend in Faridabad is based on the CAAQM station at Sector 16A. Three-year average declined 11 per cent between 2016–18 and 2018–20. The city needs to further reduce 61 per cent from 104 µg/m³ recorded in 2018–20 to meet NAAQS.

The trend in Noida is based on the CAAQM station at Sector 125. Three-year average declined 11 per cent between 2016–18 (based on two-year data) and 2018–20. The city needs to further reduce 64 per cent from 112 µg/m³ recorded in 2018–20 to meet NAAQS.

The trend in Ghaziabad is based on the CAAQM station at Vasundhara. Three-year average declined 11 per cent between 2016–18 (based on two-year data) and 2018–20. The city needs to further reduce 67 per cent from 123 µg/m³ recorded in 2018–20 to meet NAAQS.

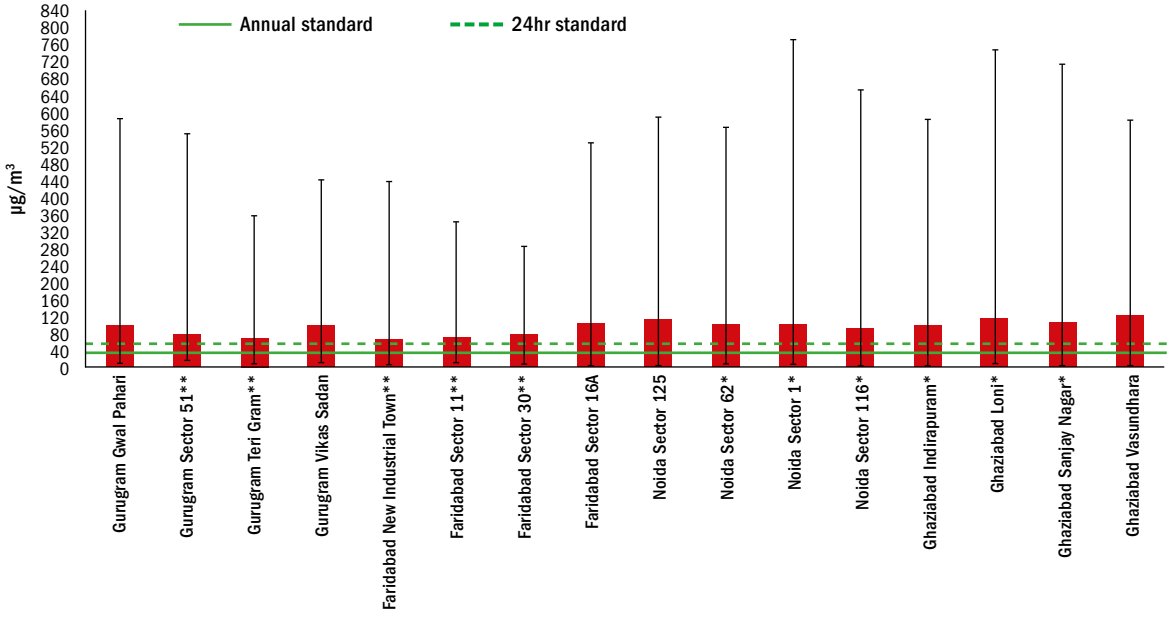
The maximum 24-hr averages recorded among these stations varied between 771 µg/m³ at Noida Sector 1 and 460 µg/m³ at Faridabad Sector 16A. Cleanest 24-hr averages varied between 17 µg/m³ at Gurugram Sector 51 and 3 µg/m³ at

Graph 6: Trend in three-year annual average $PM_{2.5}$ concentration in central NCR cities



Note: CAAQM stations used: Vikas Sadan (Gurugram), Sector 16A (Faridabad), Sector 125 (Noida), and Vasundhara (Ghaziabad).
Source: CSE analysis of CPCB's real time data using USEPA methodology

Graph 7: Maximum, minimum and average $PM_{2.5}$ concentration at CAAQM stations in central NCR cities from 2018–20



* Less than two years of data; ** Less than one year of data
Source: CSE analysis of CPCB's realtime data using USEPA methodology

Nodia Sector 116. The cleanest day for all stations was recorded during the monsoon of 2020.

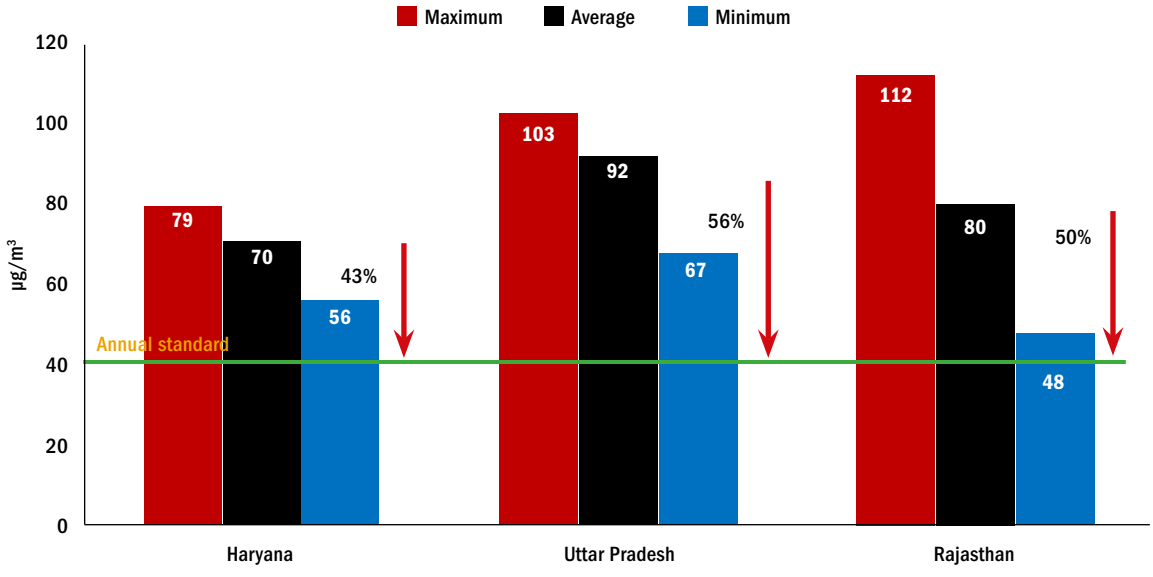
New CAAQM stations at Faridabad (New Industrial Town, Sector 11, and Sector 30) and Gurugram (Sector 51 and Teri Gram) started in February–March of 2020 and have not experienced winter pollution, therefore their average and maximum 24-hr values are considerably lower than others (see *Graph 7: Maximum, minimum and average $PM_{2.5}$ concentration at CAAQM stations in central NCR cities from 2018–20*).

Eleven out of 16 CAAQM stations in central NCR cities have over two years of data for 2018–20, which allows for computing three-year averages for these stations with limited use of data substitution. Gurugram and Faridabad have had at least one station working since 2016 while Noida and Ghaziabad got their first stations in 2017. Trends for these central NCR cities are based largely on three-year averages of one station in the respective cities. Vasundhara in Ghaziabad has the highest three-year average of 123 µg/m³ while Sector 116 in Noida has the lowest at 93 µg/m³. The mean of these 11 stations works out to be 104 µg/m³. That is only marginally (less than five per cent) lower than the mean of four stations used in creating the long term trend.

Towns in larger NCR

Most of the towns in larger NCR got their CAAQM stations in 2019. As a result, it is not possible to create any long term trend for these towns. For Manesar, Rohtak, and Sonipat in Haryana, Bagpat, Bulandshahr, Greater Noida, Hapur, and Muzaffarnagar in UP, and Alwar and Bhiwadi in Rajasthan, there is over two years of data. Mean three-year average (2018–20) of these stations is used to establish outer NCR $PM_{2.5}$ level in each state (see *Graph 8: Aggregate $PM_{2.5}$ levels for outer*

Graph 8: Aggregate $PM_{2.5}$ levels for outer NCR towns



Source: CSE analysis of CPCB's real time data using USEPA methodology

NCR towns). Haryana has a mean of 70 µg/m³ and it would require an average reduction of 43 per cent to meet the NAAQS. UP has a mean of 92 µg/m³ and it would require an average reduction of 56 per cent to meet the NAAQS. Rajasthan has a mean of 80 µg/m³ and it would require an average reduction of 50 per cent to meet the NAAQS.

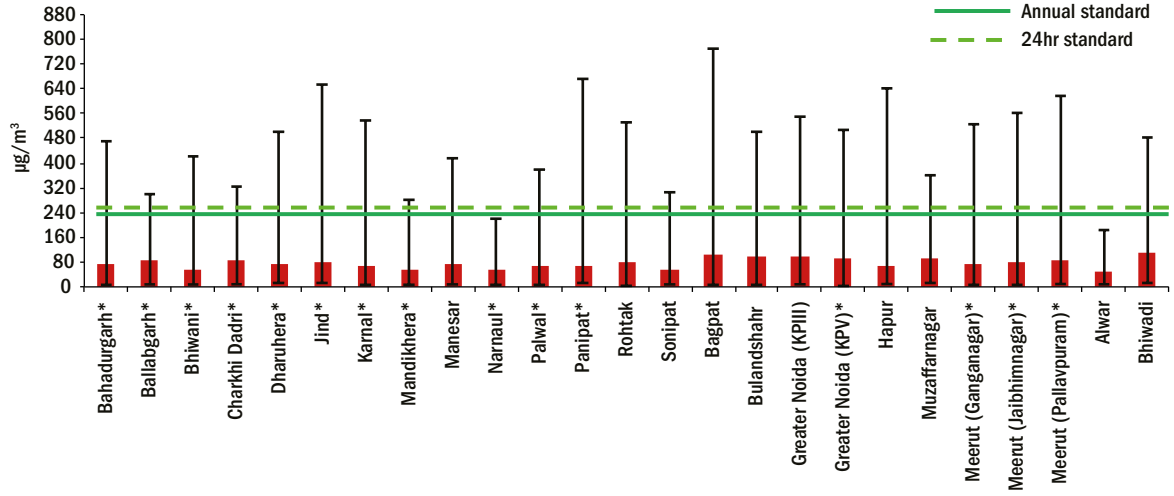
Even though Charkhi Dadri, Ballabgarh, Dharuhera, Bahadurgarh, Bhiwani, Jind, Karnal, Mandikhera, Narnaul, Palwal, and Panipat in Haryana and Meerut in UP have less than two years of data, it is possible to compute valid three-year averages using data substitution. Analysis of these shows that towns closer to Delhi have relatively higher $PM_{2.5}$ levels (see *Graph 9: Average $PM_{2.5}$ concentration at CAAQM stations in outer NCR towns from 2018–20*). Further, towns in the hinterland of NCR have considerably lower $PM_{2.5}$ levels compared to Delhi but they all fail to meet the NAAQS.

Maximum 24-hr averages recorded among these towns vary between 772 µg/m³ (Bagpat, UP) and 187 µg/m³ (Alwar, Rajasthan). Cleanest 24-hr averages vary between 13 µg/m³ (Muzaffarnagar, UP) and 3 µg/m³ (Greater Nodia Knowledge Park V). The cleanest day for all stations was recorded during the monsoon of 2020. Eastern towns have similar 24-hr peak $PM_{2.5}$ levels as Delhi while western towns show relatively lower 24-hr peaks.

$PM_{2.5}$: How daily patterns have changed

It is also insightful to see how the daily pattern of pollution has changed over time. The 24-hr average concentration of $PM_{2.5}$ each day has been classified according to the air quality categories of the NAQI. There is a clear seasonal distribution in pollution build up and drop. Overall, as expected, pollution levels are higher during winter.Smog episodes build up and become severe during winter due to inversion—adverse weather conditions including absence of wind that traps pollution.

Graph 9: Average $PM_{2.5}$ concentration at CAAQM stations in outer NCR towns from 2018–20



* Stations have less than two years of data.
Source: CSE analysis of CPCB's real time data using USEPA methodology

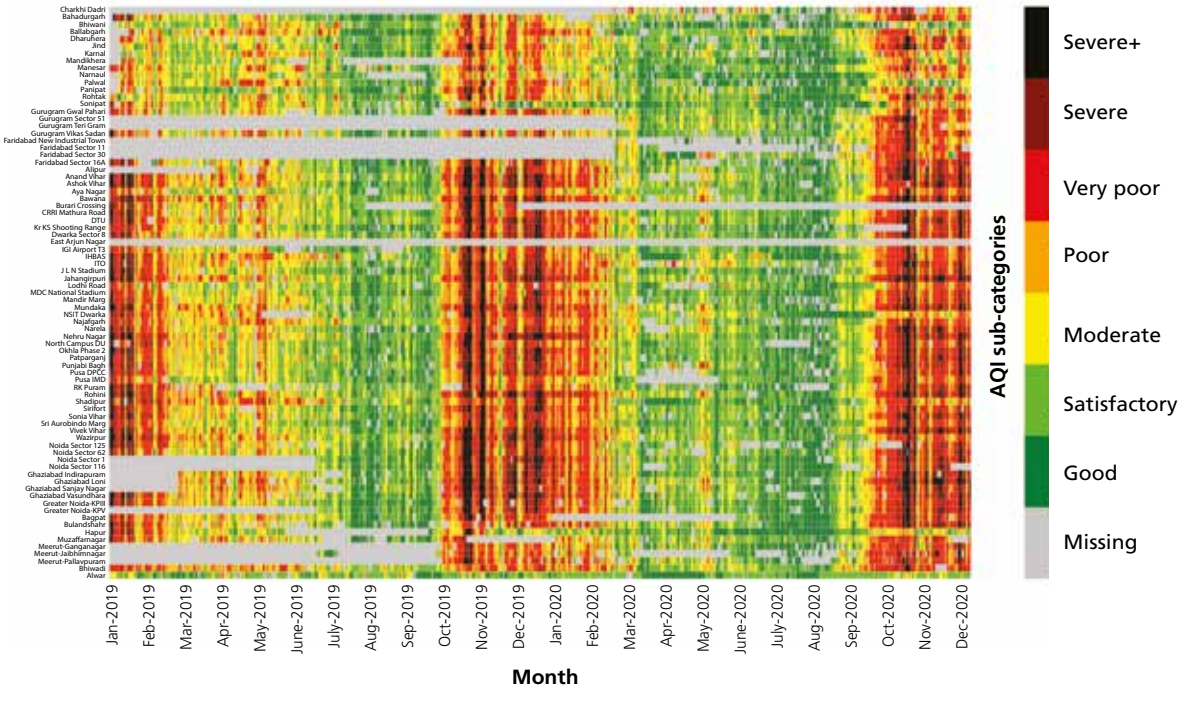
There is a near perfect synchronized pattern of $PM_{2.5}$ concentration among the 79 CAAQM stations in NCR, especially during winter. This validates that smog is a regional phenomenon (see *Graph 10: Heat map of pollution at each CAAQM station of NCR in 2019 and 2020*). Towns in western Haryana and Rajasthan show relatively milder and shorter smog episodes compared to Delhi and rest of the NCR. Alwar is an outlier, as it shows no impact of winter on its $PM_{2.5}$ concentration.

The smaller NCR towns have considerably lower annual averages for $PM_{2.5}$ compared to Delhi but their peak smog days are as bad as Delhi. The worst 24-hour average recorded at Delhi CAAQMS during the smog episodes of November 2019 ranged from 341 µg/m³ (at Shadipur) to 725 µg/m³ (at Alipur). Only seven stations (Ballabgarh, Dharuhera, Bahadurgarh, Narnaul, Sonipat, Alwar, and Bhiwadi) out of 41 non-Delhi CAAQM stations recorded levels below Delhi's lowest—Bagpat. Sector 1 Noida and Loni (Ghaziabad) recorded 24-hour levels higher than 725 µg/m³.

In 2020, the worst 24-hour average recorded at Delhi CAAQMS during the smog episodes of November ranged from 108 μg/m³ (at NSIT Dwarka) to 699 μg/m³ (at Mundka). Only Alwar out of 41 non-Delhi CAAQM stations recorded levels below Delhi's lowest—no station recorded 24-hour levels higher than 699 μg/m³ (Delhi's highest).

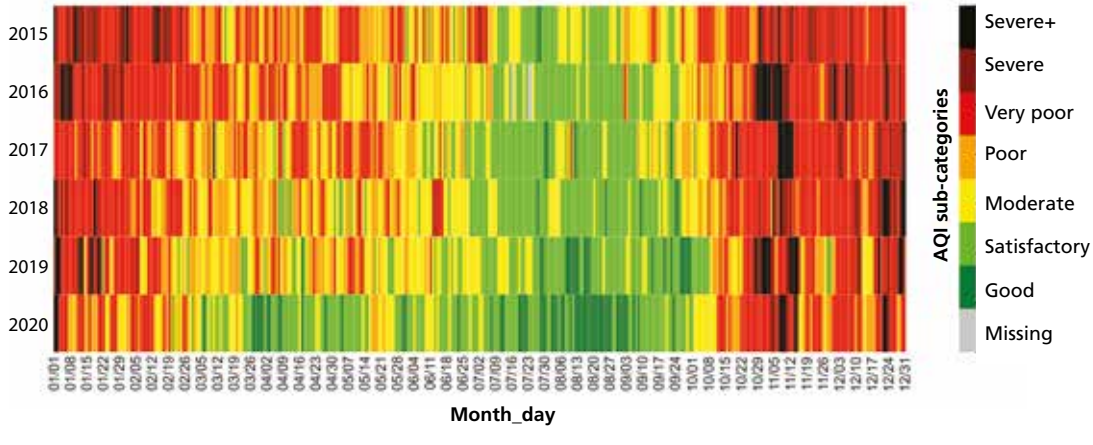
There is a little shift in this pattern in Delhi based on the average of 11 stations (see *Graph 11: Heat map of $PM_{2.5}$ in Delhi from 2015 to 2020*). The heat map also captures the impact of lockdown on the regional air quality during 2020. The number of days that met the daily NAAQS dramatically increased this summer with lockdown halting all economic activities. Impact of farm stubble burning during this summer was also stunted compared to 2019. It also led to more good air days during monsoon this year. But that did not prevent the high winter smog this October and November when the economy reopened and crop residue was burnt.

Graph 10: Heat map of pollution at each CAAQM station of NCR in 2019 and 2020



Source: CSE analysis of CPCB's real time data

Graph 11: Heat map of $PM_{2.5}$ in Delhi from 2015 to 2020



Note: CAAQM stations used were Anand Vihar, CRRI Mathura Road, IGI Airport, IHBAS, ITO, Mandir Marg, NSIT Dwarka, North Campus DU, Punjabi Bagh, RK Puram, and Shadipur

Source: CSE analysis of CPCB's real time data

Onset and dissipation of winter pollution is also changing in form. From 2015 to 2019, the days when air quality deteriorates to 'very poor' AQI have shifted somewhat from start of October to middle of October. This year also 'very poor' days commenced mid-October, almost identical to 2019 but this was preceded by a longish spell of 'moderately polluted' days unlike in 2019, which saw almost immediate jump from

'satisfactory' to 'very poor'. This gradual build-up of pollution concentration is similar to trends observed in 2018, 2017, 2016, and 2015, which implies that 2019 was an outlier probably due to unusual rains in the October of 2019.

Similarly, the concentration of days with air quality in 'very poor' category that used to start thinning out during late March in 2016 and 2017 got advanced to February during 2019 and 2020. The temporal spread of winter pollution (days with 'very poor' AQI) has somewhat been reduced— by over a month if considered from both ends (October and February).

Most winter days remain in the 'poor' to 'very poor' categories, with a few days abating into the 'moderate' category if it rains. Smog episodes largely build up once during November, when, in addition to local pollution, smoke from farm stubble fire in the surrounding states aggravates the situation. Subsequent episodes of build up happen during end of December and January due to a combination of inversion and local pollution.

It is interesting to note that the smog episodes during November 2019 have been worse than those in 2018 even though 2019 had comparatively more clean days. In this case, meteorology and changing pattern of stubble fires seem to have made an impact.

Trend in nitrogen dioxide

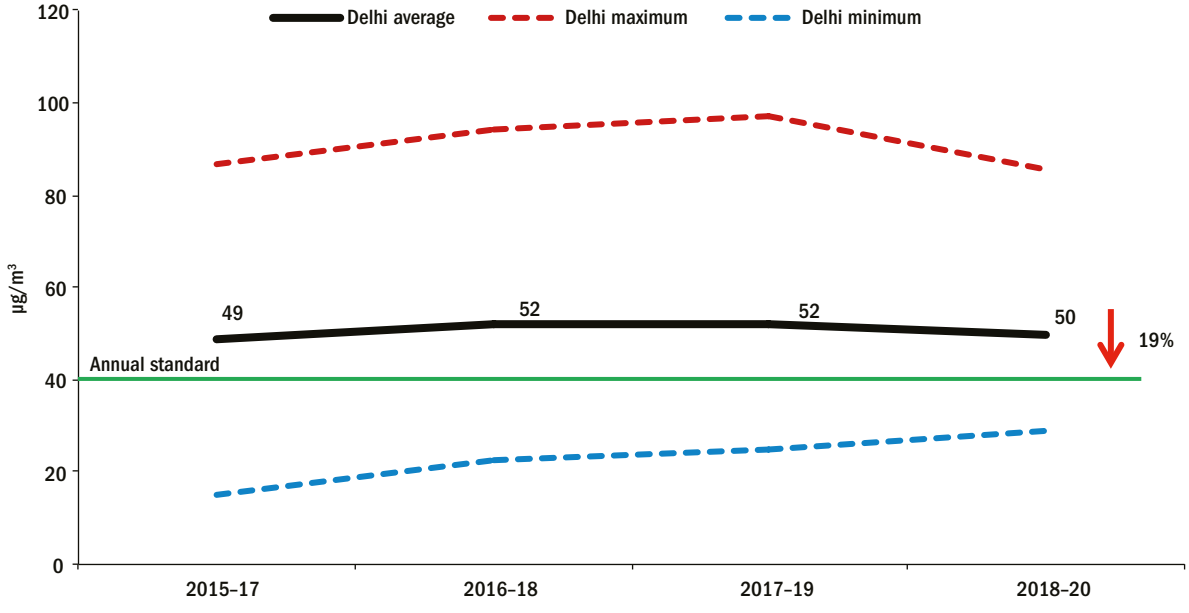
Even though the current focus of action planning in Delhi and NCR is on particulate matter, it is necessary to understand the impact of other gases that come from combustions sources. Both nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) are monitored regularly in the region. While overall SO_2 levels are low, NO_2 levels are rising. Both gases require attention as studies have shown that these gases also contribute towards formation of secondary particulates in the air. In fact, the IIT Kanpur source apportionment study shows that during winter secondary particulates can be about 25 per cent of the particulate concentration in Delhi.

Spatial averaging of same 11 stations with the most continuous data since 2015 has been done to assess the long term trends in NO_2 concentration in relation to NAAQS, using the USEPA method of long term trend analysis in which NO_2 values are shown as the composite averages among the trend sites in each area. Data from exceptional events is included. These trends are based on sites having an adequate record of monitoring data during the trend period. Year-on-year comparison in both the cases is based on three-year averages which help to even out unusual events during any one year. Three-year averages for each station were computed using CPCB's real time data with USEPA methodology. Data substitution is carried out for quarters with less than 75 per cent data with the median value of the combined data from that quarter for all three years as per the substitution test of USEPA.

The trend computed shows that Delhi's average NO_2 concentration has been stable since 2015 with the mean three-year averages between 49–52 $\mu g/m^3$ (see *Graph 12: Trend in three-year annual average NO_2 concentration in Delhi based on mean of 11 CAAQM stations*). Delhi still needs to reduce NO_2 levels by 19 per cent to meet the annual NAAQS.

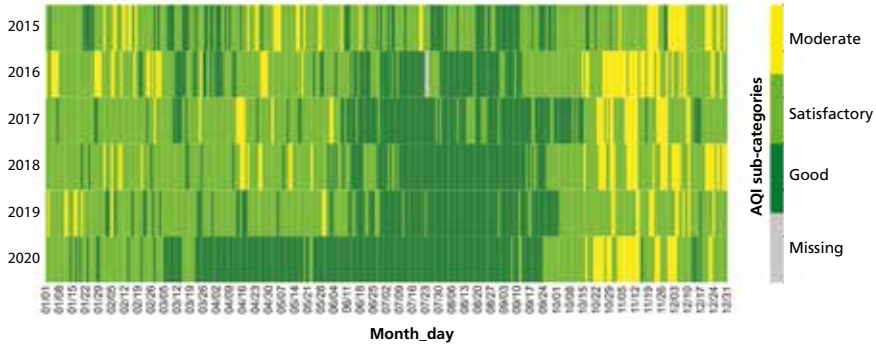
The heatmap of daily NO_2 levels in Delhi based on the average of 11 trend stations shows that high NO_2 levels roughly coincide with high $PM_{2.5}$ levels (see *Graph 13: Heat map of NO_2 in Delhi from 2015 to 2020*). The aggregate has not breached the standard in 2020 only 15 October onwards. Impact of lockdown is also highly evident as the NO_2 levels remained in 'good' AQI category almost throughout the summer of 2020, something that didn't happen in earlier years.

Graph 12: Trend in three-year annual average NO_2 concentration in Delhi based on mean of 11 CAAQM stations



Note: CAAQM stations used were Anand Vihar, CRRI Mathura Road, IGI Airport, IHBAS, ITO, Mandir Marg, NSIT Dwarka, North Campus DU, Punjabi Bagh, RK Puram, and Shadipur
Source: CSE analysis of CPCB's real time data using USEPA methodology

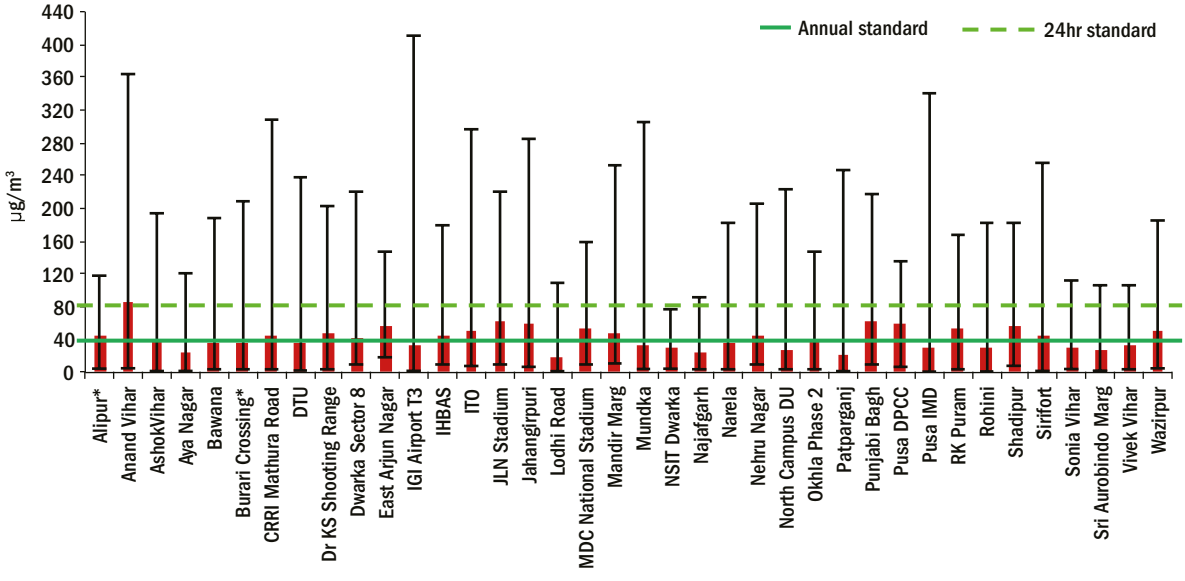
Graph 13: Heat map of NO_2 in Delhi from 2015 to 2020



Note: CAAQM stations used were Anand Vihar, CRRI Mathura Road, IGI Airport, IHBAS, ITO, Mandir Marg, NSIT Dwarka, North Campus DU, Punjabi Bagh, RK Puram, and Shadipur
Source: CSE analysis of CPCB's real time data using USEPA methodology

Thirty-six out of 40 CAAQM stations in Delhi have over 2.5 years of data for the 2018–20 period, which allows for computing three-year averages for these stations with limited use of data substitution. Anand Vihar has the highest three-year average of 85 µg/m³ while Lodhi Road station has the lowest at 20 µg/m³ (see *Graph 14: Maximum, minimum, and average NO_2 concentration at CAAQM stations of Delhi*

Graph 14: Maximum, minimum, and average NO_2 concentration at CAAQM stations of Delhi during 2018–20



* Stations have less than two years of data.
Source: CSE analysis of CPCB's realtime data using USEPA methodology

during 2018–20). The mean of these 36 stations works out to be 42 µg/m³. That is 15 per cent lower than the mean of 11 stations used in creating the long term trend.

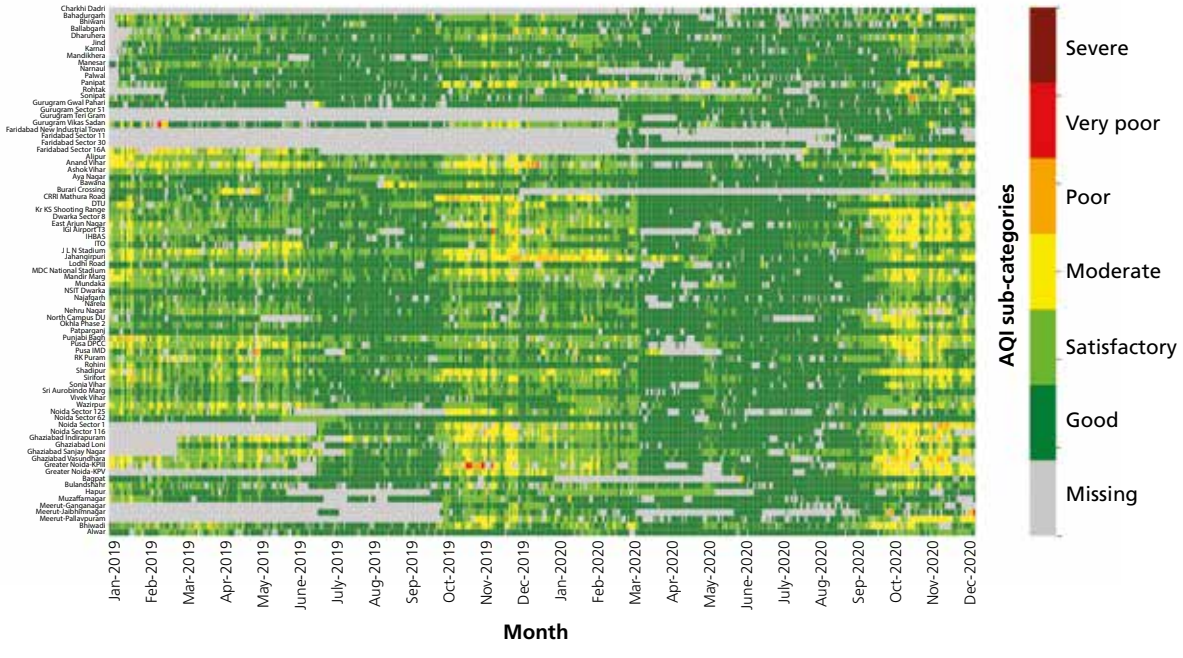
Maximum 24-hr averages recorded at Delhi stations vary between 412 µg/m³ (IGI Airport) and 78 µg/m³ (NSIT Dwarka). Cleanest 24-hr averages vary between 18 µg/m³ (East Arjun Nagar) and 1 µg/m³ (PUSA, IMD monitor). The cleanest day for all stations was recorded during the monsoon of 2020.

Burari Crossing CAAQM station has not been working since the beginning of 2020 while Alipur station only started in November 2018 and was offline for the whole first quarter of 2019.

The heat map of daily NO_2 levels in the Delhi stations shows that NO_2 levels don't fluctuate in unison among these stations as noted with $PM_{2.5}$ levels (see *Graph 15: Heat map of NO_2 at CAAQM stations of Delhi-NCR in 2019 and 2020*). This alludes to the local nature of this pollution. Impact of lockdown is also evident as the NO_2 levels remained in 'good' AQI category almost throughout the summer of 2020, which was not seen in 2019.

Also, the hourly NO_2 curve flattened during the lockdown, with morning peak almost disappearing and evening peak reducing significantly.

Graph 15: Heat map of NO_2 at CAAQM stations of Delhi-NCR in 2019 and 2020



Source: CSE analysis of CPCB's real time data using USEPA methodology

Ozone trends

Ozone is primarily a sunny weather problem in India that otherwise remains highly variable during the year. It is a highly reactive gas; even short-term exposure (one hour) is dangerous for those with respiratory conditions and asthma. That is why ozone has a short-term standard—one hour and eight hours, as opposed to 24 hours for other pollutants. Ozone is not directly emitted by any source but is formed by photochemical reactions between oxides of nitrogen (NO_x), other volatile organic compounds (VOCs), and gases in the air under the influence of sunlight and heat. Ozone can be controlled only if gases from all sources are controlled.

Even when $PM_{2.5}$ and NO_2 levels plummeted to the lowest in most cities during the lockdown and caught public attention, invisible ozone raised its ugly head on several days and in several cities. For analysis of ozone trends, CSE has adopted the global best practice of considering the maximum rolling eight-hour average during 24 hours, as opposed to the fixed time slot of 8 AM to 4 PM daily that the CPCB has adopted. The CPCB's method fails to capture the worst part of the day that poses a higher health risk—most of the time, ozone peaks after 4 PM.

There was a peculiar pattern during the lockdown phase in the region. The city-wide maximum average in Gurugram exceeded the standard on 26 days—at least one station exceeded the standard on 57 days. The city-wide eight-hour maximum average in Ghaziabad exceeded the standard on 15 days, with at least one station exceeding on 56 days. In Noida, the city-wide maximum average exceeded the standard on 12 days with at least one station exceeding on 42 days. In Delhi, the maximum eight-hour average exceeded the standard on four days, and at least one station exceeded the standard on 67 days.

The analysis found that ozone pollution is the highest in stations with the lowest NO_2 pollution—ozone levels build up in the greenest parts of the city where the NO_2 levels are very low. This is because ozone is formed when NO_x, VOCs, and gases react with each other under the influence of sunlight and temperature. A high NO_x level can again react with ozone and mop it up. The ozone that escapes to cleaner areas has no NO_x to further cannibalize it—and as a result, ozone concentration builds up in these areas. For example, Nehru Nagar near the Lodhi Garden area in Delhi.

Unlike $PM_{2.5}$ and NO_2, ozone does not have an average concentration based annual standard. It is rather defined as number of days its eight-hourly standard is exceeded. NAAQS states that eight-hourly standards shall be complied with 98 per cent of the time.They may exceed the limits but not on two consecutive days of monitoring. In other words ozone standard can be exceeded on a maximum of eight days in a year. To compute the trend in ozone pollution in Delhi, the number of exceedances was aggregated for six stations with the most continuous data since 2015. These stations are Anand Vihar, Mandir Marg, NSIT Dwarka, Punjabi Bagh, RK Puram, and Shadipur.

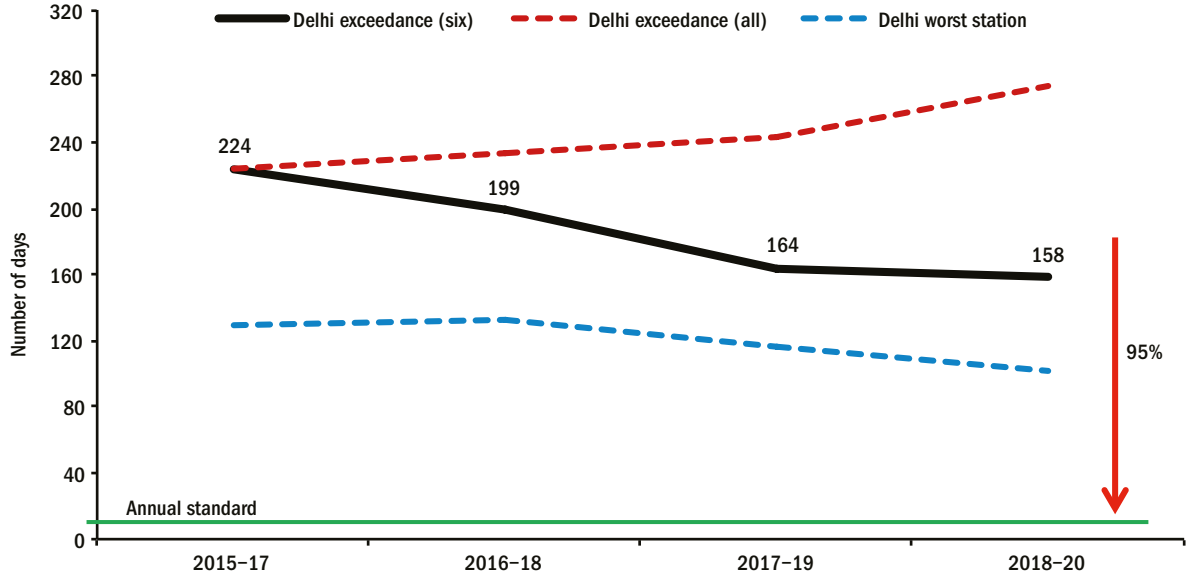
To establish exceedance at a station the maximum eight-hour average recorded in the day from rolling eight-hour averages is compared to eight-hourly NAAQS for ozone. Reference document for daily value computation is the USEPA's 40 CFR Appendix P to Part 50. To establish exceedance at a citywide level, exceedance at any of the six ozone trend stations is treated as exceedance by the city.

The trend is based on three-year average of total number of days with exceedances which helps to even out unusual events during one year. The trend is noted both for citywide exceedance and the worst performing station. No data substitution has been carried out for missing data in this analysis.

The trend computed based on six select stations shows that Delhi's number of exceedance days has declined by 29 per cent. The mean for 2015–17 was 224 days/year which has come down to 158 days/year in 2018–20 (see *Graph 16: Tread in three-year average ozone exceedances in Delhi based on six CAAQM stations*). Worst station among the six ozone trend stations is RK Puram and it has shown 22 per cent decline in average number of exceedance days between 2015–17 and 2018–20. Delhi needs to reduce ozone exceedance days by 95 per cent to meet NAAQS for ozone. But if all the stations in Delhi are considered, then number of days that at least one station exceeded the standard has climbed up to 290 days in 2020 from 260 days in 2019.

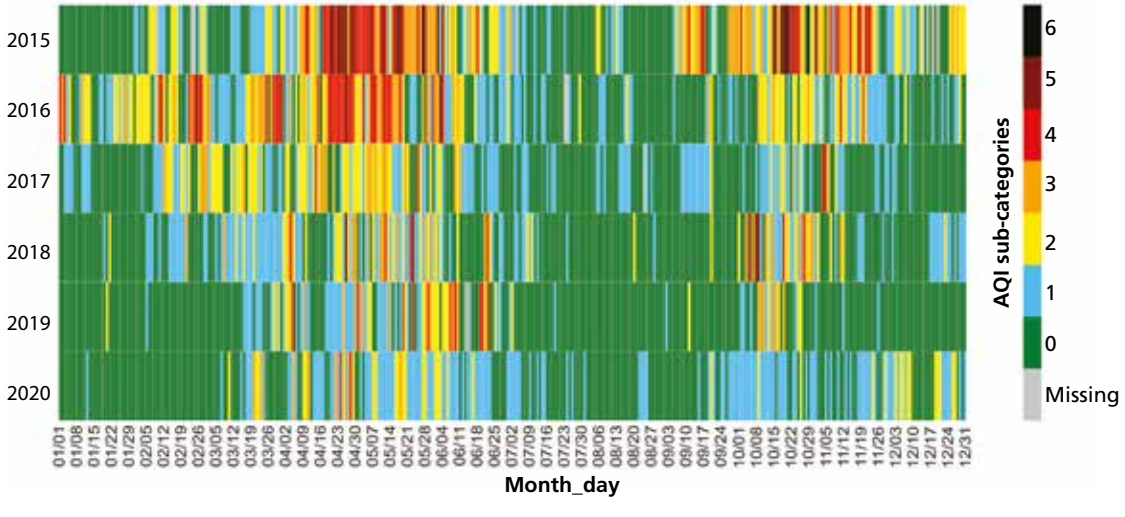
The heat map of exceedance days in Delhi based on six trend stations shows that exceedances are most regular during spring, summer, and autumn season (see *Graph 17: Heat map of ozone exceedances in Delhi from 2015 to 2020*). The number of days with multiple stations exceeding the standard has come down over the years and relatively longer spells of no exceedance have been recorded in the last few years. 2020 lockdown seems to have had no impact on ozone exceedances. In fact, 2020 saw 177 days when at least one of the six ozone trend stations exceeded the standard when only 128 days of exceedance were recorded for the whole of 2019.

