UNKNOWN HURDLES TO A TRILLION DOLLAR ECONOMY:
SOLVING AIR POLLUTION IN MAHARASHTRA
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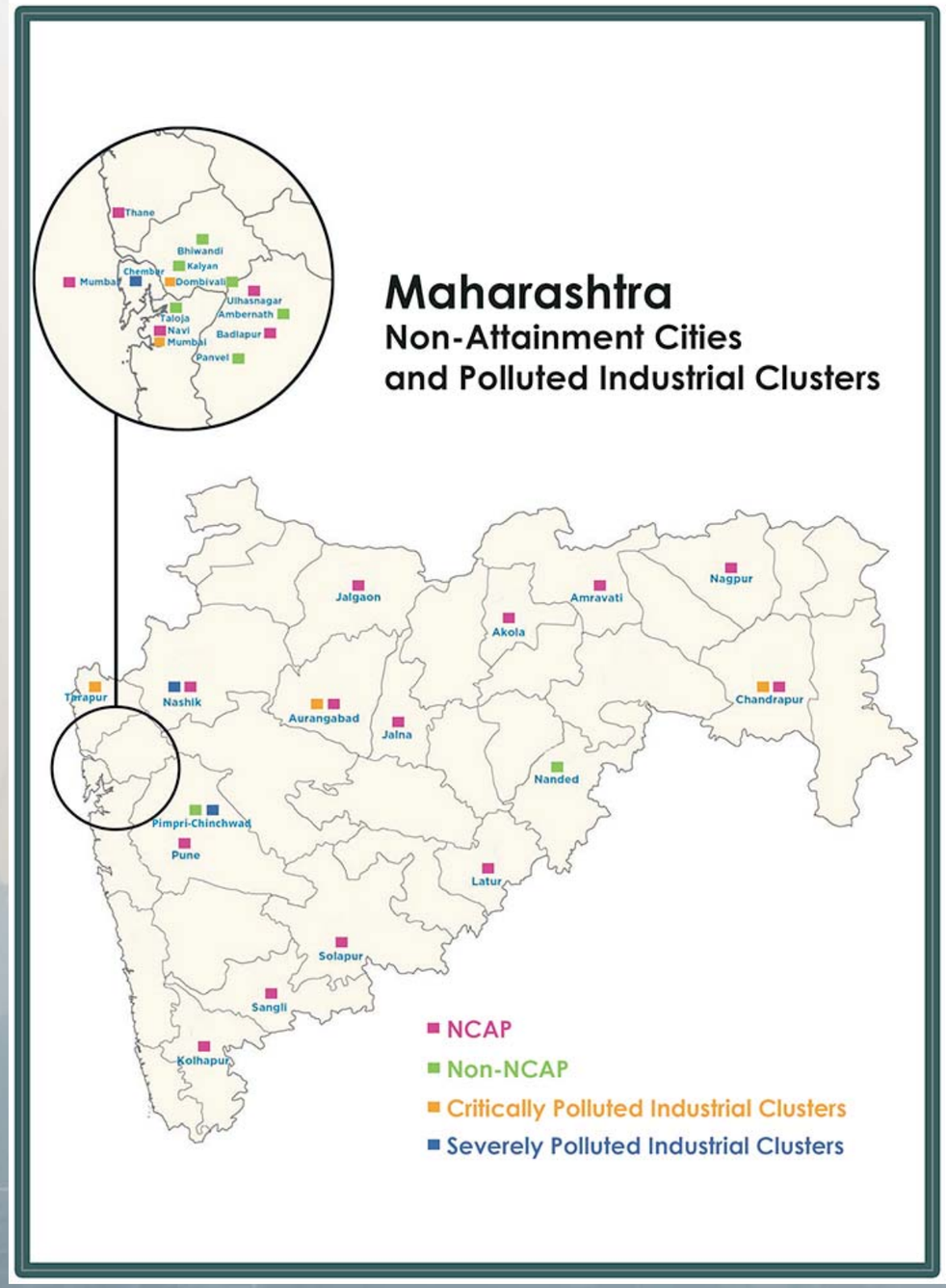
UNKNOWN HURDLES TO A TRILLION DOLLAR ECONOMY:
Solving Air Pollution in Maharashtra



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CLIMATE TRENDS

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Acronyms

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
AQI	Air Quality Index
CEA	Central Electricity Authority
CH_4	Methane gas
CO_2	Carbon Dioxide
CPCB	Central Pollution Control Board
DG	Diesel Generators
EIA	Environmental Impact Assessment
EPIC	Energy Policy Institute at the University of Chicago
EV	Electric Vehicle
FGD	Flue Gas Desulfurization
GDP	Gross Domestic Product
GHG	Green House Gas
GRIHA	Green Rating for Integrated Habitat Assessment
ICMR	Indian Council of Medical Research
IFC	International Finance Corporation
KTPS	Koradi Thermal Power Station
LEED	Leadership in Energy and Environmental Design
LPG	Liquefied Petroleum Gas
MEDA	Maharashtra Energy Development Agency
MIDC	Maharashtra Industrial Development Corporation
MIMRDA	Mumbai Metropolitan Region Development Authority
MoEF&CC	Union Ministry of Environment, Forest and Climate Change
MoU	Memorandum of Understanding
MPCB	Maharashtra Pollution Control Board
NCAP	National Clean Air Program
NEERI	National Environmental Engineering Research Institute
NGT	National Green Tribunal
NH_3	Ammonia
NO_2	Nitrogen Dioxide
NO	Nitrogen Monoxide
NO_X	Nitrogen Oxides
O_3	Ozone
PLF	Plant Load Factor
PMUY	Pradhan Mantri UjjawlaYojana
PM10/2.5	Particulate Matter 10 or 2.5
PPAs	Power Purchase Agreements
RMC	Ready Mix Concrete
RSPM	Respirable Suspended Particulate Matter
SAFAR	System of Air Quality and Weather Forecasting And Research
SO_2	Sulphur Dioxide
SO_X	Sulphur Oxides
VOC	Volatile organic Compound
WHO	World Health Organization