Graph 16: Trend in three-year average ozone exceedances in Delhi based on six CAAQM stations



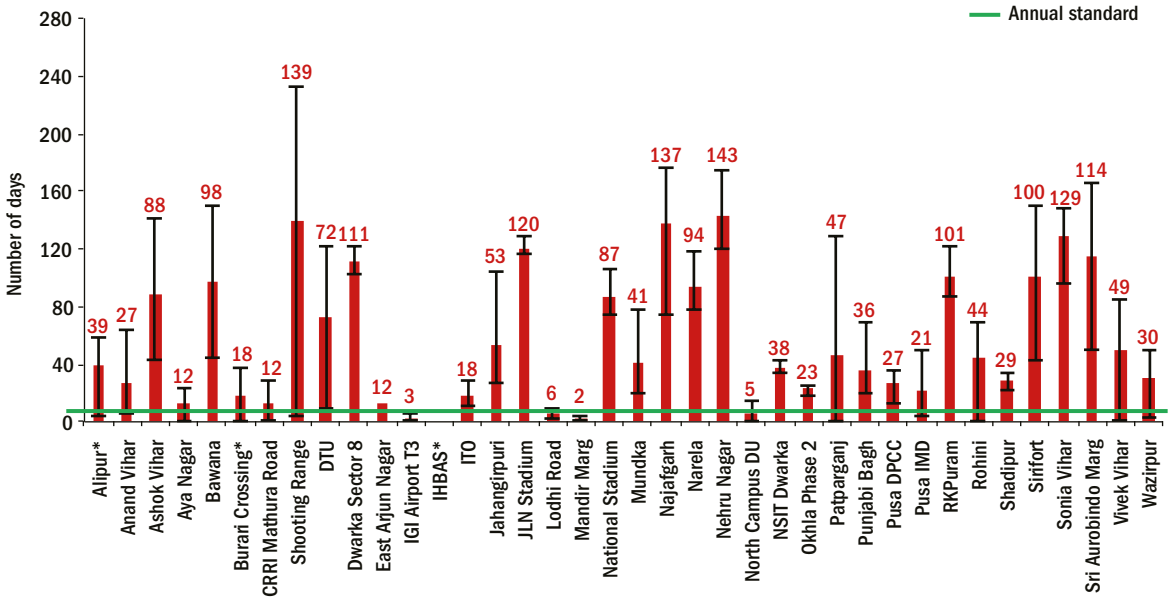
Note: CAAQM stations used were Anand Vihar, Mandir Marg, NSIT Dwarka, Punjabi Bagh, RK Puram, and Shadipur. Worst station is RK Puram.
Source: CSE analysis of CPCB's real time data using USEPA methodology

Graph 17: Heat map of ozone exceedances in Delhi from 2015 to 2020



Note: Colours represent number of stations that exceeded the standard on that day, green being zero and black being six stations
Source: CSE analysis of CPCB's real time data using USEPA methodology

Graph 18: Ozone exceedances at each CAAQM station of Delhi for 2018–20



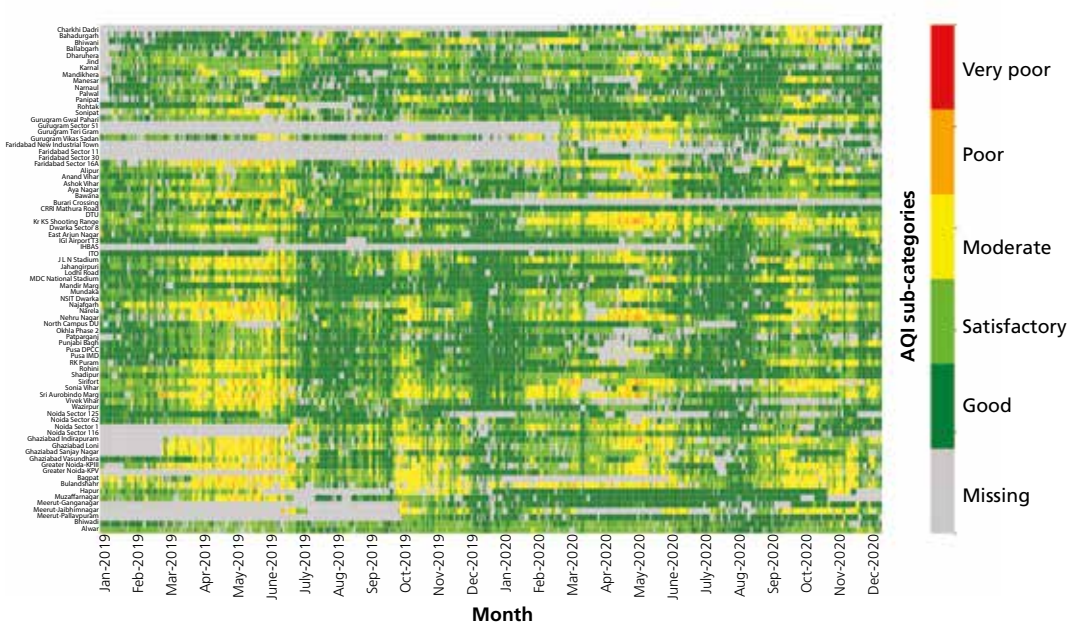
* Stations have less than two years of data.
Source: CSE analysis of CPCB's real time data using USEPA methodology

Thirty-five out of 40 CAAQM stations of Delhi have over 2.5 years of data for 2018–20, which allows for computing three-year average exceedances for these stations. Nehru Nagar has the highest three-year average exceedance of 143 days/year while Mandir Marg has the lowest at two days/year (see *Graph 18: Ozone exceedances at each CAAQM station of Delhi for 2018–20*). Aggregate exceedance at these 35 stations works out to be 275 days/year which is almost twice the aggregate exceedance at the six ozone trend stations for 2018–20.

Burari Crossing CAAQM station has not been working since the beginning of 2020 while Alipur station only started working in November 2018 and was offline for the entire first quarter of 2019. IHBAS station only has valid values from the third quarter of 2020, while IITM stations at Chandni Chowk and Lodhi Road only started functioning in the fourth quarter of 2020.

The heat map of daily ozone levels in Delhi stations shows that ozone levels tend to fluctuate in unison among these stations with a few exceptions (see *Graph 19: Heat map of ozone at CAAQM stations of Delhi-NCR in 2019 and 2020*). This alludes to the important role of meteorology in formation of this pollution. Impact of lockdown is also evident as the number of days with ozone levels in 'poor' and 'very poor' AQI categories have increased in the summer of 2020 compared to 2019.

Graph 19: Heat map of ozone at CAAQM stations of Delhi-NCR in 2019 and 2020



Source: CSE analysis of CPCB's realtime data using USEPA methodology

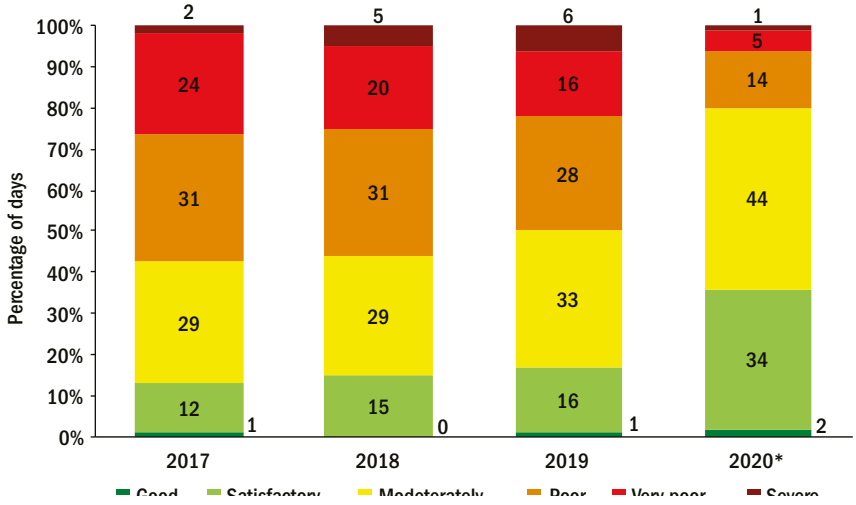
National Air Quality Index and pollution forecasting

Another big change in the region is the adoption of the National Air Quality Index by the MoEFCC in 2015 for daily relay of information to the public and also to inform emergency measures. Broadly speaking, based on the measured ambient concentrations of a pollutant, a sub-index is calculated for each of the eight pollutants separately, which is a linear function of concentration. Air quality sub-index and health breakpoints have been developed for eight pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, and Pb) for which short term (upto 24 hours or eight hours) national ambient air quality standards are prescribed. The worst sub-index determines the overall AQI of the day. The final AQI for the day can be based on one single pollutant out of the eight pollutants whose sub-index is calculated or it can be based on more than one pollutant. The air quality categories are classified as good (50 per cent below the national ambient air quality standards for the pollutant), satisfactory (which is same as meeting the standards), followed by moderate, poor, very poor, and severe. This colour coded classification method is an important public communication tool to inform people about the severity of air pollution. The NAQI is also linked with a health advisory.

It is also possible to learn from the classification of days based on NAQI the overall trend in distribution of days in different air quality categories. This analysis since 2017 shows that the number of days in very poor and severe category has reduced from 26 per cent in 2017 to 25 per cent in 2018 and 22 per cent in 2019. This indicates an overall improvement in air quality. In 2020 particularly, there are more days in good and satisfactory categories compared to earlier years as an impact of the lockdown. In 2020, the number of days with AQI in good and satisfactory categories was 100 out of 280 whereas in 2017 it was 48 (out of 364), in 2018 it was 53 (out of 365), and 61 (out of 365) in 2019.

Moving from 2017 to 2019, there has been an increase in number of days when the AQI was in 'good' category and decrease in number of 'very poor' days. In 2019, four per cent of the days were in the 'good' category. The number of days when the AQI was in 'good' and 'satisfactory' category was highest during the winters of 2019 (see *Graph 20: Categorization of the number of days based on the AQI categories from 2017 to 2020* and *Graph 21: Categorization of the number of days based on the AQI categories from 2017 to 2019 for the winter period*).

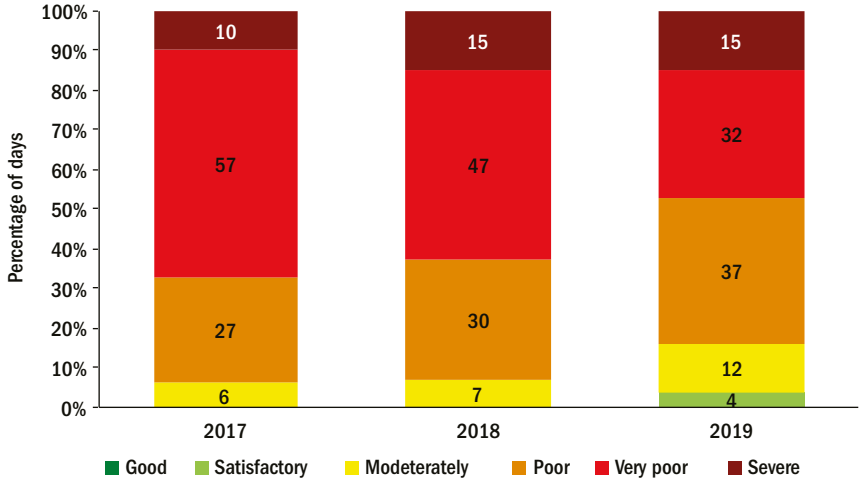
Graph 20: Categorization of the number of days based on the AQI categories from 2017 to 2020



* Data for 2020 is considered till 01 September

Source: CSE's analysis based on AQI bulleting published by CPCB daily

Graph 21: Categorization of the number of days based on the AQI categories from 2017 to 2019 for the winter period



Source: CSE's analysis based on AQI bulleting published by CPCB daily

This review shows that the region has expanded its capacity to track real time air quality data—more in Delhi than in the larger NCR. The growing evidence on multiple pollutants shows that multi-pollutant action strategy in the region has to be strengthened.

Where is pollution coming from?

At this stage there are a few studies that have assessed the profile of pollution sources and their relative contribution to the overall pollution load as well as to the particulate concentration in the air of Delhi and NCR. Studies are not directly comparable in terms of method and classification of sources. But they provide an indicative assessment.

The earliest study came from IIT Kanpur for Delhi in 2015. This was followed by an inventory study by SAFAR for Delhi and NCR in 2018 and another source inventory and apportionment by TERI-ARAI in 2018. These studies bring out the strong influence of dust. Among the combustion sources, vehicles are at the top followed by industry including power plants. In NCR, residential solid fuel burning is an important source of pollution. While in Delhi the overall influence of power plants has been minimized due to the closure of all coal power plants, their contribution in the NCR is higher (see *Table 1: Summary of studies on emissions source inventory and apportionment in Delhi and NCR*).

For the first time these studies have highlighted the problem of secondary pollutants in the air. So far the focus had largely been on primary emissions from sources. That disregarded the importance of looking at the way gases emitted from combustion sources react in the air to produce more secondary particulates. For instance sulphur dioxide converts to sulphate and nitrogen oxide to nitrate particles. In fact, during winter when the level of pollution is high, secondary particles can be as high as 25 per cent of the particulate concentration.

Such periodic assessment is needed to bring greater clarity and precision to the understanding of the changing profile of local pollution sources. However, studies need to provide better description of sources and pattern of fuel use along with better quanitification to inform action better. Currently, there is risk of underestimating pollution from informal sources and widely diverse dirty fuel used in small-scale industrial sectors without pollution control equipment. It is also important to expand regulatory capacity to carry out more dynamic real time source apportionment studies to inform action in the future.

However, the science of source assessment is also vulnerable to politics as often lobbies interpret these numbers to play down the role of different sources in the overall pollution to resist change. This was most starkly evident during the last decade when the automobile industry often interpreted the numbers to claim miniscule contribution of vehicles to deflect harder action.

It is important for the scientific community to guide the way these studies are used by policy makers. When pollution levels are very high a region needs deep action to reduce emissions from nearly all key sources.

Evidence from these studies has helped to guide the framing of a comprehensive clean air action plan for multi-sector strategy in Delhi and the NCR. After the initial proposal of the draft plan the Supreme Court had directed MoEFCC to hold consultation with implementing agencies and finalize each action with a timeline for implementation. Therefore, the ultimate notification has come as a series listing groups of action. This has laid the foundation of a comprehensive approach to source-wise action. This needs to be reviewed in terms of what has been achieved so far in each sector and what more needs to be done.

Table 1: Summary of studies on emissions source inventory and apportionment in Delhi and NCR

IIT Kanpur study: emissions inventory (in per cent)

Vehicles	Industrial stack	Industrial areas	Domestic	Road dust	Construction and demolition	MSW burning	Hotels and restaurants	Others
20	11	2	12	38	2	3	3	9

Source: IIT Kanpur source inventory

ARAI-TERI and SAFAR emissions inventory studies (in per cent)

	Agency	Vehicles	Industry	Power	Residential	Wind blown	Others
Delhi—$PM_{2.5}$ source inventory 2018	SAFAR	41	19	5	3	21	11
	TERI-ARAI	39	3	11	6	21 (including construction)	15
NCR—$PM_{2.5}$ source inventory 2018	SAFAR	39	22	3	6	18	12
	TERI-ARAI	12	23	8	24	7 (include construction)	26

IIT Kanpur: $PM_{2.5}$ apportionment 2015 (in per cent)

Sources	Winter	Summer
Secondary particles	30	15
Vehicles	25	9
Industrial	1	1
Coal+flyash	5	26
Biomass burning	26	12
Construction material	2	3
Soil + road dust	4	27
Boiler	0	0
Solid waste burning	8	7

TERI-ARAI: $PM_{2.5}$ apportionment 2018

Sources	Winter	Summer
Secondary	26	17
Vehicles	23	18
Industry	10	11
Biomass	22	15
Dust and construction	15	34
Other	4	5

SECTION 2

Industry

Delhi's battle against industrial pollution has progressed considerably over the last two decades but still remains an unfinished agenda. Steps have been taken at varying scales towards improving emissions standards and emissions control systems in industries, and to scale up the clean fuel transition. But speed and scale of this action is inadequate and not harmonized across the region. Moreover, dominance of small scale units and informal economy present a special challenge. It is therefore important to understand what has happened so far in the industrial sector of Delhi and NCR and what more needs to happen.

Delhi

The earliest effort to curb industrial pollution had started following the Supreme Court directives to shift big polluting industries out of Delhi. The Supreme Court had directed closure of 1,328 units in hazardous category that included hot mix plants, lead smelting units, stone crushers, pesticides, heavy foundries, steel rolling mills, etc. Subsequently, Delhi Pollution Control committee (DPCC) also issued closure orders to 118 more industrial units. In 2000, the Supreme Court further directed closure of polluting industrial units in non-conforming/industrial areas under the supervision of Ministry of Urban Development. Based on the criteria of polluting industries, developed by this ministry and an expert committee of the government, 5,046 more units were closed down. DPCC had also identified 557 more units for closure and directed several industrial units to install pollution control devices.

Since then the nature and character of industry in Delhi has changed. Currently, more than 50 per cent of the industrial activities are within planned industrial areas. Delhi has a number of industrial estates spread over an area of 4,647 acres. These industrial estates are either under Delhi Development Authority (DDA) or DSIIDC, MCD, and PWD. The IIT Kanpur study of 2015 listed about 26 designated industrial areas (see *Table 2: Major industrial areas in Delhi with number and types of industries*). Majority of the industries are small scale and have small boilers and some cupola furnaces. There are no major industries. Medium and small scale industries include garment, furniture, electric machinery, metal/non-metal finishing, rubber, plastic, and packaging industries. In addition, there are supposed to be about a lakh small unorganized units.

There are also large numbers of small-scale units including plastic recycling units that are not in the listed legal industrial estates but in unauthorized areas that are challenging to monitor.

Table 2: Major industrial areas in Delhi with number and types of industries

Sr. no.	Name of industrial area	No. of industries	Major sector
1.	Bawana Industrial Area	2000	Plastic (53 per cent)
2.	Okhla Industrial Area	800	Apparels, consumables, and metal based
3.	Wazirpur	700	Metal based
4.	Lawrence Road	450	Plastic
5.	Mangolpuri	350	Plastic
6.	Patparganj Industrial Area	350	Metal based and consumables
7.	Udyog Nagar	260	Plastic
8.	Kirti Nagar	200	Plastic
9.	Badli	230	Metal based
10.	Jhandewalan Industrial Area	125	IT and apparel
11.	Naraina Industrial Area Phase 2	110	Printing
12.	SMA Industrial Area	90	Metal based
13.	Anand Parbat Industrial Area	70	Metal based
14.	Rajasthan Udyog Vihar	60	Metal based
15.	Keshopur Industrial Area	NA	Metal based
16.	Shahdara	NA	Metal based
17.	Narela Industrial Area	>1000	Plastic
18.	Mayapuri Industrial Area	>700	Metal based
19.	Shahzada Bagh Industrial Area	400	Plastic
20.	Friends Colony Industrial Area	350	Metal based
21.	Najafgarh Road Industrial Area	300	Plastic
22.	Jhilmil Industrial Area	300	Metal based
23.	Naraina Industrial Area Phase 1	200	Metal based
24.	G.T. Karnal Road Industrial Area	200	Plastic
25.	Nangloi Industrial Area	100	Plastic
26.	Okhla Flatted Factory Complex	100	Engineering

Source: Data collected from DPCC; CSE survey

Nature of industrial pollution in Delhi

Industrial pollution has several dimensions—primary stack emissions that are determined by the level of emissions control technologies and use of fuels, fugitive emissions from material handling and loading/unloading, open burning of industrial waste, heavy dependence on diesel generator sets, and dust pollution due to movement of heavy duty trucks and goods vehicles especially on unpaved roads in industrial areas. This requires a multi-dimensional approach to pollution control.

The IIT Kanpur emissions inventory study showed that industrial stacks contributed about 11 per cent of the particulate load and industrial areas about two per cent. Subsequently, the SAFAR inventory in 2018 found industry responsible for

19 per cent of the particulate load in Delhi and 22 per cent in NCR. During the same year TERI-ARAI inventory study estimated that industry is responsible for three per cent in Delhi and 23 per cent of particulate load in NCR. Industry contribution to the particulate concentration in the air during winter and summer in Delhi varies between 10–11 per cent. Given the overall level of particulate pollution in Delhi and NCR this contribution is significant. Industries are also responsible for enormous exposure in and around the industrial areas.

Industrial contribution to both particles and gases in the air is substantial in Delhi. Emission load from the industries as area source is the highest for SO_2 (5,616 kg/day) followed by NO_x (1,893 kg/day), PM_{10} (1,614 kg/day), and $PM_{2.5}$ (1,367 kg/day). It may be noted that NO_x and SO_x also contribute to the formation of secondary particulates. Available evidence shows that Narela Industrial Area makes the highest contribution to PM_{10} and $PM_{2.5}$ load from industrial sources. Wazirpur Industrial Area has the highest share in the SO_2 and NO_x loading.

An additional source of pollution in industrial areas are the diesel generator sets. It is estimated that DG sets are responsible for about seven per cent of the total pollution loading from different sources. But this might have reduced in the recent years due to improvement in power availability in the city.

A unique challenge associated with industrial pollution is open burning of industrial waste. Hotspot review by the EPCA in 2018 showed large dumping of non-reusable plastic and rubber waste in industrial areas like Mundka and Bawana which was burnt in the open for disposal. This causes enormous toxic pollution.

It is within this context that action in Delhi has taken shape. It is necessary to understand the nature and direction of this change.

Clean fuel transition

One big thrust of the judicial and executive action in Delhi so far has been to push for clean fuels in the industrial sector. This required expansion of the natural gas pipeline to take gas to the door step of industrial units. Several measures have been taken in this direction.

Approved fuels: Delhi was the first state in the region to notify a list of approved fuels under the Air (Prevention and Control of Pollution) Act, 1981. This action aligns with the global best practice of eliminating dirty fuels from all sectors. As a result of this notification, no other fuel can be used in any sector other than the fuels listed. This has virtually banned use of coal, petcoke, furnace oil, and other dirty downstream fuels and recycled fuels like tyre oil.

This was not an easy battle to win. There was strong resistance from industries, especially those which had made investments in emissions control systems to continue to use coal. A small concession had to be made for use of charcoal only in tandoors and grills of hotels/restaurants/banquet halls/eating houses as there was strong plea to protect certain kinds of traditional cuisine. But the notification has asked for some kind of emissions control systems.

It may be noted that all state governments are actually required to notify an approved fuel list under the provision of the Air Act, 1981. But many of them have not done so. Only after the Delhi notification were other state governments also asked to issue their respective lists. In fact, the Supreme Court has directed all the concerned states in the NCR to issue similar notifications. But Delhi's notification is the most ambitious and also presents a learning curve as the rationale and criteria for short listing of cleaner fuels has more clarity. Other states have continued to rely on coal and there is no strategy or target to replace coal.

Approved fuels in Delhi

Delhi Pollution Control Committee published a public notice with the approved fuel list on 29 June 2018. This is a list of fuels that can be used in Delhi. Anything not on the list is banned.

- Petrol (BS VI with 10 ppm sulphur) as per the notification of Government of India as amended from time to time
- Diesel (BS VI with 10 ppm sulphur) as per the notification of Government of India as amended from time to time
- Liquid petroleum gas
- Natural gas / CNG
- Aviation turbine fuel
- Firewood for crematoriums and for other religious purposes
- Wood charcoal for tandoors and grills of hotels/restaurants/banquet halls/eating houses having emission channelization or control system
- Wood charcoal for use in ironing clothes
- Biogas
- Refuse derived fuel (only for waste–energy plants)
- Any other clean fuel notified by the govt of NCT of Delhi / Govt of India subsequent to this notification

Note: Besides the fuels mentioned above, coal with low sulphur content (less than 0.4%) is permitted for use in thermal power plants only. All other fuels will be deemed "unapproved" and so disallowed for use in NCT of Delhi. Existing industries/units shall convert/switch over to the above mentioned approved fuels within 90 days from the date of issue of this notification.[2]

The next big challenge in the sector is implementation. While this notification has helped to catalyse big change in the legal industrial areas of Delhi, its implementation in unauthorized areas and in small scale units is more challenging. Delhi will have to make the mechanism for intercepting entry of dirty fuels and stopping their illegal use much stronger.

Big fight on petcoke and furnace oil: The big fight over dirty fuels that extended beyond Delhi with nation-wide implications was over the use of petcoke and furnace oil. This matter came to light when CSE's study found that petcoke and furnace oil—the dominant industrial fuels in the region—were among the dirtiest with sulphur content as high as 24,000 ppm and 74,000 ppm respectively and were largely used without emissions control systems.

This matter was taken up by EPCA and the evidence was presented to the Supreme Court. This catalysed far reaching directives from the Supreme Court that banned these fuels in four states of Delhi, Haryana, Rajasthan, and Uttar Pradesh. Field investigation by CSE had exposed large scale use of these dirty fuels.

The Supreme Court directive of 24 October 2017 had put a ban on pet coke and furnace oil as fuels in Delhi, UP, Haryana, and Rajasthan**.** Only four categories of end-users—cement, calcium carbide, lime kilns and gassification—are allowed. Aluminium, calciners, and iron and steel manufacturers have also petitioned the Supreme Court to be allowed to import petcoke. The matter is pending in the courts. Moreover, the Supreme Court order of 17 November 2017 requested all states of India to take measures to ban furnace oil and petroleum coke usage.

This intervention had major national spinoffs. Even import of petcoke into India has been banned by the Supreme Court as per the recommendations of EPCA on the subject. The Director General Foreign Trade issued a notification on 24 August 2018 to ban import of petcoke. To be compliant with the rulings of the World Trade Organization, MoEFCC has also taken measures to restrain domestic use of petcoke.

Moreover, use of such high sulphur fuels in industries without pollution control equipment also exposed that there were no standards for SO_x and NO_x emissions for most industries in India. This raised serious concerns regarding impact of sulphur rich fuels on SO_2 emissions and secondary particulates. This led to the Supreme Court order of 31 December 2017 that mandated SO_x and NO_x standards for 34 groups of industries in the country. Following this, MoEFCC issued the first ever SO_x and NO_x standards for 16 groups of industries for nation-wide implementation. However, the implementation of these orders needs to be followed up as SPCBs currently have limited capacity to monitor and ensure compliance with these standards.

Natural gas transition: The notification on approved fuels and ban on petcoke and furnace oil accelerated transition towards natural gas in the industrial areas of Delhi. According to the information available from DPCC, Indraprastha Gas Ltd (IGL) has facilitated setting up of natural gas supply infrastructure in 47 out of 50 industrial areas of NCT.

To incentivize this change, DPCC has provided subsidies to switch to cleaner fuel. Industries which consume less than 500 SCM/day of gas would be given a one-time subsidy of fifty thousand and the industries using more than 500 SCM/day would be given one time subsidy of one lakh rupees. In addition, DPCC has also declared a subsidy on electrical tandoors for restaurants and hotels.

According to DPCC around 50 industrial areas have around 1,555 small and large fuel consuming registered industries in the NCT, out of which around 1,200 have already shifted to PNG and the rest either do not have the connections (even though the gas lines are there) or the gas lines have not reached them. Only Karawal Nagar, Anand Parbat, and Jawahar Nagar industrial areas are still to be connected to the gas infrastructure. IGL recently reported that the main gas pipeline has already been laid down in the Anand Parbat Industrial Area and now they are in talks with industries to switch to gas. Currently, official data shows 95 per cent conversion of authorized industrial units in legal industrial areas.

Introduction of NO_x and SO_x standards in industries has also created pressure to switch to cleaner fuels. Yet another pressure point was the threat of industry closure during high pollution days under the Graded Response Action Plan. In November 2019 the ban on operation of coal-based units in the National Capital Region and industries in Delhi was an added catalyst.

In Delhi as well as in the larger NCR the price of natural gas is a concern. Even though environmental regulations are driving this switch to natural gas, the price differential with coal, which is a lot cheaper, remains an issue. It may be noted that natural gas is not included in GST and the state governments are allowed to impose state taxes or VAT to generate revenue. There is often a cascading effect of state taxes that pushes up the retail price of gas. Although Delhi has reduced its VAT to just five per cent, gas is still not cheaper than other polluting fuels. This high price of gas has also incited black marketing of coal and other cheaper polluting fuels. Coal on the other hand is included in GST and attracts lower taxes. This matter will have to be addressed at the national level.

Illegal use of fuels: Regulatory action in the legal industrial areas is being undercut by the difficult to monitor small and informal industrial units in other parts of Delhi. After the large-scale industries have moved out of Delhi, micro, small and medium enterprises (MSME) and cottage industries dominate. There are also large numbers of unorganized or even illegal industries. The dimension of this challenge is not well understood yet. This requires urgent inventory of all industrial units by type of manufacturing and fuels used. As regulations get tighter in the legal areas, illegal units mushroom elsewhere.

More stringent action in legal industrial areas has also pushed a large number of small and medium scale units towards unauthorized areas of Delhi. There is no official data on these units as their legal existence is not acknowledged and therefore there is no monitoring system for these units either. There is no information on the type of fuel used in these industries, as there is no framework for monitoring illegal industries.

This has made surveillance and monitoring of these units as well as implementation of the approved fuel notification a challenge. Access to clean fuels and cleaner boilers can be the dominant strategy for pollution control in small scale units. These units are not capable of adopting emissions control systems.

Available evidence shows that there are cases of illegal usage of coal or other banned fuels in industries in different areas of Delhi. In fact, Delhi is a major recipient of imported coal from different ports of Gujarat like Kandla port as well as Indian coal from Mughalsarai and Varanasi. Urgent attention has to be given to monitoring the coal market and illegal coal procurement in Delhi.

Officially, legal use of coal in Delhi is supposed to be nil. But illegal use of coal is difficult to monitor. But visual inspection is possible as the smoke from coal combustion is a giveaway and can be inspected promptly. Steps are needed to control any illegal supply of coal in the region either through roads or rail.

The non-confirmed areas including Shiv Vihar, Mustafabad, etc. have a number of illegal industries. Illegal units have also been detected in Anand Parbat, Naraina, Okhla, New Mandoli Industrial Area, Wazirpur, and others. There are no records of these industries and these are largely small scale industries which are often located in areas where land use is mostly residential or agricultural which makes them tough to monitor. The role of DPCC is confined to monitoring of the legal industrial units that have obtained consent to operate. According to DPCC, the municipality should take action against these illegal setups which are running on non-industrial land.

There are a number of legal and illegal industries which lie very close to the borders of Delhi and are operating from neighbouring states but whose emissions are polluting Delhi's air. This has also attracted action from the NGT.

What cannot be ignored anymore is the drive to identify illegal industrial units to chart a roadmap for developing a siting policy and improving their environmental performance without disrupting livelihoods. For identification, it should be made mandatory for all units in Delhi to display a board at the entry gate of the industry that provides the details of the consent to operate along with the date of issue obtained from the Delhi Pollution Control Committee. This will help the regulators to isolate illegal industries to some extent.

NGT action on industries in non-conforming areas

On 22 July 2020 NGT directed the Government of NCT Delhi to shut polluting steel pickling units in Wazirpur. Earlier in 2019, it had also passed orders for their phasing out. It was reported that DSIIDC has listed 51,837 units operating from non-conforming or residential areas. Three municipal corporations were asked to take action. As per the reports, the analysis of the data released by DSIIDC shows most violations are noted in Moti Nagar, Kirti Nagar, Ramesh Nagar, Najafgarh and Mansarovar Garden in west Delhi; Ashram, Bhogal, Jangpura, Maharani Bagh and Mahipalpur in south Delhi; Gandhi Nagar, Jheel, Shastri Nagar, Kailash Nagar, Jafrabad and Shahdara in east Delhi; and Sadar Bazar, Chandni Chowk, Malkaganj, Ballimaran, Lal Kuan and Kashmere Gate in north Delhi.[3] Other highly affected areas are Karol Bagh, Patel Nagar, Anand Parbat, Rohtak Road, Rajinder Nagar, Old Rajinder Nagar in central Delhi; Shahdara, GT Road, Babarpur, and Vishwas Nagar in northeast Delhi; and Burari and Jagatpuri in northwest Delhi.[4]

Following this order in November 2019, show-cause notices were issued to 4,774 industries in residential areas in different municipal corporations. Delhi government had then said that the Supreme Court has already banned industrial operation in non-conforming areas and they were bound to be closed.[5]

Accordingly, NGT directed the closure notice to 4,774 units. It had further cautioned that 'failure to do so shall be viewed seriously and coercive action against the responsible municipal commissioner of the said corporation would be taken including entry in their ACR column and stoppage of salary'. The green panel also said that the pending survey of all 29,877 units should be completed, action should be taken before 31 December 31 and, status report should be filed on or before 15 January 2020.

The NGT had earlier appointed a committee to deal with nearly 52,000 industrial units operating illegally in residential areas.[6]

Industrial waste management

Yet another big challenge associated with pollution in industrial areas is open dumping of industrial non-hazardous waste and burning. This is a source of very high toxic pollution and exposure.

This matter came to light when EPCA organized surveys in Mundka and Bawana industrial areas and found huge quantity of waste plastic and rubber from numerous plastic recyclers strewn in that area. As this waste cannot be further recycled it was set on fire causing enormous toxic emissions. EPCA Report No. 106 submitted to the Supreme Court provided evidence on massive amount of plastic, rubber and other industrial waste being burnt in the open. Based on this, EPCA asked for proper disposal methods including signing of a MoU between the industrial associations and waste management companies to collect this waste for safe disposal and to eliminate such dumping. One such MoU led to the removal of roughly 80,000 tonnes of plastic and other waste for incineration, which otherwise would have been burnt in the open with disastrous consequences. Further, 8000 tonnes of plastic and other waste has been removed from Shahadra Drain after the EPCA intervention.

Following this, DPCC issued necessary direction for closure of several units in Bawana, Mundka, and Tikri as well as removal of plastic, industrial or other waste. But this was not sufficient and the problem of disposal of waste continued.[7]

Proper management of industrial non-hazardous waste requires urgent attention as illegal dumping of industrial waste within the industrial areas and its open burning is a serious source of toxic pollution.

Local hotspot action

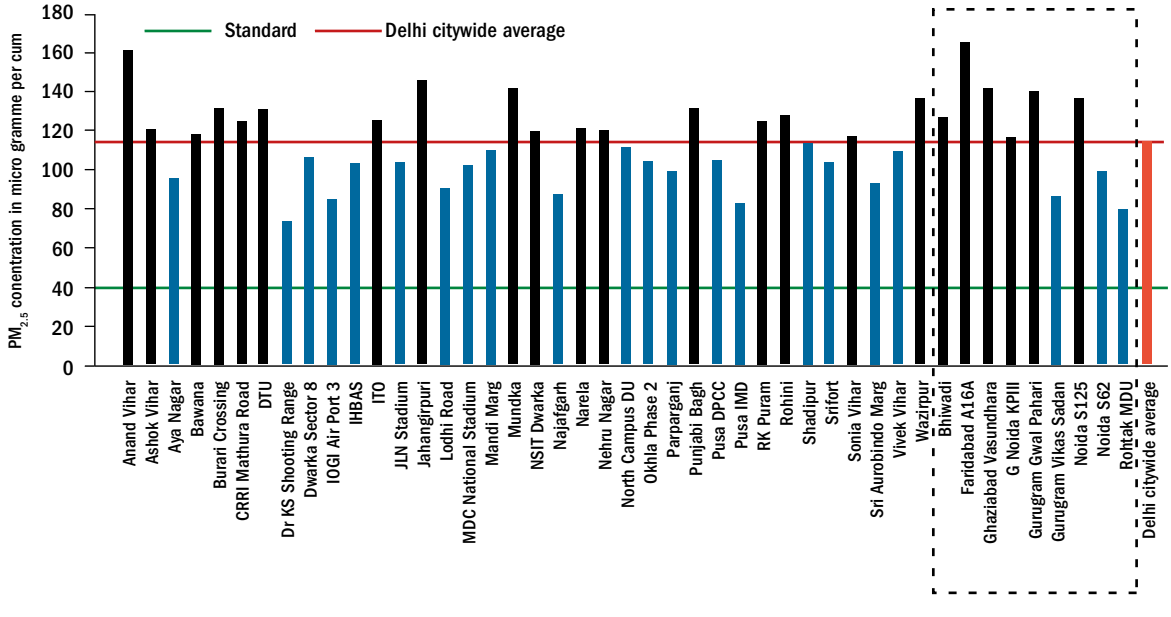
Yet another strategy that emerged over the last few years is to take the approach of local area assessment to develop hyper local action plans to reduce local exposures. Intense action in pollution hotspots can also help to improve overall ambient air quality.

Such an approach was possible with the expansion of the air quality monitoring network in Delhi around 2017–18. This expansion included industrial locations that were earlier outside the ambit of monitoring network in Delhi. This allowed more granular view of these locations. This indicated unusually high and consistent pollution levels in several of these locations.

CSE's city-wide air quality analysis in 2018 showed that not only was the city-wide average of ambient $PM_{2.5}$ levels much higher than the national ambient air quality standards, but there were about 13 locations that had annual $PM_{2.5}$ levels higher than the city average. Most of these hotspots were industrial locations including Okhla Phase 2, Dwarka, Ashok Vihar, Bawana, Narela, Mundka, Punjabi Bagh, Wazirpur, Rohini, Vivek Vihar, Anand Vihar (including Mandoli), R K Puram, Jahangirpuri, and Mayapuri (see *Graph 22: $PM_{2.5}$ concentration in all locations in 2018*).

This location-wise air quality profile is expected to change annually. But this was an important indicator of strong local influence and spurred action towards hotspot mapping of pollution sources and framing of hyper local action plans for implementation.

Graph 22: $PM_{2.5}$ concentration in all locations in 2018



*All stations that have less than 60 per cent data availability are not included in the analysis.

**Stations in black are those that are above the Delhi city average.

Source: CSE analysis

Hyper local action in industrial hotspots of Delhi

Delhi has set the trend towards hyper local action in polluted hotspots to reduce local exposures. This process was initiated in 2018 when local mapping of pollution exposed high buildup of pollution in several locations. EPCA had taken the lead on local area surveillance to identify the local sources of pollution to prepare local area plans for the critically polluted hotspots. Most of these hotspots were located in industrial areas but had multiple sources of pollution that needed a comprehensive strategy.

The last review available from EPCA, done in October 2020, brings out the importance of this strategy. These areas include Jhilmil, Mandoli (Vivek Vihar), Mundka-Tikri, Punjabi Bagh, Sanjay Gandhi Transport Nagar, UER-Narela, Narela, and Friends Colony. The review highlights the local problem, status of action taken, and what more needs to be done.

Jhilmil Industrial Area

Local problem: Local survey identified sources as open dumping and burning of plastic and other industrial waste under the metro bridges, illegal use of prohibited fuels, and vacant areas that generate enormous dust. Stored material and waste generation inside the industrial units could not be adequately ascertained. Tightly packed tiny units, stacked up in floors of buildings with open electrical wires, were found to be very unsafe. Incidences of fire have been reported in this area.

Action taken: The furnaces in these industrial units have been converted to natural gas. No violation was observed. Night patrolling is being carried out to check pollution.

Based on the local plan, East Delhi Municipal Corporation (EDMC) has cleared plastic and other wastes. This was confirmed by inspection in January 2020. But the follow up inspection by DPCC in August 2020 showed that waste dump was back but in lesser quantity. EDMC carried out its operations again in September 2020. This requires a strong and vigilant enforcement system.

Moreover, to control dust and open dumping it was decided that vacant land would be converted into park/protected area as applicable. This has been done on the vacant stretch from Gali No. 2 Friends Colony to Gali No. 8 in order to prevent fresh dumping. To address the dangerously hanging electrical lines, BSES Yamuna Power Ltd has been directed to submit an Action Taken Report.

Next steps: DPCC will put a notice on industrial units that are non-compliant and take action. DPCC inspection shows that only 10 per cent of industries have installed boards. Moreover, IGL is expected to inform about the status of gas sale to indicate its growing use. IGL will also inform about the non-usage of piped natural gas in Jhilmil.

This exercise has also underscored the importance of pinning responsibilities on different agencies for local action. EDMC has to coordinate with PWD and metro authorities for removal of garbage from metro land. Boards need to be put up on all vacant lands to show ownership and indicate who is responsible for controlling waste.

Jhilmil Industrial Association and EDMC were asked to finalize the MOU with waste incineration plants to address the non-recyclable plastic and rubber wastes.

Saboli & Mandoli Village—Mandoli Industrial Area

Local problem: Local pollution sources largely include unauthorized use of prohibited fuels, fugitive emissions from poor material management within industries, burning of waste including industrial waste, and dust pollution from poorly maintained roads. Inspection showed several oil tankers and use of coal. It appears there is supply of unauthorized fuels. Building material suppliers were found storing material for sale in the open without any sheet cover. Waste dumps were found that were set on fire.

Action taken: Periodic inspection and follow up of directives have enabled a big push towards natural gas. Most industries have shifted to natural gas. During November–December 2019, a drive was launched to ensure all functional units (aluminium and copper furnaces) switch to gas. 53 units were closed down for non-compliance. Tankers and other containers which were being used to store unauthorized dirty fuels were removed.

Follow up inspection during August 2020 led to more action to ensure that functioning units use natural gas and the units have valid consent. About seven units without consent and not using natural gas were closed down permanently. Directions have been given to shift their machinery. About 25 units with consent but using unapproved fuels were closed down and their consents were withdrawn. They will be allowed to restart only with natural gas.

Night inspections are also being carried out since July 2020 to ensure units are not being operated with fuels other than natural gas. In fact, during the follow up inspection tankers and large containers which were being used to store oil earlier were not found.

Additional efforts were made to address the complaint of the industrial units regarding inadequate pressure of gas. IGL is in the process of making additional arrangements and it is expected that the upgrading of infrastructure will be completed by the end of 2020.

The impact of local action was also visible in the disappearance of the coal shops from that area. The industrial association has come forward to take action on construction of roads and taken up the matter with DDA. Regularization of area has been done on the basis of commitment of industry association that they will take responsibility for its development. During October–December 2019, C&D waste found lying opposite Hanuman Gali was also cleared.

Next steps: To ensure that gas supply is augmented with adequate pressure. Any unit found not using gas will be closed down. All unauthorized fuels including coal and tyre oil will be eliminated. DPCC inspection has to become more robust. It will also require strong fugitive emission management from industries. DPCC will get the commitment/schedule from the industry department for re-development of the Mandoli Industrial Area.

Mundka & Tikri/North MCD

Local problem: NH 11 from Peeragarhi crossing to Tikri border is very dusty. It is dug up with construction material and plastic lying at different places. The agricultural land near Mundka Village is turning into a commercial area as big go-downs are coming up. Plastic waste is burnt along the roads of the Mundka village. Two RMC plants are operating in Lok Nayak Puram, Bakarwala without adequate dust control measures. DPCC officials were directed to check the violations and initiate action.

Action taken: After assessing the situation massive clearance drives were undertaken by PWD and North MCD from November 2019 to February 2020. Waste dumps were removed. The road was also repaired to control re-suspension of dust.

More recent inspection by DPCC officials during August 2020 found that C&D waste, municipal garbage and plastic waste have reappeared in Peeragarhi Chowk, Tikri Border and Urban Extension Road-2 (UER-2) from Mundka metro station to Tikri Village. Potholes have also re-appeared. Directions were issued to DDA, North MCD, South MCD, and PWD to remove this waste. NHAI has been assigned to maintain UER-2.

DPCC officials have also conducted inspection drives with the revenue department, NDMC and BSES to effectively close the plastic manufacturing units. Action for effective closure has been taken against 273 units. DPCC officials during inspection in August 2020 have observed that big and small warehouses and go-downs have come up on agricultural land. Directions were issued to revenue department to take notice of the fact and take necessary action. An environment penalty of Rs 0.8 crore was imposed on the illegal units and Rs 33 lakh were realized.