Executive Summary

The notification of the National Clean Air Plan (NCAP) by the Ministry of Environment, Forests and Climate change (MoEF&CC) is a humble beginning that will certainly reduce air pollution if coordinated and enforced well. Even with the 20-30% reduction envisaged over the next five years, the NCAP will not meet national permissible limits in 16 out of 26 non-compliant cities of Maharashtra. An effective approach requires prioritized strategies for pollutant reduction from each sector, which will be derived from scientific source apportionment and emission analysis. These studies are also needed to inform the number and location of adequate monitoring stations across the state. Studies need to be swift and action-oriented in nature to allow sufficient time for implementation and results till 2024, the target year for NCAP. Cost of taking swift action needs to be measured against holistic costs of delayed or no action.

TERI's report for Maharashtra Pollution Control Board (MPCB) for the year 2018-19 shows that annual average levels of Respirable Suspended Particulate Matter(RSPM) and Nitrogen Oxides (NOx) in many monitoring stations had crossed the permissible limits of either Central Pollution Control Board (CPCB) or World Health Organization (WHO). Chandrapur's Ghuggus (181µg/m3) had three times the permissible level of RSPM while Tadali MIDC industrial area had 107µg/m3 and the range in Mumbai's Bandra and Sion was similar, showing an increase from previous year. Dombivli, Ambernath, Amaravati, Ulhasnagar, Kolhapur and Pune also had RSPM levels above the prescribed limit. Monitoring stations at Nagpur, Solapur and Chandrapur recorded higher than permissible concentrations of ozone and benzene that emanate from industrial processes, power plants, and vehicle exhaust.

Household energy consumption across India contributed to 29.6% of national $PM_{2.5}$ levels average as reported by UrbanEmissions.Info, with Kolhapur, Sangli, Solapur, and Satara districts in the state emitting higher than national average. 5 cities from Maharashtra figured in the top 10 in India for sulphur dioxide(SO2) emissions.

Across India, the objectives of Air (Prevention and Control) Act, 1981 have been often defeated through project approvals and norms dilution by union government as well as state governments which don't keep air pollution in check. Recent dilution of emissions standard norms and extension of deadline to install emissions control systems for thermal power plants across India sends counter-productive message to the nation against the ambition and urgency required to address the crisis. Real-world driving emissions of diesel SUVs and cars do not meet the norms, despite government keeping weaker pollution control norms for diesel vehicles than for petrol. This makes high vehicle density in Mumbai and Pune a matter of urgent priority. A renewed focus on sustainable development by various state agencies such as collaborative efforts of MPCB with industry through Star Rating Program is a step in right direction to shift the paradigm for Maharashtra.

Beijing economy grew over 10 times with 6.5% GDP growth each year over 20 years, while reducing $PM_{2.5}$ pollution by over 50% in last quarter of 2017.

Chapter 1: Status Quo

STATE PROFILE ON POLLUTION

1. Demographics, Health Impacts & Economy

- Population- 11.24 crore (2011 census) and over12 crore (current estimate);
- Approximately 50% population urban and 46% less than 24 years of age;
- Second-most impacted state in India for lives lost to air pollution in 2017 as per Lancet Planetary Health Journal and Indian Council for Medical Research;
- Death rate per one lakh population in the state is more than Delhi;
- 36,932 lives lost in the state to household air pollution;
- The state is estimated to have emitted 368 million tons of GHG emissions into the atmosphere in 2018 with per capita emissions being 1.83 tons;
- The state GDP makes for 17% of India's GDP and the state government aspires to be the first $1 trillion sub-national economy by 2025.

2. Pollution Law Violations in Maharashtra

- 97 violations of Environment Protection Act (EPA) in Maharashtra, out of 122 cases in India in 2016 and 46 offences in 2015, second highest in India(National Crime Register Bureau);
- In 2016, 21 out of 25 air pollution rules violation cases in Maharashtra. In 2015, maximum violations under Air Action India with 42 out of 50 offences;
- In 2017, the most polluted city in the country was Chandrapur in Maharashtra with its Air Quality Index (AQI) at 824.

21 of 25 air pollution rule violation cases were in Maharashtra in 2016, maximum out of all states in India.

HEALTH IMPACTS AND STATE'S GDP LOSS

1. As per NEERI 2010 assessment, the total monetary burden of air pollution, including personal burden, government expenditure and societal cost, was estimated on Mumbai at INR 452.3 crore for a 50µg/m3 increase in PM10, and INR 872.6 crore for a similar increase in NO2. That implies INR 271.4 crore additional monetary burden since 2014-15 for 30µg/m3 increase seen in PM10 levels only in Mumbai, while the overall burden from increase in all pollutants is more;

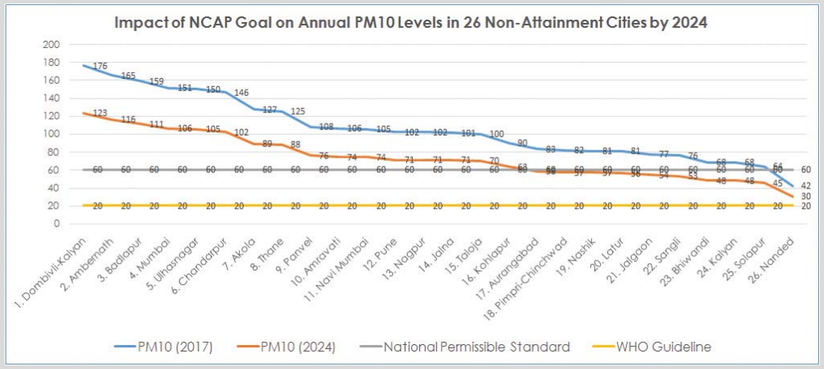
2. A study by the World Bank and the Institute for Health Metrics and Evaluation (IHME) found that India's labour losses due to air pollution stood at about $55.39 billion, or about 0.84% of its GDP in 2013. The World Bank report also revealed that air pollution cost Delhi and Mumbai as much as $10.66 billion in 2015, which is equivalent to 0.71% of India's GDP of that year.