DPCC officials inspected DDA housing project and RMC plant at Bakkarwala and found that no measures were taken by the contractor and DDA at construction site or at RMC site. No dust control measures were evident. Direction of closure was issued and EDC of Rs 50 lakh was imposed on the RMC plant. After High Court directions, the RMC owner submitted Rs 5 lakh to DPCC along with the compliance report. After verification closure was revoked.

Next steps: Peeragarhi to Tikri Border road maintenance is yet to be done properly by PWD. Directions have been issued by the Chief Secretary that land-owning agency will be responsible for removal of garbage/C&D waste and maintenance of their land. PWD is now removing all waste from the PWD roads in Mundka/Tikri.

UER-2: Alipur–Narela Industrial Area

Local problem: This location is dominated by small scale textile waste, packaging and plastic waste, rubber waste from non-regularized industries, and go-downs. Waste was found dumped along the road from Alipur to Narela Industrial Area. Open burning of waste on the road is common. Piles of waste were noticed particularly on Bhorgarh road at Dalhousie point and right opposite Narela Industrial Area. The land belonged to PWD.

Action taken: Major cleaning drives were undertaken from November 2019 to February 2020 and that led to drastic reduction in illegal dumping of waste. The garbage dumps in Narela and Bawana industrial areas were cleared in 2019 and permanent arrangement for collection and handling of industrial waste was made through the concessionaires engaged by DSIIDC.

During the recent inspection in August 2020, fresh dumping/burning of garbage was not observed at Bhorgarh Road, Narela Industrial Area. Further, Directions under section 5 of the Environment (Protection) Act have been issued to DDA.

Narela Industrial Area

Local sources: Original survey had exposed the problem of use of dirty fuels, plastic waste dumps that are set on fire, and local industrial emissions.

Action taken: Following the hyper local action plans, nearly all the units have shifted to natural gas. The factories are tracking waste generation and transporting to third party for waste treatment and disposal. There are still complaints of unsafe disposal of plastic bags. During inspection in August 2020 garbage dumping or burning could not be observed. There was no visible industrial emission at that moment in Narela Industrial Area. The system of industrial waste management is being organized through concessionaires.

Sanjay Gandhi Transport Nagar/North MCD

Local problem: Sanjay Gandhi Transport Nagar is one of the major transport hubs which caters to about 10,000–12,000 trucks every day. The facility is working without proper infrastructure or roads. Freight movement generates huge amount of dust. Emission from heavy diesel vehicles is huge. Inner road surfaces were found damaged. Green belts, parks, and parking spaces were encroached upon by bus/truck body building and repair works.

Action taken: Directions have been issued to DDA and MCD to take adequate steps to stop dust pollution and dumping of garbage and keep the roads/area clean. North MCD has prepared a plan for improvement but progress is poor. In fact there is already an approved scheme with Rs 68 crore funding from Ministry of Housing and Urban Affairs. Till the roads are built, North MCD will have to use anti-smog guns/sprinklers to control dust pollution.

This exercise helps to push implementation, address missing links in the enforcement mechanism, bring clarity in the responsibilities of different agencies involved in the local areas, detect violation, address infrastructure gaps, and ensure compliance at the ground level. Further, this also helps to identify the systemic changes needed to make ongoing surveillance and monitoring more rigorous.

Delhi's unfinished agenda

Delhi's action on industrial pollution control provides an important learning curve for other states. But a lot more will have to be done for deeper cuts in industrial pollution.

Delhi needs a second generation industrial pollution control plan to take forward the unfinished agenda. This includes clean fuel transition that now requires city-wide mechanism for enforcement of clean fuel policy or the approved fuel notification to ensure complete stoppage of entry and illegal use of banned fuels in industry.

This needs time bound implementation of gas pipeline infrastructure in the industrial areas for 100 per cent coverage and penalty on the use of non-approved fuels. In the meantime, Delhi government along with other state governments and the union government needs to work out a mechanism for making prices of natural gas more competitive and harmonize the approach across NCR.

It has to be made mandatory for all industrial units to put up boards outside their gates providing details of the consent obtained from DPCC for operations to help identify the illegal units. A good siting policy has to be developed for rearranging the illegal units based on proper consent system and clean fuels so that monitoring is possible while protecting livelihoods. But illegality will have to eliminated. DPCC along with other land owning agencies will have to come up with integrated plans to identify the illegal units and see to their conditional rehabilitation. State support may be provided for this strategy.

Industrial pollution control plan needs special focus on management of industrial non-hazardous waste to prevent open dumping and burning. Municipal corporations, DPCC, industry associations, and waste management agencies need to come up with plans for each industrial area for implementation.

A detailed inventory of all air polluting industrial units—legal and illegal—should be made periodically to inform on-ground action.

NCR

Industrial pollution control in the NCR is a more difficult challenge given the scale and structure of industries. NCR cannot shift industries but will have to adopt stringent emissions control and clean fuel strategy for its industry clusters.

Scale and nature of the problem

CSE has carried out extensive surveys of the industrial clusters in NCR districts including Alwar, Bhiwadi, Sonipat, Panipat, Faridabad 1 and 2, Bahadurgarh, Gurugram (including Udyog Vihar), Ghaziabad, and Saibabad to understand the nature of stack emissions, use of fuels, fugitive emissions from material handling, disposal of non-hazardous industrial waste, and dust pollution from heavy truck movement on unpaved roads in the industrial areas. These surveys have been conducted during 2019 and 2020 (see *Map 2: Industry clusters surveyed*). The surveys have been possible with the help of the concerned state pollution control boards and information from the consent documents.

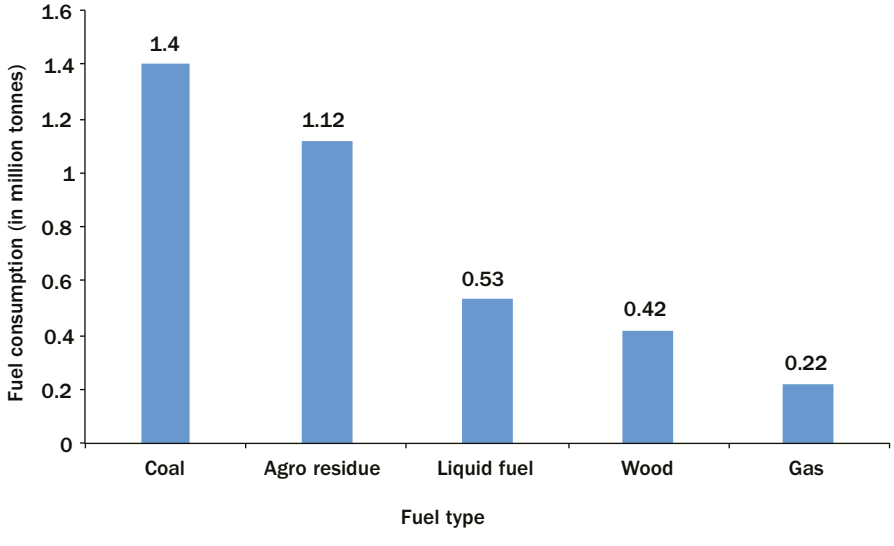
Map 2: Industry clusters surveyed

Source: CSE Report on Assessment of Industrial Air Pollution in Delhi-NCR, 2020

Coal dominates: The surveys have shown predominance of coal use in NCR. Share of industries using cleaner fuels (natural gas and electricity) is very low. In the districts of Ghaziabad and Panipat, almost 86 per cent and 56.2 per cent of the industries are still using coal. Available evidence on fuel usage shows that around 1.41 million tonnes of coal is being consumed annually by the industries in these seven districts compared to 0.22 tonnes of natural gas. Sonipat is the largest coal consuming district and has the highest overall pollution load in the region. Industries are largely small scale and very difficult to monitor for enforcement of pollution norms. The major hotspot areas contribute between 35 to 80 per cent of the pollution load of that district (see *Graph 23: Total annual fuel consumption by industries in seven districts of Delhi-NCR*).

However, an interesting trend is emerging in the districts where industrial use of agro residues is growing. Consumption is around 1.12 million tonnes per annum. Pollution emergency action during winter that requires closure of industry on dirty fuel and the pressure to implement the comprehensive action plan is pushing this organic change. While emissions profile of agro-residue combustion is yet to be assessed fully, it is expected to lower the gaseous emissions and nearly eliminate SO_x emissions. This also has the co-benefit of absorbing biomass waste in the region that otherwise is burnt in the open causing enormous pollution.

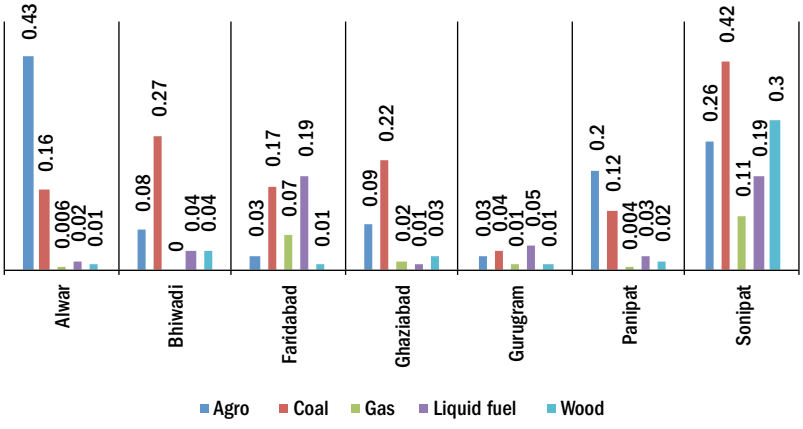
Graph 23: Total annual fuel consumption by industries in seven districts of Delhi-NCR



Source: CSE Report on Assessment of Industrial Air Pollution in Delhi-NCR, 2020

Bhiwadi consumes the second-highest amount of coal after Sonipat, which is also the highest consumer of gas among all districts. Alwar is the biggest consumer of agro-based fuel (see *Graph 24: District-wise annual fuel consumption*).

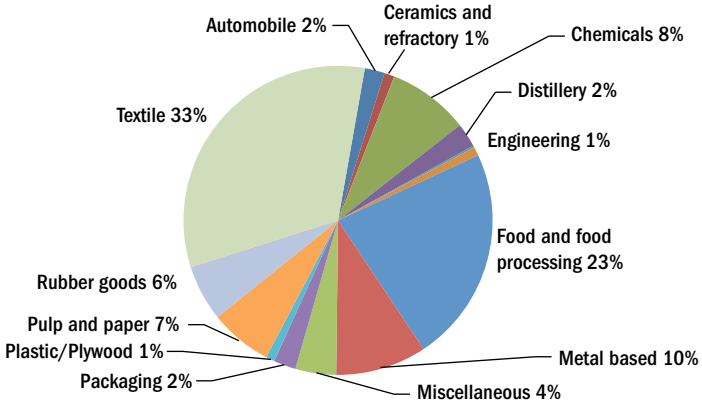
Graph 24: District-wise annual fuel consumption (in million tonnes per year)



Source: CSE Report on Assessment of Industrial Air Pollution in Delhi-NCR, 2020

Use of fuel also varies across industrial sectors. Broadly, the sectors that dominate include textile, food processing, automobiles, plastics and rubber, chemicals, engineering, paper and pulp, ceramics and refractory, etc. CSE study on sector-wise share of coal consumption shows that textile is the highest user of coal at 33 per cent, followed by food processing at 23 per cent, metal based units at 10 per cent, paper and pulp at seven per cent, and rubber goods a six per cent (see *Graph 25: Sector-wise share of coal consumption*).

Graph 25: Sector-wise share of coal consumption



Source: CSE Report on Assessment of Industrial Air Pollution in Delhi-NCR, 2020

Challenge of small units and small boilers

This assessment of industry clusters in NCR has shown the problematic prevalence of small scale units and small boilers. As much as 70 per cent of the boilers in these industrial areas have a capacity lesser than two tonnes per hour (TPH). Usually, small boilers lead to high coal consumption as there is no mechanized system for

fuelling and firing. Manual coal feeding makes small boilers a highly inefficient system that are difficult to monitor.

Alwar and Bhiwadi for instance have quite a number of small furnaces and boilers. MIA and Neemrana in Alwar contribute to more than 60 per cent of the industrial pollution load of the district. Bhiwadi Industrial Area contributes around 65 per cent of the industrial pollution load of the region. Bhiwadi with a total of 328 air polluting industries, predominantly metal based and chemical and pharmaceutical units, has three major designated industrial areas—Bhiwadi, Chopanki, and Khuskhera. Majority of the boilers have a capacity under three TPH. Bhiwadi Industrial Area is the largest coal, agro, and wood consumer. Chopanki Industrial Area is the largest liquid fuel consumer.

Compliance with emissions standards for boilers is quite meaningless as the standard at 1,200 mg/Nm^3 is very lax. MoEFCC is revising the standards. Tighter standards need to be notified immediately.

It will be more effective to adopt a centralized common boiler policy to replace small boilers. Replacing numerous decentralized and highly inefficient small boilers with large common boilers can maximize emissions gains. Common boilers can be more efficient and be better managed from the perspective of emissions control. Thermal efficiency of a common FBC boiler is in the range of 80–85 per cent as opposed to 65–70 percent in case of small boilers. Common boilers can reduce particulate emissions substantially and also enable SO_2 and NO_x emission control. Small boilers usually do not have emission control systems. Common boilers can also enable availability of steam at the doorsteps of units. This would be an improvement over small boilers as the quality of steam in terms of pressure and temperature is a concern in small boilers (see *Table 3: Small boilers—big pollution*)

In fact, common boilers have already been adopted in Gujarat's Industrial Policy of 2015 that includes a scheme of assistance for common environment infrastructure. At present, three such projects are in operation in Gujarat with around 90 units connected to three common boiler facilities. NCR needs to explore this approach seriously.

Table 3: Small boilers—big pollution

District/ region	Number of boilers	Boiler capacity (in percentage)			
		<2 tonnes per hour	2–10 tonnes per hour	10–15 tonnes per hour	>15 tonnes per hour
Alwar	63	70	13	8	10
Bhiwadi	111	48	43	6	3
Gaziabad	140	73	17	3	7
Faridabad	132	41	49	6	4
Gurugram	69	Data not available			
Panipat	163	33	60	4	3
Sonipat	212	Data not available			

Source: CSE Report on Assessment of Industrial Air Pollution in Delhi-NCR, 2020

Approved fuels in NCR

Following the notification in Delhi, the Supreme Court had also directed other state governments in NCR to notify an approved fuel list. Both Haryana and Rajasthan have notified approved fuels under the Air Act, 1981. Uttar Pradesh is yet to release the notification but even the notifications from Haryana and Rajasthan have not applied well thought out criteria to develop their approved fuel list (see *Table 4: List of approved fuels for Rajasthan and Haryana*).

The lists have been unable to change the status quo because they have allowed continued use of polluting fuels like coal, kerosene and naptha without assessing their pollution potential. These states have adhered to only the Supreme Court directives banning furnace oil and petcoke. Rajasthan banned use of petcoke and furnace oil in December 2017 and as per the notification issued by MoEFCC on 19 January 2018, lime kilns and cement plants were permitted to use pet coke as a fuel but with provisions that units must not store more pet coke than required for three months. Pet coke can be procured only from registered producers and dealers; trading of pet coke is not allowed and purchase of and consumption of pet coke will have to be reported by the units every month.

Table 4: List of approved fuels for Rajasthan and Haryana

Rajasthan	Haryana
Petrol (MS) including branded MS (as per the notification of Govt of India as amended from time to time)	Petrol (as per the norms prescribed by Govt of India from time to time)
Diesel (HSD) including branded HSD (as per the notification of Govt of India as amended from time to time)	Diesel (as per the norms prescribed by Govt of India from time to time)
Kerosene (SKO) (as per the notification of Govt of India as amended from time to time)	LPG and PNG for domestic and commercial use.
LPG/propane/butane	Natural gas / CNG for vehicles
Natural gas / CNG / PNG / LNG	PNG and LPG for boilers, furnaces, lime kilns, and thermic fluid heaters
Aviation turbine fuel	Aviation turbine fuel
Firewood/wood charcoal	Coal for boilers, furnaces, thermic fluid heaters, lime kilns, and brick kilns
All types of bio fuel / biogas	LSDF for boilers, furnaces, lime kilns, thermic fluid heater, and incinerators
Refused derived fuel (from waste to energy plants)	Biomass/agriculture refuse such as rice husk, mustard husk, bagasse, almond husk, and walnut husk either in the form of briquettes or loose to be used in boilers, furnaces, and brick kilns
Coal/coke/lignite	Firewood and dung cake for domestic use, crematoriums, and for other religious purposes
Biomass/agriculture refuse and/or briquettes made from biomass/agriculture refuse	Wood charcoal for use in cloth ironing
Dung cake	Biogas, bio fuel, and charcoal
Waste suitable for co-processing in cement kilns approved by CPCB	Refuse derived fuel for power plants, cement plants, and waste–energy plants
LDO/LSHS/naptha	
Hydrogen/methane	

Source: RSPCB, 2019. Source: HSPCB, 2018

Slow transition to natural gas

The states still do not have comprehensive industrial fuel policies to promote and accelerate clean fuels in industry. However, the Haryana Industrial Investment and Business Promotion Policy of 2015 has provided for a natural gas pipeline network. The Industrial Investment and Employment Promotion Policy of Uttar Pradesh of 2017 states that gas grid will be developed and prominent industrial areas will be identified. Rajasthan has also adopted a policy to expand natural gas pipeline in the state.

There is varying progress in all three states. In the order dated 02 March 2019, RSPCB had directed all units in Bhiwadi to shift to piped natural gas by 31 March 2019. Only Alwar (Bhiwadi), Kota and Bharatpur currently have gas pipeline infrastructure. RSPCB started pushing industry clusters in Bhiwadi to move to natural gas in 2019. Sizeable number of units have shifted to natural gas and made necessary investments to change the boilers. But the gas supply infrastructure is limited up to Bhiwadi and Neemrana industrial areas. The scope of change is still limited in MIA, the biggest industrial area in Alwar district.

Similarly, in August 2019, UPPCB had directed all industries in Ghaziabad and Gautam Buddh Nagar districts to shift to piped natural gas within 15 days. The industries protested against this short notice. Currently, the gas pipeline is available in Gautam Buddh Nagar and Ghaziabad.

In Gurugram, Faridabad, Panipat, and Rohtak in Haryana, gas supply pipelines have been provided but all units do not have access to gas yet. Out of 948 air polluting industries in Faridabad, only 81 industries are using gas and 11 industries are using electricity as a fuel. Similarly, out of 125 air polluting industries in Gurugram, only 11 industries are using gas. In Panipat district, out of 231 air polluting industries, only four industries have switched to natural gas.

One of the impediments to scaling up gas infrastructure is inadequate gas supply. The situation is complicated further due to competition and conflict between different gas supply agencies over territorial jurisdiction. This often requires executive and judicial interventions. In Alwar district for instance, Haryana City Gas Distribution Pvt Ltd was assigned the region of Bhiwadi whereas Torrent Gas Pvt Ltd was assigned the rest of the district. In fact, the Supreme Court had to intervene to resolve the issues between Haryana Gas Distribution Ltd and Indraprastha Gas Ltd over the supply of gas in Gurugram district. Conflicts delay the expansion of cleaner fuel infrastructure. This has added to the complexity and slowed down the process.

Moreover, industries that have already invested in emissions control systems like scrubbers and cyclones resent new capital investment in gas systems. Industries are asking for government support for this investment.

Natural gas pricing in NCR

While the region requires massive clean fuel transition and phasing out of coal, fuel pricing policy is a major roadblock. It is evident that under the current fuel pricing regime, switching to natural gas from coal can increase industrial fuel cost 2.5 times. As mentioned earlier, while coal is under GST, natural gas is not. As a result, tax on coal is much lower than on natural gas, which attracts value added taxes in states. Dirty coal is under GST so tax is lower and industries also get credit. Coal is also under Open General License that allows easy import. Broadly, the total loading of taxes on natural gas can be as high as 40 per cent as opposed to eight per cent on coal. State taxes on natural gas are attractive sources of revenue for states like Gujarat and

Maharashtra. VAT is being charged on natural gas once in Gujarat and then again in the respective states, thus increasing the price of gas. For example, Rajasthan government charges 10 per cent VAT on natural gas, which an add-on to the 15 per cent VAT that is charged by the Gujarat government. The price of industrial piped natural gas in Bhiwadi ranged between Rs 38 and Rs 40/SCM as of October 2020.

It is the same scenario in Haryana where the state government is charging 5.3 per cent[8] as VAT on natural gas which is added on after the 15 per cent VAT charged by the Gujarat government. The industrial gas price in Haryana was Rs 31.63/SCM as of October 2020.

In Uttar Pradesh as well the government is charging 10 per cent VAT on natural gas which is added on to the 15 per cent VAT charged by the Gujarat government. The industrial gas price in Ghaziabad and Noida was Rs 31.63/SCM as of October 2020.

There are other distortions that make gas unattractive. The gas companies charge some amount from industries every year/month for the continued supply of gas. But industries have to pay this charge even if they are not in operation to keep their access to gas supply.

This has created perverse incentives for using coal. Urgent attention is required from both central and state governments to rationalize fuel prices to make natural gas more competitive and eliminate coal from industries in NCR. It is important to address the way in which the natural gas pipeline is being expanded without a pricing strategy for its increased uptake and for the creation of a sustainable market.

Industrial waste management

Industrial non-hazardous waste management has emerged as an important issue both in Delhi and NCR states. There is an urgent need to streamline the collection and disposal of such industrial waste, as it is otherwise burnt in open dump sites. There have been some initiatives as in Bhiwadi Industrial Area where authorities have tied up with an organization named 'Saarthak' to collect industrial waste and recycle and reuse using a material recovery facility. Such initiatives will have to be scaled up for the entire region.

Control fugitive emission

Fugitive emissions due to material handling, unpaved roads and truck movement are a huge concern across all industrial clusters. Industrial units from mineral grinding and stone crushing sector—an important sector in the region—are the major contributors to the problem of fugitive emissions and need to stringently adhere to the guidelines issued for the sector. This requires intense monitoring.

Explore agro-residue as an intermediary fuel

Growing pressure on industries has catalysed a new trend in the sector. Industrial units are shifting to agro-residue as a fuel. Alwar has witnessed the highest use of agro residues. This is gaining popularity to escape the stringent measures on industry. While the emissions profile of this change will have to be studied well, it does help to reduce emissions of SO_2 and NO_x. This also has the co-benefit of adding value to the agricultural waste that is otherwise burnt causing huge pollution.

Continuous emission monitoring system for compliance and monitoring in industries

Given the very large number of industries in NCR districts it is not usually feasible for the State Pollution Control Boards to monitor each and every industrial unit physically. There is both technical and human resource constraint. Therefore, smart monitoring with the help of continuous emission monitoring (CEMS) is required for effectiveness. There is an urgent requirement to strengthen the CEMS regime so that it can be used as a compliance monitoring tool by the regulators. However, the major concern regarding CEMS installation is quality control of data generated from the system. It is often not credible due to lack of proper calibration and wrong installation.

Illegal industries

Like Delhi, NCR also faces the challenge of illegal industries which remain unaccounted. Their contribution to the total industrial pollution load cannot be estimated. There is no legal framework to address the issue of illegal industries that largely operate outside the demarcated legal industrial areas. A framework is required for their regulation.

Brick kilns: special challenge

Brick kilns—tiny small scale units—are widely dispersed in the NCR. But given the nature of kiln technology and fuels they use, these have strong potential to pollute the common airshed. CSE has carried out surveys in the NCR and even generated emissions data. This shows that these units will require interventions to change the kiln technology to reduce emissions at source. The approach of setting emissions standards will not be as effective as it is difficult to monitor stack emissions and adopt expensive pollution control equipment. There is an interesting trajectory in the way the action on brick kilns has evolved in the NCR.

In October 2015, MoEFCC introduced a draft notification for the clay brick manufacturing sector. That was based on monitoring and deliberation by the CPCB and the Punjab State Council for Science and Technology (PSCST). The draft notification was stringent—it proposed to bring down the emission standard for particulate matter from 750 mg/Nm^3 to 500 mg/Nm^3 for natural draft kilns, and to 250 mg/Nm^3 for induced draft kilns. The existing emission standard varies from 1,000 mg/Nm^3 for smaller brick kilns to 750 mg/Nm^3 for medium and larger kilns. The draft notification also proposed that all brick kilns (irrespective of size) must improve their manufacturing process by converting to induced draft kilns to comply with the standards within five years.

In December 2015, the CPCB directed all brick kilns in Delhi-NCR to convert from natural draught to induced draught within 90 days. However, the order made no mention of changes required in brick setting. Brick entrepreneurs presumed—erroneously—that they could comply with the order by simply fitting a fan in their kilns, and did not need to introduce any other changes (such as changes in the brick setting, fuel feeding practices, etc.).

In August 2016, MoEFCC came up with a modified draft notification which proposed to fix the emission standards for PM at 250 mg/Nm^3 for all kilns. It also stated that existing kilns should comply with these new standards for particulate matter and convert to zigzag within three years. In the intervening period, the existing brick kilns (except the down draught kilns) would be allowed to comply with the PM standard of 500 mg/Nm^3.

In the same year, another order came from the CPCB: in November 2016, it directed the state pollution control boards of Uttar Pradesh, Rajasthan, and Haryana to shut down those brick kilns which had not converted from natural to induced draught (with rectangular kiln shape and zigzag brick setting) by 31 March 2017. Brick entrepreneurs in the region were confused by the two orders, and intrigued by the multiple terminologies (induced draught, high draught, etc.).

Following a request from the All India Brick and Tile Manufacturers Federation (AIBTMF), EPCA stepped in to clear the air. After a series of discussions with all stakeholders in May 2017, EPCA ordered all kilns in Delhi-NCR to shift to rectangular zigzag, with entrepreneurs having the option to choose between natural or induced draught. The deadline of 30 September 2017, as given by different SPCBs, remained.

Meanwhile, in June 2017, CPCB issued another directive which asked brick kilns across India to convert to zigzag setting with rectangular kiln shape. This directive clearly stated that brick kilns operating without permission and consent from respective SPCBs would be shut down. It also recommended brick paving of the area around brick kilns to prevent fugitive dust emissions. No deadlines were, however, offered.

In October of the same year, EPCA directed that brick kilns which had not converted to zigzag by 30 September 2017 whould not be allowed to operate in the winter season (till 15 March 2018). Following an interjection from the AIBTMF, EPCA agreed to discuss the matter based on the progress reports received from the three SPCBs of Uttar Pradesh, Rajasthan, and Haryana on conversion of fixed chimney bulls trench kilns (FCBTKs) to zigzag kilns.

The Association also requested EPCA to allow brickmakers to operate their FCBTKs for one last season, which would also allow them some time for conversion; the brickmakers offered to provide an undertaking that they will not operate during winter—from October 2017 to February 2018—and will convert their kilns before they start operations in the next season in 2018. The EPCA allowed brick-kiln owners who had submitted affidavits that said they would convert after 01 July 2018 to operate for one last season from 01 March 2018 to 30 June 2018. The EPCA order clearly mentions that from 01 July 2018, only zigzag kilns will be allowed to operate. EPCA further added that the kilns which had already converted to zigzag needed to be verified by the SPCBs (see *Table 5: Advantages of zigzag kilns over FCBTKs*).

Table 5: Advantages of zigzag kilns over FCBTKs

Sr. no.	FCBTKs	Zigzag kilns
1.	Specific energy consumption is in the range of 1.1–1.5 MJ/kg of fired bricks	Specific energy consumption in comparison to the FCBTKs is 20 per cent less
2.	Percentage of Class I bricks produced is between 50–60 per cent	Percentage of Class I bricks produced is much higher than 80 per cent
3.	Range of particulate emission from FCBTKs is between 250–1,250 mg/Nm^3	Range of particulate emission from the kiln is less than 250 mg/Nm^3
4.	Black carbon emission ranges from 0.07–0.27 g/kg of fired bricks	Back carbon emission is less than 0.05 g/kg of fired bricks

Source: CSE's report on National Brick Mission: A scoping paper, 2016 and CSE's report on Emissions monitoring of brick kilns-Zig zag vs FCBTK, 2019

The most recent draft notification by MoEFCC on 16 March 2018 followed the 2016 notification by leaving the particulate matter emission standard at 250 mg/Nm^3 but it allowed one year for conversion to zigzag in the case of kilns located near non-attainment cities, and two years for other kilns. It also said that in cases where various pollution regulatory bodies (such as the CPCB or SPCBs) have separately laid down timelines for conversion, such orders shall prevail.

Following EPCA's intervention the number of conversions had gone up from around 1,400 in 2018 to around 2,000 in 2019. The latest number of converted kilns is debatable but its clear brick kiln entrepreneurs have accepted the change.

Subsequently, the NGT has not allowed even those brick kilns that have zigzag technology to operate in NCR based on a carrying capacity report submitted by the CPCB which showed that no area in NCR has the carrying capacity to sustain brick kilns even with zigzag technology. Further decisions from NGT are awaited regarding operation of brick kilns in NCR. Currently, the clay brick industry in NCR is in a state of stagnation. There is also a big question mark over quality of conversion in NCR. A team of experts needs to visit all kilns and ensure conversion quality of zigzag is appropriate and all CPCB directions to control fugitive dust emissions have been implemented.

SECTION 3

Power plants

It will be a challenge to meet the regional air quality goals in Delhi-NCR if power plants continue to use dirty coal and do not meet the 2015 emissions standards. There is a variance in the trajectory of Delhi and rest of the NCR in addressing power plant pollution. While more aggressive steps have been taken to shut down coal power generation completely in Delhi, about 11 coal power plants have continued to operate in NCR without meeting the new emissions standards fully. The next steps in the region will have to be charted within this context.

CPCB has identified 11 coal based power plants within a 300 km radius of Delhi. These 11 plants together have 37 units, with a total operating capacity of 13.5 GW. Five of these are located in Haryana, four in Punjab and two in Uttar Pradesh. These plants are located in the common airshed of Delhi and NCR and cause enormous pollution and exposure.

Pollution challenge

Coal based power plants contribute substantially to particulate matter, sulphur dioxide, and nitrogen oxides as well as air toxins like mercury. The latest emissions inventory conducted by TERI-ARAI in 2018 has estimated that power plants contributed about eight per cent of Delhi's particulate load (when Badarpur power plant was operational) and 11 per cent of NCR's particulate load. The IIT Kanpur study of 2015 identified coal and fly ash as major contributors to Delhi's air pollution. In the summer, coal and fly ash contributed up to 30 per cent of PM_{10} and in winters about 10 per cent. When these studies were done, two coal based thermal power stations—NTPC Badarpur Thermal Power Station and Rajghat Thermal Power Station—and four gas based power stations were operational in Delhi (see *Table 6: Power generating stations in Delhi*).

Earlier, a study by Desert Research Institute using data from 2010 had estimated that power plants contributed 16, 15, 55, and seven percent of total $PM_{2.5}$, PM_{10}, SO_2 and NO_x emissions in Delhi. The researchers modelled areas of Delhi and its satellite cities Gurugram, Noida, Greater Noida, Faridabad, and Ghaziabad. Additionally, in 2010, Indian Institute of Tropical Meteorology had estimated power plants in Delhi contributed about 18 per cent of SO_2 emissions in Delhi. The researchers modelled areas of Delhi and its adjacent industrial regions covering approximately 70 km by 65 km.

After the closure of most of the coal-fired stations, the source apportionment study done in 2018 by Ministry of Earth Sciences indicated that the share of $PM_{2.5}$ load from coal-fired stations dropped to 3.3 Gg/year.

Table 6: Power generating stations in Delhi

Plant name	Company name	Capacity in MW	Unit size	Fuel
Rajghat Power Station	Indraprastha Power Generation Company Ltd	135	2*67.5 MW	Coal
Indraprastha Combined Cycle Power Plant	Indraprastha Power Generation Company Ltd	270	6*30 MW gas turbines + 3*30 MW steam turbines	Natural gas
Pragati Combined Cycle Power Station – 3 (Bawana)	Pragati Power Corporation Limited	1500	4*250 MW gas turbines + 2*250 MW steam turbines	Natural gas
Pragati Combined Cycle Power Station	Pragati Power Corporation Limited	330	2*104 MW gas turbines + 1*122 MW steam turbine	Natural gas
Rithala Combined Cycle Power Station (now retired)	Tata Power and Delhi government joint venture	108	2*31.6 MW gas turbines + 1*31.6 MW steam turbine	Natural gas
NTPC Badarpur	National Thermal Power Corporation Ltd	705	2*210 MW + 3*95 MW	Coal

Source: CSE, 2020

Delhi: fighting coal in power sector

A protracted battle had to be waged to shut down all coal power plants in Delhi. The plants in the heart of Delhi including Indraprastha and Rajghat were shut down in due course, but the final closure of Badarpur power plant was strongly resisted and contested. The Rajghat power station had been in a reserve shutdown mode since 2014. Its closure was pending settlement of commercial issues such as affixing of the residual value, employee relocation, etc. In mid-2019, the Delhi government finally decided to 'officially' shut down the plant. The 45-acre land area of the power station will be used to build a 5,000 kW solar park.

However, shutting down Badarpur power plant was not so easy. Recognizing the pollution risks these coal power stations posed, EPCA had asked the Government of Delhi to consider switching to cleaner fuel like natural gas for power generation. Government of Delhi had also approved the plan. A study was initiated on the feasibility of up-scaling the NTPC Badarpur plant to a 2000 MW gas-fired station. However the attempts failed as such conversion would need significant investment as opposed to establishing a new plant. But this conclusion could be reached only after four to five years of study.

The subsequent focus since 2011 had been to get the coal power plants to meet the existing standards. DPCC had repeatedly directed NTPC Badarpur to comply with tighter particulate matter emissions norms of 50 mg/Nm^3 and not the common minimum national standard of 150 mg/Nm^3. But the plant continued to report 'compliance' with 150 mg/Nm^3, even though it was not applicable and even after retrofitting its ESP.

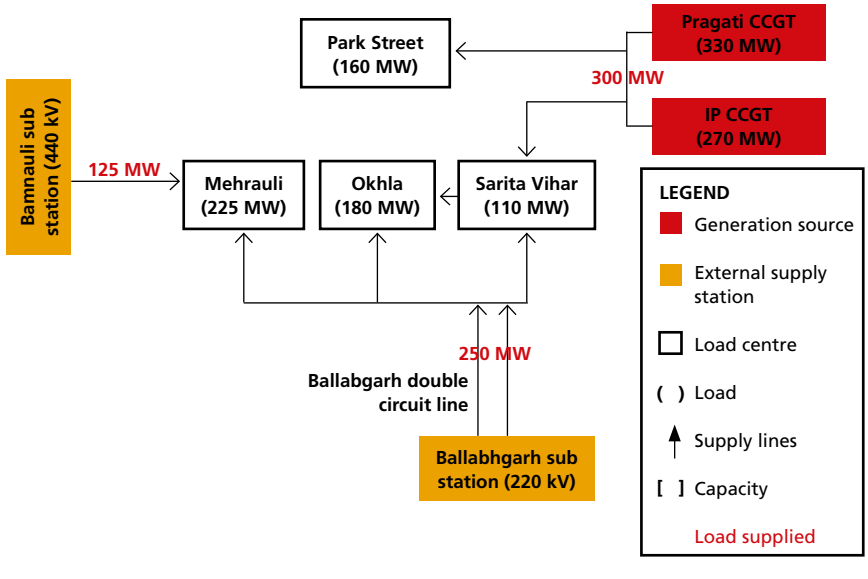
CSE's study conducted in 2015 showed that NTPC Badarpur was not meeting even the 150 mg/Nm^3 norm. Frequent thick plumes from the stack were evidence that the emissions were a lot higher than reported by NTPC Badarpur. In fact, the plant in its tariff application of May 2011 to Central Electricity Regulatory Commission (CERC) requested for approval to revamp its electrostatic precipitator and mentioned that emissions were in the range of 300–400 mg/Nm^3.

Frequent meetings with the plant authorities and inspection of the site brought out the defunct emission monitoring systems and inadequate pollution control measures. There was considerable resistance to the proposal to completely shut down the plant. Partial operation of the plant was insisted as one of the emergency measures to reduce pollution in Delhi during winters.

August 2015 onwards, the NTPC Badarpur plant began to operate at a partial load. Only two 210 MW units were operational. After November 2015, only one 210 MW unit was functional. The station was inefficient and generated expensive power. There were also practical hurdles to shutting down the plant completely. NTPC Badarpur supplied power to three substations—Okhla, Sarita Vihar, and Mehrauli—that cover parts of South Delhi. The plant also supplied power to Alwar but Alwar had the option of getting power from other sources. Okhla, an industrial area, was connected only to NTPC Badarpur, while Mehrauli and Sarita Vihar had additional connections to the grid through Bamnauli and Pragati substations respectively (see *Figure 1: Schematic diagram of power access for Okhla, Sarita Vihar, and Mehrauli*).

Delhi Transco Ltd (DTL) / State Load Dispatch Centre (SLDC) estimated that south Delhi areas supplied by NTPC Badarpur would have peak demand of 515 MW during winter. In addition Park Street substation needs 160 MW of which around 100 MW would be supplied by 'expected' generation of Pragati Power station. Thus, the net demand would be around 575 MW.

Figure 1: Schematic diagram of power access for Okhla, Sarita Vihar, and Mehrauli



Source: CSE, 2020

The most feasible solution was to establish a new inter-state transmission line (ISTS) which could bring in the necessary power to compensate the deficits. It was after this line got commissioned in 2018 and after repeated recommendation from the EPCA that the NTPC Badarpur station was retired in October 2018 after four decades of operation.

While stack emissions could be eliminated with this closure, the legacy of ash dump still remains a problem. The plant had two-third of its 1200 hectares area under fly ash dump. A credible waste management plan was recommended. Now the plant is proposing to set up an ecological park in this area.

Gas based power plant in Delhi

Bawana gas fired power station is a state-of-the-art facility that faced serious challenges due to lack of reliable and adequate supply of affordable gas. The promise of gas supply from the Reliance Industries Limited's (RIL's) D6 field in the offshore Krishna-Godavari (KG) Basin did not materialize and the plant remained idle. EPCA intervened to get two directives from the Supreme Court in 2018—one in February and another in July—to allot affordable gas to Bawana power station. The Ministry of Petroleum and Natural Gas also responded positively. The power station was allotted affordably priced gas (APM gas) for unit 3 by GAIL under 'no-cut' category. DISCOMS supplying power to Delhi are hoping that the Court would replicate its order and allot similar quantum of gas at-least to Pragati Power Station 1.

Next steps in Delhi

Only gas based power plants are operational in Delhi. With closure of all coal power plants Delhi has avoided burning of two million tonnes of coal annually that was a cause of enormous pollution in the city. After decades of effort Delhi has been able to push out coal based thermal power stations from its territory. This move must be upheld and no coa lbased stations must be allowed inside Delhi in the future.

Procure clean power: Even though Delhi has stopped coal power generation it has to take the next step to procure power only from clean stations. Currently, Delhi procures electricity from Chandrapura power station that according to the CSE ranking falls in the red category or the category of those power plants which are worst performers in terms of meeting emissions standards. Chandrapura TPS is the only station amongst the lot Delhi procures from which has not taken adequate measures to meet the sulphur dioxide norms as on date. Similarly, NTPC Singrauli and NTPC Farakka are once through plants which are guzzling enormous fresh water for electricity generation and have not advanced in the direction to meet the water norms specified by MoEFCC.

Majority of the other states have contracts to procure over 30 per cent of their electricity from clean sources. But Delhi is low on this list—40 per cent of its electricity is procured from the yellow category of power plants (see *Graph 26: Sourcing of electricity by different states*). Delhi has to source cleaner coal power—for example by sourcing less electricity from TPPs like Chandrapura TPS that have not taken adequate steps to meet the new emissions norms. Delhi needs to play a proactive role in putting pressure on the power plants to meet the new emissions standards through its procurement policy.

Ensure remediation of coal based power plant sites: This has to be the next big step to ensure that the legacy fly ash dumps are reclaimed and the land is put to

sustainable use including solar power generation. Remediation techniques will have to be implemented immediately.

Strengthen distribution and transmission network: Existing infrastructure to supply electricity must be strengthened to prevent power cuts and dependence on diesel generator sets. Imposing diesel generator set ban even as a back-up was initially met with strong resistance. Even state officials maintained that supplying power without cuts would be difficult, not only in summer but also in winter when electricity demand is low. The power distributor for the area cannot provide adequate temporary connection either as it doesn't have the required structures and facilities. A substation would be required to supply that much power. The Delhi power department was asked at the review meeting to make people aware about temporary connections they could use in place of diesel generators. Power distribution officials said there are tatkal or fast-track schemes for such connections. It was after three years of struggle by EPCA that DISCOMS and the Delhi government became confident of supplying power without the need for diesel generator sets. This network must be further strengthened.

Get APM gas/low price gas for Pragati 1 Power station—allow only natural gas plants to operate: This will require consistent and reliable supply of affordable gas.

NCR: Struggling

The CPCB has identified 11 coal power plants within a 300 km radius of Delhi adding up to 13.5 GW of power (five in Haryana, four in Punjab, and two in Uttar Pradesh). So far old capacity upto 1,720 MW commissioned before 1990 has been retired. Other plants are being reviewed for closure and modification.

All existing plants are required to meet the 2015 emissions standards notified by MoEFCC. While the other power plants in the country are required to meet the delayed deadline by 2022, the deadline for NCR plants was advanced to 2019 following the intervention from the Supreme Court. But full implementation has not been possible so far. The assessment of the current plants by CSE shows that two plants are complying with SO_2 norms, three plants show work-in-progress and are most likely to comply, but the rest are lagging behind. Seven plants have reported compliance with NO_x norms and rest are in the process of awarding tenders. All stations comply with PM norms.

Imperatives of coal based thermal power plants in NCR

Speed up process of implementing new emissions standards in state GENCOs: Coal power plants in NCR were mandated to meet the 2015 emissions standards (otherwise delayed for the rest of the country to 2022) by 2019. But these plants have not been able to meet the standards yet and are at varying stages of progress. Future action will require diligent tracking of plant-wise progress in implementing emissions standards for particulate matter, sulphur dioxide, and nitrogen oxides (see *Table 7: Plant-wise progress in implementation of emissions standards*).

CPCB issued show-cause notices to the plants on 31 January 2020 demanding their response within 15 days. Not satisfied with the response, CPCB sent penalty notices to 35 non-compliant electricity generators in 15 coal-fired thermal power stations on 08 May 2020. The units were ordered to deposit Rs 18 lakh per month to CPCB for six months beginning from 05 June. Punjab state government's power

Table 7: Plant-wise progress in implementation of emissions standards

UTTAR PRADESH

Plant name	Age	District	Total units	Total capacity (in MW)	Implementation progress as of October 2020
NCTPP Dadri – Stage 1	26	Gautam Buddh Nagar	4	840 (210*4)	SO_2 – FGD/DSI installed PM – Complying NO_x – Complying
NCTPP Dadri – Stage 2	10	Gautam Buddh Nagar	2	980 (490*2)	SO_2 – FGD work in-progress PM – Complying NO_x – Complying
Harduaganj TPS (UPRVUNL)	8	Aligarh	3	610 (250*2 + 110*1)	SO_2 – Re-tendering, FGD budget submitted for approval PM – Complying NO_x – Tender awarded to GE

*retired

HARYANA

Plant name	Age	District	Total units	Total capacity (in MW)	Implementation progress as of October 2020
Aravali thermal power (Indira Gandhi TPS)	8	Jhajjar	3	1500 (500*3)	SO_2 – Tender awarded, work under progress PM – Complying NO_x – Tender awarded
Mahatma Gandhi STPS (CLP India Pvt Ltd)	8	Jhajjar	2	1320 (660*2)	SO_2 – FGD installed, bid awarded for up-gradation PM – Complying NO_x – Complying
Panipat TPS (HPGCL)	15, 31	Panipat	4	920 (250*2+ 210*1)	SO_2 – Re-tendering PM – Complying NO_x – Tender will be awarded in 3 months
Rajiv Gandhi TPS (HPGCL)	10	Hisar	2	1200 (600*2)	SO_2 – Tender floated PM – Complying NO_x – Tender will be awarded in 3 months
Yamunanagar TPS (HPGCL)	12	Yamuna Nagar	2	600 (300*2)	SO_2 – Tender floated PM – Complying NO_x – Tender will be awarded in 3 months

PUNJAB

Plant name	Age	District	Total units	Total capacity (in MW)	Implementation progress as of October 2020
Guru Hargobind TPS (Lehra Mohabbat TPS)	21, 10	Bathinda	4	920 (210*2+ 250*2)	SO_2 – Tendering stage PM – Complying NO_x – Complying
Rajpura TPP (Nabha Power Ltd)	6	Patiala	2	1400 (700*2)	SO_2 – Work has begun at site PM – Complying NO_x – Complying
Ropar TPS	32	Rupnagar	4	840 (210*4)	SO_2 – Tendering stage PM – Complying NO_x – Complying
Talwandi Sabo TPP	4	Mansa	3	1980 (660*3)	SO_2 – Tender stage – L1 was Chinese firm but they have back tracked, retendering to be done PM – Complying NO_x – Tender floated

Note – Plants whose progress is slow have been highlighted in red

station and a few other thermal power stations challenged the penalty order in court. The Supreme Court on 19 June 2020 stayed the recovery of environmental compensation. CPCB informed the Supreme Court on 30 August 2020 that the timelines given in the 'Revised schedule' will be adhered to. Accordingly, the timelines of the TPPs within 300 km from Delhi were advanced by CPCB.

Power stations in the NCR are still in denial mode. Pressure has already built up from the industry to dilute the norms further, especially SO_2 norms. This must be countered as SO_2 is not only harmful by itself but also contributes to sulphate particles. IIT Kanpur study has estimated that 90 per cent reduction in SO_2 from power plants within 300 km of Delhi can reduce approximately 35 $\mu g/m^3$ of $PM_{2.5}$.

Seek progress report on implementation and put that in public domain: The action plan and progress made by each plant should be updated on a quarterly basis. Ensure that the Gantt charts of the project/milestone with L1 progress in execution of the projects are put out and shared. Currently, CEMS are installed in these stations. However, the data from these systems is not available in the public domain.

Need steps to enable implementation of the SO_2 standards: Currently, eleven power plants are meeting particulate standards and most of them are on track to meet the NO_x standards. But most plants are lagging behind with regard to SO_2 control. This will require special attention. State-run coal-fired power plants have given excuses stating that they have tendered for the installation of pollution control equipment like FGDs to lower SO_2 emissions in power stations. But they are not getting adequate response to those tenders. Manufacturers, on the other hand, argue that state-run stations have convoluted the tendering system. The creditworthiness of state-run companies is also an issue. This requires meeting and coordination between manufacturers, vendors, and GENCOS to resolve the issue. Once tenders are awarded and zero dates signed, the probability of implementation can improve.

Retrofitting of old power stations should be decided expeditiously based on techno-economic analysis: Within a 300 km radius around Delhi, 2,140 MW (15 units in four power stations) capacity was commissioned before 1990. All except 420 MW (two units in PSPCL–Ropar) have been retired (see *Table 8: Old plants which require immediate attention*).

Table 8: Old plants which require immediate attention

Plant name	Age	District	Total old units	Total capacity (in MW)
Ropar TPS	32	Rupnagar, Punjab	4	840 (210*4)
Panipat TPS (HPGCL)	31	Panipat	1	210 (210*1)
NCTPP Dadri – Stage 1	26	Gautam Buddh Nagar	4	840 (210*4)
Guru Hargobind TPS (Lehra Mohabbat TPS)	21	Bathinda	2	420 (210*2)

Older power stations should be asked to do a quick techno-economic study. Only if it is cost-effective to retrofit pollution control equipment should such systems be installed. Otherwise, these stations should be converted to run only on biomass/co-fire biomass as an intermediate strategy till the time they are phased out. This can help to prevent accumulation of stranded assets. Usage of biomass residue for firing can reduce particulate emissions and nearly eliminate SO_2 emissions.

Direct the states (Haryana, U.P. and Punjab) to implement first-run concept: To push implementation of new norms, preferential scheduling of electricity from cleaner power stations should be adopted. Along with renewable energy or 'must-run' plants, a new category of clean coal power plants needs to be made. This new category of 'first-run'/'priority-run' plants needs to include all coal based thermal power plants which are headed towards meeting the new environmental norms by 2022. Power stations which meet the new norms should be run at full load, and all non-complying plants should be kept at the bottom of the merit order dispatch.

Adopt a labelling approach to classify the plants based on their level of progress: Plants that have progressed in terms of awarding tenders or are in the process of meeting the norms can be asked to run on full load and can be labelled 'yellow'. Those that are slow in progress can be labelled 'orange'. Plants that are in the stage of tendering, doing feasibility study or those with no plan yet to meet the norms can be labelled 'red' category (see *Table 9: An updated 'yellow', 'orange', and 'red' category of plants that are supplying electricity to the respective states*).

Revise the penalty for non-compliance with the 2022 deadlines for strong deterrence: The penalties levied currently on coal power stations are a small fraction of fixed costs they receive and cannot effectively push implementation. A deterrence mechanism which includes drastic punitive measures such as levying of fines or closing down non-compliant plants is neither effective nor practical. Preferential scheduling on the other hand could serve as an incentive to stations which are in the process of meeting the new norms. A multi-disciplinary committee can assess and suggest effective penalty and deterrence.

Ensure that data is in public domain to ensure transparency and build pressure: Currently, CEMS are installed in these stations. Data from these systems needs quality control and analysis to track improvement. This should also be placed in public domain.

Currently, NCR burns about 35 million tonnes of coal. To eliminate coal, natural gas power plants are needed in the region. But the existing gas based power plants are working at a capacity that is much less than the installed capacity. The key reason preventing switch to cleaner power is the pricing of natural gas. Massive use of coal in captive power plants and furnaces across the region remains a problem.

Table 9 – An updated 'yellow', 'orange', and 'red' category of plants that are supplying electricity to the respective states

DELHI

Station	Plant capacity, MW	Capacity allotted to state, MW	Fixed cost, Rs/unit	Variable cost, Rs/unit	Total cost, Rs/unit	Category
DADRI TPS	840	692	4.25	1.01	5.26	Yellow
MEJIA TPS	1,340	219	3.05	1.25	4.3	Yellow
RIHAND STPS	1,000	92	1.42	0.88	2.3	Yellow
RIHAND-II STPS	1,000	119	1.42	0.73	2.15	Yellow
RIHAND-III STPS	1,000	124	1.47	1.5	2.97	Yellow
SASAN UMPP	3,960	419	1.18	0.13	1.31	Yellow
DADRI-II TPS	980	692	3.84	1.48	5.32	Yellow
JHAJJAR	1,500	657	3.6	1.67	5.27	Yellow
KAHALGAON - I	840	46	2.33	1.09	3.42	Yellow
KAHALGAON-II	1,500	148	2.21	1.12	3.33	Yellow
MAITHON POWER LIMITED (MPL)	1,050	281	2.7	1.5	4.2	Yellow
UNCHAHAR-I TPS	420	22	3.53	1.12	4.65	Yellow
UNCHAHAR-II TPS	420	43	3.56	1.04	4.6	Yellow
UNCHAHAR-III TPS	210	26	3.53	1.4	4.93	Yellow
CHANDRAPURA THERMAL POWER STATION (CTPS)	760	300	2.49	1.45	3.94	Orange
FARAKKA*	-	21	2.84	0.85	3.69	Orange
SINGRAULI STPS*	2,000	140	1.43	0.67	2.1	Orange

PUNJAB

Station	Plant capacity, MW	Capacity allotted to state, MW	Fixed cost, Rs/unit	Variable cost, Rs/unit	Total cost, Rs/unit	Category
ADANI POWER LIMITED (APL - MUNDRA) STG-III	1,980	1,424	2.52	1.01	3.53	Yellow
JHAJJAR (CLP)	1,320	1,320	3.53	1	4.53	Yellow
KODERMA (DVC)	1,000	100	2.64	1.7	4.34	Yellow
MEJIA TPS	1,340	100	2.84	1.48	4.32	Yellow
RAGHUNATHPUR (DVC)	1,200	100	3.01	1.37	4.38	Yellow
RIHAND STPS	1,000	60	1.34	0.83	2.17	Yellow
RIHAND-II STPS	1,000	54	1.34	0.85	2.19	Yellow
RIHAND-III STPS	1,000	53	1.32	1.47	2.79	Yellow
SASAN UMPP	3,960	419	1.26	0.17	1.43	Yellow
JHAJJAR	1,500	657	3.53	1.65	5.18	Yellow
KAHALGAON - I	840	23	2.26	1.03	3.29	Yellow
KAHALGAON - II	1,500	65	2.15	1.1	3.25	Yellow
UNCHAHAR IV	500	40	3.35	1.59	4.94	Yellow
UNCHAHAR-I TPS	420	10	3.55	1.06	4.61	Yellow
UNCHAHAR-II TPS	420	21	3.58	0.98	4.56	Yellow
UNCHAHAR-III TPS	210	11	3.55	1.36	4.91	Yellow
SINGRAULI STPS*	2,000	186	1.39	0.63	2.02	Orange
FARAKKA*	-	10	2.75	0.85	3.6	Orange
RGTPP (KHEDAR) (IPP)	1,200	1,200	3.57	0.96	4.53	Orange
CGPL MUNDRA UMPP	4,000	380	1.91	0.9	2.81	Orange
LANCO AMARKANTAK POWER LIMITED (LAMKPL)	600	285	1.78	1.2	2.98	Orange
PTPS UNIT-6	210	210	3.89	1.47	5.36	Orange
PTPS UNIT-7	250	250	3.49	0.95	4.44	Orange
PTPS UNIT-8	250	250	3.49	1.47	4.96	Orange
YTPP - I & II - (YAMUNANAGAR)	600	600	3.48	1.11	4.59	Orange
PTPS UNIT-5	210	210	3.89	1.23	5.12	Red

HARYANA

Station	Plant capacity, MW	Capacity allotted to state, MW	Fixed cost, Rs/unit	Variable cost, Rs/unit	Total cost, Rs/unit	Category
ADANI POWER LIMITED (APL - MUNDRA) STG - III	1,980	1,424	2.52	1.01	3.53	Yellow
JHAJJAR (CLP)	1,320	1,320	3.53	1	4.53	Yellow
KODERMA (DVC)	1,000	100	2.64	1.7	4.34	Yellow
MEJIA TPS	1,340	100	2.84	1.48	4.32	Yellow
RAGHUNATHPUR (DVC)	1,200	100	3.01	1.37	4.38	Yellow
RIHAND STPS	1,000	60	1.34	0.83	2.17	Yellow
RIHAND-II STPS	1,000	54	1.34	0.85	2.19	Yellow
RIHAND-III STPS	1,000	53	1.32	1.47	2.79	Yellow
SASAN UMPP	3,960	419	1.26	0.17	1.43	Yellow
JHAJJAR	1,500	657	3.53	1.65	5.18	Yellow
KAHALGAON - I	840	23	2.26	1.03	3.29	Yellow
KAHALGAON - II	1,500	65	2.15	1.1	3.25	Yellow
UNCHAHAR IV	500	40	3.35	1.59	4.94	Yellow
UNCHAHAR-I TPS	420	10	3.55	1.06	4.61	Yellow
UNCHAHAR-II TPS	420	21	3.58	0.98	4.56	Yellow
UNCHAHAR-III TPS	210	11	3.55	1.36	4.91	Yellow
CGPL MUNDRA UMPP	4,000	380	1.91	0.9	2.81	Orange
YTPP - I & II - (YAMUNANAGAR)	600	600	3.48	1.11	4.59	Orange
LANCO AMARKANTAK POWER LIMITED (LAMKPL)	600	285	1.78	1.2	2.98	Orange
PTPS UNIT-5	210	210	3.89	1.23	5.12	Orange
PTPS UNIT-6	210	210	3.89	1.47	5.36	Orange
PTPS UNIT-7	250	250	3.49	0.95	4.44	Orange
PTPS UNIT-8	250	250	3.49	1.47	4.96	Orange
RGTPP (KHEDAR) (IPP)	1,200	1,200	3.57	0.96	4.53	Orange
SINGRAULI STPS*	2,000	186	1.39	0.63	2.02	Orange
FARAKKA*	-	10	2.75	0.85	3.6	Orange

UTTAR PRADESH

Station	Plant capacity, MW	Capacity A\ allotted to state, MW	Fixed cost, Rs/unit	Variable cost, Rs/unit	Total cost, Rs/unit	Category
ANPARA - A	567	567	1.64	0.72	2.36	Yellow
ANPARA - B	900	900	1.38	0.44	1.82	Yellow
ANPARA - D	900	900	1.54	1.55	3.09	Yellow
MEJIA TPS	660	545	3.39	2.26	5.65	Yellow
ROSA - I	570	570	2.88	1.56	4.44	Yellow
ROSA - II	570	570	2.88	1.56	4.44	Yellow
SASAN UMPP	3,960	465	1.3	0.15	1.45	Yellow
TANDA	396	396	3.14	1.28	4.42	yellow
BARA (PRAYAGRAJ POWER)	1,980	1,980	2.48	1.24	3.72	Orange
BEPL, BARKHERA	82	82	3.44	1.83	5.27	Orange
BEPL, KHAMBHARKHERA	80	80	3.44	1.84	5.28	Orange
BEPL, KUNDARKHI	82	82	3.33	1.84	5.17	Orange
BEPL, MAQSOODPUR	82	82	3.47	1.82	5.29	Orange
BEPL, UTRAULA	82	82	3.39	1.89	5.28	Orange
DHARIWAL	300	161	1.88	1.87	3.75	Orange
HARDUAGANJ	94	94	3.37	1.48	4.85	Orange
HARDUAGANJ EXT.	405	405	2.95	1.57	4.52	Orange
KSK MAHANADI	1,200	949	2.84	2	4.84	Orange
LALITPUR POWER	1,875	1,875	3.04	2.25	5.29	Orange
LANCO (ANPARA-C)	1,080	1,080	1.75	1.49	3.24	Orange
MB POWER	600	343	2.82	2.49	5.31	Orange
OBRA - B	900	900	2.55	0.67	3.22	Orange
OBRA - A	175	175	0	0	0	Orange
PARICHHA	198	198	0	1	1	Orange
PARICHHA - EXT.	378	378	3.17	1.25	4.42	Orange
PARICHHA - EXT. STAGE - II	405	405	2.93	1.47	4.4	Orange
RKM ENERGY PVT LTD	720	190	1.93	2.42	4.35	Orange
TRN ENERGY PVT LTD	600	370	2.35	1.71	4.06	Orange

*Plants have awarded tenders but are water guzzlers, they use OTC technology which requires intake of maximum freshwater up to 100 cum/MWh

First-run analysis:

- List sourced from MERIT India website
- Analysis done comparing data with November 2020 CEA's status report on FGD. State Pollution Control Board certificates can be obtained to verify the same.

SECTION 4

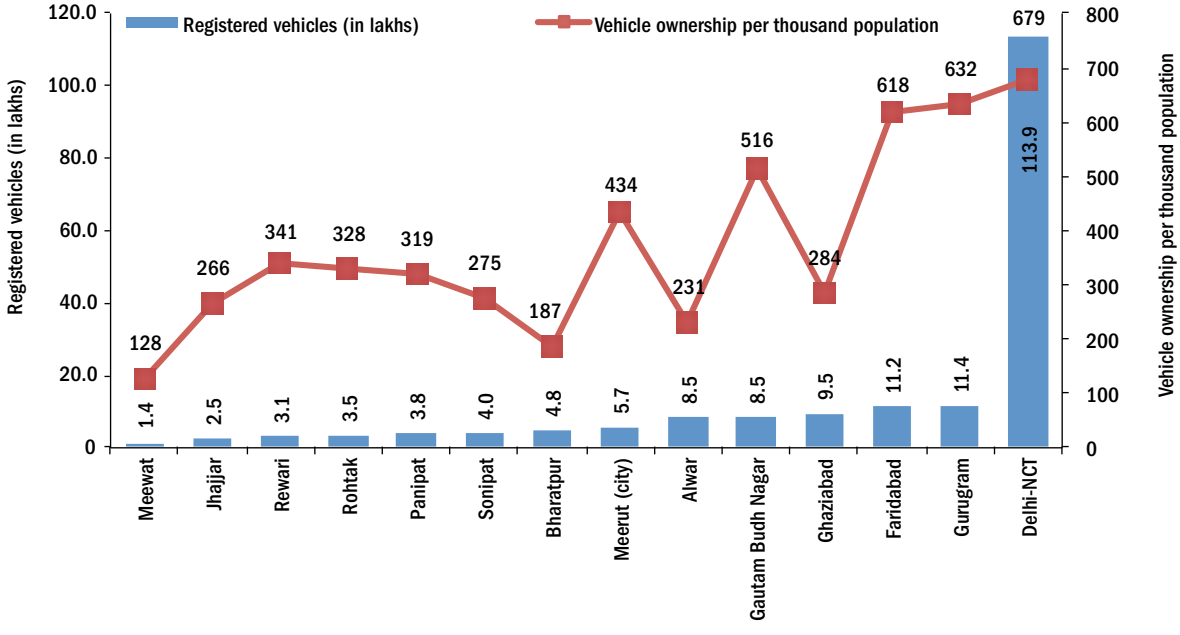
Vehicles and fuels

Explosive motorization is locking in enormous amounts of pollution. Between 2000 and 2018, vehicle numbers in Delhi alone increased four-fold from 25 lakh to 103 lakh.[9] According to the last available Road Transport Year Book (2016–17) released by MoRTH, Delhi is ninth among all states and top among all cities in terms of cumulative vehicle registrations. Combined share of two-wheelers and four-wheelers is 95 per cent and both have increased at the rate of more than six per cent per annum in the last 10 years.

Motorization in Delhi is significantly higher than the entire NCR. Presently, Delhi-NCR has around two crore registered motor vehicles (excluding Baghpat and Bhulandshahr), of which Delhi accounts for 60 per cent, followed by Gurugram and Faridabad with six per cent in each district (see *Graph 27: District-wise registered motor vehicles in Delhi-NCR*).

Even though the total vehicle stock in other districts is comparatively small, vehicle density in some of the highly urbanized districts like Gurugram

Graph 27: District-wise registered motor vehicles in Delhi-NCR



Note: Graph does not contain vehicle registration data of Baghpat and Bhulandshahr districts; in case of Meerut district, only city level data is available.
Source: Statistical abstract 2015–16, Haryana government; Statistical abstract 2018–19, Rajasthan government; Road Transport Yearbook 2015–16, Ministry of Road Transport and Highways (MoRTH), Peeyush Khandelwal, 2019[10]; Sohil Sehran, 2018[11]; Economic Survey of Delhi 2018–19, Planning Department, Government of Delhi.

and Faridabad in terms of per capita vehicle ownership is comparable to Delhi. While there are 679 vehicles per 1000 population in Delhi, the number is 632 in Gurugram and 618 in Faridabad. If NCR-wide public transport strategies are not scaled up immediately, dependence on personal vehicles will only worsen and increase toxic exposure.

Vehicular pollution

Vehicles have remained one of the most obstinate sources of pollution. This not only contributes substantially to the ambient pollution concentration but also to the local exposure. In 2015, the IIT Kanpur study observed that vehicles are the most consistent and dominant sources of pollution throughout the year, while most other sources are variable.[12] In fact, the two most consistent sources for PM_{10} and $PM_{2.5}$ in both seasons are secondary particles and vehicles.

The 2018 study for Delhi-NCR by SAFAR shows that the $PM_{2.5}$ emission load from vehicles is 41 per cent in Delhi and 39 per cent in NCR.[13] The contribution of the transport sector to $PM_{2.5}$ concentration was 25.4 per cent in 2010. It increased to 41 per cent in 2018. Vehicles also contribute to 62.5 per cent of the NO_x load.

The TERI-ARAI inventory study shows that the transport sector contributes 38.8 per cent of particulate load in Delhi and 12.6 per cent in NCR.[14] The transport sector also contributes 81.3 per cent of NO_x in Delhi. Source apportionment studies show that the contribution of vehicles to particulate concentration in the air increases during winter. While vehicles are the top polluters among combustion sources, they rank second after road dust overall. This is evident in nearly all available studies in the region.

Moreover, other studies have shown that vehicles are also responsible for high exposure due to their proximity to the population. A study by Health Effect Institute in Delhi has shown that maximum influence of vehicular emissions is upto 500 meters from the road side and about 55 per cent of Delhi's population lives within that zone. Control of vehicular pollution requires a diverse set of solutions related to improvement in vehicle technology and fuel quality as well as mobility strategies to reduce vehicle miles travelled.

Technology roadmap

Level of vehicle technology, quality of fuels, performance of emissions control systems during the useful life of vehicles on roads, and vehicle maintenance determine the level of real world emissions from vehicles. Stringent emissions standards are required to accelerate improvement in vehicle technology, fuel quality and on-road emissions management. Delhi and NCR have witnessed substantial improvement but with some variance. This agenda will have to be taken forward.

Leapfrogging emissions standards: The past five years have seen a dramatic push for a leapfrog strategy to move directly from BS IV emissions standards that were implemented in April 2010 to BS VI emissions standards nation-wide in 2020. In this process Delhi took the lead to become the first city in the country to switch to BS VI fuel (10 parts per million sulphur diesel) from 01 April 2018, two years ahead of the national schedule. NCR switched to BS VI fuel from 01 October 2019, six months ahead of the national schedule.

In January 2016, the Government of India decided to skip BS V emission norms altogether and leapfrog directly to BS VI norms by April 2020. The 2017 notification asked for nation-wide introduction of BS VI emissions standards from

01 April 2020. As a result, particulate matter standard for different categories of diesel cars was tighter by 82–93 per cent, and that of nitrogen oxide tighter by 68 per cent. Similarly, in trucks and buses, the particulate limit was 50–67 per cent more stringent compared to BS IV counterparts. The gap between petrol and diesel norms became narrower. Moreover, in addition to the existing practice of weighing mass of particles for certification of vehicles, a new measurement method and standard has been adopted to count the number of invisible tiny particles in the exhaust. This requires use of the most effective diesel particulate filter, with over 95 per cent efficiency, for effective reduction.

The BS VI norms have thus enabled adoption of more advanced diesel emissions control systems. These include advanced particulate filters to control particulate emissions and lean NO_x traps, selective catalytic reducing system, and exhaust gas recirculation systems for NO_x emissions control. These advanced systems are hugely sensitive and require high level of maintenance. In addition, BS VI norms for two-wheelers are also significantly more stringent. They now require separate norms for hydrocarbons and NO_x that were earlier regulated in combination as well as compliance with evaporative emissions.

This national move to leapfrog directly to BS VI norms was to a great extent catalysed by the development in Delhi—one of the largest vehicle markets in Delhi. Several measures were adopted in Delhi to control and penalize dieselization. The Supreme Court had cracked down on diesel trucks, diesel SUVs, big diesel cars, and old diesel vehicles in Delhi and NCR. Toxic potential of diesel emissions was well recognized and polluter pay principle was accepted by the courts. Despite strong opposition from the automobile industry, the apex court had imposed environment pollution charge on purchase of SUVs and diesel cars with more than 2000 cc engines.

What changed the game was the submission from oil companies and Ministry of Petroleum and Natural Gas (MoPNG) to the Supreme Court committing to the nation-wide introduction of 10 ppm suplhur fuels by 2020. This enabled the decision to introduce BS VI compliant vehicles nation-wide from 2020 onwards. Facing serious action against diesel vehicles in Delhi-NCR, the automobile companies also agreed to commit to that deadline. The impact of stronger action to control dieselization is evident in the plummeting sales of new diesel cars. In fact, following the introduction of BS VI norms, several auto companies announced that the production of some of the smaller diesel cars would be discontinued as the incremental cost of the new emissions control systems are not affordable in this segment.

While introduction of BS VI norms has enabled a paradigm shift in the way we manage emissions from vehicles powered by internal combustion engines, this has also created pressure for more improved on-road emissions monitoring and management to ensure that the advanced emissions control systems remain durable and effective during the useful life of vehicles on road and real world emissions remain under control.

Towards real world emissions regulations: At the time of crafting BS VI regulations, a CSE assessment had brought out the importance of aligning the detailed BS VI regulations and testing procedures for certification of vehicles with the European reform packages that had followed after the Volkswagen scandal called dieselgate. These reforms have become necessary to control emissions in the real world. Some of these reforms include testing procedure for measurement

of real world emissions from vehicles (emissions measured with the help of portable emissions monitors as vehicles are driven on road), in-service emissions compliance, fixing the margin of deviation, adopting more exacting driving cycle for certification, etc.

Initially, the automobile industry was hesitant to adopt real world emissions regulations and preferred lab based test procedures. But the industry finally agreed and informed EPCA and the Supreme Court about its consent. The BS VI regulations have now provided for real world emissions requirement. At this moment this is being applied to generate data. But this will be enforced for compliance from 2023 onwards.

Make the new technology work: The paradigm shift in the emissions control systems in BS VI vehicles has implications for on-road emissions management. This makes adoption of more advanced on-road emissions monitoring necessary. The current system of PUC certificates is no longer appropriate. BS VI vehicles are equipped with highly sophisticated and advanced emissions control systems, especially the diesel vehicles. These are highly sensitive to maintenance. Some of these systems like the SCR also add to the cost of operation because SCR requires periodic refilling of autograde urea solutions like AdBlue for its operation and to control NO_x emissions. This therefore requires a network for dispensation of autograde urea in the region. But global experience has also shown that these systems are vulnerable to tampering and fraud, and that vehicle users disable these systems to avoid the recurring costs. This requires surveillance and physical checks to prevent damage or tampering. If not addressed, this can lead to unregulated emissions despite the investment in advanced BS VI technologies. PUC centres will have to be equipped with a basic physical check-list to ensure such tampering has not occurred.

Action on diesel emissions

Over the past two decades, concern over toxic diesel emissions has been driving action on vehicle technology and fuels in Delhi. The IIT Kanpur study of 2015 showed that diesel four-wheelers were about 25 per cent of the fleet in Delhi but were responsible for about 78 per cent of the $PM_{2.5}$ emissions from vehicular sources. These estimates were further evaluated by International Council on Clean Transportation (ICCT) which showed that emissions from diesel vehicles posed four times higher cancer risk than petrol cars in the city. This translates into more than 280,000 avoidable cancers in Delhi-NCR due to lifetime exposure to diesel exhaust. The World Health Organisation has also declared diesel particulates as class I carcinogen for their strong link with lung cancer and air quality regulators like the California Air Resources Board have declared it as a toxic air contaminant. This along with more health information was shared with the Supreme Court from time to time and that helped to sharpen the action on diesel emissions.

Heavy-duty vehicles

Heavy-duty truck traffic has drawn a lot of attention from the Supreme Court over the last two decades. According to the IIT Kanpur source apportionment study of 2015, trucks contributed about 46 per cent of the emission load from vehicles. The concern over toxic emissions from trucks has led to diverse set of action in Delhi.

Diversion of truck traffic: The action on trucks started with the Supreme Court order dated 06 December 2001. The apex Court had banned the entry of non-

destined commercial traffic, or the trucks that only passed through Delhi without any business in the city. The order, however, could not be implemented immediately due to the unavailability of alternate routes for non-destined trucks. Subsequently, the Supreme Court in 2005 ordered the creation of two peripheral expressways—eastern and western—to divert transit traffic away from Delhi. The eastern and western peripheral expressways that had to cut across the neighbouring states of Uttar Pradesh and Haryana, had to be executed by the National Highway Authority of India and the respective state governments. But lack of coordination, rigid investments and lack of timely action delayed these projects considerably. This order was reiterated by the Supreme Court once again in December 2015. EPCA then took the initiative to coordinate with the concerned state governments to execute the projects. Finally, both the expressways became operational in 2017. It has been reported that immediately after the implementation of the two expressways nearly 60,000 trucks a day could be diverted.

Environment compensation charge (ECC) on each truck entry: In 2015, CSE had conducted a survey that included round-the-clock counting of incoming traffic using video recording in 13 key entry points of Delhi (between 29 June and 18 July 2015). These 13 entry points let in about 70 per cent of the incoming commercial traffic. The survey had counted all categories of trucks and other commercial vehicles including mini-light goods vehicles, light goods vehicles, and two- three- four- five- and six-axle trucks. This showed massive number of non-destined commercial vehicles entering and leaving Delhi and criss-crossing the city.

On a daily basis about 38,588 commercial vehicles (excluding taxis) entered Delhi from these 13 entry points. If these numbers are extrapolated for all the 127 entry points, this could be as many as 52,146 vehicles per day. If all commercial light and heavy duty trucks are combined then about 115,945 vehicles entered the city daily. In terms of pollution load, these incoming light and heavy duty trucks spewed close to 30 per cent of the total particulate load and 22 per cent of the total NO_x load from all vehicles in Delhi. This survey also found that the trucks preferred to transit through Delhi even when alternative routes were available because of the lower toll rates on those roads compared to the entry tax charged by the Municipal Corporations. Thus, there was an added economic incentive to transit through Delhi. These findings were shared by EPCA with the Supreme Court. This led to a few significant rulings on truck entry.

Firstly, the Supreme Court applied the polluter pay principle and on 09 October 2015 imposed environment compensation charge on all commercial goods vehicles entering Delhi to make it more expensive to go through the city. Secondly, the Supreme Court directed that the revenue collected fromECC should be utilized to create a dedicated fund for pollution control including augmentation of public transport and improving non-motorized transport infrastructure for pedestrians and cyclists. Thirdly, any vehicle registered before 2006 should not be allowed to enter the city. Subsequently,the Court fixed differential rates for vehicles empty and laden with goods, and also permitted exemptions for vehicles carrying 'essential' goods. The court further reiterated its previous order of 2001 that any non-destined vehicle should not be allowed to enter Delhi.

The rate of ECC was differentiated based on types of trucks—Rs 700 on light-duty trucks and Rs 1,300 on trucks having two or more axles. Trucks carrying essential commodities like food and petroleum were exempted. Since November 2015, ECC is being collected through the concessionaire appointed by South Delhi Municipal Corporation (SDMC).

It was however clear that manual collection of ECC in cash was vulnerable to fraud and corruption. This required electronic cashless transaction and monitoring to reduce the chances of corruption and leakages. Imposition of ECC had led to huge volumes of cash collection—approximately Rs 9 crore/week. But it was difficult to estimate the quantum of leakage in the system, as there was no physical count of the number of vehicles entering Delhi. The CCTV cameras installed by Delhi government at the key entry points were not designed to count the exact number of vehicles entering Delhi.

To address this concern, EPCA submitted a report to the Supreme Court on 10 August 2016 recommending installation of Radio Frequency Identification (RFID) system for effective and credible ECC collection. This was needed to streamline the collection of huge volumes of cash through the system. EPCA recommended installation of RFID systems at the earliest. This meant that each vehicle entering Delhi would have to pay online or make deposits at the issuing points. Vehicles could pre-register. This would help to enforce the ban on pre-2006 vehicles. RFID system could also track destination of the trucks. The exempted vehicles could pre-register or seek reimbursement from government after entering the city.

On 22 August 2016, Delhi government was asked by the Supreme Court to release Rs 120 crore from the ECC account to the SDMC, which is the executing agency for the installation of RFID at thirteen key entry points. Delhi's transport department and the Municipal Corporation shared the funds created from ECC to implement RFID.

In 2017, EPCA directed SDMC to commission a traffic study to ascertain the numbers of commercial vehicles entering Delhi from 20 major entry points of Delhi that accounted for about 85 per cent of the total heavy commercial vehicles entering the city. One of the objectives was to assess the impact of ECC on truck numbers. At that time, collection of ECC was manual. Around this time, CSE had also commissioned a third-party survey to conduct an independent verification. It was challenging to track the change given the varying categories of ECC collection. For example, only 23 per cent of the vehicles were paying full ECC, and 23 per cent were paying only half ECC. Also, the existing system was not able to check entry of pre-2006 vehicles as the VAHAN database was incomplete and it was difficult to cross-check manually. But the survey also showed that there was barely any difference in the numbers of commercial vehicles entering the city in 2015 and in 2017. The impact of ECC on truck numbers was not discernible. This indicated weakness in the collection system. This initially prevented the ECC system from becoming an effective deterrence. This shifted the focus towards timely implementation of the RFID system.

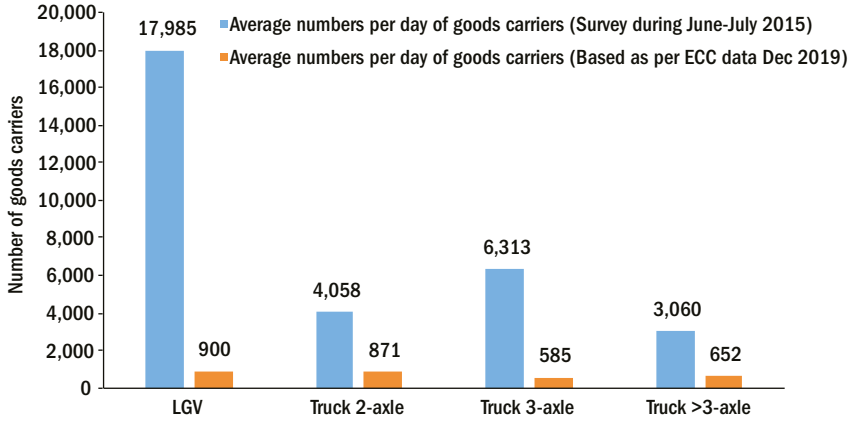
Impact of RFID system on the truck number and pollution load: The RFID system has now becomefully operational at 13 entry points. This has made a dramatic difference. It is now possible to track real time data on truck entry from these points and this can be monitored by SDMC remotely. Now, the date of vehicle manufacture is provided in the database during pre-registration for obtaining RFID tags that has allowed the system to blacklist the pre-2006 vehicles and deny them entry. All of these are electronically monitored.

To assess the improvement, EPCA compared the real time truck entry data of SDMC for the13 major entry points for the period 01 December 2019 to 01 January 2020 based on the surveys conducted during June–July 2015. This shows dramatic reduction in truck numbers. The number of heavy and light duty vehicles entering the city from 13 entry points has reduced from 22,000–38,000 per day estimated in

2015 to 2500–3000 per day in 2019–20. The successful completion of eastern and western expressways in 2019 has also contributed to this trend.

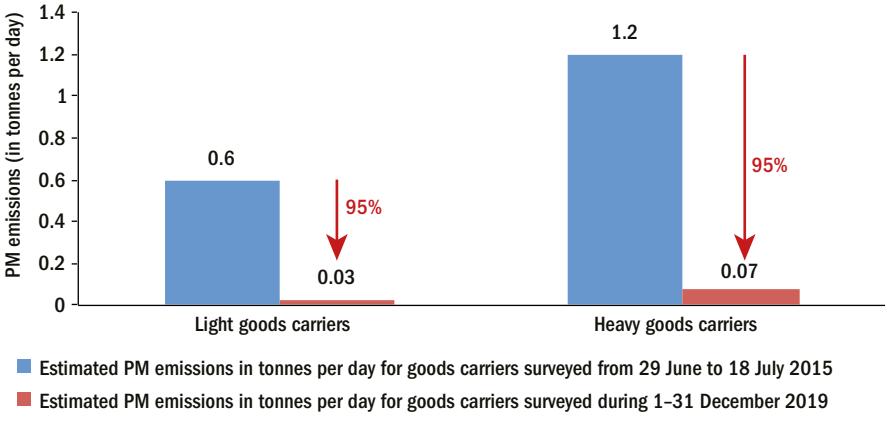
This translates into drastic reduction in pollution load from trucks. Compared to 2015, total particulate load from trucks entering from these 13 locations have reduced by as much as 95 per cent. There is 87–94 per cent reduction in NO_x load from light-heavy duty vehicles (see *Graph 28: Reduction in number of goods carriers of different categories in 13 major entry points*, *Graph 29: PM emissions from different segments of commercial vehicles* and *Graph 30: NO_x emissions from different segments of commercial vehicles*).[15] This is a direct evidence of emissions gains because of strategic intervention.

Graph 28: Reduction in number of goods carriers from 13 major entry points



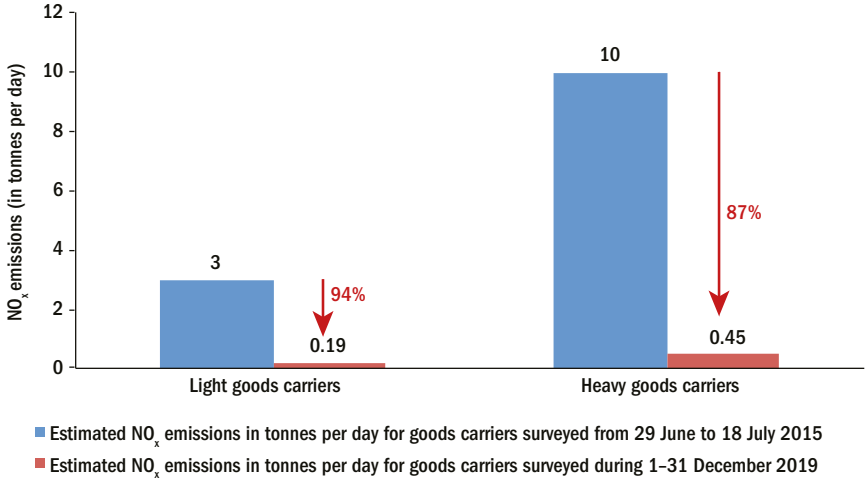
Source: CSE commissioned survey data of June–July 2015 and SDMC data of December 2019

Graph 29: PM emissions from different segments of commercial vehicles



Source: SAFAR study from 2018, CPCB study titled Status of Pollution Generated from Road Transport in Six Mega Cities from 2015, and CSE commissioned survey data of June–July 2015

Graph 30: NO_x emissions from different segments of commercial vehicles



Source: SAFAR study from 2018, CPCB study titled Status of Pollution Generated from Road Transport in Six Mega Cities from 2015, and CSE commissioned survey data of June–July 2015

SDMC has now put a proposal for extending RFID installation to 10 additional locations based on the learning from phase one of the project. EPCA had recommended implementation of RFID project in additional 111 entry points in early 2020. The objective was to ensure that all 133 entry points (13 implemented, 10 with RFID booths, and 101 with handheld devices) have RFID controls to make ECC enforceable. As per SDMC's plan, RFID will be completed in 113 entry points by January 2022. However, all 113 toll plazas were equipped with hand-held control systems for the winter of 2020.[16] Even though recent ground assessment shows that there is little progress in this direction, overall this initiative has demonstrated that successful implementation of a policy decision requires systemic change and commensurate infrastructure for enforcement.

Action on big diesel cars and SUVs

When global oil prices peaked in 2014, dieselization rate of new cars sales had increased significantly from four per cent in 2000 to about 50 per cent. Massive dieselization of the car segment based on weak emissions standards was seen as negating the benefit of the CNG transition in Delhi as well as other efforts. Cheaper diesel prices acted as an incentive. As a result, the official policy of low taxes on diesel for farmers and freight was being misused for luxury cars. This drew the attention of the Supreme Court. EPCA in its report to the Supreme Court had estimated that to recover the extra fuel tax that petrol car users pay over life-time use of the car, the diesel car users need to pay at least (on an average) 20 per cent of the ex-showroom price of the car as a one-time environment compensation charge. This was intensely debated in the Court and hotly contested by the automobile industry.

As the Chief Justice's bench heightened pressure, the automobile industry volunteered to agree with one per cent of the cost of big diesel cars/SUVs with 2,000 cc engines and above as the environment pollution charge in Delhi and NCR. The Supreme Court accepted this and further directed that the revenue from this charge be taken to the dedicated fund to be managed by the CPCB and be used for pollution control measures and assessment. This policy must continue and the charges should

be increased on all diesel cars. The EPC fund has been utilized for setting up of monitoring stations in Delhi-NCR and also for funding of studies.

Judicial pressure and fiscal disincentives in Delhi have helped lower the sale of diesel cars in the capital. Combined with the introduction of BS VI standards, these factors have hit the small diesel car market hard as well. Several manufacturers such as Maruti Suzuki have announced their decision to stop production of smaller diesel cars. It has been reported that from the peak of 47 per cent of new car sales in 2012–13, diesel car sales have plummeted to 19 per cent in 2018–19. Even in the SUV segment, a strong diesel bastion, the share of diesel SUVs sold has declined from 98 per cent in 2012 to 83 per cent in 2018–19.

While all these measures combined have helped to lower emissions from the diesel fleet, the implementation of BS VI standards now requires systems for real world emissions monitoring and on-road emission management.