STATUS OF NCAP IN MAHARASHTRA

The 18 cities of Maharashtra covered under NCAP are Akola, Amravati, Aurangabad, Badlapur, Chandrapur, Jalgaon, Jalna, Kolhapur, Latur, Mumbai, Nagpur, Nashik, Navi Mumbai, Pune, Sangli, Solapur, Thane and Ulhasnagar, where PM2.5 andPM10 air pollution had crossed national safe standards as per 2011-15 air pollution data -

1. NCAP city plans aim for 20-30% reduction in PM2.5 and PM10 by 2024 in 18 polluted cities of Maharashtra, with Thane being the latest addition;
2. Mumbai aims for 25% reduction by 2022 although an effective action plan for the city, along with Nashik and Solapur, is still awaited, as per media reports;
3. The baseline year for NCAP to measure 30% reduction is 2017, using which total 26 cities in the state become qualified for NCAP though the additional 8 cities are not covered yet, leaving these cities vulnerable to higher levels of pollution;
4. 16 out of 26 cities in Maharashtra will remain polluted in 2024 withPM10 levels higher than national permissible standard even after 30% reduction as aimed by NCAP.

Despite 30% reduction of PM10 under NCAP, 16 cities will remain polluted above national permissible standards.



Data source: Airpocalypse III, Greenpeace 2019

NCAP plans for 6 cities - Pune, Solapur, Thane, Nashik, Nagpur, Aurangabad - will be converged and implemented through the Smart Cities Mission. As of now, in Pune the bus rapid transit system (BRTS) plan does not indicate learning and corrective measures for existing BRT corridors that have had dismal results due to flawed design and operations after over INR 1100 crores spent. The 2021 assessment of smart cities will serve as mid-term review for NCAP progress also. 24 polluted cities in the state also part of AMRUT scheme must use funds to enhance public transport systems although no such projects have been taken up in any city, as per government data.

SOURCES OF POLLUTION, DRIVERS & POLICY LOOPHOLES

1. Sources of Pollution in NCAP Cities

Pollution source apportionment studies will be commissioned to identify the respective mix of sources and the respective share of various pollutants. These studies shall become the basis to revise and re-focus NCAP city action plans. As per Hindustan Times report, Maharashtra NCAP considers sources in Figure 3 for the overall pollution mix in the state.

Chapter 1: Status Quo

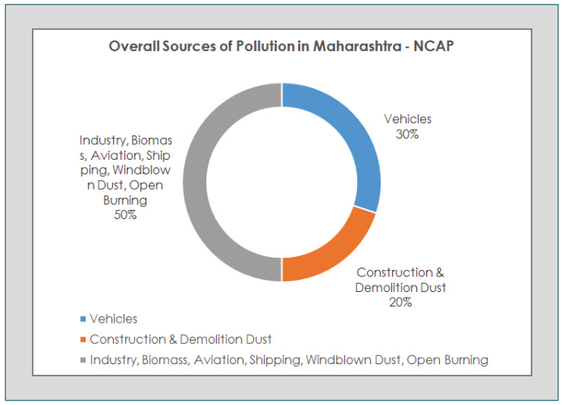


Figure 3: Sources of Overall Pollution in the State

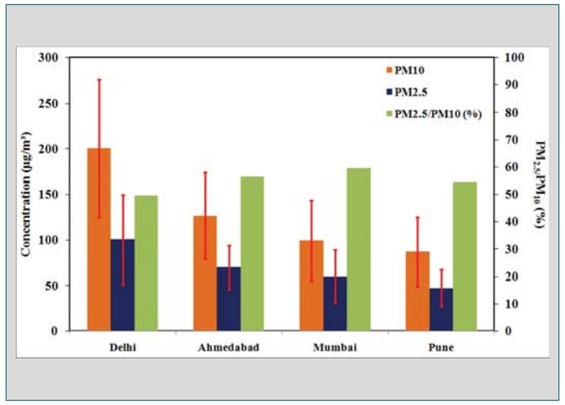


Figure 4: Share of Toxic PM2.5 in PM10, SAFAR

1.1 Pollution in Mumbai

- MPCB commissioned source apportionment study for Mumbai, with NEERI which identified vehicles, construction and demolition waste (re-suspended dust), and open burning of biomass as well as waste to be primary sources. Industry and thermal power sector pollution in Mumbai city was lower in proportion compared to other regions of the state. PM is the main pollutant of concern for Mumbai;

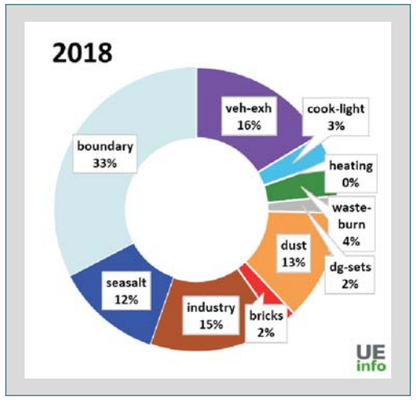


Figure 5: PM2.5 Sources in Mumbai

- Pune-based IITM's SAFAR program under Ministry of Earth Science suggests in its emission inventory study that industry and power generation are the biggest causes for pollution in Mumbai, followed by biomass burning and wind-blown dust