On-road emission management

Accelerated change in vehicle technology with improvement in emissions standards has also made it necessary to ensure that vehicles remain low emitting throughout their useful life on road. From that perspective, the focus has been on improving the ongoing PUC programme and also to phase in more advanced on-road emissions monitoring. This will have to be taken forward.

Revamping pollution under control certificate

The national PUC certification is the existing mechanism to check the emission levels of in-use vehicles in India.[17] But this programme continues to suffer from quality control issues, improper testing, rampant malpractices, and lax enforcement. This is undermining investment in the programme and defeating the purpose of identifying grossly polluting vehicles on roads.

PUC audit in Delhi and NCR: On 02 December 2016, the Supreme Court directed EPCA to audit and inspect PUC checking centres located in Delhi and NCR to appraise the court on the efficacy and integrity of the PUC programme. This audit looked at structural and institutional issues.

Nationally, PUC certificates are issued as per Rule 115 of the Central Motor Vehicles Rules (CMVR), 1989. The rules, along with the Code of Practice prepared by the Automobile Research Association of India (ARAI) provide the protocol for testing petrol, diesel, and CNG/LPG vehicles, specification of testing centres, and operators' protocols. The state transport department is the regulatory institution that licenses and monitors the PUC testing centres within its jurisdiction. The test results are transferred to a central server hosted by the state government. Each test result is sent to the central server after completion of the test and then displayed at the testing centre to minimize human intervention. In Delhi, this network is hosted and maintained by the Delhi E-Governance Society, IT Department GNCTD.

The audit highlighted some of the systemic challenges:

- **Lax regulatory enforcement of PUC norms and regulations**: The audit revealed systemic issues related to lack of quality control, accountability of testing centres, and lax regulatory oversight in licensing and monitoring of these testing centres. This resulted in numerous small PUC testing centres mushrooming around the NCR border that operated without compliance with the operating protocols set by the CMVR. PUC centres are operating without

properly trained staff or type approved emission testing equipment, and using fake testing software. The regulatory inspection and monitoring of testing centres was compromised further by the knowledge gap and shortage of skilled staff in the transport department. At the time of the audit, Delhi alone had 971 centres but the transport department had only 28 inspectors and among them only one inspector was available for actual on-ground inspection. These issues became evident in the gap in tracking the number of vehicles inspected and identified through the PUC programme.

- **Poor data recording and reporting**: Without uniform format for data reporting, data retrieval and analysis of emission data for compliance, the assessment of the system has become complicated and difficult. The test data from centres in NCR was recorded manually. It must be noted that despite huge investments in the online and automatic system in Delhi, data accessibility and usability for monitoring purpose has remained poor. For instance, out of 13.7 lakh tests conducted in Delhi, nearly 20 per cent recorded zero values for emissions data. Values of carbon monoxide (CO) and hydrocarbon (HC) can be negligible in many new vehicles. But sensitivity of instruments (lowest value that it can record) should be verified in case any PUC centre reports many zero values.
- **Lax PUC test norms**: Two key issues emerged through the inspection: a) poor failure rate and b) inadequacy of the simplified tests to assess emission compliance of new age vehicles. From the analysis of the pass-fail data, it emerged that failure rate for vehicles was very low. Older generation vehicles were passing the test with as high as 80 per cent margin from the norm. In Delhi, only 1.68 per cent of diesel vehicles failed the smoke density test and about 4.5 per cent of the petrol vehicles failed the CO and HC tests. Ideally, according to the global benchmark, on-road emissions monitoring should be able to identify at least 15–20 per cent as the worst emitters.
- **Antiquated testing procedures**: Smoke density test for diesel vehicles was originally designed for old diesel technologies that had high visible smoke emissions. The low failure rate has also been attributed to simplification of emission compliance tests over the years. For instance, for diesel vehicles the oil temperature test to ascertain the warm up condition of the vehicle was removed in June 2015 by Ministry of Road Transport and Highways.
- **Further reforms needed to be BS VI ready**: It was highlighted that PUC programme needs further strengthening to be BS VI ready.

Audit triggered reforms

The PUC audit in Delhi and NCR has catalysed a few systemic changes:

- **PUC norms for BS VI compliant vehicles**: On 26 November 2019, MoRTH notified new PUC norms for diesel/petrol/CNG/LPG vehicles meeting BS VI mass emissions standards.[18] All PUC centres need to calibrate their instruments to be able to measure the new norms. This will have to be followed through. According to ARAI all current in-service equipment (gas analysers and smoke meters) can be used for BS VI vehicles. These will require calibration.
- **Linking of insurance with PUC certificate**: Based on recommendations from EPCA, the Supreme Court has directed linking of annual vehicle insurance with valid PUC certificates. Following this directive, the Insurance Regulatory and Development Authority of India issued a notification on 20 August 2020 stating

'Please ensure that the above direction of the Hon'ble Supreme Court of India is followed scrupulously with special focus on compliance in National Capital Region of Delhi (Delhi-NCR).' This requires implementation.

- **Direction on use of hologram-based colour coded stickers based on fuel type:** In August 2018, the Supreme Court approved the government proposal to use hologram-based colour coded stickers. These stickers were to contain the registration date of the vehicle thereby aiding identification of vehicles running on high-polluting fuel and control their entry on routes during high pollution days. This was also to be utilized to identify and weed out older diesel and petrol vehicles banned in the earlier Supreme Court order in April 2015. Due to delays in implementation of the order it has not been possible to weed out old vehicles from the road or to keep out the orange sticker (diesel) vehicles from the road during high pollution periods. This implementation has started in Delhi. This needs to be scaled up NCR-wide.
- **Centralized inspection and maintenance centre to be better integrated:** Already, with support of the Union Government, a state-of-the-art and well equipped centralized testing centre has been set up in Jhuljhuli near Delhi for annual fitness and roadworthiness tests of the commercial vehicle fleet. This, along with the one that is already operating in Burari, needs to be leveraged better to improve the inspection regime.
- **Need stronger action on OBD**: The BS IV and BS VI vehicles now come equipped with OBD systems which can detect malfunction in the emission control systems of the vehicles and alert the driver by flashing the malfunctioning light on the dashboard of the vehicles. Globally, this tool is being integrated with vehicle inspection and maintenance programs. MoRTH at this moment has issued an advisory for checking of the malfunctioning light at the time of inspection and to return the vehicle for repair in workshops if the light is found on. However, additional measures are needed to introduce some basic tests in the PUC centres to see if the OBD is functioning and responding or if it has been disabled. Such integration is important as under the basic PUC framework more advanced testing of particulate and NOx emissions measurements are not possible. For diesel engines, OBD can detect major failure in vehicle components such as the de-NO_x system, monitor the vehicle fuel-injection systems and actuators, etc.
- **Physical inspection of emissions control systems to prevent tampering**: Regional Transport Officers require a checklist of physical and visual checks to ensure there is no attempt to tamper, damage or remove the key emissions control systems in the vehicles. This step has not been taken yet for implementation.

Towards remote sensing monitoring

Smart monitoring of on-road emissions has become necessary and inevitable as most of our on-road fleet has become BS IV compliant and India is poised to leap to a more sophisticated genre of BS VI technology for new vehicles in 2020. PUC programme was originally designed for older vehicle technologies. It is becoming increasingly ineffective and even irrelevant for more advanced emissions control systems in the newer fleet that need a very different policing approach to keep vehicles low-emitting on the road. Remote sensing monitoring is needed to ensure that vehicles remain low emitting throughout their useful lives. If grossly polluting vehicles are not addressed, on-road emissions can be very high.

At a global level, in response to the widespread incidents of emissions fraud and mounting evidence of very high on-road emissions from diesel vehicles even after meeting the Euro VI standards, regulators are relying more on smart monitoring. They have implemented real world emissions monitoring with a portable emissions monitoring system. But the entire on-road fleet still requires screening. Such large-scale screening is possible only with remote sensing. Remote sensing measurements are more reflective of real world conditions as measurements happen when vehicles are passing by under different ambient environmental conditions. Remote sensing results in other countries have demonstrated how this helps the regulators to evaluate the durability of emissions control systems and track the emissions performance of vehicle fleets over time on road.

Simply put, remote sensing is a light source and a detector that is placed on the side of the road or at a height to transmit a laser beam to measure exhaust emissions remotely via spectroscopy as vehicles pass by and cross the light path. This can measure the exhaust plume and detect a range of pollutants including nitric oxide, carbon monoxide, hydrocarbons, and carbon monoxide in 0.5 seconds.

It can record emission rates from thousands of individual vehicles along with speed and acceleration across all driving conditions daily. This can test several vehicles per hour within an interval of one second. A camera captures the image of the vehicle's number plate which, if connected with a vehicle registration database, can identify the make, model, certified emission standard, fuel type, rated power and other details. This system can screen large number of vehicles in a day.

How remote sensing is applied: Globally, remote sensing is done with three key objectives—

i) Identify high emitting vehicles that are the worst polluters on road to pull them over for proper checks and repair. This 'dirty screening' identifies vehicles that are not in compliance and are high emitters. They are then sent for proper inspection.

ii) 'Clean screening' of vehicles so that low emitting vehicles do not have to unnecessarily go for physical inspection tests. Clean screening identifies clean vehicles and exempts them from regular physical inspections. This reduces the cost of inspection and also improves public acceptance of the programme.

iii) To characterize the emissions profile of the on-road fleet. That can help to evaluate the established inspection and maintenance programmes and also to provide feedback on the performance of emission control technologies.

Pilot project in Delhi

The Supreme Court on 10 May 2018, while responding to recommendations from EPCA, instructed the Delhi government to look into the implementation of remote sensing technology for on-road screening of polluting vehicles. This was among the recommendations of EPCA in response to an earlier Supreme Court order of 23 March 2018 that had asked to examine the new parameters that could help improve the PUC programme. If implemented, remote sensing can dramatically alter the way we monitor emissions from on-road vehicles and allow more efficient screening of highly polluting vehicles. The Supreme Court has now directed MoRTH to carry out necessary amendments to Central Motor Vehicles Rules and Regulations to enable using remote sensing for enforcement.

ICAT pilot study on remote sensing in Delhi: The ICAT has been entrusted with the responsibility to pilot remote sensing in Delhi to generate data needed for designing a detailed programme for implementation. Based on this, MoRTH, ICAT, and ARAI are expected to detail out the implementation framework. Some of the key objectives of the ICAT's pilot study (New Delhi real world emission study) include:

Threshold limits: ICAT is developing 'gross threshold points' to identify the dirtiest vehicles plying on road. It is evident from the submission of the preliminary report by ICAT in Supreme Court that the gross polluter threshold points were kept at 96 percentile (determined from analysis of initial data collection of 70,905 vehicles) to minimize false positives. Vehicle emissions, vehicle speed and acceleration, and vehicle registration number were captured for these vehicles during data collection. Vehicle details were further matched using VAHAN database. However, the proposed gross polluter threshold point will require more scientific assessment as it seems very lenient now (see *Table 10: Gross polluter threshold point*).

Table 10: Gross polluter threshold point

Pollutant	Gross polluter threshold point	Remarks
CO	1.8%	CO and HC were developed mainly for petrol and CNG vehicles pull over & NO and UVSmoke were used for diesel vehicles pull over
HC	1600 ppm	
NO	1500 ppm	
UVSmoke	0.368 gms of carbon particulate per 100 gms of fuel burned	

Source: ICAT, 2019

Co-relating remote sensing with PUC results: It is evident from the preliminary report of ICAT that it has further analysed the pulled over vehicles based on 99 percentile gross polluter threshold (taking CO: 3.34 per cent, HC: 2782 ppm, NO: 2083 ppm & UV Smoke: 0.92). Approximately 62.5 per cent correlation (10 out of 16 vehicles) of gross polluter vehicles with respect to remote sensing data could be established for regulated pollutants as per Rule 116 of CMVR. For passenger car segment vehicles, approximately 33 per cent correlation (17 out of 52 vehicles) of gross polluter vehicles with respect to remote sensing data could be established for regulated pollutants.

Instrument used by ICAT in Delhi: The ICAT report submitted to the Supreme Court shows that the study was performed using a remote sensing RSD4600 system from M/s Opus Inspection, USA. The RSD4600 detects vehicle emissions when a car drives through an invisible light beam the system projects across a roadway. Three principle components are as follows: Source/Detector Module (SDM) which measures pollutants of interest using absorption spectroscopy; Speed/Acceleration Module (SAM) which captures vehicle's operating mode at time of emissions generation**;** and Camera module which captures an image of license plate from the rear of passenger vehicles. It is important to understand the different remote sensing technologies available for procurement to achieve best results.

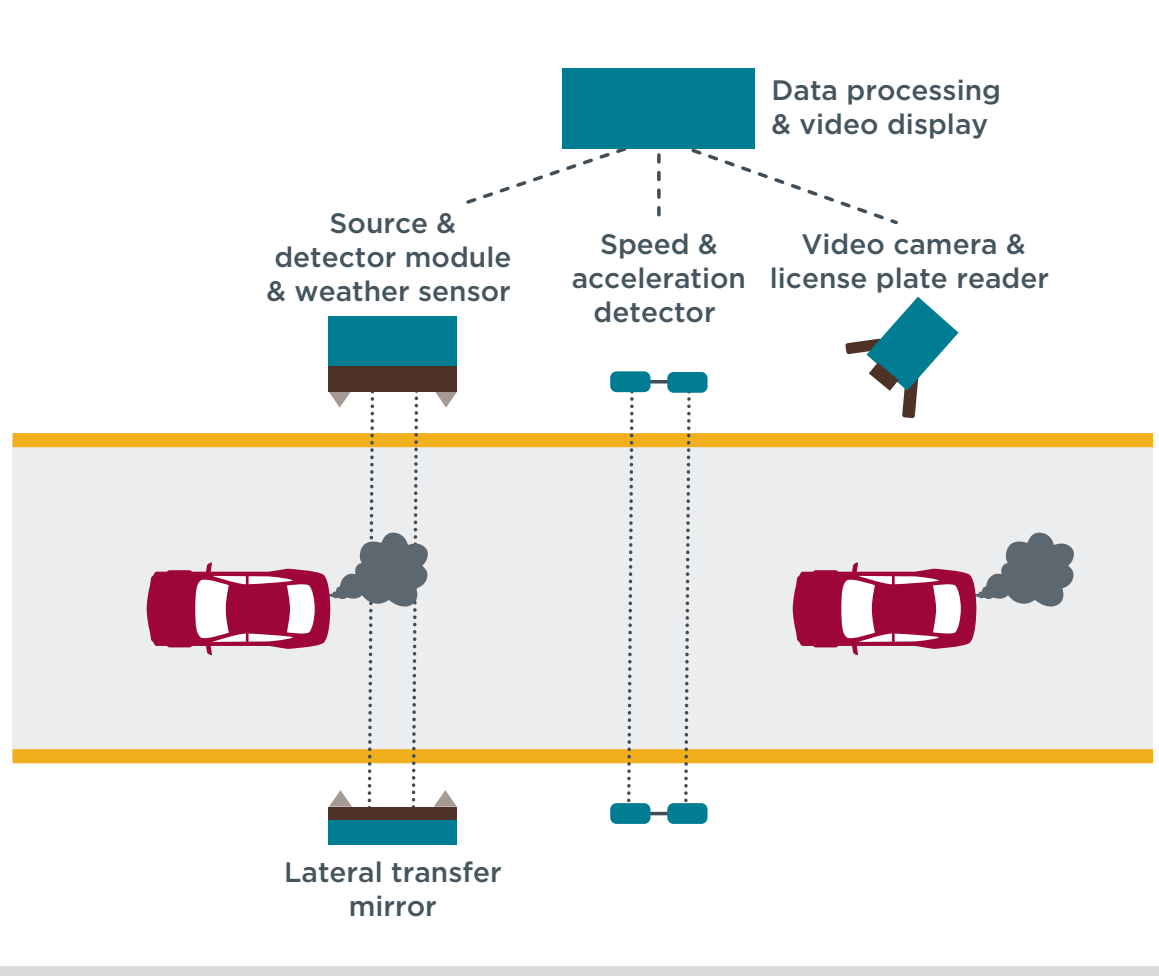
Needs implementation strategy: The Automotive Industry Standard Rules will have to be developed under the Central Motor Vehicle Act to enable implementation and enforcement of remote sensing methods. Currently, only the Transport

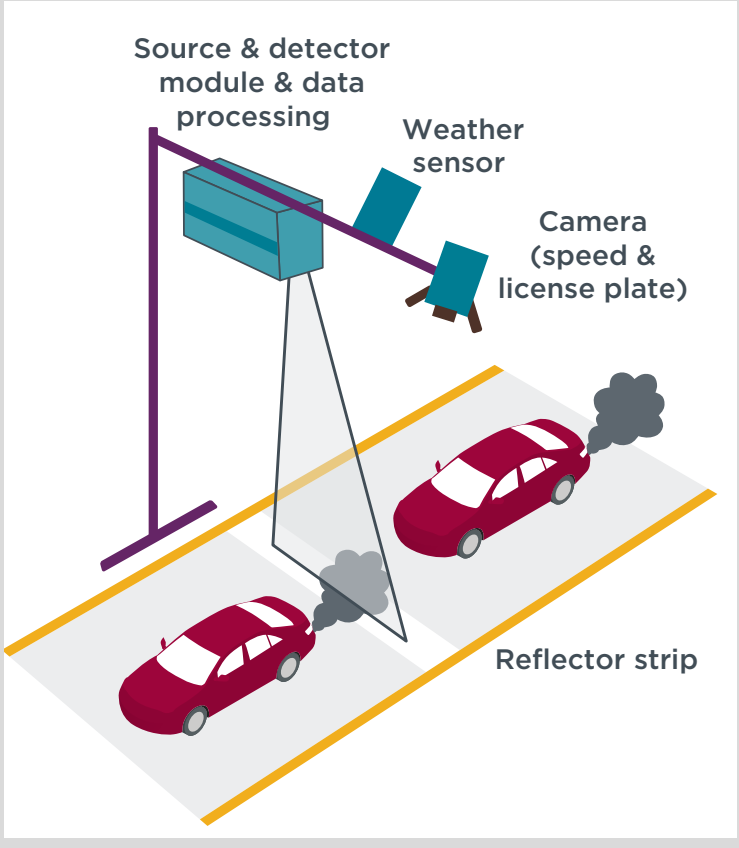
Types of remote sensing devices in the market

Availability of remote sensing technology is limited in India. The White Paper on Worldwide use of remote sensing to measure motor vehicle emissions published by ICCT in April 2019 shows that remote sensing technology has evolved quite significantly over the last decade. A highlight of some of the new technology approaches described in the white paper is as follows:

Open path: A light source and light detector are placed either at the side of or above a roadway, and the light source is reflected back by a mirror or reflective strip on the other side. The light absorbed by the exhaust plume as the light passes through is measured and correlated to the concentration of certain pollutants in the exhaust plume. The pollutant concentration as measured before the vehicle crosses the light beam is taken as background pollution and subtracted from the measurement. The system also includes speed and acceleration detectors and a license plate camera. All systems currently use infrared and ultraviolet light sources through arc lamp such as xenon or lasers. The use of lasers as the light source can increase the sampling rate along an individual exhaust plume from about 100 times per second to more than 10,000 times per second, potentially improving speed and accuracy.

Setup 1 – Crossroad



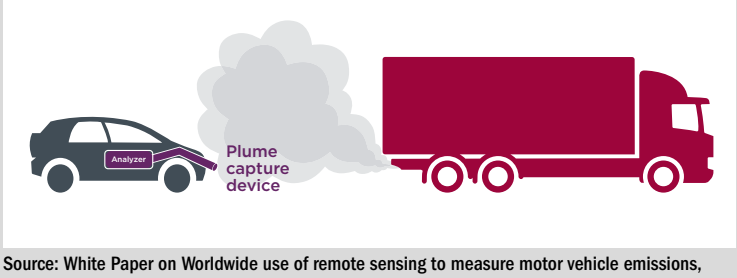


Source: White Paper on Worldwide use of remote sensing to measure motor vehicle emissions, ICCT, April 2019

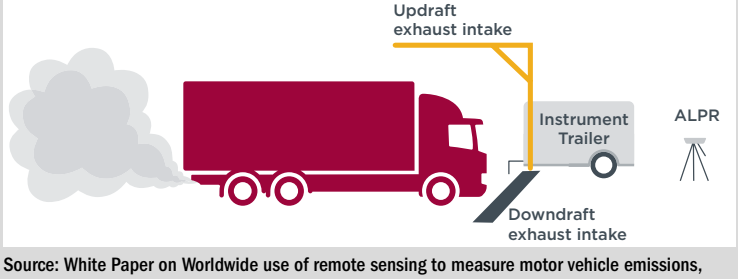
Setup 2 – Overhead: Overhead systems work similarly to crossroad systems and are capable of conducting measurements at sites with multiple lanes as well as collecting measurements from any vehicle independently of exhaust stack height. Crossroad systems must be positioned in line with the height of the exhaust stack.

Extractive (academic domain): Extractive remote sensing captures a portion of the target vehicle exhaust plume and directs that exhaust to pollutant analysers to measure exhaust concentrations.

Setup 1 – Exhaust plume chaser: A vehicle equipped with on-board emission analysers chases vehicles while sampling the air behind them. A portion of the target vehicle exhaust plume is captured using a sampling line with its inlet on the exterior of the chase vehicle. This exhaust sample is routed to pollutant analysers to measure exhaust concentrations.



Source: White Paper on Worldwide use of remote sensing to measure motor vehicle emissions, ICCT, April 2019



Source: White Paper on Worldwide use of remote sensing to measure motor vehicle emissions, ICCT, April 2019

Setup 2 – Stationary sampling: The measurement method is similar to the plume chaser, except that target vehicles drive past a fixed sampling location with sampling inlets placed in close proximity to the tailpipes/exhaust stacks of passing vehicles

Department in Kolkata is issuing show cause notices to vehicle owners based on remote sensing screening. These are directly addressed to the vehicle owners with the license plate numbers. The challan mentions the date and the location where the vehicle was detected with high pollution level. It also gives the emissions results for CO, CO_2, HC, NO_x and smoke. It makes reference to the PUC limit values as per Rules115 and 116 of CMVR. The vehicle owners are requested to bring the vehicle to a specified inspection centre for verification within 15 days. Failing that, the owner is liable to payment of fine under section 190(2) of Motor Vehicle Act and any other action as per law. The notice carries the picture of the vehicle with registration plate and the emissions results compared with PUC norms. When vehicle owners are intimated by the department about their polluting vehicles they often challenge the notice on the grounds that they have a valid PUC certificate and should not be penalized. MoRTH needs to clarify how remote sensing monitoring will co-exist with the PUC programme.

Supreme Court has directed MoRTH to frame the rules for remote sensing based on the ICAT pilot and EPCA recommendations. MoRTH should also provide technical guidance on remote sensing equipment and remote sensing data reporting which specifies design, construction, networking and data sharing of motor vehicles. Various measures have to be adopted by the Department of Transport which include issuing of tender for procurement of remote sensing equipment, site selection and sampling plan, and setting up system for management of data and network. MoRTH has already framed the draft rules and put them out for comments. They will have to be notified for implementation urgently.

In the meantime, Delhi and other cities in NCR need to frame their implementation strategy. This will require proper designing of the programme and procurement of remote sensing devices. Such procurement will require detailed RFPs and tendering. It is therefore important to review some of the performance indicators that other governments and agencies globally have focused on. The planning will have to address sampling plan for measurement, data collection plan and analysis, pollutants to be monitored, data processing and number plate matching, detailed analysis of the collected data by vehicle type, model year, emission control level, operating mode, etc., and data reporting fields and identification of the grid for monitoring.

This is an emerging opportunity in the region and should be leveraged to upgrade on-road emissions monitoring for more effective pollution profiling of the fleet and identify worst polluters on the road for real world change.

Inspection and certification

To adopt and utilize advanced emission testing technology in India, it is crucial to address structural issues within the existing PUC programme. The relaxed licensing regime along with lax regulatory inspection has led to the PUC system becoming a cash grab opportunity for operators and vehicle owners alike. An examination of global best practices indicates a centralized automated testing centre can minimize the manipulation of the PUC testing mechanism. This is achieved primarily by preventing the test operator and the vehicle owner from coming in contact during the testing process.

Though vehicles with new technology meeting stringent emission and safety standards have been introduced, there are still a lot of old vehicles which are running on the road. Studies have indicated that a small quantity of ill maintained vehicles contribute a great extent of the pollution. With the increase in vehicle population,

it is essential to ensure that in-use vehicle meet safety and emissions requirements. The most effective tool to improve in-use vehicle fleet is the vehicle Inspection and Certification Programme.[19] This new system not only inspects the vehicles to check their road worthiness but also examines their emissions.

These centralized systems can also be utilized to integrate remote sensing programme with the existing centralized inspection and maintenance centres. They can be equipped with simple dynamometers to measure emissions like NO_x, etc. These measurements are possible in loaded tests that are more capable of identifying high emission malfunctions as the air-fuel control and emission after-treatment systems evolve. The loaded tests are carried out on a dynamometer and thus require centralized testing centres. However, it is not possible to test each and every vehicle in the fleet to identify gross polluters and, for this purpose, commercial vehicles can be prioritized. Commercial vehicles must mandatorily visit these centres for annual vehicle fitness and roadworthiness tests.

The new vehicles that are fitted with OBD should be tested and certified in these centres. The vehicles failing the OBD tests should be sent to these types of centres (accredited inspection and certification (I&C) centres) for rigorous loaded mode testing. MoRTH may also provide their plans to set up centralized inspection centres like the ones set up in Jhuljhuli and Burari near Delhi for wider coverage of all commercial vehicles in Delhi and NCR. These centres are urgently needed to do high-level roadworthiness, safety, and emissions inspection tests in commercial vehicles.

Expansion of natural gas programme

CNG expansion in NCR: The CNG programme in Delhi was introduced two decades ago to reduce particulate pollution, especially toxic emissions from diesel fuel. A series of Supreme Court directives since 1998 in the on going public interest litigations on air pollution have led to the introduction of one of the largest ever natural gas vehicle programmes for public transport. CNG vehicles have replaced diesel run buses, taxis, autos, and small commercial vehicles. The CNG programme has been further scaled up for nearly the entire commercial vehicle fleet of the city. CNG stations have increased from the original nine to more than 500 stations in Delhi-NCR.

Over the past few years, taxi aggregator companies like Ola and Uber have become the preferred modes of public transport in Delhi-NCR. But these were largely diesel run. The Delhi High Court took cognizance of this and in an interim order dated 29 July 2015 directed using only CNG cars. The Delhi State Transport Authority (STA) has been mandated to implement this order. Currently, both the services run on CNG.

H-CNG: The CNG programme in Delhi has opened up the opportunity to introduce hydrogen blended CNG to further improve the emissions. The IOCL R&D centre has developed this technology for compact reforming process for blending CNG and hydrogen. This technology, called H-CNG—hydrogen CNG— has been introduced on an experimental basis in Delhi. Globally, hydrogen is blended (20–30 per cent) with natural gas to run vehicles. US, Brazil, Canada, and South Korea have conducted trials and observed emissions reduction.

IOCL R&D centre's technology of compact reforming process has been piloted with18 per cent hydrogen blend in Delhi. MoRTH has issued a draft notification on 17 July 2018 to include H-CNG as a fuel in the Central Motor Vehicle Rule

(CMVR). ARAI and IOCL have carried out tests in six CNG heavy duty engines (BS IV) using H-CNG (with 18 per cent blend) and found that the engine passed the endurance tests, and demonstrated improved performance. The emissions results show drastic reduction of 70 per cent in carbon monoxide emissions, and 15 per cent reduction in hydrocarbon emissions. But NO_x emissions have remained same as that of the standard CNG bus. There is, however, four to five per cent improvement in fuel economy that is very important from the perpective of bus operations. The comparison with BS VI norms has shown that with H-CNG the overall emissions performance of the CNG buses improves even further.

This system can be located in different CNG dispensing stations or even in bus depots. The most promising aspect of this technology is that it allows utilization of the existing infrastructure of CNG dispensation.

Vehicle phase-out programme

Delh-NCR has been battling emissions from old and end-of-life vehicles for a long time. Older vehicles that are designed to emit higher than the current technologies are among the high emitters on road. A quick review of the emission factors for different generation of vehicle technologies available from ARAI shows that there is a significant difference in emissions rates of old and new vehicles. Older generation heavy-duty diesel trucks meeting BS I norms spew 36 times higher particulate matter compared to BS VI compliant trucks.

The Supreme Court, upholding a 2015 National Green Tribunal order, has directed the Delhi government to ban diesel vehicles older than 10 years and petrol vehicles older than 15 years in Delhi-NCR. The government by fixing the age of vehicles has substantially reduced the resale value of these vehicles. The Transport Department of Delhi government on 24 August 2018, in a bid to reduce the number of ageing and polluting vehicles on the roads, issued guidelines for scrapping of end-of-life vehicles (ELV) in the national capital territory of Delhi. Although the guidelines apply only to vehicles plying in the NCT, it is for the first time that such guidelines have been issued at the state level. These guidelines are applicable to all petrol vehicles older than 15 years, all diesel vehicles older than 10 years and any vehicle rendered inoperable by accident or otherwise. In Delhi only authorized scrapping centres can issue certificates of dismantling.

Currently, dismantling and material recovery of spare parts and materials are done through an extensive network of informal recyclers. But these operations are not equipped to minimize environmental and occupational hazards. Mayapuri, a recycling hub in Delhi, is one such location of recycling which also acts as a wholesale marketplace of spare parts. This sector has strong potential for livelihood generation and material recovery. In May 2015, the National Green Tribunal had ordered that all 'illegally and unauthorised operating scrap industries in Mayapuri generating chemicals, oils and poisonous fumes resulting in air pollution, deaths and diseases at large scale' be shut. The NGT issued four orders in the last four years—May 2015, October 2018, January 2019, and April 2019—against the scrapping units at Mayapuri addressing the serious public health and environmental concern raised by residents living in Mayapuri. Delhi authorities under the supervision of the Supreme Court's Monitoring Committee have attempted to seal the dismantling business activity in the area. Amid reports of non-compliance, in 2018 the NGT further directed that a seven-member Special Task Force (STF) comprising representatives from CPCB, DDA, DPCC, DSIIDC, SDMC, District Magistrate, and DCP be formed to stop illegal activities.

However, in the absence of a structured scrap dismantling and recovery system, the informal sector continues to remain an important channel of recycling and recovery of materials. The sector also forms an important source of livelihood in cities. It is therefore important to find ways of integrating the informal sector with the formal sector with adequate support to help establish common treatment facilities for pollution control and disposal of non-usable components.

This sector is expected to grow once the environmental safeguards under the CPCB Guidelines for Environmentally Sound Facilities for Handling, Processing and Recycling of End-of-Life Vehicles 2019 and MoRTH draft notification become enforceable. The guidelines envision extensive infrastructure for ELV recycling including systems for environmentally sound de-pollution, dismantling, shredding, material recovery, and disposal of ELVs.

At present, there is no composite national strategy that comprehensively addresses ELVs or sets the target for rolling out infrastructure for scrapping and recycling material with enforceable environmental safeguards across regions.

The formally organized recycling units are still in their nascent stages. CERO-Mahindra MSTC Recycling Pvt Ltd is an automobile dismantling and recycling unit in Delhi-NCR (greater Noida) which holds a license from the Delhi government. This is a joint venture with equal stakes between Mahindra, the Ministry of Steel, and Metal Scrap Trade Corporation Limited. CERO gives fiscal incentives for scrapping of the vehicles. It sells the components and the good parts are reused and sold to sellers, etc. The batteries are not sold and generally, once fluid is extracted, are sent to Exide for recycling. This plant has been operational for more than two years.

Currently, MoRTH is also working on a policy for national scrappage. Delhi has framed its policy as it is important for developing scrappage infrastructure. Regulatory and fiscal measures are needed to discourage use of old vehicle vintage meeting very old emissions standards.

Towards zero emissions: Electric mobility

While improving internal combustion (IC) engines remains an unfinished agenda, this decade has to be about accelerating pathways to zero emissions in Delhi and NCR for drastic cuts in emissions. This is also consistent with the global trend that indicates conscious policy decisions in global cities to phase out vehicles powered by internal combustion engines in the time frame of 2030–2040. The pollution imperative of Delhi and NCR builds the case for similar transition.

This opportunity has already been created in Delhi with the notification of Electric Vehicle Policy to achieve the target of 25 per cent electrification of new vehicle fleet by 2024. Within three years, 25 per cent of all new vehicle registrations will be battery-operated electric vehicles. According to the VAHAN database, electric vehicles were only 3.2 per cent of the new vehicles registered in Delhi in 2019–20.

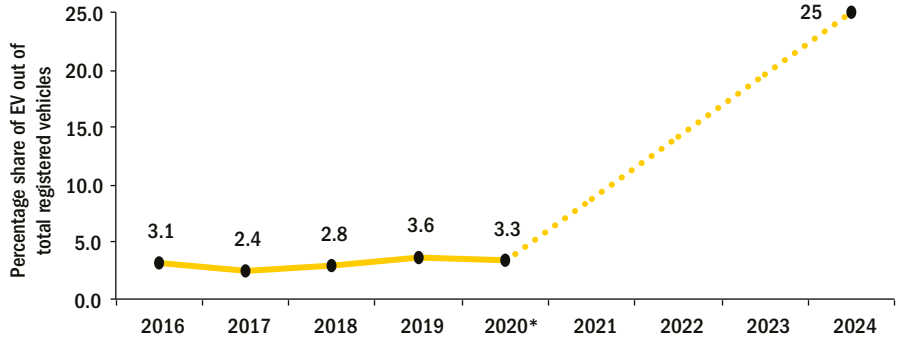
This step in Delhi will not only accelerate zero emissions trajectory to reduce air pollution and toxic emissions from internal combustion engines, it can also have a national spin-off. The proposed 25 per cent transformation of Delhi's new vehicle market can catalyse electric vehicle production and bring more product diversity. The incentive programme designed by the Delhi government is in addition to the central government's already existing incentive scheme called FAME II. This combination is expected to make the incentives package more attractive in Delhi.

This intervention is critical at this moment given the devastating impact of the lockdown and pandemic on the overall vehicle market, especially the electric vehicle market. CSE's analysis of the VAHAN database shows that while overall vehicle sales

nosedived during the lockdown period, electric vehicle sales plummeted even lower. Nationally, the registration of electric vehicles dropped by a whopping 93.4 per cent between March and April 2020.

The sector recovered to some extent, registering a seven-fold increase between April and July, although the numbers were still less than about 50 per cent of the March 2020 registration levels. In Delhi, the impact of COVID-19 lockdown on electric vehicle registration was just as bad, reducing it by 89 per cent between March and April 2020, though a partial revovery did happen in June and July. The challenge, therefore, is to recover from this abysmally low level to meet the 25 per cent target by 2024. Currently, penetration of electric vehicles in Delhi is very low, less than five per cent of total vehicle registration per year (see *Graph 31: Share of new electrical vehicle registration in Delhi*). Presently, Delhi has over 83,000 electric vehicles of which over 75,500 are e-rickshaws. There are only over 900 private electric cars and over 3,700 e-two-wheelers.[20]

Graph 31: Share of new electric vehicle registration in Delhi (including targeted share as per Delhi EV policy 2020)



*Note: 2020 registration numbers till 31 July
Source: MoRTH 2020, VAHAN Dashboard

The Environment Department of Delhi government created the Air Ambience Fund in 2008 by levying 25 paisa cess on per litre diesel sale. A part of this fund has now been shifted to the Transport Department to fund the electric vehicle programme. In 2018, GNCTD had also proposed to procure 1000 e-buses using the fund created from the environment compensation charge on trucks. That did not materialize due to lack of technical detailing of the proposal. In 2019, GNCTD, under the FAME II incentive scheme, had tried to procure 1000 e-buses. But the pandemic has delayed procurement.

Need strategy for meeting the milestones for incentives, charging network, and requisite infrastructure to achieve the 2024 target: While ensuring that all the elements of the electric vehicle policy are implemented, a time bound action plan is needed. This may prioritize some areas of interventions. The current cap on auto-rickshaw numbers and registration may be relaxed in a phased manner to allow only e-rickshaws. All new replacements and additions should only be e-auto-rickshaws. Delhi policy has targeted 50 per cent of all new city buses (including DTC and cluster services) to be e-buses. All government owned cars

Meet the milestones: Key highlights of Delhi's newly notified electric vehicle policy

Two-wheelers

- A purchase incentive of Rs 5,000 per kWh of battery capacity (advanced battery).
- Maximum incentive of Rs 30,000 per vehicle owner.
- Rs 5,000 per vehicle for scrapping old ICE two-wheelers.
- Conversion of 50 per cent and 100 per cent of all fleet used by delivery services.

E-autos

- A purchase incentive of Rs 30,000 per vehicle (advanced battery).
- Interest subsidy of five per cent on loans and/or hire purchase scheme for e-auto.
- Registered e-auto owner to get Rs 7,500 per vehicle for scrapping old vehicle.

E-rickshaws and e-carts

- A purchase incentive of Rs 30,000 per vehicle for purchase of one e-rickshaw and e-cart.
- Interest subsidy of five per cent on loans for vehicles with advanced battery.

Buses

- Conversion of 50 per cent of all new stage carriage buses (all public transport vehicles with 15 seats or more) by 2022.

Goods carriers

- A purchase incentive of Rs 30,000 per vehicle for the first 10,000 e-carriers (applicable on advanced battery vehicles).
- Interest subsidy of five per cent on loans.
- Registered e-carrier owner to get Rs 7,500 for scrapping old IC vehicles.

Four-wheelers

- A purchase incentive of Rs 10,000 per kWh of battery capacity (advanced battery) and maximum incentive of Rs 1,50,000 per vehicle shall be provided to the first 1,000 electric four-wheelers.

Applicable to all vehicle segments

- Complete removal of road tax and registration fee for all battery electric vehicles.
- For swappable technology—if battery is not sold along with vehicle, then 50 per cent purchase incentive shall be provided to vehicle owner and the remaining 50 per cent shall be provided to the energy operator.

and leased/hired cars for government uses are targeted to be replaced with e-cars. All new metro feeder buses are to be e-buses. Delhi EV policy targets to convert all delivery fleet (aggregators like Zomato, Swiggy, Amazon, etc.) by 31 March 2025. Therefore, this 100 per cent conversion of delivery service vehicles into EV may be implemented in a time bound manner.

NCR needs to implement a comprehensive electric vehicle policy: Some of the NCR states are working on state level policies. The NCR sub-regions will require special focus. This will require a timeline and mandate for vehicle segment-wise electrification; provision of infrastructure for charging, and amendment of building byelaws and design code with dedicated metering system to integrate changes for vehicle charging; incentive structures and charging enabled parking areas. A policy for safe disposal of batteries as per the Waste Management Rules 2016 issued by MoEFCC should also be implemented. Incentives/schemes should be made available to IPT owners to ease transition such as road tax rebate, concession on charges, credit on transition to EV, etc.

Specific mandate with target may be notified for public transport and para transit. NCR cities like Gurugram, Faridabad, Noida and Gaziabad that have a dedicated bus service or are planning to introduce such a service need to set a target for electric bus procurement. Keeping in view that para transit is the dominant form of public transport in smaller towns of NCR, a targeted electrification of this segment is needed. This target should be combined with the complete phase out of diesel autos from the region. All state governments need to indicate the target and timeline for implementation. Supportive action in terms of incentives, tax measures and charging infrastructure may be planned and implemented accordingly. Financing strategy for electric vehicles, addressing barriers to charging and appropriate electricity tariff, and registration process will have to be streamlined.

SECTION 5

Mobility

Delhi's experience shows that technology improvement can improve emissions per unit of vehicle but this improvement can get easily swamped and negated if the volume of traffic and travel are not restrained. That was yet another compelling aspect of change that drew attention over the last five years. In fact, the comprehensive clean air action plan for Delhi and NCR includes specific strategies related to public transport improvement, multi-modal integration, walking and cycling strategies, and vehicle restraint measures like parking policy.

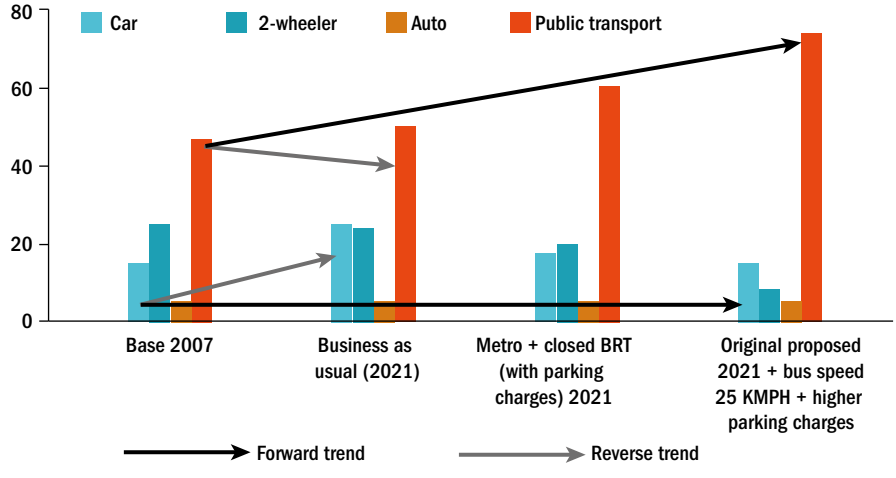
Transportation and mobility strategies have been slowest to improve in Delhi and across NCR. This is also an area that is least understood as a pollution control measure. In fact, the assessment of how people travel by different modes, nature of travel demand, and the relative share of modes is not regularly updated to inform planning. The recent report 'Accelerating Delhi's Mobility Transition' put out by Dialogue and Development Commission of Delhi in 2019 has stated that if walk trips are excluded then cars and two-wheelers are 14 per cent and 23 per cent of the modal share respectively. Buses represent 41.5 per cent, and metro about five per cent. If all trips are included, then walk trips are 35 per cent of all trips and combined share of bus and metro is 30 per cent. This indicates that personal vehicle trips are still not the most dominant in the city.[21]

With this baseline there needs to be a targeted approach to meeting the Delhi Master Plan 2020–21 target of achieving 80 per cent public transport ridership by 2020. But this makes it necessary to understand the shortfall in public transport infrastructure and services in the city. In fact, the Decongestion Plan for Delhi prepared by the Ministry of Housing and Urban Affairs has proposed a schematic plan to move forward to meet this target. This includes expansion of bus and metro services along with protected bus lanes and restraint measures to meet the target (see *Graph 32: Schematic plan to improve share of public transport*).

Other cities of NCR do not have adequate data on the current modal share and travel pattern to indicate the baseline and the extent of improvement needed to increase share of public transport ridership substantially. The older mobility plans of some of the cities like Gurugram and Noida do indicate high walk share, short trip length, and higher dependence on personal vehicles.

Yet another dimension of mobility management that needs immediate attention is the inter-city movement within NCR. Public transport connectivity of the Delhi-NCR region is weak and that has led to huge dependence on personal vehicles for long distance travel that traps enormous pollution. One CSE survey along the borders of Delhi in 2015 had shown that the daily entry of cars from the NCR into Delhi was nearly equal to the total number of cars registered in Delhi during the year 2014–15. This requires more holistic transportation planning for inter-city travel.

Graph 32: Schematic plan to improve share of public transport



Source: Delhi Decongestion Plan

Public bus service in Delhi

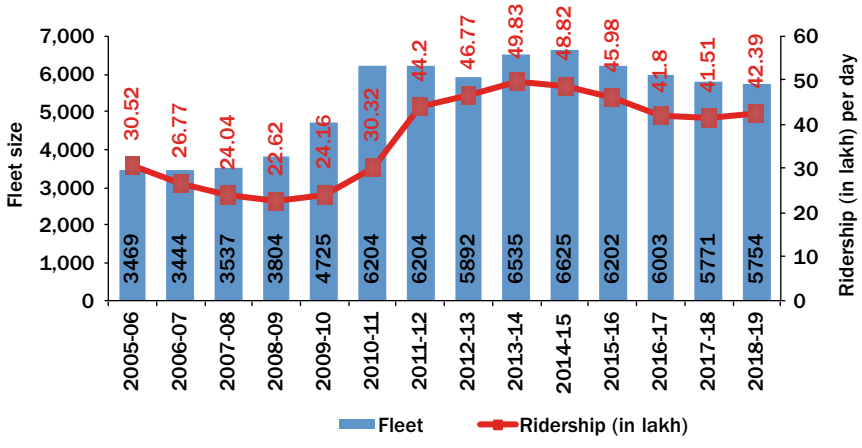
Bus fleet renewal and augmentation

Over the last two decades Delhi has gone through successive stages of bus fleet renewal but still falls short of the requisite number. In 1998 the Supreme Court while directing replacement of diesel run buses with CNG run buses had set a target of 10,000 buses for fleet augmentation. Subsequently, around the Commonwealth Games another fleet renewal followed based on CNG run specially designed urban buses that were different from the earlier approach of 'bus body on a truck chassis'. Subsequently, the High Court asked for bus fleet augmentation to at least 11,000 buses. But even today Delhi falls hugely short of these targets.

Delhi Transport Corporation (DTC)—a State Transport Undertaking—and Delhi Integrated Multimodal Transit System (DIMTS), a public sector company to manage 'Cluster Scheme' on behalf of Transport Department of Delhi, are responsible for intra-city daily stage carriage services within Delhi. At present, Delhi has approximately 5652 buses, of which 3849 buses are being operated by DTC on their own, whereas around 1803 buses are being operated by DIMTS with the help of private operators.

A detailed analysis shows that from 2013–14 to 2018–19, Delhi's bus system has experienced a continuous decline in ridership and fleet size (see *Graph 33: Trends of Delhi's bus services including DTC and cluster services*). Post 2010–11, bus numbers had increased compared to the previous decade and with that the ridership as well. 2013–14 saw the maximum number of buses in the fleet—about 6313 with daily ridership of 49.83 lakh. But thereafter there has been a steady decline primarily due to phasing out of older buses and inability to add new buses. By 2018–19 there were 5652 buses with a ridership of 42.39 lakh per day. Even though allocation was made in the successive budget of the state government, actual procurement did not happen. This was also complicated by the convoluted tender porcess.

Graph 33: Trends of Delhi's bus services including DTC and cluster services



Source: DTC operational statistic 2016; Economic survey of Delhi 2018–19

While the buses are well short in numbers, the age profile of the existing fleet poses an even bigger concern. Presently, the average age of a DTC bus is 6.2 years. The scrappage age of a DTC bus is 10 years. Thus, CSE had estimated in 2017 that if no further procurement is done, then the whole fleet would be off-road within the next five to six years.

Buses: late beginning

Fleet expansion started once again in 2019–20 when Delhi added approximately 733 buses to its fleet. The GNCTD in its 2019–20 budget had promised to induct 4000 buses—1000 new CNG buses for DTC and 3000 buses (1000 standard CNG, 1000 low-floor CNG and 1000 electric buses) for cluster services managed by DIMTS.[22]

It is important to highlight that even though Delhi inducted more than 700 buses in 2019–20, approximately 350 buses have also crossed their regulated age of 10 years during the same period. Thus, effective increment of fleet size is only around 350 buses. Although the recent augmentation of new fleet into the cluster services has helped to improve the availability of buses, Delhi still need more than 4700 buses just to match the requirement of 11000 buses as prescribed in the route rationalization study conducted by Delhi government and subsequently approved by Delhi High Court in 2007. Here one should remember that even if someone matches the fleet size as per numbers set in 2007, it would still be insufficient as the mobility demand has increased drastically in the past 13 years.

Recently GNCTD floated a tender to procure 1000 e-buses under the FAME II scheme of the central government but the process got delayed due to the pandemic and now the delivery of all e-buses is likely to be completed by March next year.[23]

Other than augmentation of new buses, GNCTD is also developing transit infrastructure like bus depots, terminals, bus queue shelters (BQS), etc. Presently, 58 bus depots are in operation and another 12 bus depots are under construction including six bus depots at Ghumanhera, Mundhela Kalan, Rohini, East Vinod Nagar, Bawana, and VIU Burari area.[24] Delhi State budget of 2019 also provided funds for construction of new terminals at five locations i.e. Dwarka Sector-4, Dwarka Sector-12, Narela, Vikaspuri and Central Secretariate in addition to the

16 operational terminals for city bus services. Along with these new bus terminals, state goverment is also keen to modernize three existing bus terminals at Azadpur, Najafgarh, and Nehru Place.[25] Till 2018, Delhi had approximately 1690 BQS. In 2019 Delhi Transport Infrastructure Development Corporation (DTIDCL) floated a tender to construct approximately 1397 additional BQS within Delhi.

2019–20 proved to be an outstanding year for Delhi's bus system as lots of transit infrastructure augmentation happened. Presently, the combined strength of bus fleets is considered to be the highest after the 2014–15 number.

It has been recently reported that according to the Delhi Government's socio economic survey, over 60 per cent of 1.2 crore people surveyed between November 2018 to November 2019 preferred buses as a mode of transport. This is the most affordable public transport service. While the metro ticket fares range between Rs 10–60 depending on distance, the minimum and maximum bus fares vary between Rs 5–15 for non-AC buses and Rs 10–25 for AC buses.[26] This brings out the importance of bus reforms.

Finding space for bus parking

For a considerable length of time, lack of adequate bus parking spaces had held up bus procurement in the city. This required intervention from EPCA to engage with land owning agencies like DDA to identify land where buses could be parked. In 2016, under the direction of the Supreme Court, EPCA reviewed Delhi's bus parking issue and suggested the optimization of existing bus terminal space and revision of Master Plan 2021 by replacing bi-level parking with multi-level depot parking for buses.[27] It should be noted that as per the observation made by EPCA, a simple optimization of existing depot space and additional spaces identified was more than enough to accommodate an additional 2000 buses at that time. But still Delhiites had to wait for another two to three years for new buses.[28]

Route rationalization

Efforts have been made to increase service capacity of buses by rationalizing route networks and adopting advance public transit systems. As per the directions given in Delhi-NCR Clean Air Action Plan to improve bus services, DIMTS has conducted a pilot route rationalization exercise for 17 routes and a fleet size of 285 buses connecting Najafgarh area. This has increased frequency of services in that particular area leading to increased earnings per kilometre (EPKM) by 19 per cent.[29] This exercise has proven to be a stepping stone to improve connectivity in far-off neighbourhoods that face major problems in accessing public transport. The city-wide extension of this pilot project is still awaited.

ITS based smart management of buses

In 2013–14, DIMTS introduced integrated intelligent transport system (ITS) based applications such as electronic ticketing, passenger information systems (PIS), etc. for operation of cluster scheme buses and a central monitoring command centre that monitors both DTC and cluster bus operations. In 2018, GNCTD introduced a common mobility card 'ONE' for its citizens which allows integrated tickets for a single journey consisting of both metro and bus. It should be noted that according to an official statement in 2019 almost 14,000 people used the ONE card on a daily basis. GNCTD has also launched 'One Delhi' app which allows commuters access to real time information about bus stops and bus and metro services including routes, fares, expected time of arrivals (ETAs), etc.

As of now, around 3781 DTC buses and all cluster buses are equipped with on-board PIS whereas around 250 BQS in Delhi have off-board PIS facilities.[30] Similarly, all cluster buses and around 2386 DTC buses are equipped with electronic ticket vending machines (ETVMs).[31] Recently, GNCTD planned to upgrade 5500 buses (including both DTC and cluster buses) with CCTVs, panic buttons, and GPS.[32] Accordingly, the government awarded the project to a vendor and it was expected to be completed by December 2020. Due to the pandemic, DTC has also initiated a trial on contactless e-ticketing for the convenience of passengers.

GNCTD has also taken up some initiatives for better safety and security of women passengers. Presently, more than 10,000 marshals have been deployed in DTC and cluster buses for women's safety. Along with this DTC is also conducting gender sensatization programmes for the bus crew. They have increased the night bus services to 27 routes with 88 buses. During the peak hours DTC is plying 30 ladies special buses on 30 routes for their lady commuters. Other than that 25 per cent seats in all buses (except ladies special) are reserved for women pasengers.

IT management for improved monitoring of bus services requires priority attention.

Need recovery strategy from pandemic disruption

The pandemic has created a lot of uncertainty as it has deepened the financial burden of almost all STUs in India. GNCTD has adopted social distancing norms and hygiene requirements including restricting the bus capacity to maximum 20 passengers at a given time. They have also deployed traffic personnel to manage boarding-alighting of passengers at busy locations. Special norms have been implemented regarding boarding-alighting, ticketing, etc. But this social distancing norm has drastically reduced the service capacity of Delhi's bus system. According to an earlier study conducted by CSE, after social distancing norms Delhi required an additional 13,000 buses to match their pre-lockdown service capacity.[33]

CSE has analysed Google travel data that shows massive predictable drop in visits related to work place, transit, residence, and recreation in Delhi. Visits to transportation nodes show the steepest decline making public transport revival challenging. While traffic is bouncing back, transit visits have been the slowest to improve. Public transport has been functioning at a very low capacity during the pandemic—service capacity of the fleet reduced on an average by 73 per cent—with variation across different phases of lockdown and post-lockdown. This demands a well-planned bailout package not just to recover from the pandemic induced losses but also to meet the augmented travel demand.

Thus, there is no doubt that immediate augmentation of the bus fleet has to be the priority. But for more efficient deployment and to improve service capacity, the GNCTD needs to plan dedicated bus lanes on selected route networks.

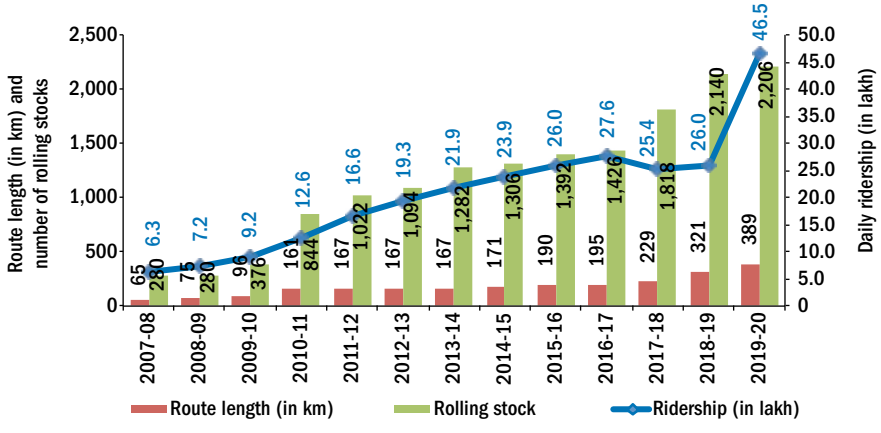
Looking at the current financial strains of the STUs as well as the government, it is also desirable to adopt better route rationalization—keeping in mind the upcoming bus fleet, Regional Rapid Transit System (RRTS), and phase-IV of the Delhi metro—and fleet management practices, so that maximum fleet can be utilized in an efficient manner.

GNCTD should also focus on phasing out the older fleet and replacing it with new zero-emission electric buses as much as possible in the longer term. This will need to be worked out hand in hand with the development of charging infrastructure in advance and clearing of the road space for these buses to prevent them from getting stuck in traffic. Further, advanced technologies have to be adopted to provide better passenger convenience and all available ITS facilities should be extended to entire service areas.

Metro services

Delhi Metro Rail Corporation (DMRC), a special purpose vehicle (SPV), has been entrusted to provide metro rail services in Delhi. Presently, Delhi metro has an operational network length of 389 km, which connects Delhi with neighbouring NCR cities including Noida, Ghaziabad, Gurugram, and Faridabad. Since its commencement in 2002, metro connectivity has been continuously expanding (see *Graph 34: Year-wise augmentation of metro services in Delhi*). Delhi metro carries almost five per cent of total trips on a daily basis.[34]

Graph 34: Year-wise augmentation of metro service in Delhi



Note: DMRC introduced a new method of calculating ridership which is responsible for the sudden jump in 2019–20
Source: Economic Survey of Delhi 2018–19; DMRC

Since the introduction of services, DMRC has followed a phase-wise development of metro network where the entire metro network has been envisaged to be developed through four phases. In phase-1, 65.1 km of network was developed by 2006. Phase-2 added another 124.9 km network by 2011. Currently, DMRC is carrying out the phase-3 development work. 153.6 km out of 160 km of phase-3 network development was commissioned by October 2019. The remaining 6.4 km network is scheduled to be completed in this financilal year. Phase-4 of Delhi metro network of 103 km has already been approved by GNCTD. Construction work on three priority corridors of phase-4 has started. The entire phase-4 network is expected to be completed by 2025 (see *Map 3: Existing and proposed network of DMRC*).[35]

Dense network of Delhi metro makes it one of most convenient modes of transport available for the citizen. DMRC already has state-of-the-art control room facilities to manage operations. Along with service frequency and infrastructure availability, extensive use of advanced technologies—smart card with integrated ticketing facilities, PIS display board showing ETA of available services, mobile app, journey planner, etc.—has added further to the comfort and reliability of service.

DMRC added about 120 km network in the last two years which resulted in a relative increase in ridership. However, reported average daily ridership in March 2020[36] of 46.5 lakh (higher than annual average daily ridership of 26 lakh) was mainly due to introduction of a new mechanism by DMRC for calculating metro trips.

In 2017, Indian Green Building Council (IGBC) awarded DMRC a green metro certificate for their efforts to adhere to green building norms while developing phase-3 stations, major buildings, and installations.[37] In addition, Delhi metro also successfully achieved the target of generating 20 MW of solar power by 2017.[38]

While DMRC needs to take these initiatives forward it also has to ensure that metro fares are affordable for the majority in the city. It may be noted that overall affordability for people in the city is poor. In fact, one-third of Delhi's population cannot afford the metro.[39] This requires a well-designed financial strategy to keep fares affordable and journey costs low so the system remains sustainable in the long term. Maintaining financial viability is always considered a major issue for all kinds of public transport modes. Strategies for affordable commuting have to be the priority. Metro system creates the need for more interchanges that adds to the journey costs. This demands well thought out fare integration policy that will minimize the effect of interchange penalty.

Multi-modal integration (MMI)

The Clean Air Action Plan has categorically provided for multi-modal integration to maximize public transport services and their ease of use. Delhi has both metro and bus systems. These need to be integrated for convenient interchange as well as supported by last mile connectivity and accessibility. Importance of multi-modal integration and accessible metro stations is evident from the fact that once the entire metro network is built nearly 80 per cent of Delhiites will live within 400 meters from some metro station. Therefore, improved accessibility and walking and cycling access and opportunities for easy interchange and efficient last mile connecivity can improve usage of the system and reduce dependence on personal vehicles.

This process has been monitored by the Supreme Court and EPCA. In 2019, to ensure the seamless integration of all modes of transport at metro stations, DMRC in consultation with GNCTD identified 14 metro stations to be developed as multi-modal integration hubs. The focus was to make space around metro stations for non-motorized transport (NMT) facilities, public transport drop-off, para-transit operation, and private vehicles. United Traffic and Transportation Infrastructure Planning and Engineering Centre (UTTIPEC) developed MMI norms for Delhi.

All 14 metro stations were taken up for retrofitting solutions. Kashmere Gate metro station has already been transformed into a MMI hub. The work at Chattarpur metro station is also near completion. Similarly, UTTIPEC, a governing and approval body for all transportation projects within Delhi, has identified another 68 stations to be developed as MMI hubs. All these metro stations were identified in close consultation with DMRC, Delhi Development Authority (DDA), Public Works Department (PWD) of GNCTD, respective Municipal Corporations of Delhi, and Delhi Traffic Police.

Recently, the Lieutenant Governor approved a proposal for transforming 59 stations as MMI hubs. Subsequently, tender for 20 metro stations was released. It is to be noted that all MMI hubs need to have pedestrian zones around metro stations for easy and safe dispersion of commuters towards the bus stop; dedicated bays for three-wheelers, e-rickshaws, and feeder bus services along with non-motorized vehicle lanes, cycle stands, etc.; pick-up and drop-off facilities, pedestrian crossing facilities, etc. Junction geometry also has to be improved for better visibility. Traffic calming measures shall be implemented by creating tabletop junctions with synchronized traffic signals, etc.

Feeders for public transport

Feeder systems for metro: At this stage DMRC has developed its own plan for implementing feeder system for its metro stations for easy accessibility. It is operating non-AC feeder bus services to provide last mile connectivity. Presently, 174 non-AC feeder buses are plying in various routes. There are other initiatives as well.

Metrolite train service is needed for areas with weaker public transport frequency. These trains will have three coaches which can accommodate around 300 passengers at a time[40] and the services will operate at a speed of 60 km/hour.[41] The DMRC approved this project in October 2019 and later submitted detailed project reports for the two proposed Metrolite corridors—Rithala to Narela (21.7 km) and Kirti Nagar to Dwarka Exhibition-cum-Convention Centre in Sector 25 (19 km)—to GNCTD for approval in January 2020.[42] Recently, DMRC floated a tender to carry out topographical survey and geotechnical study work for a stretch between Kirti Nagar and Bamnaoli Village.

DMRC is also planning to introduce 427 battery operated midi buses to be run on 48 new routes on the cluster model.[43] DMRC has already floated tenders for the same.

In February 2020, DMRC launched 250 smart e-rickshaw services at 12 metro stations in Delhi. These rickshaws are equipped with GPS and have facilities like covered cabin, full front windscreen, etc. At present, the total fleet of 1,000 e-rickshaws are available at 29 metro stations and 500 more shall be added at another 29 metro stations within the next two to three months.[44]

DMRC in partnership with Yulu is also offering 250 electric bikes at nine metro stations on the Yellow and Blue line. Similarly, they have also tied-up with qQuick to provide e-scooter rental services at four metro stations.

Make bus infrastructure accessible: Buses require accessible footpaths, at grade approaches, and passenger crossings to maximize usage. Increasingly, roads are being designed for high speed, signal free access for vehicles. Flyovers and one way lanes do not allow pedestrian access and crossings. This makes access to bus nodes unsafe and difficult and discourages bus use. This connection is often not well understood. Even while investing to improve public transport, system design of the larger road network for pedestrian accessibility is ignored. That makes public transport sub-optimal.

Intermediate para-transit (IPT) services

Intermediate para-transit also known as 'para-transit' is an integral part of the mobility ecosystem. IPT modes play various roles depending upon the city size and available mobility options. In case of bigger cities, it mainly functions as a feeder service to more formal services like metro or bus, whereas in small and medium size cities it acts as a main public transport service. In general, IPT provides both point-to-point and route-based stage carriage services. A whole range of vehicles comes under the category of IPT vehicles including cycle-rickshaws, auto-rickshaws, shared auto-rickshaws, shared passenger van type vehicles like Gramin Seva, taxis, app-based cabs, etc.

At present, there are more than around 5.28 lakh IPT vehicles plying in the streets of Delhi on a daily basis (see *Table 11: Description of IPT vehicles in Delhi)*. Despite playing an important role in a city which already lacks public transport, the service is hardly given any importance.

In Delhi, IPT services are complementary to formal public transport modes and particularly popular where formal public transport is not easily accessible. They also play a special role in augmenting last mile connectivity to bus and metro services.

Table 11: Description of IPT vehicles in Delhi

IPT mode	Description
Auto-rickshaws	Delhi has around 113,240 auto-rickshaws catering to two per cent[45] of total travel demand in the city.
Taxis	Delhi has around 1.09 lakh taxis.
Gramin Seva service vehicles	At present, there are 6,153 Gramin Seva vehicles operating on 166 routes authorized by Regional Transport Authority (RTA).[46] The average daily ridership of those services is approximately 80,000.
E- rickshaws	Presently, more than 1 lakh e-rickshaws are there in Delhi, a large chunk of which ply without any registration.[47]
App-based cabs	In case of app-based cabs, there has been no study to find out the exact numbers. After including cabs which enter from neighbouring states into Delhi, the total cabs which ply in the city daily come out to be approximately two lakh.[48]

Cap on auto-rickshaw permits[49]: In the first phase of air pollution action about two decades ago, auto-rickshaws that were largely two-stroke engine powered or diesel driven were considered the most polluting segment and therefore were replaced with CNG fleet with a cap on their numbers. In December 1997, the Supreme Court had frozen their numbers and, in 1998, allowed 50,000 new registrations as replacement of old ones. In 2002, registration of additional 5000 new autos on CNG/LPG mode was allowed. While this move provided emissions benefits, the capping of their numbers harmed mobility choices in the city. Auto-rickshaws are high frequency but low occupancy vehicles and are attractive for direct connectivity of the origin and destinations of the commuters.

In 2011 the original cap on numbers was relaxed a little and the Supreme Court order increased the number from 55,000 to one lakh auto-rickshaw permits. This was meant to account for population increase. The new auto-rickshaw registration was based on the certificate of replacement of old auto-rickshaws.

This matter has come up again now as the Supreme Court is examining the possibility of further relaxation of the cap. This considers the fact that BS VI technologies are in place for CNG and electric mobility policy of the Delhi government is also in place. The vehicle manufacturers have pleaded before the Supreme Court to re-examine the cap. This may be examined from the perspective of increased travel demand and demand for this service. The removal or relaxation in cap can be linked with conditional introduction of electric auto-rickshaws. This is also part of the newly notified electric vehicle policy of the Delhi government.

E-rickshaws: Factors like low operational cost, convenience for short trips, no noise and pollution, no registration requirement, cap on auto permit, and growing mobility need of the city have led to the growth of e-rickshaw services in the city. This is zero emissions transport for the masses. However, these largely lie outside the pale of regulations related to vehicle design or any other certification system. These vehicles are easy to manufacture through local assembly system with imported parts. There are numerous assembling units in Delhi that are not compliant

with ARAI/ICAT standards. There are concerns regarding unsafe body design and non-supervised disposal of lead acid batteries. This is largely an unorganized ecosystem in which e-rickshaws do not even have authorized charging facilities. In Delhi, many unorganized businesses have been developed to provide bulk charging facilities at night. In view of their popularity both for livelihood and mobility needs, it is necessary to find an appropriate framework for their safe operations and charging requirements.

Gramin Sewa services: Gramin Sewa services were first initiated in 2011 by Transport Department of GNCTD for improving first and last mile connectivity in unplanned colonies such as JJ clusters, urban and rural villages, unauthorized colonies, etc. It's a specially designed passenger minivan type vehicle with a seating capacity of seven people including drivers. However, due to lack of enforcement, majority of the vehicle owners modify the vehicles to accommodate 10 or more people, almost double the passenger limit (i.e. maximum six passengers per vehicle) allowed by the Transport Department of GNCTD.

This kind of design deformation is illegal because it makes vehicles unstable and poses a threat to other road users. According to GNTCD regulation, all Gramin Seva vehicles need to be fitted with GPS devices. Although, according to a media report almost 50 per cent of these service vehicles are operating without such facilities.[50] Other than that, these vehicles are lacking in basic amenities such as first-aid boxes, fire extinguisher, head and tail lights, etc. Vehicle conditions are horrific—rusted body and unclean seats have now become their characteristics. Usually, Gramin Sewa services are confined to specific routes, but traffic violations are rampant.

Although there are several faults in the services, they have already become part of the city's public transport scene and source of livelihood for several people. On the other hand, as these services are very affordable, they have become indispensable for people living in areas with poor public transport accessibility. Therefore, special attention is needed from the government to improve service quality.

Walking and cycling

The Clean Air Action Plan has made clear provisions for cycling and walking infrastructure and network plan to be implemented based on the street design guidelines keeping in view all road users. The plan has directed all the road owning agencies to implement zonal plans with adequate NMT network.

Walking and cycling account for 39 per cent of total trips (35 per cent walk and four per cent cycling).[51] Almost 50 per cent of metro users travel to/from the stations on foot. Walking is also a dominant mode of travel for approximately 77 per cent of the urban poor in Delhi.[52] This large walking and cycling base, despite the fact that Delhi is largely considered as a car friendly city, shows why Delhi requires more focused action towards creating walking and cycling infrastructures.

Presently, around 45 per cent of the road network in Delhi does not have any footpath on either side. It is important to mention here that more than 60 per cent fatalities on city roads involve pedestrians. Lack of adequate and safe cycle infrastructure, including cycle lanes, parking spaces, etc. has also resulted in a continuous decline of cycle-users from 17 per cent in 1981 to 4.5 per cent in 2011 although 2011 Census data shows that approximately 35 per cent city dwellers own bicycles. This tiny section of people who are still using cycles as their main mode of transport belong to low-income groups. In addition to the lack of adequate non-motorized

transport infrastructure, weak enforcement of traffic rules, encroachment of walking and cycling space, poor maintenance, lack of continuity, and barrier free pedestrian network further degrade its status.

Steps towards improving walking and cycling infrastructure: In May 2017, the Lieutenant Governor of Delhi initiated a decongestion plan for 77 busiest corridors in Delhi. The key interventions under the plan include improvement of road geometries, providing sufficient non-motorized transport infrastructure, etc. After two years of commencement of project, 70 per cent work of 11 selected corridors has been completed and rest is under progress.[53]

In addition to this, there is proposal to pedestrianize 21 commercial streets. After the pilot project of pedestrianization of Chandni Chowk and Ajmal Khan Road, NDMC is now planning to expand it to other areas including Kamla Nagar Market and Kirti Nagar. It was expected that the learning from the pilot projects of NDMC will be helpful in extrapolating it at city-wide level.

The current pandemic situation stimulated additional demand for contact-free active transportation—walking and cycling—to maintain social distancing. GNCTD has announced redesigning of 500 km of 162 road stretches at a cost of Rs 5,000 crore. Recently, the government has floated tenders in multiple packages for engaging consultants to prepare DPRs on 'street scaping'. The work will start by 2021 and is expected to be completed in three years.[54]

Delhi has a huge opportunity to transform mobility patterns in the near future. Almost 60 per cent of all trips are less than four km and 80 per cent are below six km—an ideal distance for using non-motorized modes like walking and cycling. Other than that, the city already has its own street design guidelines for walking and cycling facilities. Recently, DDA has formulated a draft policy for improving walkability in the city.[55] All these show that the city has both potentiality and regulatory support to increase its walking and cycling share as well as infrastructure. This will require time bound implementation.

There are however serious causes of concern. Even after pioneering the implementation of pedestrianisation of commercial streets like Ajmal Khan, action has slowed down and even these projects are not finding strong enough support. Media reports show dismantling of some of these efforts. Next steps will require implementation at a scale as well as a strategy to prevent roll back.

Parking management

The most important vehicle restraint and demand management measure that has been included in the 2018 comprehensive clean air action plan for Delhi-NCR is parking policy. The discussion on parking policy in Delhi has been going on since 2006 when, following the recommendations of EPCA, the Supreme Court had directed all land owning agencies to provide parking as a restraint measure. But for a long time, this strategy was not very well understood and most of the proposals that were submitted by the municipalities to the Supreme Court were more oriented towards parking supply management focusing only on construction of multilevel parking.

Around 2012 the first ever policy note was prepared under the aegis of the Lt. Governor in consultation with EPCA. Simultaneously, Delhi Master Plan 2020–21 was amended to include the provisions of parking district management plan. The plan asked for an area based approach that would provide organized legal on-street and off-street parking based on local surveys while putting a cap on the total parking

provision. It also aksed for the adoption of priced parking. Intervention from EPCA also led to the amendment of the Delhi Master Plan 2020–21 to prohibit parking in green areas and parks.

Policy level change could not alter the ground reality and implementation remained stalled. CSE assessment of the parking situation in Delhi around that time showed that rapid increase in vehicle numbers was increasing demand for parking insatiably. This led to enormous demand for diverting land from other more important uses. In fact, the size of the plot planned for one parking spot at 26 sqm in a multi level car park was more than the 18–20 sqm alloted for poor people's housing. This can have huge equity impact. Even today, Delhi requires about 1050 hectares of land, equvalent to 1,470 football fields (area of one football field is 0.714 hectare) just to fulfill the annual demand of 1.5 lakh ECS to park four-wheelers, considering three parking spaces are requied for every single car as prescribed by Ministry of Housing and Urban Affairs. If we addd the two-wheeler demand as well, the number goes up to 2,740 football fields. Just to put this into perspective—the area of Indian Institute of Technology (IIT) Delhi is only 131 hectares or equivalent to 183 football fields. It is high time for GNCTD to come up with some innovative and implementable solutions to manage parking demand.

However, in 2019, GNCTD notified the first ever parking rules—Delhi Maintenance and Management of Parking Rules—under the Central Motor Vehicle Act and Rules. This provides local governments the required power and regulatory support to exercise some of the measures to manage parking in their respective jurisdictions. It has explicitly taken on board the principle of restraint and demand management and taken the area based 'parking management area plan'. This is expected to identify the areas where legal parking can be provided—on-street and off-street. While doing this, parking cannot be provided on footpath, on green areas or parks, near junction or bus stops, etc. All plans have to ensure that a lane is always kept free for emergency vehicles. It has proposed variable pricing policy. There will be penalty for illegal parking. These, along with other requirements, are expected to delimit the available parking in a given area.

Subsequently, as part of the implementation of the comprehensive clean air action plan, the Supreme Court diretced implementation of parking area management plan (PAMP) as per the rule in three pilot areas—Lajpat Nagar, Krishna Nagar, and Kamala Nagar. These projects have been implemented and are in the process of being taken forward. In 2020, while reviewing the satisfactory results of pilot projects, the Supreme Court directed EPCA to prepare a strategy to implement the policy city-wide and also prepare a parking policy addressing the entire NCR.[56] Adhering to the order of the apex court, EPCA recently submitted both the strategy and separate parking policy for NCR.

However, experience with the three pilot projects in Delhi has shown that lack of requisite technical knowledge and guidance for the preparation of the PAMPs, methodology for ITS application, design contracts for facility managers, etc. at local level is a challenge. Now, city-wide implementation of PAMP will also require a huge amount of coordination among different stakeholders to reach common ground. Thus, a city level technical expert committee, including the key technical urban design and planning bodies and experienced professionals and experts, is required to assist the implementation work. Along with that, the respective Municipal Corporations need to strengthen their own capacity by creating a dedicated cell for parking which shall have required technical professionals including urban designers and planners to carry out the work.

This initiative has to stay on track and needs to be executed at top speed. Slowdown is a serious cause of concern. It may also be noted that without the implementation of PAMP city-wide it will not be possible to implement the emergency action of increasing parking fees by three to four times during the days with severe pollution. Such a strategy cannot be enforced if legal parking areas are not identified and demarcated on ground across the city.

Traffic management

The 2018 comprehensive clean air action plan provides for traffic management to address congestion bottlenecks that can aggravate pollution. To maintain smoother and safer traffic flow, the Delhi traffic police has initiated several measures. Presently, there are 793 traffic signals in the city which are installed and maintained by the traffic police. Till date around 1,337 CCTV cameras have been installed by the traffic police and additional 3,975 CCTV cameras are proposed to be installed in the near future. The city has 15 variable message sign (VMS) boards which provide real time information to the travellers. Delhi police has created a traffic control room to control and manage operations across the city. They have also introduced e-challan facilities for smooth management of traffic on road.

Delhi traffic police is also extensively using ITS and various other communication platforms for information dissemination. All information related to maps of signal locations, accident prone areas, frequent water logging locations/stretches, jurisdiction area, major arterial corridors, traffic alerts, etc. are made available on the official website of Delhi's traffic police. Same information can also be made available through social media and mobile-apps.

In 2019, for a push to reduce traffic violations, Delhi Traffic Police along with Maruti Suzuki jointly launched Red Light Violation Detection System (RLVDS) and Speed Violation Detection System (SVDS) to autometically detect violations through electronic devices. It has been implemented in a 14 km long stretch between Dhaula Kuan and Sarai Kale Khan for a pilot basis. After implementation of the system safety of pedestrians and motorists has been enhanced drastically. It detects a violation and sends the information to the Delhi Traffic Police headquarters and later on the traffic police issues an e-challan to the violator along with photo proof. Along with new e-challan system, traffic police has also implemented a new e-payment gateway through which the violator can remotely pay the penalty charges to the department.

Though traffic police have successfully piloted the traffic violation detection system in selected areas, the same has to be implemented city-wide. Along with adopting modern technologies to manage city traffic, the traffic police should also concentrate on other aspects to improve road safety including proper marking of lanes and zebra crossings, installing proper signages, constructing pedestrian crossings and bays, enforcement of traffic rules, etc.

However, it is important to keep the focus of traffic management on clean air gains. As part of the clean air action plan all NCR cities need to cohesively develop and implement traffic plans to protect all road users. More people oriented plans are needed to ensure that pedestrians, cyclists, and public transport users have safe and at grade access. We need to reduce speed differential between motorized and non-motorized traffic, adopt road signages for all road users, carry out IT based monitoring to ensure road safety for all road users, and adopt zero tolerance policy for road accidents.

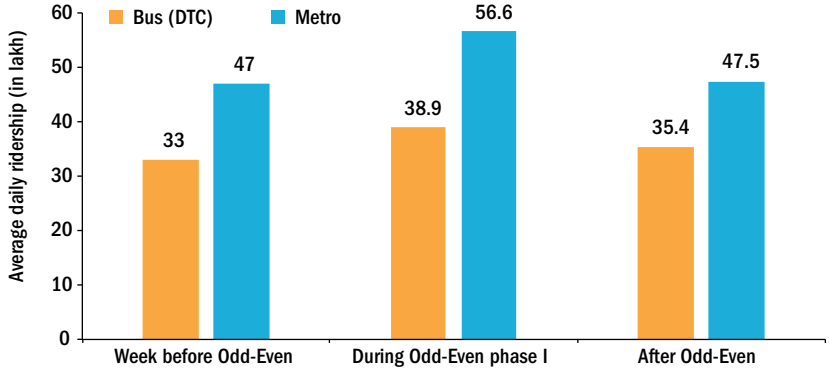
Emergency response: Odd-even scheme

Odd-even scheme was first implemented by the Government of Delhi in 2016 as an emergency response to control peak air pollution during severely polluted days of winter. Subsequently, this scheme was implemented during the winters of 2017 and 2019 as well. Accordingly, based on the vehicle license plate numbers, odd and even numbers are allowed on alternate days. This can remove at least 50 per cent vehicles at a time if implemented without exemption. However, Delhi scheme has several exemptions including two-wheelers, women, CNG powered vehicles, etc.

Like any other emergency measure the purpose of this scheme is to prevent adding more to the problem when meteorology has already created adverse conditions like trapping air with no wind to blow away the pollution. This can only help to lower intensity and peak pollution but not clean up the air. Reduced number of vehicles help to reduce emissions, exposure and also reduce congestion. Several studies have been conducted by different agencies that show reduced emissions intensity. If combined with other emergency action in other sectors this can help to shave off the pollution peaks.

However, the bigger interest in this scheme stems from the assessment that bear out the improvement in the performance of the public transport systems due to reduced congestion pressure. This is evident from the assessment of the last programme carried out by DTC and DMRC that found the average speed of vehicles during the odd-even phase had improved by five per cent over half of the radial and arterial roads in Delhi. There were 23 per cent fewer private cars.[57] But the number of two-wheelers and taxis had increased. During this phase the average daily ridership of DTC increased from 33 lakh the week before to 39 lakh during the odd and even week. Similarly, average daily ridership of metro increased from 47 lakh to 56.6 lakh during the odd and even week.

Increase in public transport ridership during the odd-even scheme in Delhi



Source: DTC; DMRC

NCR cities

The comprehensive clean air action plan includes mobility strategies for NCR as well. According to an estimate, over 11 lakh vehicles (both passenger and goods vehicles) enter Delhi every day from eight entry points.[58] By 2025, more than 80 lakh trips will take place between Delhi and other NCR towns/cities on a daily basis.[59] In addition, a high intensity of traffic, approximately 2.21 lakh vehicles including trucks (30 per cent), cars (29 per cent) and others, enters NCR on on a daily basis and in the end majority of these vehicles accumulate in Delhi.[60] Mobility challenges of NCR cities vary depending on their size and other mobility attributes.

Inter-city bus services

Across almost all NCR cities, inter-city connectivity with Delhi is predominantly dependent on road-based transport services like buses. The respective road transport corporations including DTC, Uttar Pradesh Road Transport Corporation (UPSRTC), Rajasthan State Road Transport Corporation (RSRTC), and Haryana Roadways, provide inter-city services for commutes on a daily basis. Delhi has three major Inter State Bus Terminals (ISBTs) at Kashmiri Gate, Sarai Kale Khan and Anand Vihar. Kashmiri Gate ISBT is the biggest and oldest ISBT is Delhi. It provides bus services to connect Delhi with almost all neighbouring NCR cities and areas. Sarai Kale Khan ISBT was specially developed to take care of additional load of services and is dedicated to provide services in Haryana and Rajasthan. Anand Vihar ISBT takes care of services for Uttar Pradesh and Uttarakhand.

Though the NCR is connected, lack of adequate buses and integrated service planning is hampering the overall service quality of the system and forcing people to be dependent on other private options. The Integrated Transport Plan for NCR, 2007 had showed the big difference between need and available services in all NCR sub-regions. According to the estimates provided in the study, approximately 8500 buses were required for entire NCR to have decent bus services, following the standard norm of 40 buses per lakh persons (see *Table 12: NCR sub-region wise bus availability*).

Table 12: NCR sub-region wise bus availability

Sub-region	Population (in lakhs)	Total buses in sub-regions under STU	Buses per lakh population	No. of additional bus required
Haryana sub-region	108.5	1,285	12	3,055
Uttar Pradesh sub-region	136.7	1,204	9	4,264
Rajasthan sub-region	34.8	278	8	1,114

Note: Total registered buses include State Transport Undertaking (STU) fleet and privately owned buses
Source: Study on Integrated Transportation Plan for NCR

Transportation is a state subject and therefore transport related taxation regimes keep the transport sector segmented. There is no progress towards a harmonized taxation regime in the region. Problems with NCR become more complex as it comprises four different states. The present taxation structure distorts the modal preferences of commuters who cross one or more state borders within the NCR frequently or on daily basis. They prefer to travel on private vehicles as those are tax

free. Public transport and para transit attracts higher fares. For instance, entry tax on interstate buses in Haryana is substantially high and acts as a disincentive.

Looking at the complexities created due to different taxation structures of NCR states, a memorandum of understanding, namely Reciprocal Transport Agreement, was signed among states to resolve this issue. It should also be noted that the notified agreement supersedes all previous agreements on the same subject of interstate movement of passenger vehicles (bus, taxi, auto) for NCR and a uniform single point taxation is expected to be applied to vehicles covered by both stage and contract carriage permits. However, no further progress on implementing the same has been done till date.

Expansion of rail-based services to connect other urban centres of NCR

Metro services: Along with bus services, DMRC has also extended its metro services to major growth centers of NCR including Noida, Ghaziabad, Gurugram, and Faridabad. Both Noida and Ghaziabad were first connected to Delhi in 2009, when Blue line of DRMC started operating services till Noida City Centre and Vaishali (Ghaziabad). Gurugram first got connected with DMRC network through yellow line in 2010 and Faridabad got connected via violet line in 2015. Later on, in 2017, DMRC's magenta line connected another area of Noida by extending the services till Botanical garden. Similarly, in 2019, the red line connected Saheed Sthal in Ghaziabad.

Additionally, DMRC metro connects with rapid metro lines in Gurugram by providing transfer points at Sikanderpur metro station. Similarly, a 300 meter long pathway has been created to connect Sector 52 metro station of Delhi metro and Sector 51 metro station of Noida metro, which helps in providing smooth interchange between the services.

Metro rail services first commenced in Gurugram in 2013. Initially, there were privately built metro services operated by Rapid Metro Gurgaon Limited (RMGL). However, since 2019, Haryana Mass Rapid Transport Corporation Limited (HMRTC) owns the system and operates it with the help of DMRC.[61] Presently, the entire system is 11.6 km long with 11 stations. In order to provide metro connectivity in old Gurugram area, the Haryana government approved Detailed Project Report (DPR) of metro rail connection from HUDA city centre to various important locations in the city at a cost of Rs 6821.13 crore. The total length of the corridor will be about 28.8 km, consisting of 27 elevated stations with six interchange stations.[62]

Metro network in Noida is being developed by the Noida Metro Rail Corporation (NMRC) and became operational in 2019. The entire metro network is 29.7 km long and has 21 stations. As of March 2019, the NMRC had a total of 56 standard gauge coaches. It has been developed mainly to provide connectivity within Noida and Greater Noida areas. Since the commencement of services, both ridership and revenue has increased to 23,095 passengers per day and INR 6.62 lakhs per day.[63]

NMRC has taken up some proactive steps to generate revenue from non-fare sources as well. Accordingly, they have floated tenders in February 2020 for licensing of parking rights at selected 16 metro stations (i.e. Sector 51, Sector 76, Sector 101, NSEZ, Sector 83, Sector 137, Sector 142, Sector 143, Sector 144, Sector 145, Sector 146, Sector 147, Sector 148, Pari Chowk, Alpha 1, and Delta 1) and commercial spaces at five metro stations (i.e. Sector 101, Sector 81, Sector 83, Sector 142, and Depot metro stations).[64] Additionally, according to a NMRC policy, its properties including stations, trains and depot can be hired for a particular duration for the purpose of

shooting films, audio-visuals, documentaries, and TV commercials.[65] Recently, in June 2020, a tender has been floated to conduct traffic and transportation study for further extension of 3.8 km Noida metro network[66].