- A paper published by IITM demonstrates that although Delhi has the highest level of particulate matter, the percentage share of PM2.5 in PM10 is highest for Mumbai (60%) as compared to 50% of Delhi (Figure 4). This is of significance considering the toxicity of PM2.5 is far more damaging, thereby showing that the impact of air pollution in Mumbai will be significant, even if overall number of particulate matter is less than those found in Delhi. Further, the study shows that the highest share of PM2.5 in Delhi is observed only in the month of November whereas Mumbai has the highest percentage share of PM2.5 in almost all the months;

- UrbanEmissions.Info in Figure 5 presents its analysis of sources of $PM_{2.5}$ in Mumbai that includes 'boundary' emissions from long-range transfer and natural sources such as dust-storms and seasalt that come in through winds;

- MPCB aims for 25% reduction in Mumbai air pollution by 2022. The city is one of the 28 cities across India to have received INR 10 crore, besides Pune and Nagpur, as higher assistance than other NCAP cities due to the higher than 90µg/m3 PM_{10} pollution levels. They city action plan has been asked to be re-submitted to CPCB such that it can be effective to meet the goals.

As is evident, the analysis on source apportionment and emission inventory for pollution seems to be varying across the scientific institutions that requires consensus-building efforts from the NCAP governance body in the state.

1.2 Industry and Infrastructure

- Maharashtra has over 100,000 industries spread over several industrial complexes and industrial clusters;
- Out of these, 23,500 industries have been identified as those with high pollution potential and 25,500 with medium pollution potential;
- Cement industry has benefitted from multiple easing of emissions norms and extension of deadlines for compliance;
- Several mega infrastructure projects and land banks for industry are under development leading to further energy and land-use related emissions.

A report by the MoEF&CC reveals that Nanded, Dombivali, Ambernath, Badlapur, Ulhasnagar, Thane, Bhiwandi, Pimpri-Chinchwad and Pune are the most polluted industrial towns and cities with the highest levels of SO2 and NO2. After notices to non-compliant industries from MPCB, usually only a few industries submit emissions equipment and compliance adequacy report along with bank guarantees. The MPCB then has to do surprise checks in the area or issue shutdown notices.

MIDC has set out with an investment promotion drive that includes green industrialisation in its focus through measures such as effluent treatment and RE power, though it does not address the core of air pollution generation from industrial processes that require technology innovation and commercial viability. Targeted efforts are needed to bring industry, governance and enforcement entities together to mobilise finance and R&D.

1.3 Brick Kilns

Maharashtra is estimated to have more than 15,000 brick kilns, producing around 17 billion bricks/year. Most of the brick kilns (authorised and illegal) in Maharashtra are in rural areas in and around Thane, Palghar, Pune, Karad, Navi Mumbai, Nagpur, Nashik, Kolhapur, and Sangli. Most of the kilns are using fly ash and other industrial waste, thus, reducing use of clay. Besides direct emissions, dust from unpaved roads and brick work is generated so they are classified under orange category in the state requiring consent under Air and Water Pollution Acts. The state rules on brick kilns make it mandatory for units producing more than 50,000 bricks to seek clearance though there is no

Over 15000 clamp brick kilns operating across the state are yet to be thoroughly assessed for pollution levels. While small kilns self-certify for consent to operate, large kilns do not require cleaner emissions technology to get clearance.

specific reference to use of emissions reduction technologies or fuels. Most of the brick kilns use clamp kiln technology still there is lack of studies on air pollution from clamp kilns and effective ways to control their pollution. No permanent solution is found yet to illegal kilns as they start operating again days/months after closure while the non-compliant kilns.

1.4 Shipping Industry

According to a plea filed to NGT, ships have severe impact on the ambient air quality of the Indian coastal areas as they emit PM, SOx or NOx into the atmosphere by burning fuel while sailing or waiting in the docks. Fishing vessels consume about 20 litres of diesel per day and other vessels consume about 60-70 litres per day. The port trucks emit even more than ships. The International Maritime Organisation (IMO) regulation requires lower emission fuel to be used from January 2020 making the ships to switch from heavy fuel oil high in sulphur. The options are LNG and marine diesel for which refineries and LNG ports need to play a role in ensuring adequate supply. The Sentinel satellite image in Figure 6 indicates NO2 over shipping lanes from west coast of India.

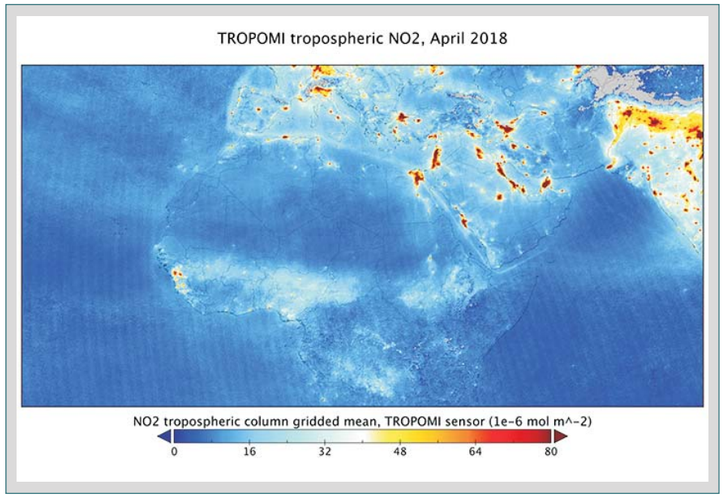


Figure 6: NO2 over Shipping Lanes

5 years after Paris Agreement on climate change, shipping industry will start using low emission fuels from January 2020, preparations for which are far from ready.

The number of vehicles in the state increased by over 11,000 % in less than fifty years. Maharashtra Transport Commissioner has still allowed NOC for re-registration of 15 years old diesel vehicles.

1.5 Vehicles

According to data from the Economic Survey of Maharashtra for 2018-19, the total number of vehicles on road in the state as on 1st January, 2019 was 3 crore 49 lakh, having grown by 11,000% since 1971. Average density is 115 vehicles per km road length while it was 5 vehicles per km in 1971. In Mumbai and Pune, density has reached 510/km and 359/km, respectively, highest and second-highest in the country, while Delhi is at 108/km. This density adds to the air pollution in close competition with industry.

In response, the state government has issued Electric Vehicle Policy in 2018 with major focus on manufacturing, while the focus on encouraging transition from fossil to electric vehicles by users and buyers is not there. The policy does not give incentive to exchange fossil fuel-based vehicles or impose a levy on them as green cess to create a transition fund such as feebate[1] in Delhi to make electric vehicles cheaper. Private commercial charging infrastructure subsidy is limited to the first 250 stations which seems to be less for a large state with high vehicle population and density. In this context, the adoption of electric public transport such as in Mumbai and Pune where expansion of electric bus fleet is underway becomes key to provide visibility and experience to citizens of these cities. These buses have recorded over 200km mileage per charge, are fitted with back-up power banks and operate at lower costs than diesel and CNG buses.

In counter to state's EV and Urban Transport policies aiming at pollution reduction, the Maharashtra Transport Commissioner's Office allowed NOC for re-registration of 15 year-old diesel vehicles in cities other than the 26 most polluted cities of the state.

1 A system of charges and rebates whereby clean energy vehicle purchases are rewarded while fossil fuel vehicles are penalized through taxes and other charges.

1.6 Construction & Road Dust

PM levels are rising in the cities because of dust pollution resulting from construction and excavation work, transportation of construction materials, road dust resuspension, traffic congestion and ready-mix concrete RMC plants. MPCB has been sending notices to RMC plants and later shutting down those that did not have mechanisms to suppress cement dust and/or were located close to human habitation and eco-sensitive zones. Enforcement of provisions under Maharashtra Regional & Town Planning Act 1966 pertaining to construction dust management at site and during transportation is required besides deployment of machines for road dust cleaning, planting trees and paving roadsides.

The Chief Minister-led Urban Development department notified revised regulations for integrated township, allowing more land under construction in green belts and buffer zones of national parks. Construction norms have been eased for industries, allowing horizontal expansion, and permitting certain construction even in areas marked as mandatory open space.

The real estate developers will be permitted to exploit greenbelts, allowing more land under construction and industries to be setup in tribal areas.

1.7 Open Burning of Waste

Figure 7 indicates 4% share of open waste burning as estimated by Urban Emissions. Info for 2018. Apart from PM, garbage burning releases lead, mercury and dioxins that enter the food chain. Recently Deonar landfill site in Mumbai has caught fire multiple times leading to AQI levels similar to Delhi. Similar cases have been reported in Pune while the city has banned open dumping practices and adopted 20 bio-methanation plants to generate clean energy.

Scientific and inclusive waste management practices, such as the erstwhile successful Advance Locality Management (ALM) initiatives that mobilised community participation across Mumbai are needed along with law enforcement.

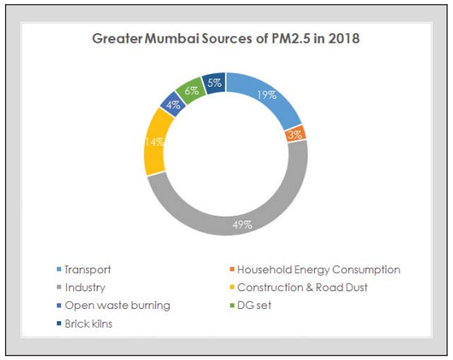


Figure 7: PM2.5 Sources in Greater Mumbai

1.8 Household Energy Consumption

Kolhapur, Sangli, Solapur, and Satara have been reported by Urban Emissions for household energy emissions to be higher than national average. The state government aims to create 'smoke-free' state by replacing biomass cookstoves with LPG. Maharashtra has 24 million households as per 2011 census of which 49% (11.76 million) used traditional/biomass fuels in 2015, which came down to 10 million in 2017, as per Prayas NGO in Pune. As per government data, by August 2019, Maharashtra had provided 4.3 million LPG connections under Pradhan Mantr Ujjawla Yojana (PMUY). With the scope of the PMUY scheme expanding to non-BPL poor households recently in 2019, the scheme aims to provide LPG connection to 9.8 million households in the state by 2030 (with population projections).

1.9 Thermal Power Plants (TPPs)

- Nagpur district has the most number (5) of thermal power plants in the state followed by Chandrapur;
- While Nagpur's 30 lakh population has over 7000MW installed capacity in their district, Vidarbha has 17000MW installed for only 1,600MW local consumption, making these regions over-stressed with pollution and water shortage;
- As of 31st June 2019, thermal (coal, lignite, gas, diesel) power generation capacity in the state was 30,806 MW while RE (excluding nuclear and hydro) capacity was 9,321 MW;
- Over 2100MW thermal plant capacity is lying idle in the state while new thermal units of equivalent capacity such as in Koradi (Nagpur) and Bhusawal are being sanctioned.