Regional Rapid Transit System (RRTS): Looking at the huge mobility demand in between Delhi and its surrounding NCR cities, Regional Rapid Transit System (RRTS), a heavy suburban rail type system, was proposed in 2006. It was conceptualized as a mode of transport that would connect the NCR with Delhi and provide for modern and convenient transport options for people. Thus, The National Capital Region Transport Corporation (NCRTC), a joint venture company of Government of India and States of Delhi, Haryana, Rajasthan, and Uttar Pradesh, was formed for the purpose of developing RRTS network.

Eight corridors have been identified for the implementation of RRTS network, namely:

- Delhi–Ghaziabad–Meerut
- Delhin–Gurugram–Shahjahanpur–Neermana–Behror–Alwar
- Delhi–Panipat
- Delhi–Faridabad–Ballabhgarh–Palwal
- Ghaziabad–Khurja
- Delhi–Bahadurgarh–Rohtak
- Ghaziabad–Hapur
- Delhi–Shahdara–Baraut

Out of these eight corridors, development of the first three corridors is being taken under phase-1 of the project. Although detailed project report (DPR) for Delhi–Ghaziabad–Meerut was approved by NCRTC board in December 2016, it only got final approval from state and union governments in 2019. Currently, construction work is in progress and priority section between Sahibabad and Duhai is targeted to be completed by 2023. Once completed, the journey time between Delhi and Meerut is expected to be reduced to one hour. The second RRTS corridor between Delhi–Gurugram–Shahjahanpur–Neermana–Behror–Alwar has been planned to be executed in three stages and subsequently DPR of first section between Delhi–Gurugram–Shahjahanpur was approved by NCRTC board in December 2018. Following the final approval from state as well as union government, construction work started in 2019. NCRTC approved the DPR of second section of this second RRTS corridor in March 2020. Similarly, DPR of third RRTS corridor between Delhi–Panipat was approved by NCRTC in March 2020.

It's been four years since the project was first conceived, but only recently at the end of 2019 did actual ground work begin in two sections of two corridors. It has been observed that issues related to arrangement of project finances and coordination among states are the main hurdles in making progress. EPCA and Supreme Court had to intervene to ensure that the concerned state governments contribute their due share to expedite the process. Thus, NCRTC has to take some more proactive steps for better coordination among states and both state and union governments have to ensure timely availability of funding to carry out the project within a defined timeframe.

Intra-city bus services

Only a few cities in NCR have a dedicated bus service. Most of the local transport services are provided informally by private players and IPT operators. Only Gurugram and Noida have their own city based public transport services.

Gurugram city bus services: City bus services in Gurugram first commenced in 2018. At present, Gurugram Metropolitan City Bus Limited (GMCBL), a special purpose vehicle, is operating the bus services on 18 city routes with 154 buses. All GMCBL buses are low-floor CNG buses are fitted with modern ITS facilities like GPS, CCTV, etc. All the buses have special provisions for handicapped persons. In 2019, GMBCL launched 'Gurugaman' app which helps commuters track the live location of buses. Due to quality service delivery, the services have also experienced improved ridership day-by-day and within two years of commencement ridership has reached close to one lakh.[67]

City bus services in Noida: Intra-city bus services in Noida are catered by 300 DTC and 1,600 private buses.[68] Additionally, Noida Metro Rail Corporation (NMRC) has started operating 50 AC low floor feeder bus services to improve last mile connectivity from Noida metro.[69] NMRC operated buses are specially equipped with GPS devices, panic buttons, CCTV cameras and also have a special provision for women and differently-abled people. Recently, NMRC has also launched smart card services—'One City One Card'—with integrated ticketing facilities with Noida metro system, discounted fare facilities for online ticket transaction, etc.[70]

City bus services in other NCR cities: City bus services among other NCR cities including Ghaziabad and Faridabad are completely owned and operated by multiple private operators. Presently, 160 buses are operating on 16 routes in Ghaziabad whereas 250 buses[71] are operating in Faridabad. Although, recently, a special purpose vehicle called 'Faridabad Smart City Transport Service Limited' (FSCTSL) has been formulated to operate 90 non-AC buses on 19 routes covering 150 km of road network, 50 of these 90 buses will be running on nine intra-city routes and the rest will serve as a feeder to the metro services.[72]

Intermediate public transport

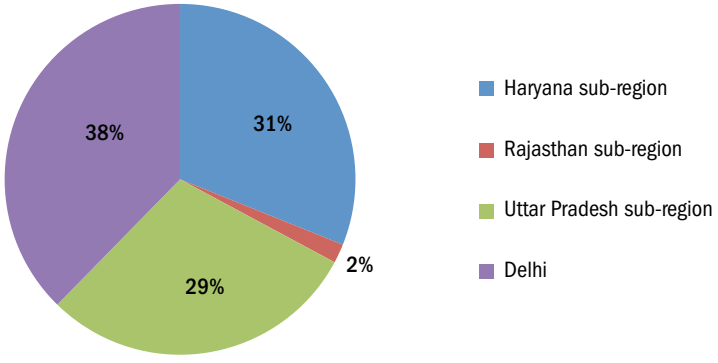
In most NCR cities, IPT plays a major role in passenger mobility. Although the exact number of IPT vehicles is not officially available, according to an approximation NCR has around three lakh registered auto-rickshaws. While Delhi constitutes around 38 per cent of these auto-rickshaws, both Haryana sub-region and Uttar Pradesh sub-region have almost equal share of auto rickshaws at around 30 per cent each, while Rajasthan sub-region has only two per cent of the total auto-rickshaws in NCR (see *Graph 35: NCR sub-region wise registered auto-rickshaws*).

As mentioned earlier, Delhi has implemented a cap on auto-rickshaw registration which has led to proliferation of illegal and unregistered auto-rickshaws in nearby NCR cities like Noida and Ghaziabad. Similarly, while diesel is banned in Delhi, there is proliferation of diesel autos in Noida, Gurugram, and Faridabad. Diesel autos are a major source of toxic exposure in the NCR region. Currently, the entire region is expected to enforce an age cap.

The quality of IPT services in NCR cities appears to be far from satisfactory. The city of Alwar has introduced mini-van based IPT service called Alwar Vahini that

has approximately 1,300 vehicles and carries more than 115,000 passengers daily. IPT segment will require a lot of attention for organised deployment, GPS based monitoring for improved services, and fare regulation. In many smaller towns and cities of NCR, IPT is the only source of public transport. There is a great potential to link this segment with mandatory electrification with appropriate support.

Graph 35: NCR sub-region wise registered auto-rickshaws



Source: Statistical abstract 2015–16, Haryana government; Statistical abstract 2018–19, Rajasthan government; Road Transport Yearbook 2015–16, Ministry of Road Transport and Highways (MoRTH); Economic Survey of Delhi 2018–19, Planning Department, Government of Delhi; EPCA report number 95

Electric mobility

At this moment deployment of e-rickshaws characterizes the electric vehicle programme in NCR with a small step taken towards city based electric bus programme. In 2016, under the 'Stand-up India' initiative 5100 e-rickshaws were distributed in Delhi-NCR cities including Delhi, Gurugram, Faridabad, Noida, and Ghaziabad.[73] Similarly, state e-rickshaw schemes implemented by both Uttar Pradesh and Haryana have accelerated e-rickshaw penetration within NCR cities.

Recently, three NCR cities—Gurugram (GMBCL), Ghaziabad, and Meerut—was each awarded 50 electric buses. All of them have completed the bid process and buses shall start operating on road from next year. GMBCL is also procuring 50 additional electric buses, along with their 50 FAME-II funded buses.[74] Similarly, state government of Uttar Pradesh is planning to deploy 25 electric buses in Noida on a pilot basis.[75] Other than this, NCR cities are gearing up with charging infrastructure. Energy Efficiency Services Ltd (EESL) has signed an agreement with the New Okhla Industrial Development Authority (NOIDA) to set up 162 charging stations in Noida.[76] Similarly, EV Motors has signed an MoU for installing public charging infrastructure at Rajiv Chowk in Gurugram.[77]

Among three states in NCR, except Delhi, only Uttar Pradesh has notified its Electric Vehicle policy. Whereas it is under progress in Haryana and Rajasthan. To promote the adoption of EVs in Uttar Pradesh, the state government came up with Uttar Pradesh Electric Vehicle Manufacturing and Mobility Policy (UPEVMP) in 2019. This policy aims at EV manufacturing, creation of charging infrastructure, and increasing demand.

Similar to Uttar Pradesh, both state governments of Haryana and Rajasthan are also framing their own EV policy. These electric vehicle policies shall provide the desired impetus to develop electric vehicles. It is important to highlight that the Rajasthan State Industrial Policy, 2019 had already proposed a set of measures for

EV development in the state, which included research on electric vehicles, financial assistance to encourage electric vehicles and their component manufacturing units, and allotment of land for short-term and long-term leases to reduce land cost for entrepreneurs.

As a next step, the concerned state governments need to frame an electric vehicle policy for their respective sub-regions in NCR to mandate time bound phase in of electric vehicles in targeted segments including buses, autos and taxis, fleet delivery, government owned vehicle fleet, and two-wheelers. This will require supportive incentives, charging infrastructure and building based charging facilities, electricity tariff and financing schemes, etc.

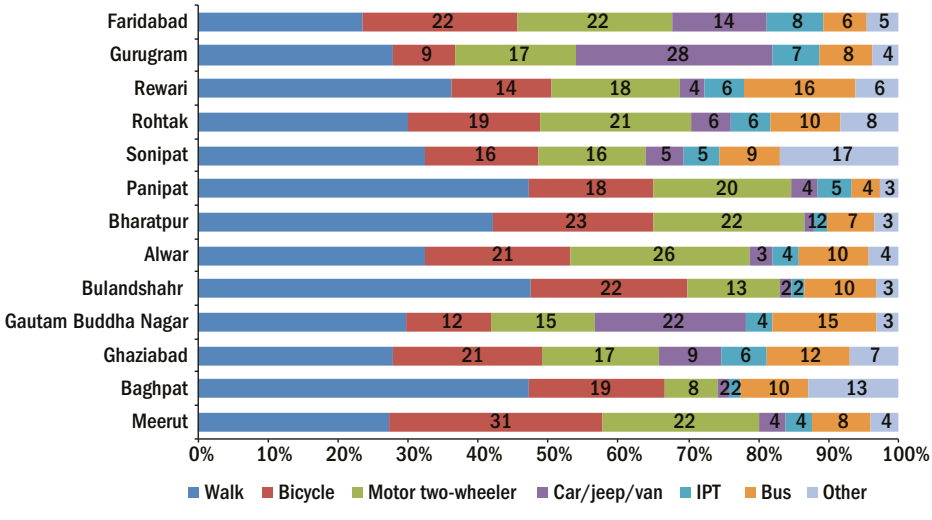
Walking and cycling

Majority of NCR cities have severe deficits in walking and cycling infrastructure. According to the records of Municipal Corporation of Gurugram (MCG), only 28 per cent of city roads have walkable footpaths. They were either never constructed or got depleted or, in a majority of cases, were encroached upon. Over 70 per cent of these footpaths are not wide enough as per Indian Road Congress standards.[78] Some major urban centres have a few stretches of good footpaths and cycle tracks. But these are either encroached or are not safe for walking due to lonely stretches. These are also not continuous and appropriate for differently-abled persons. In 2016, 65 km and 100 km cycle tracks were developed in Noida and Ghaziabad but those stretches are presently under stress. Haryana Urban Development Authority (HUDA) has built a bicycle track in Faridabad Sector 11 and 12 at a cost of Rs 25 lakh. However, cyclists rarely use it as it is encroached in several places.[79]

In 2017, Mobycy launched a bicycle sharing scheme in Gurugram with a fleet of 200 bicycles and later on increased its fleet size to 350. This cycle sharing scheme is spread across the locality near Golf Course Road, Golf Course Extension Road, DLF Phase-4, South City-2, Sector 31, etc. This has also improved the last mile connectivity in areas near Huda City Centre Metro station.[80]

An analysis of modal share data of major NCR cities shows that except Gurugram all other cities still have a very high share of walking and cycling trips. This is an

Graph 36: Modal share of urban areas in NCR



Note: Data does not include no travel and distance not stated category
Source: Census of India, 2011

opportunity to leverage this inherent advantage to prevent car centric growth. There is also an inherent advantage in short trip length (see *Graph 36: Modal share of urban areas in NCR*).

Even though the need for contact free travel during the pandemic has increased dependence on personal vehicles, a survey carried out by CSE during the lockdown phases in Delhi and NCR shows strong preference for walking and cycling. This needs to be leveraged.

In fact, the Gurugram Metropolitan Development Authority (GMDA) has launched a 10 km dedicated colour-coded bicycle lane between Huda City Centre and Subhash Chowk. Further, the authority is planning to create similar cycling tracks across the city in a phased manner. Additionally, GMDA is also planning to set up cycle and rickshaw stands at designated places to encourage bike rentals and sharing.[81]

In Noida, the NMRC is planning to roll out an electric cycle system for the city. For this, NMRC has signed an agreement with a private operator which will initially provide 10 cycles each at eight metro stations in sectors 51, 50, 76, and 148, Pari Chowk, Knowledge Park 2, Alpha1, and Delta 1. The project partner is also planning to deploy more cycles according to future demand.[82] Other NCR cities should also take up projects to improve their infrastructure with at least 1.5-meter-wide footpath and dedicated cycle lanes wherever possible. This will require zonal network plan based on newly amended IRC guidelines for each city and town with a timeline for implementation.

As a next step, all concerned state governments in NCR need to create a network plan to identify the street network for development of footpaths and cycle tracks, make roads to public transport nodes more accessible with at grade facilities for pedestrians, and identify high footfall areas in commercial areas for pedestrianization.

Parking

Even though the clean air action plan has provided for parking management area plan and pricing strategy, the larger NCR has not yet moved in that direction. The Supreme Court in August 2020 directed sub regions of NCR states to implement parking policy and plan along the same lines as Delhi. The guidelines have already been shared with the urban development departments of NCR states.

The experience in key cities shows that focus is still on supply side management and not restraint. The approach is still limited to a few commercial areas. For example, in Gurugram illegal parking is quite common. According to an estimate in 2018, Gurugram has around 150 unauthorized parking areas vis-à-vis 44 authorized ones. As a result, till the month of August in 2018, as many as 1.23 lakh challans were issued for illegal parking. However, commuters still continue to park alongside roads, especially in the market and other commercial spaces, as there is no local management plan to demarcate legal parking areas across the ward with an effective pricing and zoning plan.[83] Unregulated parking charges are another area of concern in Gurugram. They are more rampant in unauthorized parking areas and can be five times higher than an authorized fee.[84] Rationalization of variable pricing can help to make the pricing more market driven while improving revenue generation potential.

Similar issues including lack of well-planned and organized parking and unregulated parking fee collection practices plague Faridabad as well. Commercial vehicles like lorries and mud trippers generally parked alongside highways contribute to congestion.[85]

In Ghaziabad, roadside parking issue has been linked with high traffic jams for years now, especially in residential and commercial areas of Indirapuram, Kala Pathhar Road, and Swarn Jayanti Park road. Heavy traffic jams even on the widest of roads in Indirapuram's residential complexes during peak hours of mornings and evenings is a challenge. Other problem areas include Vaishali, Rajendra Nagar, Shalimar Garden, and parts of Sahibabad as well. Residential areas are facing such problems because the prescribed 150 sqm for every plotted area has been used up by contractors to create commercial spaces.[86]

Noida is one of the fastest growing cities in terms of infrastructure development and connectivity with surrounding areas. Noida Sectors 18 (especially Atta market), 29 (especially Mahavir locality), 31 (especially near the Red Light), 37, and 41 are the most infamous for parking issues.[87]

A zone-based/area-based parking management approach and pricing is needed. The framework provided by the Supreme Court, the Delhi policy and the pilot project need to inform the implementation of parking policy. Under the smart cities programme, Faridabad, Ghaziabad, and Meerut have proposed to implement smart parking management systems. But these need to be developed based on the principles of demand management and restraint.

As a next step all NCR cities need to follow the Supreme Court direction of August–July 2020 to prepare and implement PMAP city-wide—along the lines of the pilot projects in Delhi—to identify and demarcate legal parking areas in all land uses, prevent parking on footpaths and in green areas and play grounds, penalize illegal parking, introduce variable parking charges, etc. to restrain supply and demand for parking.

Traffic management

The present situation of traffic management in almost all NCR cities including Noida, Ghaziabad, Gurugram, and Faridabad is not satisfactory. This is evident in badly designed junctions to poor condition of signalized intersections, and congestion bottlenecks. Additionally, poor enforcement has led to illegal traffic violations including signal violation, wrong side driving, and driving on footpath.

Ghaziabad has 46 signalized junctions of which only 20 junctions are actually managed through signals. At 14 locations, signals are not functioning and at 12 locations the incoming traffic has been eliminated and replaced by strategic U-turns. The city requires traffic signals at an additional 33 locations. In 2019, Uttar Pradesh government decided to implement Intelligent Traffic Management System (ITMS) in Ghaziabad.

Noida has a total of 95 signalized junctions (90 in Noida and five in Greater Noida). However, 50 per cent of these signal lights are not functioning properly. Thus, traffic police have closed the junctions at different locations and manage the traffic through U-turns. Presently, Noida authority is planning to introduce Integrated Traffic Management System. In view of this, a budget of Rs 88.44 crore has been approved. The system will be introduced at 84 intersections across the city and will be monitored from an Integrated Control and Command Centre (ICCC).

Gurugram and Faridabad have installed 315[88] and 700[89] cameras respectively. These cameras can automatically detect traffic violations and data is transferred to ICCC through which e-challan is sent via SMS followed by a post.

Along with signalizing the junctions, bigger NCR cities like Gurugram, Noida, Faridabad, and Ghaziabad should also focus on doing the basics right, as majority of streets are lacking simple road markings, proper sign boards, etc. Traffic police also has to be much more vigilant to reduce traffic related violations.

As part of the clean air action plan, all NCR cities need to cohesively develop and implement traffic plans to protect all road users. More people oriented plans are needed to ensure that pedestrians, cyclists, and public transport users have safe and at grade access. Further, the cities must reduce speed differential between motorized and non-motorized traffic, adopt road signages for all road users, carry out IT based monitoring to ensure road safety for all road users, and adopt zero tolerance policy for road accidents.

Need compact urban form and implementation of transit oriented development policy

Both Delhi and NCR need to implement national transit oriented development policy. In fact, Delhi has adopted its own policy that is also included in Delhi Master Plan 2020–21. This is needed for mixed use and mixed income development within 400 meters of all metro stations or transit nodes with improved accessibility, well designed street density, small block sizes, and no gated development. This will improve usage of the public transport systems.

All new development and redevelopment in cities will have to adopt these principles and these should be the basis of project approval. It has been estimated by UTTIPEC that after the full implementation of Delhi metro about 80 per cent of Delhiites will be within 400 meters of some metro station. This is an enormous opportunity to ensure improved access for the majority. This can reduce dependence on personal vehicles, prevent locking in of pollution, and promote usage of public transport, walking, and cycling.

As next steps all new development and redevelopment projects in the region need project approval process that will mandate and ensure adoption of the design principles that are included in transit oriented development policy as well as those that are consistent with compact urban form.

SECTION 6

Waste

Curbing waste burning

Clean air action plan has a strategic focus on waste burning which is the source of very high episodic pollution in the region. It is also responsible for high level of exposure in neighbourhoods.

The source apportionment studies available from IIT Kanpur (2015) and TERI-ARAI (2018) indicate that biomass burning can be responsible for 22–26 per cent of $PM_{2.5}$ concentration in the air during winter and about 12–15 per cent during summer. Waste burning contributes to this problem.

In addition to open burning of municipal garbage and horticulture waste, fire erupts in landfill sites due to spontaneous combustion. All municipal corporations in Delhi and NCR will have to internalize key waste management solutions to address this problem at scale and with zero tolerance. But its success depends on efficient municipal services. This gets more complicated as a large number of people live outside the municipal boundaries.

Delhi

Five municipal authorities are responsible for solid waste management in the city—the North Delhi Municipal Corporation (North DMC), South Delhi Municipal Corporation (SDMC), East Delhi Municipal Corporation (EDMC) the New Delhi Municipal Council (NDMC), and the Delhi Cantonment Board (DCB). The three corporations—North, East and South—alone manage 96 per cent of the total area of the city.

Capacity to dispose waste is weak and therefore burning becomes the easiest way to dispose of waste. As per official data, the five MCDs of Delhi generate 10,817 TPD of municipal solid waste. The city also has over 1,630 unauthorized colonies in three municipalities alone where there is no waste management system in place. The corporations lack capacities to enforce rules and to ensure compliance. There is dearth of infrastructure to support decentralized processing. The city has over 2,300 dhalaos—structures to collect and store waste.

Over 80 per cent of the waste is processed through incineration, though studies show that the calorific value of Delhi's waste does not support incineration. Not only have these plants received flak owing to NIMBY, but they have been contributors to air pollution as well due to lack of appropriate emission monitoring and compliance systems. Delhi has three waste to energy (WTE) plants with combined capacity of 5250 TPD at three different locations in Delhi namely Okhla, Ghazipur, and Bawana, for generating 52 MW electricity. One new WTE plant is proposed at Tehkhand under SDMC. Expansion of existing two WTE plants at Okhla and Ghazipur has also been proposed to increase their capacity.

Moreover, all three existing dumpsites in Delhi—Okhla, Bhalswa, and Ghazipur—exceeded their capacities way back in 2008. MCD has been asking for

more land to process and dispose garbage. South Delhi Municipal Corporation is primarily managing and disposing all its solid waste in the facility at Okhla dumpsite where waste to energy plant and compost plant exist. WTE plant at Okhla receives approximately 1950 TPD of mixed municipal waste from SDMC, NDMC, and DCB for generating 16 MW electricity.

North DMC has covered all areas under its jurisdiction for door to door collection of solid waste. Fifty per cent of collection is done by motorized vehicles and remaining 50 per cent by containerized tricycle handcarts. No cases of throwing waste into streets/roads have been observed by North DMC. The municipal corporation is primarily managing and disposing almost all its solid wastes in the facility at Okhla dumpsite. North DMC has 36 Auto Tippers, two JCBs and two Hook Loaders. The waste processing technologies involved are waste to energy (280 TPD), OWC (550KPD), biogas plant (500 KPD), and compost pit (11 MT per cycle).

The only secured landfill site of Delhi is operational in Bawana under jurisdiction of North DMC. No vermi-composting facility is available. However, four bio-methanation plants with capacities of five TPD and six plants with capacities of one TPD specifically for cow/animal dung are under consideration. At the Bawana facility being run by M/s Delhi MSW Solutions Ltd, 2000 TPD of waste is disposed of into RDF which is used in the WTE plant for making 24 MW of electricity. The total waste collected by NDMC is about 4000 TPD out of which 2300 TPD is processed at integrated waste disposal facility at Bawana where composting, deposition of rejects in secured landfill site, and waste to energy plant is available.

EDMC has one dumpsite at Ghazipur and one secured landfill site is coming up in Ghonda Gujran. EDMC has covered 90 per cent of households for door to door collection of solid waste generated. The collection of waste is done by motorized vehicles. EDMC has attained 90 per cent of the area and an equal percentage of population for street sweeping. EDMC has one WTE plant at Ghazipur which is being operated by Infrastructure Leasing & Financial Services (IL&FS). About 1000–1500 TPD of waste is processed here for generating 12 MW of electricity.

As per the 2021 Master Plan, community bins or dhalaos need to be provided in 100 sqm of space for every 10,000 people; in addition to this, another 200 sqm of space must be provided for segregation of non-biodegradable wastes. But the DDA does not provide adequate space for storage of waste in both existing and new colonies that are being planned. In SDMC area, all the dhalaos are being converted to fixed compactor transfer stations (FCTS) due to the menace and nuisance that dhalaos have created in the past. Also, in all the other MCDs, the plan is to phase out dhalaos. A proposal has been made to either convert them to Material Recovery Facilities or FCTSs.

Considering Delhi's data made available by the MCDs, of the 65 per cent treatable material, 60–70 percent can be processed through composting or bio-methanation technologies, while 18–20 per cent (textile, cloth, rubber, LPV) can be thermally treated through incineration-based technologies. Presently, everything that is recyclable is also being incinerated; MCDs are encouraging mixed waste to be processed in the WTE plants.

All the three existing dumpsites of Delhi exceeded their capacities way back in 2008. The dumping sites in Delhi do not have any methanization or gasifiers to control the methane being produced naturally by the biodegradable garbage. There are no fire protection systems at these sites, thus making them potentially flammable locations. There is no landfill gas-collection system either. One LFG pilot project at

Ghazipur was established in 2013 by GAIL for extraction of landfill gas to reduce greenhouse gases. The project at Ghazipur is functional only a few days in a month due to unavailability of the gas.

Solid waste byelaws not implemented

It has been more than two years (15 January 2018) since the Solid Waste Management (SWM) Rules were notified, but the MCDs have not yet implemented them in true spirit. The expert committee set up by the Delhi High Court had submitted a detailed action plan in August 2017 on solid waste management. Based on the recommendations, the committee also prepared the draft byelaws on solid waste management which were notified in January 2018. All five municipal corporations are now bound to enforce the byelaws in their areas of jurisdiction.

Byelaws mandate that waste be segregated at source into three streams—biodegradable (wet waste), non-biodegradable (dry waste), and domestic hazardous waste. These streams of waste have to be stored in separate colour-coded bins—green for wet, blue for dry, and black for domestic hazardous waste. Municipal corporations have to ensure collection and transportation of segregated solid waste. They have to publicize the time slots for waste collection for each area.

To avoid the mixing of segregated waste, all secondary storage points (dhalaos) have been mandated to have colour-coded containers to store wet, dry and domestic hazardous waste. Municipal corporations have to convert the existing dhalaos into recycling centres for further segregation of dry waste. Further, under the byelaws, they have to set up a deposit centre for each ward to collect domestic hazardous waste.

To minimize transportation cost and avoid landfills, the byelaws mandate decentralized processing mechanisms such as biomethanation and composting in the colonies themselves. For WTE plants that incinerate directly, absolute segregation has been made mandatory. To fund the waste management infrastructure, corporations have been asked to fix and regularly collect a user fee. To ensure compliance with the byelaws, provision has been made for imposing a penalty for non-segregation, open burning and dumping of solid waste in vacant plots.

Infrastructure for segregation not in place

So far, no systems have been developed by MCDs to support segregation. Segregated waste is collected and sent to the dumpsite or the waste to energy plants. The segregation of the waste becomes futile if everything is ultimately dumped at a landfill. MCDs state land is an issue. However, the dhalaos could be easily converted into dry waste sorting centres or material recovery facilities. Moreover, the collector needs to be incentivized for the same.

Waste management in unauthorized areas and slums

Delhi has 1,634 unauthorized colonies in the MCD jurisdiction area. These unplanned colonies pose a major challenge for waste collection and transportation as well. Even though by the law the municipal bodies are responsible for extending waste management services to these households, these unauthorized colonies are not developed in accordance with the city planning norms. In SDMC, there are 932 unauthorized colonies where a corporation provides sanitation-related activities only as of now. As per the orders of Government of National Capital Territory of Delhi, the development work in unauthorized colonies is entrusted to the Delhi State Industrial & Infrastructure Development Corporation. Until road construction,

drainage, and other allied work is not undertaken, waste collection also becomes a major issue. Moreover, no bins are placed in such areas.

Inventory of waste not done

There is no clear idea about how much waste Delhi generates; figures do not take into account the quantum of garbage managed by the informal sector.

Processing of mixed waste in WTE plants adds to pollution

As per the SWM Rules, 2016 and NGT order dated 22 December 2016, WTE plants cannot operate on mixed waste. So far, no systems have been established to ensure only segregated high calorific value non-recyclable waste goes to such plants. Delhi has three WTE plants—Okhla (2,000 tonnes, 16 MW) operated by Jindal Ecopolis, Ghazipur (1,300 tonnes, 14 MW) operated by IL&FS, and Narela-Bawana (2,000 tonnes, 24 MW) operated by M/s Delhi MSW Solutions Ltd. Mixed recyclable and organic waste is fed into these plants in order to meet the required high calorific value of 1,400 kcal/kg. This is in contradiction with directions of NGT in its order dated 22 December 2016 as well as SWM Rules that have mentioned that no recyclables and mixed waste is to be used in these plants.

The Okhla plant has been in the news since its inception as its neighbours have taken the management of the plant to court, alleging pollution. After many legal battles, the case was finally heard at the National Green Tribunal, which, in its February 2017 order, directed Jindal Ecopolis to 'adopt better technology for segregation of waste before it is put in the furnaces' and also fined the proponent an environmental compensation of Rs 25 lakh. However, there is still no resolution as the residents remain unconvinced by these measures and have taken the case to the Supreme Court.

Management of dump sites

CSE has carried out a detailed assessment of dump sites or landfill sites in Delhi. This shows problems of uncontrolled dumping of mixed municipal waste that is further aided by the flawed laws. These dumpsites are designated by the municipal authorities to dispose of mixed waste. Waste gradually decomposes by a combination of biological, chemical and physical processes. During the process of decomposition, two major emissions of primary concern—leachate and landfill gas—affect the environment.

The process of decomposition creates anaerobic conditions due to the presence of plastic and other large-surface-area materials. These anaerobic conditions lead to the formation of landfill gas, comprising a mixture of carbon dioxide and methane, both of which are greenhouse gases that contribute to global climate change. Methane is known to be more potent as a heat-trapping gas. These dumpsites are the third largest source of methane emissions. It is also flammable with slight exposure to flame or high temperatures. In extreme cases, the gas can build up in a landfill and explode, with risk of devastation.

Ghazipur dumpsite: The Ghazipur dumpsite was set up in 1984 and reached its capacity in 2002. According to the authorities, about 2,000 tonnes of garbage is currently dumped at Ghazipur each day. The dumpsite is now 65 metres high and is rising at the rate of nearly 10 metres a year.

Okhla dumpsite: The Okhla dumpsite was commissioned in 1996. SDMC, the civic body that operates the dumpsite, was dumping 1,200 tonnes of waste until 2018. It is 40 acres (16.2 hectares) in area and 58 metres high, which is thrice the permissible limit. The civic body officially shut the dumpsite in 2018.

Bhalswa dumpsite: The Bhalswa dumpsite was commissioned in 1994 and is spread over 42 acres (17 hectares) in north-west Delhi. The dumpsite exhausted its capacity in 2002. The legacy waste at Bhalswa site is estimated to be 80–90 lakh tonnes. Trommel machines have been installed at the site for bio-mining and bioremediation, a major step towards clearing the legacy waste (see *Table 13: Status of dumpsites in Delhi*).

Table 13: Status of dumpsites in Delhi

Name of the dumpsite	Ghazipur	Bhalswa	Okhla	Narela-Bawana
Height in meters	45	40	48.5	15–20
Land mass in square metres	280,000	206,000	161,000	404,000

Source: Yamuna River Project report, 2016

Bioremediation of Ghazipur dumpsite is in progress. The NGT on 17 July 2019 directed the Delhi government and civic bodies to deposit Rs 250 crore to an escrow account for a bioremediation and biomining project that is to be undertaken to deal with the Okhla, Ghazipur and Bhalswa landfill sites.

The Bhalswa landfill is situated in north-west Delhi and handles dumping of around 2,400 TPD of mixed waste. The dumpsite has been operational since 1994 and reached an estimated height of 62 metres by 2019. The dumpsites stretches to 70 acres (28.3 hectares) with estimated legacy waste of 80 lakh cubic metres above ground level and eight lakh cubic metres below ground level. The biomining operations started on 01 October 2019. The process is being administered by North Delhi Municipal Corporation.

Seven trommels are being installed and 15 trommels are currently processing the legacy waste at the Bhalswa dumpsite (14 trommels of 30 mm screen size and one trommel of 6 mm screen size). As on 18 August 2020, around 661,454 tonnes of legacy waste were processed by biomining. Of this about 85,631 tonnes of inert material has been lifted from Bhalswa and dumped at the eco-park site of NTPC at Badarpur and other low-lying areas. About 97,075 MT of combustible waste or refuse-derived fuel has been sent for co-processing in Jabalpur and the WTE plant in Bawana.

The urban local body had to pay Rs 3,240 per tonne for co-processing the recovered plastic at Jabalpur and Rs 1,800 per tonne for the WTE plant in Bawana. The biomining process recovered 10,129 tonnes of construction and demolition waste. Legacy waste of about 52,700 sqm area and 11 metre height from the first mound and about 6,100 sqm area and 12 metre height from the second mound has been cleared from the Bhalswa dump. About 4,200 MT of legacy waste is being processed per day. The corporation plans to install more trommels to increase the processing capacity to 5,500 tonnes per day.

Lack of compliance and enforcement capacities: Lack of supervisory staff to oversee operations of waste management is a big challenge. Also, there is no task

force or committee created to monitor the progress of waste management in the city—efficiency of C&T systems, processing of segregated waste and proper disposal. Rag pickers or kabadiwallahs form a vital part of waste management in Delhi but they are not authorized. MCDs should rope in the informal sector to strengthen their collection systems.

Waste generation on roadside/kerbside by street vendors/hawkers: Hawkers and roadside eateries generate garbage throughout the day and dump them on the roadside. Poor vigilance and monitoring by the MCDs further aggravates the problem.

Waste from fruit and vegetable markets: No in-house treatment of wet waste generated in such mandis.

NCR

Even though waste burning is widely reported in NCR towns, there is very little information on waste management except in key cities like Gurugram. It is however evident that household based segregation of waste and transport for recycling is still not practiced. It is largely mixed waste that is dumped in the landfill sites.

This challenge is illustratively evident in Gurugram and Faridabad that share the Bhandwari landfill. In these land constrained cities, this landfill is already saturated and there is little possibility of finding new land for dumping. In fact, in 2017, the NGT had directed the Municipal Corporation to clear waste from 12 hectares of land in Bhanwari. Even though Gurugram has taken several steps to improve waste collection and disposal as well as to develop good public information system to prevent waste burning, it remains a challenge. Currently, the centralized third party waste collection system does not include horticultural waste and that is more prone to burning. Only recently has Gurugram Municipal Corporation taken steps to get this stream of waste included as well and also separate out days for wet and dry waste collection.

Overall, for all NCR towns it is important to amend the municipal byelaws based on central waste regulations and rules, scale up infrastructure for decentralized segregation and collection, prevent dumping of mixed waste, develop zero landfill policy, and set up recycling facilities for resource recovery.

Next steps on solid waste management

Delhi has already taken the lead to amend its municipal byelaws based on the solid waste rules and regulations, 2016. But it is yet to implement the byelaws. This requires infrastructure for decentralized waste segregation and recycling and composting. This will have to be implemented ward wise with clear milestones to prevent accumulation of waste in the open. This will require systemic reforms. Other NCR cities and sub-regions will require similar systemic reforms.

Cities need zero landfill policy to minimize need for disposal of waste in landfills in land constrained cities. Focus needs to be more on material recovery from waste through segregation than energy recovery from waste to energy plants. Dependency on centralized technologies like WTE plants needs to be cut down. If waste to energy plants are at all necessary these should be set up far away from habitation.

Promote implementation of composting in all public parks, housing societies, official buildings, schools, etc. MCD should provide subsidies to households/DDA flats/gated societies for adoption of composting/biomethanation technologies for

wet waste management at source. Horticultural waste (garden waste) generated in residential and commercial areas and public parks should be segregated and composted in gardens or parks, wherever it is feasible.

Construction and demolition waste

Huge amounts of toxic dust particles from construction sites and construction debris pollute the air while heaps of concrete, bricks, and metal waste from building construction and infrastructure choke public spaces, water bodies, and green areas in Delhi and NCR. Stopping construction is now a temporary emergency measure during smog episodes as part of the graded response action plan. Yet the state governments are struggling to implement the rules and regulations that have already been adopted for controlling pollution from C&D waste. While there has been progress in Delhi, some early steps have also been taken in the rest of the NCR.

Delhi

The National Capital Territory of Delhi officially started looking into scientifically managing its C&D waste in 2004–05, way before any national regulation or rules came into existence. Then unified Delhi Municipal Corporation carried out a survey to estimate and characterize C&D waste being generated in the city in 2004 and engaged IL&FS to develop a C&D waste management system for the city. The first plant to recycle C&D waste became operational at Burari (North Delhi) in 2009 with a recycling capacity 500 TPD. This was also driven by the need to address waste from prolific construction that was initiated in Delhi to prepare for the Commonwealth Games.

The infrastructure has been growing since and has benefited by subsequent formulation of Construction and Demolition Rules and Regulations in 2016 followed by C&D waste management policy of the state governments. But a lot more is required to bridge the gap between policy and implementation to achieve zero littering and close the loop of C&D waste circular economy.[90]

Fight to make recycled C&D waste legitimate building material: The initial big fight was a legal battle to allow use of recycled material in construction. It came to light in 2013 that the recycling plants in Delhi could not find uptake of recycled material. This matter was taken up by EPCA. CSE's investigation found that ISS:383-1970 of India Standard Specification relating to aggregates for concrete laid down by the Bureau of Indian Standards (BIS) had stipulated that concrete can be made only with naturally accessed material. Based on this, construction agencies expressed their inability to use recycled material as recycled material was treated as illegal.

This changed when this matter was taken up by EPCA and a public conversation was initiated to change the rules. BIS responded to this concern and to the EPCA deliberations and changed the rules in early 2016. There was an additional recommendation for the Central Public Works Department (CPWD) to issue guidance and revise its schedule of rates to allow use of products like paver blocks and flowing tiles made out of recycled C&D waste as it had done for recycled fly ash products. Subsequently, iconic buildings like that of the Supreme Court have used recycled material.

Delhi government's C&D waste policy: In 2010, MCD piloted C&D waste management system in seven municipal zones in North Delhi to cater to its recycling

facility in Burari. After the trifurcation of MCD the entire pilot project fell into the jurisdiction of North Delhi Municipal Corporation and got limited to it. East Delhi Municipal Corporation framed its own rules to support its own recycling facility that become operational in 2015. The C&D Waste Management Rules of 2016 recommended ULBs to impose handling and processing fee on C&D waste generators as part of building permit. ULBs of Delhi took the lead and started levying C&D waste generation fees at the time of sanction of building plans in 2017.

Delhi government's notification of SWM byelaws in 2017 partly incorporated the provisions of C&D Waste Management Rules 2016. These have been adopted by all city ULBs. As ordered by NGT, ULBs also started imposing fines for improper transportation and disposal of C&D waste.

Also following the lead of the CPWD, Delhi PWD issued an advisory to all Delhi government departments in 2015, mandating two to ten per cent use of recycled C&D waste products in all Delhi government building construction and road works. The advisory was reissued by the PWD in 2018.

Subsequently, local action in the region gets further reinforced and strengthened by the central government rules, policies, and programmes. The MoEFCC notified the C&D waste rules and regulations in 2016. Ministry of Housing and Urban Affairs made it mandatory for CPWD to use recycled material if this is available within 100 km of construction sites. Building Materials and Technology Promotion Council issued guidelines for utilization of C&D waste in construction of housing in 2018. CPCB issued Guidelines on Environment Management of C&D waste in 2017. C&D waste management is now included in the Swachh Survekshan of the Union Government and its toolkit for 2021 has been further strengthened that makes it more performance oriented.

Delhi expands C&D recycling capacity: Currently, Delhi has three recycling plants (at Burari, Shastri Park and Mundka) with combined capacity of 2,650 TPD, up from 500 TPD in 2009. Three more plants that will add 2,000 tonnes to existing capacity are in the pipeline.

North Delhi Municipal Corporation has commissioned a new recycling plant with capacity of 1,000 TPD to be located at Rani Khera. Another recycling facility is proposed to be located at Libaspur with a capacity of 500 TPD to exclusively cater to C&D waste generated by the Delhi Public Works Department projects. SDMC currently has no functional plant but is adding two plants, one with a capacity of 500 TPD by the end of 2020 in Bakkarwala in North Delhi and another one of 1,000 TPD in Maidan Garhi in South Delhi. This would bring the total recycling capacity to 4,650 TPD, which is almost at par with the city's generation estimate of 5,000 TPD.

Collection of C&D waste: In 2010, 168 collection points were established across the city for small scale C&D waste generators to deposit their waste. In 2020, there are more than 240 collection points. These are spread across three municipalities—East Delhi Municipal Corporation has 54 collection points, North DMC has 87, and South DMC has 100 collection points.

Finding new collection points is a challenge given the land constraint. This has been overcome by identifying collection points in municipal Junior Engineer (JE) stores or vacant land of ULBs. Their sizes also vary significantly. For instance, the point near Lok Nayak Jai Prakash Hospital is spread across a vast area. The point receives large quantities of waste since it caters to most of the walled city, which is

very congested, as it is challenging to find multiple designated collection points. While it is suggested to designate collection points no further than three km from generation sites, identification of collection points can be challenging in mega cities such as Delhi.

CSE's survey of these collection points revealed that many are not accessible to the general public, and none have provision to store waste in a segregated manner. Further, public information about their existence and location is almost zero, even the official city helpline operators were found to be clueless about this infrastructure. Often, long commutes to collection points and additional costs are resented and that leads to littering.

Transportation of C&D waste: Bulk generators (greater than 300 tonnes per month or 20 TPD) are required to directly bring their waste to the C&D waste recycling facilities currently active in the city. Small generators (generating less than 20 TPD or less than 300 tonnes per month) are required to bring their waste to the multiple collection points that have been provided by the municipalities. The waste from these collection points is either picked up by the trucks owned by the recycling plant or is sent by the municipality through their own means. Two slips are generated at the collection points with details of the transporting entity and the amount of waste picked up. The municipality retains one slip, while the other is collected at the recycling facility where the amount of waste received is verified.