The state consumption of electricity was 13,416 million units in June 2019, the highest in India and more than the combined consumption of eastern region states. The installed capacity is over 44 GW while peak demand met in June 2019 was 22.9 GW. TPPs make up for a majority share of power supply in the state which had no power deficit in June 2019 and the quarter of April-June 2019. 5 private sector TPPs–Lanco Vidarbha, Rattan India Amravati, Sinnar Nashik, Bijora Ghanmukh Yavatmal, Shirpur Dhule - in the state have 16 units either stressed or in uncertain situation as per CEA report for May 2019 due to reasons ranging from financial crunch during construction to no PPA.

India has become the largest emitter of SO2 in the world passing over Russia and China, as per Greenpeace analysis in 2019 based on NASA's OMI satellite data. . TPPs are a major source of SOx emissions in the state as well as across India. Chandrapur and Koradi TPPs/clusters figure in the major SO2 hotspots in India. MoEF&CC's 2017 report also had listed 5 cities from Maharashtra amongst top 10 cities in India for highest annual average SO2 emissions. ETH Zurich's Institute of Environmental Engineering found health impacts of Indian coal plant emissions highest in the world, saying, "more than half of the health effects can be traced back to just one-tenth of the power plants (globally). These power plants should be upgraded or shut down as quickly as possible. India has the highest number of such power plants."

According to a study by ETH Zurich's Institute of Environmental Engineering (2019), health impacts of Indian coal plant emissions are the highest globally.

2. Air-shed & Long-range Transfer of Pollution

Wind-blown PM10 and PM2.5 from a city's air-shed[2] and long-range inter-state or inter-country transfer is also a contributor to local pollution, though this must not make an excuse for inaction by city jurisdiction. Though it may vary with season and location of the city, it can account for a significant share in some locations. For example, as per SAFAR's study, Pune receives pollution from south-east, east, north-east, south-west and north-west by winds in the form of dust, seasalt and other particulate matter in different quantities in different seasons. Similarly, Nagpur receives pollution from thermal power stations and industries in Koradi, Khaparkheda, Butibori, Mauda, and Hingna which likely form part of Nagpur's air-shed. Aurangabad's PM2.5 long-range transport aka 'boundary' emissions estimate for 2018 and 2030 are presented here in Figure 8 by Urban Emissions -

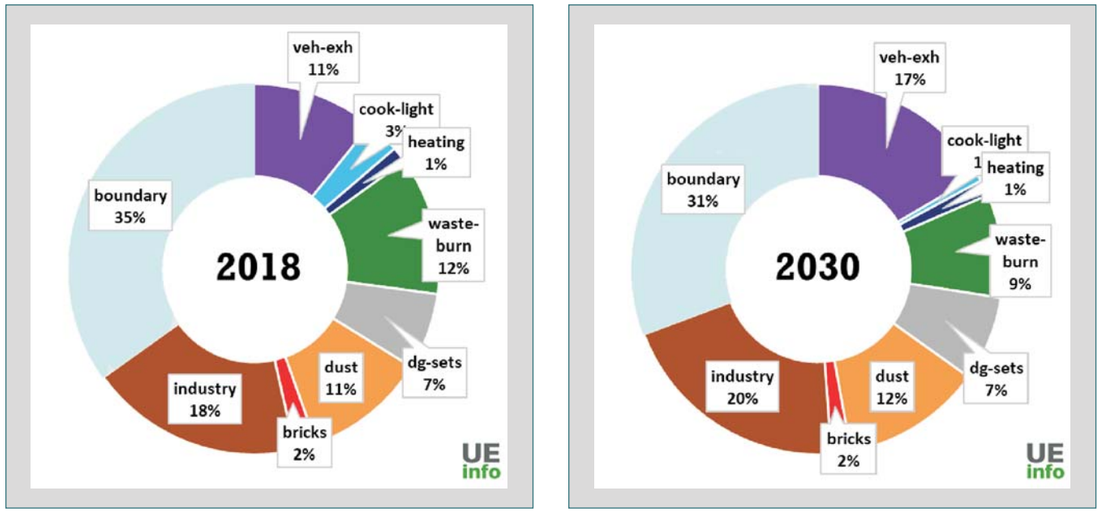


Figure 8: PM2.5 Sources in Aurangabad including 'Boundary' Emissions

The air shed approach to mitigate pollution remains subject of expert study by various institutions in India and globally to map the air-sheds and pollution movement across multiple cities and rural areas. A collaborative study (under review) by Indian and Canadian scientists has identified 11 air-sheds in India. While more analysis is underway at IIT-Delhi, in their assessment till date Western Ghats in Maharashtra seem to play a major role in not allowing air pollution dissipation by dividing the state into two parts. The western and eastern side of the Ghats are likely in 2 separate air-sheds implying the cities and rural areas within each air-shed must plan in coordination, and with the knowledge of the role of Western Ghats.

Western Ghats in Maharashtra seem to play a major role in not allowing air pollution dissipation by dividing the state into two parts.

2 Air-shed is the region where the variability of PM2.5& PM10 at multiple time scales and the dominant source are similar. This depends on topography, meteorology and emission source strength, pattern and distribution – Prof SagnikDey, IIT-Delhi.