Segregation and processing: Delhi does not have an effective mandate on on-site segregation nor a system in place for segregated collection and transportation. All the segregation happens at the processing facility. The waste received at the recycling plant first passes a weigh-bridge and then is manually segregated to take out rejects such as rags, metal, plastics, etc. The waste is then divided into two streams to be processed separately—one with only concrete and the other with mixed waste comprising bricks, mortar, mixed concrete, etc. The only-concrete stream undergoes a dry process and mixed waste undergoes a wet process. About 90 per cent of the waste received at the Burari plant has been mixed waste, which has undergone wet processing.

Uptake of recycled products: The city initially struggled to find takers for recycled C&D waste products. An advisory was put out saying all Delhi government agencies will be required to incorporate a clause in their tenders that mandates use of a minimum of two per cent recycled products from construction waste in all future contracts for building works and 10 per cent recycled products for road works. Urban local bodies are expected to mandate five per cent use of such products for non-structural applications while examining and approving building plans.

Due to a poor response from government departments, Delhi government reissued its 2015 advisory in 2018 mandating public agencies to use products made from recycled C&D waste for non-structural applications while examining and approving building plans.

The city's recycling plants cleared most of their unsold itinerary of recycled C&D waste products by the start of 2020. ULBs themselves purchased most of the itinerary. CPWD had procured 1.8 million recycled C&D waste blocks from the city recycling plant for construction of the prestigious Extension of Supreme Court of India project.

National Buildings Construction Corporation (NBCC), in the redevelopment of East Kidwai Nagar, commissioned a temporary C&D waste recycling facility (150 TPD) to be run by M/s Enzyme India Pvt Ltd. The PPP model for the project included 100 per cent buy back of recycled C&D waste by NBCC. The redevelopment project involved a demolition of 2,444 existing houses and allied structures. The C&D waste generated from the demolition was recycled to produce concrete blocks that were utilized in the construction of the new buildings, to produce fine aggregate, course aggregate and manufactured soil that was directly used in construction as a fill material and also in manufacturing of downstream products like RMC (ready-mix concrete), bricks, blocks, tiles, pavers, etc.

In 2017, EDMC and SDMC started levying C&D waste generation fees at the time of sanction of building plans. A waste generation fees of Rs 60 is charged by EDMC per sqm of the proposed built-up area at the time of sanction of building plan. The fee is 1.5 times higher for unauthorized construction. Similarly, SDMC is imposing a processing fee of Rs 205 per tonne at the time of sanctioning a building plan and Rs 225 per tonne for lifting waste. Transportation charges would be increased by 10 per cent every two years.

DMRC sets up a recycling facility: In August 2017, DMRC started its own C&D waste recycling facility at Mundka (North Delhi) specifically for C&D waste generated from DMRC phase 4 constructions. The facility is managed by IEISL. Before this, DMRC had disposed of approximately 225,000 tonnes of C&D waste at the Burari plant.

Next steps in Delhi

Delhi has taken several steps forward but the elimination of the problem will require immediate action on the current gaps in implementation. After all the recycling plants are constructed the recycling capacity will match the waste generation in the city. This is an important opportunity to close the loop of circularity.

Implement on-site management and segregation of C&D waste: The city has not properly spelled out requirement for on-site management and segregation of C&D waste. Lack of guidelines for C&D waste management plans is a roadblock for both builders making these plans and authorities accessing and approving them. Focus needs to be on reducing generation of waste and maximizing on-site reuse or recycling and not just collection and transportation to city's recycling facilities.

Implement public information system to build awareness regarding collection system: Level of awareness regarding C&D waste rules and ULB provided services and facilities is extremely poor among the public and even construction agencies. ULB websites and helplines don't offer information on C&D waste management. ULBs regularly publish list of collection points in the city in print news media but these collection points are plagued with poor signage and access.

Collection and transportation services: City does not offer an affordable on-call C&D waste transportation service to the public like many other cities in the country. There is very poor public database of empanelled transporters that people can engage to properly dispose of their C&D waste.

Uptake of recycled products: Currently, recycling plant operators have a monopoly over the manufacturing and sale of products made from recycled C&D waste. The plants prefer large-scale orders from government agencies. This leads to limited public access to these materials and also stunted product innovation and development.

Reduce GST rates on recycled products: Products from recycled C&D waste are charged 18 per cent GST, while same products from conventional material are charged only five per cent GST. This hinders development of a true self-sustaining circular economy.

Enforcement and vigilance: There is very limited monitoring for proper handling of C&D waste and poor vigilance against illegal littering and dumping of the waste. There are regular cases of the debris being dumped illegally across the cities in waterbodies, drains, municipal solid waste dhalaos, isolated stretches, or by the roadside. It is mostly done during the night when vigilance is low.

Demolition management: City doesn't issue independent demolition permits nor does it have any guidelines to ensure maximum resource recovery and minimum C&D waste generation from demolition process. Demolition work in the city is dominated by the informal sector with negligible regulation and oversight.

Informal sector: There exists a vibrant informal system of salvaging, recycling, reusing, and reselling of building elements and material from demolished buildings. Demolishers salvage valuables like doors, windows, iron, bathroom fittings, and electrical equipment and are supported by an informal network. Interface between formal and informal will have to be strengthened.

Gurugram

Municipal Corporation of Gurugram (MCG) passed orders to penalize illegal dumping and provide for safe disposal of C&D waste in 2015:

- Designated disposal points with the city and introduced penalty for illegal dumping in the city (15 in total).
- First violation attracts a penalty of Rs 5,000 with a 20 per cent increment with every subsequent violation.
- Waste to be segregated into six streams on-site (brick and masonry; concrete and steel; soil, sand and gravel; wood and plastics; other metals; and miscellaneous).
- A fee of Rs 360 per tonne for each stream of waste. Unsegregated waste will be charged at Rs 720 per tonne for disposal.
- All developers will have to submit plan for the clean-up. Violation of the conditions will be punishable under sub-section (1) of section 15 of the Environment (Protection) Act, 1986. Each failure is punishable with imprisonment for a term which may extend to five years or fine up to Rs 1 lakh or both and with repeated violations additional fine will be imposed at Rs 5,000 for every day and for as long as the contravention continues.
- All large generators of waste will have to pay charges for transportation, collection, processing, and disposal.
- They will be responsible for segregating construction and demolition waste before disposal.

MCG starts a helpline number for C&D waste in 2016: MCG started its C&D waste pick-up service through a toll-free number. The service can be availed by residents, builders, and private firms. The service is provided at a cost of Rs 1,000 per trolley and Rs 3,000 per dumper.

MCG mandates registration of private C&D waste carriers in 2018: All private C&D waste carriers need to register with MCG. The owners would need to display registration number on the carriers, along with the MCG logo painted in purple. Failing to register will attract penalties and repeated offenders will be seized.

City gets multiple recycling plants in 2019: Gurugram got its first recycling facilities in March 2019, in the form of two mobile plants with a capacity to treat 400 TPD, near the Auto market. By the end of the year, the city commissioned a permanent C&D waste recycling facility at Basai, five km from the main city, with a capacity to treat 300 TPD of C&D waste, taking the total capacity to 700 TPD. The plant is operated by IEISL and only produces aggregates from the C&D waste.

MCG ropes in private agencies for transportation in 2019: MCG empanelled private agencies which can be called up using the helpline number provided by the corporation. These agencies can also help waste generators to assess the waste generated and provide pick up service for C&D waste disposal.

Increased monitoring and enforcement in 2019: The practices include night patrolling to identify illegal dumping activities, increased monitoring of C&D waste dumping hotspots with CCTV cameras at select locations, and impounding of vehicles which are found dumping illegally. The corporation has also moved to an e-challan system for collection of fines. The city collected Rs 20 lakh through challans and fines in 2019.

Mandatory payment and disclosure of C&D waste generation in 2019: The corporation is also sealing building sites with any demolition or construction activity if the owner/developer fails to pay the C&D waste generation fees as stipulated by the corporation. Non-disclosure of the estimation of the C&D waste generated attracts penalty of Rs 5,000.

Penalties increase fivefold in 2020: Penalties for non-disclosure of C&D waste estimation increased by five times in 2020. The city collected Rs 40 lakh through challans and fines.

MCG mandates usage of recycled C&D waste in 2020: MCG made changes to contracting guidelines and now will require all contractors to buy 10 per cent of recycled C&D waste products. The prices for the products have been cross subsidized by the corporation so these products are comparatively cheaper.

Ghaziabad

The city notifies C&D waste management policy in 2019: In March, Ghaziabad Nagar Nigam (GNN) notified its C&D waste management policy. It defined responsibilities of waste generators and stipulated that generators must ensure that collection, segregation, and storage of C&D waste generated by them is done according to the new rules. It also stipulated the transportation arrangement and

the fees to be paid to the authorized agencies to store, process, and dispose of the waste. The notification also provides the penalties in terms of fines to be paid and imprisonment in case of contravention of the notification.

The city gets its first C&D waste recycling facility in 2019: A recycling plant of 150 TPD capacity started functioning in the city.

Noida

First C&D waste recycling facility comes up in 2020: In the beginning of 2020, the city of Noida got its first C&D waste recycling facility with a capacity to treat 150 TPD of C&D waste. Noida Authority plans to increase the capacity to 300 TPD in the near future. The residents can call a helpline number to register complaints regarding dumping of C&D waste. Unidentified C&D waste is also collected from across the city and is taken to the C&D waste processing facility.

Dust control in construction sites

SC order dated 16.12.2015 directed the Delhi government to ensure measures are taken to mitigate dust pollution from construction. EPCA has given a concise checklist for inspection of construction sites. This should be implemented. Control measures should be taken for fugitive emissions from material handling and conveying and screening operations through water sprinkling, curtains, barriers and dust suppression units. Penalties have also been enhanced.

For material handling and construction and demolition, it should be obligatory on part of the developers to provide evidence of debris disposal at designated sites. Recycling of construction material should be promoted. Provisions of central regulations for construction and demolition waste need enforcement. Municipal bodies, PWD, CPWD, DSIIDC, DTTDC, and road owning agencies will have to address this.

SECTION 7

Crop fires

Scale of the problem

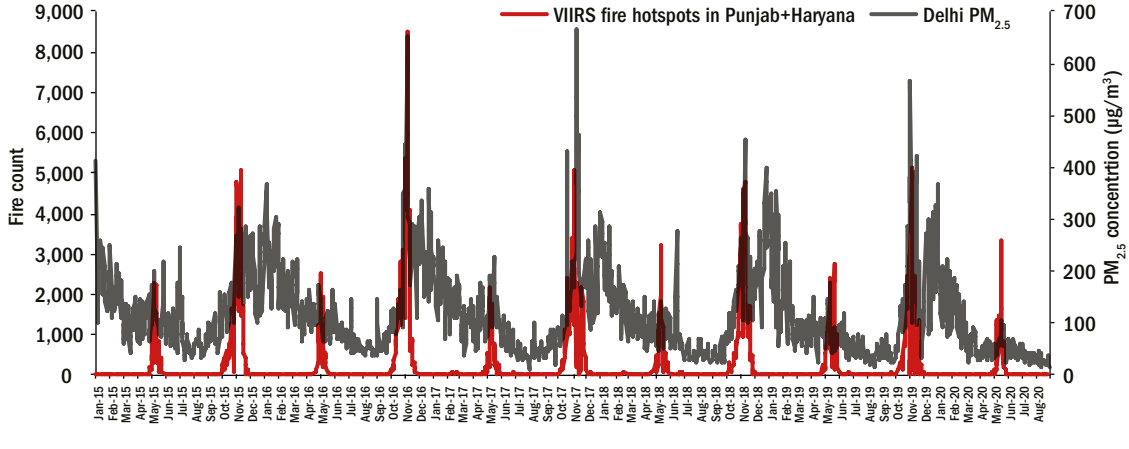
Seasonally, fires make an impact on regional smog in northern India. A concentrated plume saturates the atmosphere's natural ability to disperse and dilute pollution and results in a significant increase in pollutant concentration. Regional scale robust studies are not available to indicate the seasonal contribution of crop fires to regional smog.

The bigger interest that has gripped attention is its contribution to Delhi's winter smog. The timing, duration, and intensity of Delhi's winter smog episodes have often aligned with the trend in the daily active fire hotspots in Punjab and Haryana since 2015. But stubble fires in summer do not show similar influence or alignment with Delhi's pollution level (see *Graph 37: Trend in stubble fire hotspot data and Delhi's $PM_{2.5}$ concentration*).

There is a need for further investigation into the more granular linkage between fire, pollution, and meteorology which is beyond the scope of this analysis. Fortunately, a few government research and development centres have already started working on this aspect.

The Union Ministry of Earth Sciences' research and forecasting initiative SAFAR has investigated the link between stubble burning fires and Delhi smog. SAFAR has observed that it is not only the quantum of fire but also the direction and speed of transport and surface winds that determine the contribution of the fire incidents to the Delhi smog. According to their calculations, this contribution can vary between 4–30 per cent on a daily basis.

Graph 37: Trend in stubble fire hotspot data and Delhi's $PM_{2.5}$ concentration



Source: CSE analysis of NASA FIRMS fire data and CPCB real time air quality data

Tracking fire data

Satellite images have been captured by the National Aeronautics and Space Administration (NASA) and made public under their Fire Information for Resource Management System (FIRMS).

More specifically, they come from satellite observation of NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Terra and Aqua satellites and NASA's Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the Suomi National Polar orbiting Partnership (Suomi NPP) and NOAA-20 satellites.

MODIS data is available from November 2000 (for Terra) and July 2002 (for Aqua) to the present. VIIRS data is currently available from 20 January 2012 to the present. FIRMS makes near real-time (NRT) active fire data available within three hours of observation by these satellites on its online portal.

NRT data from both MODIS and VIIRS is useful for informing immediate disaster mitigation and management. But due to time constraints, the raw data is not processed to the fullest and NASA recommends not using it for scientific enquiry. FIRMS provides validated science-quality data as well, but with a two–three months lag from the time of satellite observation.

Both MODIS and VIIRS detect fire by processing thermal imaging of the Earth's surface but use different technologies and algorithms. MODIS uses a contextual algorithm that exploits the strong emission of mid-infrared radiation from fires.

The MODIS algorithm examines each pixel of the MODIS swath and ultimately assigns each to one of the following classes: Missing data, cloud, water, non-fire, fire or unknown.

In contrast, VIIRS uses radiometric signals from four micron, 11 micron and a few other bands for detection. It uses a hybrid threshold and contextual algorithm that identifies thermal anomalies. It uses a suite of tests for internal cloud masking and rejection of false alarms.

Each red dot or hotspot on the FIRMS map represents at least some fire. But it can be more than or even less than one fire. The number of red dots on FIRMS is not actually the real count of fires but an indication of the presence of fire(s) within a particular area (1 km x 1 km for MOIDS and 375 m x 375 m for VIIRS). A red dot can be one single instance of fire or multiple fires, at times a single big fire can appear as a cluster of multiple red dots

Technically, each MODIS active fire or thermal hotspot (red dot on the map) represents the centre of a 1 km x 1 km pixel that is flagged by the algorithm as containing one or more fires. Each VIIRS active fire or thermal hotspot location represents the centre of a 375 m x 375 m pixel.

The VIIRS data complement the MODIS fire detections but the improved spatial resolution of the 375 m data provides a more accurate picture and has improved night-time data-collection performance.

Can this data be wrong?

The data is not wrong but it is susceptible to errors and its interpretation is subject to multiple caveats. For instance, NASA notes that a few VIIRS active fire hotspots are occasionally located outside the reported perimeter of a large fire.

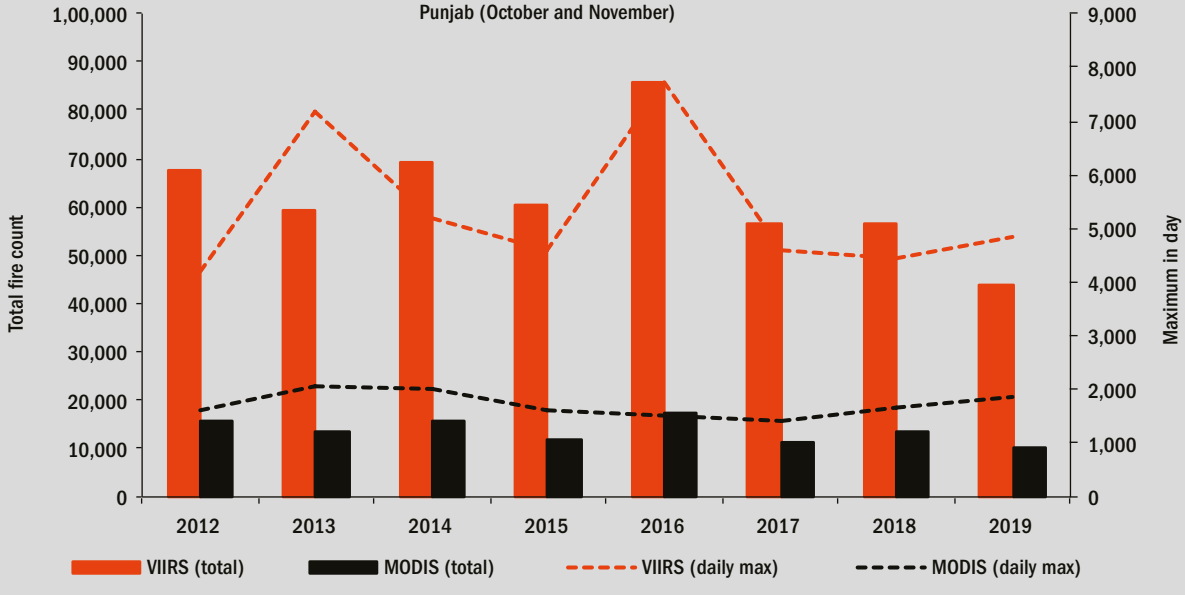
VIIRS has been routinely found guilty of categorizing areas with no surface fires as active fire hotspots. This has been reported in instances of large and intense wildfires when the VIIRS instrument detected the surface fire along with part of a super heated plume (outside wildfire) and categorized all of them as active fires. NASA recommends that if this happens, one may need to look for additional clues to see if it is a data artefact.

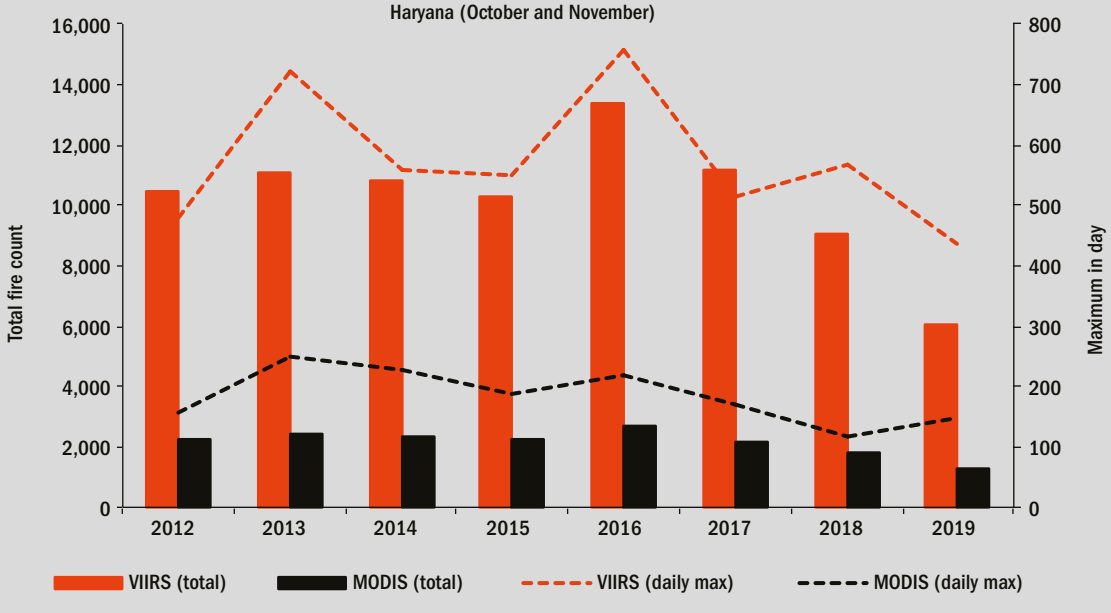
There have also been instances when both MODIS and VIIRS failed to detect a certain fire. This can happen due to several reasons: a fire may have started and ended between satellite observations; cloud cover, heavy smoke or tree canopy may have completely obscured the fire; instruments may have become inoperable; or a fire may have been too small or not hot enough to be detected.

Overall, it is safe to assume that even if satellite images do not show a fire, it does not necessarily mean that nothing is burning on the ground. When they show a red dot or an active fire hotspot, there certainly is a strong fire burning on the ground directly at the spot flagged or nearby (geo-location accuracy is poor for NRT data). NASA data has a tendency to exaggerate the magnitude of the fire in its NRT data, but not significantly.

Most media reportage of stubble burning in Punjab and Haryana is based on the NRT data of FIRMS. This data is indicative by design and often exaggerated. Therefore, all these reports need to be taken with a pinch of salt, especially if they are comparing

Observed active fire hotspots in Punjab and Haryana for October and November





Source: CSE analysis of NASA FIRMS data

current NRT data with processed scientific data from previous years. For any comparative analysis, one ought to use science-quality data that FIRMS makes available with a lag of few months.

Also, people have a tendency to just refer to VIIRS as its more granular grid leads to a larger hotspot count compared to NASA's MODIS. For instance, a fire spread over one square kilometre will be reported as one active fire hotspot by MODIS and nine active fire hotspots by VIIRS. This sensationalizes the issue but is undermined by the fact that VIIRS is more prone to reporting false positives than MODIS and both don't give an actual count of fires.

FIRMS data simply confirms the existence of the practice of burning farm stubble in Punjab and Haryana. Its science-quality data (not NRT data) provides a scientific measure of the geographical and temporal spread of the problem. But it doesn't provide an actual count of the number of fires nor the quantification of volume that is burnt and the area over which it is burnt.

Despite the many ifs and buts of FIRMS data, it remains the most reliable, publicly available data on instances of fire in India. By adopting a robust methodology, it can be used for various scientific and policy applications. A good practice would be to refer to both MODIS and VIIRS data while assessing the problem.

CSE has analysed MODIS and VIIRS science-quality data for India from 01 January 2012 to 2019. This data can be read keeping the caveats in mind. This shows that the total active fire hotspot count during months of October and November peaked in 2016 in Punjab and Haryana.

Punjab has five to eight times more active fire hotspots than Haryana. On the question of fires on a daily level, the two datasets diverge. According to MODIS data, the number of active fire hotspots recorded in a single day was highest in 2013 for both Punjab and Haryana.

VIIRS data also shows high numbers for 2013 but the numbers for 2016 are even higher. There can be multiple explanations for this mismatch between MODIS and VIIRS data and more data might help in arriving at an informed inference in this regard.

MODIS and VIIRS data show that the total number of hotspots in 2017 was almost 35 per cent lesser than the number in 2016. There was virtually no change in 2018 but 2019 numbers were 20 per cent lesser compared to 2018.

On the other hand, Haryana shows a milder (about 16 per cent) decrease in the number of hotspots in 2017, and increases in 2018 and 2019. Since the two datasets agree, it would be prudent to use this aggregation of FIRMS data to analyse impact of policy.

It is possible that this change in the number of hotspots doesn't actually add up to any change in actual number of fires. If neighbouring farms that earlier burned their stubble on different days start burning stubble at the same time, the fires will be recorded by the satellites as a single hotspot. This will bring down the overall count of hotspots even though the actual number of fires might have remained static

Placement of geo-locational controls can rectify this anomaly but it is a complicated and time-consuming process beyond the scope of quick analyses (like ours). What is the alternative? One can look for trends in the daily count of hotspots to get some idea about what might be at play on the ground.

The story reverses for Punjab if one looks at the behaviour of daily count of hotspots or the temporal concentration of these fires. Unlike the seasonal total count that has been on decline, the maximum number of fires within a single day has been rising in last three years.

Haryana is not showing a rising trend like Punjab on this matrix but it is not declining either like its total season hotspot count. This is an indication that the total hotspot counts in the season might be down over the years but the number of fires with each hotspot is on rise.

Or in other words, each hotspot has more instances of fire now than three years back. This should be investigated further as this is useful information that can improve our understanding of smog formation.

SAFAR has been publishing this daily contribution percentage on their website since last year. UDAL browsed through this information and noted that the highest contributions from the fire were noted on the most polluted days observed in early November.

This analysis reinforces the need for stronger data science to assess different dimensions of the smog problem in northern India. Advance satellite monitoring is enabling that process.

Addressing the problem

This matter has drawn a lot judicial attention. While NGT has been monitoring this matter for a while, the Supreme Court has taken stronger interest this year. On 28 February 2020, the Supreme Court directed the Union and state governments to take stronger measures to stop the problem as it has serious adverse health

impacts. While the Supreme Court had taken on board the action plan proposed by the Ministry of Agriculture and Farmers Welfare in its affidavit dated 26.2.2020, it had additionally asked EPCA to review the implementation of the action plan with the Union and state governments. This status report has provided comprehensive information on what is being done in the three states of Haryana, Punjab, and Uttar Pradesh.

Reasons why farmers burn crop residues

Mechanization of crops leads to smaller stubble left on the ground that is difficult to collect. This combined with labour shortage increases the cost of collecting it. Moreover, in Punjab and Haryana, the state governments have notified that sowing of rice will be delayed to June because of concerns of ground water depletion. This leaves farmers with less time between the harvesting seasons of rice and sowing of winter wheat. Therefore burning of residues is the most feasible option in that small window.

What is being done?

The Union government as well as the state governments have promoted several measures with varying results. The in-situ measures provide subsidized agricultural machines to farmers that can help till back the stubble to mulch and compost the straw on the land itself. The governments have to ensure that the costs of these machines are subsidized to make them affordable and also ensure rental to small and marginal farmers.

The other supportive ex-situ measures include making the straw marketable and adding value for the farmers. This particularly applies to rice straw as it is not attractive as fodder and requires other usage to add monetary value. This includes setting up straw based power generation plants, bio-CNG or bio-ethanol plants, that can procure straw from farmers at a price. This creates incentive to not burn the straw. But this will require added machinery like balers to help collect and compress the straw for easy transportation for processing. In the longer term the fundamental solution will emerge from crop diversification to reduce dependence on paddy, which is also a water guzzler.

The Supreme Court had closely monitored the situation during the winter of 2019 and had directed the state governments to strengthen action and asked for a comprehensive plan. The Union Ministry of Agriculture and Farmers Welfare in its affidavit of 26 February 2020 provided a plan that was directed by the Supreme Court.

EPCA Report No 117 (Special Report on implementation of Hon'ble Supreme Court directions on stubble burning before the onset of the season 2020), dated 30.9.2020, reviewed the status of implementation in three states in September 2020 and brought out the latest development in the area.

EPCA reviewed the status of implementation around September–October 2020. This brought out that Union Ministry of Agriculture and Farmers Welfare has sanctioned the scheme for the year 2020–21. The state governments of Haryana, Punjab, and UP have bought stubble management machines. They have set up CHCs and have targets ensuring implementation this season.

The states have worked out schemes to make machines available to small and marginal farmers. Haryana government, as on 24 August 2020, had issued directions that small and marginal farmers will be given preference in the use of these machines in the panchayat run CHCs through reservation of 70 per cent of

Salient feature of the action plan submitted by the Ministry of Agriculture and Farmers Welfare

In-situ action

Central sector scheme on promotion of agricultural mechanization for in-situ management of crop residue for Punjab, Haryana, UP, Delhi to be continued during 2020–21 with appropriate modification and tentative budgetary provision of Rs 600 crore (100 per cent central assistance). Under this scheme, agricultural machines and equipment for in-situ crop residue management for straw management system (SMS) will be provided to the farmers on individual ownership basis at 50 per cent subsidy. These machines enable farmers to till back the stubble into the ground and so improve soil carbon. Custom Hiring Centres (CHC) will be set up to make this equipment available to small and marginal farmers on reasonable rent. The government will provide machines costing up to Rs five lakh to each village panchayat, primary agricultural cooperative society, and farmer producer organization where paddy straw burning has taken place.

The multi-lingual mobile app, CHC Farm Machinery, will be used widely to make farmers aware of the closest machinery available for rent. This app will be popularized and extensively used for optimum utilization of agricultural machines available with CHCs for the benefit of small and marginal farmers. The rental charges for different machinery will be rationalized by the state governments.

Information, education and communication (IEC) activities will be taken up vigorously to make farmers aware of the problems of stubble burning and the availability of machines. An amount of Rs 100 crore will be earmarked for IEC during 2020–21

Ex-situ action

Oil PSUs have launched the 'Sustainable Alternative Towards Affordable Transportation (SATAT)' which will convert straw into CNG. The problem of transportation of residue will be tackled through the Sub-Mission on Agricultural Mechanization (SAM) which is providing balers for collection of straw, also making transportation easier. The scheme for balers will continue for 2020–21.

The state government will take all necessary administrative measures to control burning of paddy residues such as strict enforcement of provisions under section 19 (5) of the Air Act 1981, action on enforcement measures directed by NGT, mandatory fitting of SMS on combines, disincentivizing farmers from government assistance and red entry in Khasra Girdawari. In addition, they will ensure close monitoring of fire events at village level and any such administrative measures within the delegated powers of the district commissioners.

After deliberations it was found that inclusion of cost of stubble removal in MSP may not be a viable option. It has been agreed that any such incentive, if at all necessary, should be provided by the state government from their own budget.

the machines for them. While the state government has not prescribed any rates for CHCs run by the panchayats, the government has informed EPCA that panchayats are not charging for rental for the equipment. However, EPCA has written to the state asking for more clarity on this so that small and marginal farmers get access to these machines which have been provided at 80–100 per cent subsidy to the panchayat run CHC's.

Punjab government, as on 14 August 2020, issued directions to ensure that these machines are available to small and marginal farmers on priority basis and that these farmers are charged an operational cost but no rental for the machines. The government has clarified that the operational charges include source of power and operator wages, etc. but not the cost of capital. EPCA has written to the state that this requires clarification and that as the machines have been provided at subsidy to the panchayat run CHC there should not be any recovery of capital in any case. They are providing 80–100 per cent subsidy for procurement and supply of these machines to make sure that small and marginal farmers have easy access and that these are available at concessional cost/free to the farmers for use.

There is need for widespread publicity and awareness creation of the directions against stubble burning and the alternatives and the health costs, not just to city residents, but also to farmers. Information on ex-situ (biomass power projects and compressed bio-CNG projects) methods is important so that farmers have alternatives to burning stubble. Rakes and balers must be available to farmers for collection of the straw. Enforcement of these directions will require daily monitoring through the use of satellite imagery and action at the village/block and district level. The local administration will be required to ensure compliance. The state governments need to set up a control room for monitoring daily fire reports and enforcement action that is being taken.

The Union Ministry of New and Renewable Energy is working on the proposal sent by Punjab government that biomass power projects should be given Viability Gap Funding so that the power from these projects can be sustainably bought by discoms. It is also reviewing the proposal for a biomass-solar hybrid power project scheme.

Compressed bio-gas (CBG) projects are being commissioned. RBI has included CBG in its list of priority sector lending; SBI has circulated a loan scheme and oil companies have agreed on a buy-back rate of Rs 46/kg for five years; and to agree that beyond this period this rate will be the floor price. The private sector has shown great interest and already many CBG projects have been cleared. These projects, once commissioned, will create a market for straw and provide farmers an incentive not to burn the resource.

The funds already provided and the plan that exists should be implemented this season and in the coming period. The effort must be to ensure that farmers have easy and affordable access to the machines which allow them to do smart straw management. Based on the plan, the state governments of Haryana, Punjab, and UP have set targets for this year and the in-situ plans are available for each state (see *Table 14: Status of action on crop fires*).

Table 14: Status of action on crop fires

Salient features	Haryana	Punjab	Uttar Pradesh
Estimated crop residues in 2019 (in million tonnes)	7	20	16
Estimated crop residue burnt (million tonnes)	1.24	9.8	0.0042
Area affected by stubble burning	5.93 lakh acres	27.70 lakh acres	25 lakh acres
Percentage of the total cultivated paddy area burnt	17.7	37.42	0.2
Total number of CHCs set up	2,879	7,378	3,989
Total machinery provided	15,928	50,815	39,553
Panchayats reached	851 (in numbers)	59%	28%
Number of machine registered	18,758 (76%)	9,390 (19%)	9,484 (24%)
Number of balers	230	219	3
Incentive given to farmers for not burning stubble in 2019 (in Rs crore)	1.63	28.51	None
Number of farmers	3,930	31,231	None
Decrease in area under paddy (in per cent)	9.80	13.73	Nil

Next steps

The plan that has been adopted by the Union government and the state governments includes in-situ mulching and composting of straw and ex-situ value addition by making other products with straw.

For in-situ measures, access to machines has to be scaled up ensuring all small and marginal farmers who cannot buy these machines have access to these machines through the panchayats or other community run centres. Farmers have to be provided assistance to do smart straw management and also strict enforcement against violators. Sufficient numbers of stubble management machines need to be procured and made available for use in the state. Rental/operational cost rates need to be fixed in such a manner that the cost is minimal for small and marginal farmers.

For ex-situ measures strong policy needs to be framed to promote enterprise in the region to absorb straw as a raw material and create value for the farmers. Some important steps have been taken in this direction in terms of power generation. Agro residue as fuel and production of bio-CNG and ethanol will require bigger scale of investments. This will also require infrastructure support for bailing, collection, and transport of straw.

Longer term solutions will emerge with change in cropping patterns to reduce acreage under paddy by promoting other locally appropriate crops and reforming the support price structure accordingly.

SECTION 8

Clean household energy

For a long time the use of solid fuels for household cooking and its use in open eateries has been treated in isolation and not in relation to the total air quality. But it is now accepted that household air pollution from cooking fuel is not only a serious health risk for women and children in homes but it is also an important contributor to outdoor ambient air quality. In fact, a recent policy brief on the Contribution of Household Fuels to Ambient Air Pollution in India from Collaborative Clean Air Policy Centre, New Delhi, shows that household air pollution can contribute upto 30 per cent of particulate pollution in India with serious health consequences. Therefore, controlling this is critical to meet the ambient air quality targets. This matter has also been taken on board by the report of the expert committee of the Union Ministry of Health and Family Welfare on air pollution and health.

In Delhi, LPG penetration increased after the implementation of 'Kerosene Free City' scheme around 2012–13. LPG connections to economically weaker sections were issued and free chullah with regulator and pipe distributed. The scheme was discontinued after Delhi was declared as 'Kerosene Free City' in October 2013. Further, with implementation of approved fuel list, the Municipal Corporations in Delhi have stopped the use of fire wood and coal in hotels and eateries. However, wood charcoal is allowed, as wood charcoal is approved fuel in NCT of Delhi for use in tandoors and grills of hotels/restaurants.[91] Available evidence shows substantial increase in LPG and piped natural gas (see *Table 15: Sale of cooking fuels in Delhi*).

Table 15: Sale of cooking fuels in Delhi

Energy product	2015–16	2016–17	2017–18	2018–19
Cooking gas LPG in thousand metric tonnes	777	798	808	825
Kerosene oil in thousand metric tonnes	1	1	1	1
Piped natural gas PNG connection/ consumers in numbers	461,881	522,747	611,292	737,653

Source; Delhi Statistical Hand Book 2019, published by Directorate of Economics & Statistics, Government of National Capital Territory of Delhi

The official data from Petroleum Planning & Analysis Cell of Ministry of Petroleum & Natural Gas as on 1.1.2020 shows that LPG coverage in Delhi and NCR states is

more than 100 per cent. According to the MoPNG, LPG coverage is estimated on the basis of domestic LPG consumers by dividing estimated number of households. As on 01.02.2020 estimated domestic LPG consumers were 2772.2 lakh against the estimated households at 2850.5 lakh and the percentage comes to 97.25 percent.[92] (see *Table 16: LPG coverage of households in Delhi and NCR states*). Government of India has several programmes to improve access to LPG. These include Pradhan Mantri Ujjwala Yojana (PMUY) and direct benefit transfer to LPG consumers (PAHAL).

Table 16: LPG coverage of households in Delhi and NCR states (LPG coverage as on 1.1.2020)

State/union territory	Number of households as per Census 2011	Estimated households* as on 01.01.20	Active domestic connections of PSUs OMCs as on 01.01.20	LPG coverage (in %)
Delhi	33.41	39.66	49.04	123.7%
Haryana	47.18	55.47	68.07	122.7%
UP	329.24	387.99	398.77	102.8%
Rajasthan	125.81	149.48	161.39	108.0%

*The estimated number of households as on 1.1.2020 is arrived at using household growth rate during the decade 2001–2011 as per Census 2011

Source: Petroleum Planning & Analysis Cell of Ministry of Petroleum & Natural Gas provides 'LPG Profile (Data on LPG Marketing)'

While the official estimate indicates more than 100 per cent coverage, this masks the problem of unreliable supply, use of mixed fuels by households, and delayed refill that push households to fall back on dirty fuel. According to the MoPNG's Demands For Grants (2020–21), Second Report, Lok Sabha Secretariat, LPG refill status is 8.26 refills every 12 months in Delhi NCT, whereas it is as low as 5.48 in Haryana, 3.17 in Rajasthan, and 3.55 in UP. Data on refill in NCR is not available.[93] There is challenge to increase refills of LPG and sustain adoption.

Solid fuels and household cooking: Next steps

Delhi and NCR will require a more targeted strategy to ensure households below poverty line get adequate support for access to LPG as well as for refill. The new affordable housing typologies including rental and dormitories need to be equipped with clean cooking systems for the migrant or floating population to use.

It needs to be strictly ensured that all open eateries have access to LPG and electricity and that this is linked with their commercial license.

Way forward

What has been achieved in Delhi is not small and yet not enough. NCR has a lot more catching up to do and also raise its ambition for locally appropriate solutions. Given the target reduction of over 60 per cent to achieve the particulate standards in a large part of the region, multi-sector action has to gather speed, scale, and urgency.

This requires strategic shifts to achieve mobility transition, clean energy transition, circular economy at a scale, and clean energy access at a regional scale. Even though action has started in each of these areas, the region is waiting for firm targets for transformative changes.

Mobility transition has to ensure widely distributed and integrated transport services that are also modernized and kept affordable. This needs to be supported by well deployed para transit services, especially in smaller towns, and walking and cycling infrastructure. The region has to take steps towards vehicle restraint measures like parking policy and parking management area plans. After the leapfrog to the BS VI emissions standards for vehicles and fuels, the entire region has to develop its capacity to move to more advanced and effective on-road emissions management systems for dealing with old and end-of-life vehicles. The next big transition in the sector is large scale electrification of the targeted vehicle segments focusing mainly on buses, para transit, and two-wheelers. Respective state governments need to firm up the targets, mandate, and milestones for this deployment.

Clean energy transition in this region is not negotiable. After the ban on furnace oil and petcoke in the industrial sector, coal will also have to be replaced with clean fuels. Delhi has implemented the most ambitious clean fuel policy that has also outlawed coal. But the airshed cannot clean up if coal combustion remains dominant in industrial clusters of the NCR. This requires strategic shift to natural gas and electricity for all energy needs. But this is possible only if the state governments and the Union government address the issue of fuel taxation and reduce local taxes on natural gas as well as bring natural gas within the five per cent slab of GST.

Simultaneously, implementation of 2015 emissions standards for coal based thermal power plants has to be done in a time bound manner by 2022. The plants are already capable of meeting the particulate standard and the NO_X standards have already been diluted. But any further effort to dilute the SO_X standards will have to be resisted. At the same time, incentive schemes like first run approach of putting more capable plants higher in the merit dispatch order for electricity procurement need to be adopted. A plan has to be developed to retire the older plants and carry out diligent fly ash management. Plant by plant progress will have to be tracked and made accountable for time bound implementation.

Circular economy that promotes zero land fill strategies and decentralized management of all waste streams (municipal solid waste, construction and demolition waste, plastics and e-waste, industrial waste, etc.) for resource recovery,

recycling and reuse will have to be scaled up across the region to ensure waste is not burnt and dust from waste does not contaminate the air. This will require change in municipal byelaws to align with the central rules and regulations, infrastructure for segregated collection, composting and recycling facilities, and market uptake of the recycled material and management strategies for the landfills. Industrial waste disposal will require special attention.

While scaling up action for the entire region, there is urgent need for the hyper local action agenda in the targeted polluted hotspots so that the local solutions for solid waste, C&D waste, industrial waste, plastics, and unpaved roads and vehicular movement can be implemented.

Clean energy access is non-negotiable and all efforts will have to be made to ensure 100 per cent LPG in households and eateries. While central schemes and state government support have helped to scale up this transition, there are still challenges with regard to reliable access and refills and use of mixed fuels especially in the hinterlands.

The future scale of action will also depend a lot on the capacity of the implementing bodies, adequate investment in infrastructure, designing of solutions and processes for implementation, and more high end monitoring and compliance strategy. System audit and remedial action will become critical to carry forward the agenda.

Pushback and dilution will have to be fought

Even though there is a long way to go, the region cannot lose what has already been won. In the matter of clean fuel transition, the calciners and steel industry are already seeking dilution of the Supreme Court order on ban on petcoke import. There is a demand to delay the deadline of 2022 for power plant standards, especially SO_X and NO_X standards. There is delay and prevarication on implementation of parking rules city-wide and NCR. Pricing of parking has been mandated as a car restraint measure but this is not being implemented. Follow through strategies to ensure clean fuel policy with zero tolerance are not in place and this is leading to illegal use of coal. Further expansion of the regulations and penalty related to truck entry into Delhi has slowed down.

This also shows that public engagement and awareness have to be further deepened to build understanding of the solutions and also to build support for difficult solutions. Future solutions are going to be more difficult, complex, and expensive and will also require lifestyle changes.

This region cannot build ambition if even what has been achieved cannot be sustained. This decade has to be about transformative changes.

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After years of battling air pollution, the time has come to assess what has worked, what has not, and what more is needed to clean the air of Delhi and the National Capital Region (NCR). The real challenge at this juncture is to build ambition, speed and scale of action to push even more difficult and inconvenient solutions. At the same time, it is necessary to ensure that gains made so far are not lost. This review by the Centre for Science and Environment (CSE) aims to further the conversation and propel action.

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