Chapter 1: Status Quo

3. Inadequate and Imbalanced Monitoring

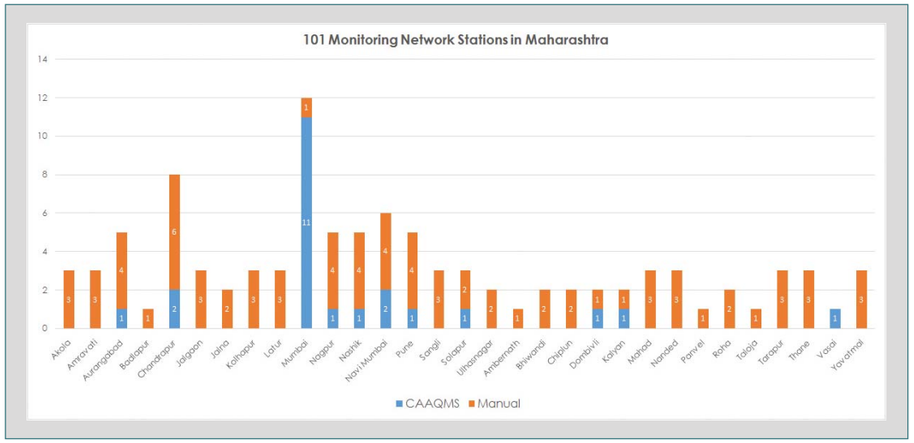


Figure 9: Monitoring Network Stations in Maharashtra

Maharashtra currently has 101 stations as indicated in Figure 9 – 23 continuous and 78 manual – against 308 continuous needed to cover both urban and rural areas, as derived by Urban Emissions.Info from CPCB Guidelines for Air Monitoring. Highly polluted districts such as Nagpur, Pune, Aurangabad need 14, 19 and 11 continuous monitoring stations (CAAQMS), respectively, while there are 5 in each city (continuous and manual, combined). Since resources are a concern, state government needs to support innovation for low cost monitoring devices. As per CPCB guidelines, the location of a station is also of significance to adequately track pollution levels. The source apportionment studies are required to inform the appropriate location and number of monitoring stations.

The total number of monitoring stations in Maharashtra are 101 out of which 25% are continuous while308 monitoring stations, ideally continuous, are needed to meet CPCB guidelines and accurately present real-time data.

4. Pollution despite Meteorological Benefits

While the wind in Mumbai comes to rescue, the high humidity allows the finer pollutant particles to get suspended for longer.

"Mumbai was more polluted than Beijing in 2018. Mumbai has high natural dust and it's driven away by the monsoon for only a limited period. Due to construction and demolition activities, high vehicle congestion and occasional waste burning the city is resulting in poor air quality," said Dr Rakesh Kumar, Director of NEERI, Pune.

As per recent CSE report, PM was highest in Mumbai as compared to any other coastal city. The three-year average PM10 concentration for Mumbai stood at 149µg/m3 as compared to 126µg/m3 for Kolkata and 65µg/m3 for Chennai. The average PM10 level for warm and humid climatic zones in the country is 110µg/m3.

Chapter 2: Stakeholder Actions

CHALLENGES TO EMISSIONS NORMSCOMPLIANCE BY TPPs & VEHICLES

1. Emissions Control Norms & Timelines Relaxation

Several TPPs in India including in Maharashtra have not been able to adhere to timelines and standards decided originally in 2015 by MoEF&CC due to claims of unrealistic timelines and/or lack of clarity on technical guidelines, costs and approvals. Additionally, procedural delays from CEA led to extension of timeline from 2017 to 2022 for installation of emission-reducing systems such as FGD. Emissions standards for PM, SOx and NOx have also been revised since MoEF&CC's notification. This is when Maharashtra's coal consumption and SO2 emissions had increased by approximately 30% during 2012-16. Given that Chandrapur and Koradi TPPs in Maharashtra are major SO2 hotspots in the country, priority action from regulators and state administration is required. NOx and PM control technologies are relatively much cheaper than FGD for SOx which should have been deployed while the government subsidy for FGD is under consideration. Despite the capital costs, the overall benefit, when compared with losses, which will come to public health is far greater than the cost of installing the equipment (INR 1.5-5 million per MW and INR 0.6 million maintenance cost per annum).

Coal-fired power plants have been pursuing extension of timelines for installing emissions control systems as well as loosening of emissions control limits.

Also, despite Maharashtra adopting 100% fly ash free giveaway and utilisation policy to reduce pollution and make bricks, cement, construction, the Mahagenco and private company TPPs have not been complying. Reports indicate very low fly ash utilisation and instead going to ash-ponds.

Figure10: MoEF&CC, 2017

2 Emissions Control System Waiver for Koradi Thermal Power Station

According to media reports, Mahagenco, the power generation state utility company, apparently through the state's Energy Ministry and Chief Minister Devendra Fadnavis has repeatedly sought a waiver of FGD system requirement for Koradi thermal power station (KTPS) from MoEF&CC claiming FGDs to be unnecessary.

Mahagenco had assured NGT regarding set up of FGD in KTPS and had floated EOI in July 2016 which was later abandoned. The 2 new 660MW units of KTPS approved by the state government have been denied environment clearance from the Union Environment Ministry as the plant's emissions were found by CPCB to be 7-14 times the national permissible standards.

2.1) CPCB report on Koradi Thermal Power Station

In June 2017, on a complaint by RTI activist Ankita Shah, the Prime Minister's Office (PMO) issued a directive to CPCB team from Vadodara that went on a visit to KTPS and found SOx levels at 1400-1500 mg/Nm3 against prescribed limits of 100-200 mg/Nm3 and NOx at 2.7 times the permissible standards, making FGD mandatory. The CPCB report also indicated that KTPS was not following many mandatory norms.

2.2) Ground evidence from orange crop losses

Nagpur's agro-produce economy based on oranges and other crops is getting severely affected from fly ash generated in KTPS, forcing farmers in the area to reduce the size of orchards or give up on agriculture completely. This is besides the health impacts reported from the region.

2.3) Myths regarding FGD

i. **Myth: FGD system has not been effective**

NTPC Vindhyachal and Solapur have successfully deployed 100% FGD and NOx control systems. This is done with 90% plant load factor (PLF) against national average of 61%. Private plants have also installed FGD systems.

ii. **Myth: FGD is unnecessary because Indian coal has low sulphur content**

Though Indian coal is low in sulphur content, its calorific value is also low, thus, more quantity of coal is used per unit of electricity generated and Indian SO_2 emissions are very high, crossing those of China.

iii. **Myth: FGD is expensive**

The change in law allows for pass-through of the additional costs on to the end consumers (range INR 0.32-0.8/kwh) and to avoid this a case for government subsidy has been made. The FGD system gives a by-product of high-quality gypsum that has good market value giving additional revenue to recover the investment in FGD. With several companies supplying FGD systems, costs have come down considerably depending on technology (INR 1.5-5 million per MW).

iv. **Myth: FGD is natural resource-intensive**

Limestone is the major raw material for FGD, the availability of which is not an issue in India.

Box Source: CSE, CEEW-IISD

Deployment of emissions control technologies in thermal power plants besides supplementary measures such as access to high grade coal, ban on pet coke and furnace oil, and upgrade of plant technology will help r educe emissions. The dynamic and flexible generation PPAs allow greater RE integration in the grid. Reliable and affordable power supply will reduce reliance on DG sets.

3. Diesel Cars and SUVs Fail the Real-World Test on Emissions Standards

The State Urban Transport Policy of Maharashtra aims to ensure compliance with Bharat emissions standards through PUC and monetary penalties. International Centre for Automotive Technology (ICAT), the Indian vehicle testing agency, and International Council on Clean Transportation (ICCT) tested Indian diesel cars and SUVs for real-world emissions in 2017 with following outcomes and analysis

Diesel cars and SUVs not compliant with emissions standards

i) Tests show NOx and ultrafine PM at much higher levels than the national emission standards, not reported in the lab certified results;

ii) The on-board diagnostic system (OBD) as an in-built system and PUC checks are unable to detect problems or high emission levels;

iii) Diesel cars and SUVs are subject to weaker emissions standards than petrol at Bharat Stage IV (BS-IV);

iv) Real-world emissions tests do not come into effect at the same time as BS-VI standards in 2020, so the emissions are likely to remain high;

v) PUC suffers from lack of enforcement, low quality test procedures and relaxed norms. For example, diesel vehicles tested for smoke density do not measure PM emissions and the test reforms need portable monitors to report actual emissions.

The state government must advocate with central government to introduce real-driving emissions (RDE) and other rigorous tests in 2020. Till then the union government can strengthen PUC test norms and procedures, including for older vehicles, through portable monitors and remote sensing. Delhi already has BS-VI auto fuel available ahead of the April 2020 timeline which can be used in existing BS-III and BS-IV engines. High vehicle density cities such as Mumbai and Pune could also take similar initiative.

INITIATIVES BY THE STATE GOVERNMENT

The state government and its agencies have taken initiatives through policies such as the State Urban Transport Policy that aims to decongest traffic by discouraging private vehicle ownership; promoting public transport, walking and cycling to enhance air quality; and making transport infrastructure focused on people than vehicles. Satellite offices are planned and companies encouraged to develop accommodation facilities for employees within 5km radius of the work area. MPCB has, thus, issued guidelines to companies in Mumbai to reduce private cars, starting with BandraKurla Complex, while proposals for congestion charge are being considered. When private vehicles occupy 49% of road space in Mumbai, these policies and efforts become mandatory.

Chapter 2: Stakeholder Actions

The New Industrial Policy 2019 offers financial assistance for pollution control systems and captive RE power. Critical Industrial Infrastructure Fund (CIIF) is continued from previous policy with enhanced corpus of INR 1000 crore to meet the needs of industry for last mile connectivity, reliable electricity supply and ETP that will help reduce pollution from transport, DG sets and waste. Green Building Policy 2018 led to MoUs with TERI-GRIHA, GBCI-LEED and IFC to give incentives based on the green building rating of the property. 3500MW solar capacity is being added for 100% agriculture sector demand to be met from solar by 2025 which is currently getting supply for only 9 hours/day.

POTENTIAL OF INDUSTRY STAR RATING PROGRAM

MPCB's Star Rating program to disclose information on industrial particulate matter emissions to industry as well as general public has the aim to encourage abatement of pollution through transparency, peer learning and recognition. It has over 300 industries currently participating in the program across 10 sectors, namely, cement, chemicals, metal works, paper, pharmaceuticals, power, sugar and distilleries, textiles, food processing, glass and ceramics, with plans to include a total of 900 industries. Workshops are conducted for industries to issue them rating report-cards as well as hold a dialogue on options available to them for mitigating pollution. These industries are mostly located in Mumbai, Navi-Navi Mumbai, Aurangabad, Solapur, Nagpur, Kolhapur, Pune, Thane, and Raigad. Connected with this is the city ratings based on PM_{10} levels.

The state star rating program will cover 900 highly polluting industries to build transparency and encourage action.

Though the highly polluting industries in the state are over 23,500 in number as identified by MPCB, not all industries are understood to be in a position to make investments for pollution control equipment. Thus, the focus of the program is on large industries with turnover of INR 25 crores and above. While this leaves 95% of industries out of scope, the program intends to create a precedent for industry-led collaborative action for wider industrial community in the state to take a cue from and foster necessary conditions for comprehensive industrial pollution remedial action.

These ratings give a basis for MPCB to issue notices to industries with 1 and 2 star ratings for corrective actions needed. Additionally, banks can be asked to support industries by extending loans and financial instruments for pollution control equipment. Also banks need to deny finance to program participants with consistently low ratings and non-participant industries with pollution levels higher than prescribed standards.

The transparency created by the program has benefits for an Emissions Trading Scheme (ETS) planned between Maharashtra, Gujarat and Tamil Nadu. The first step towards implementation was taken this year in Surat through MoUs with partners and launch of pilot for over 350 industrial units in the city that have real time emissions monitoring devices. A regulatory framework and trading platform for all participating states based on the pilot is aimed to be developed by 2020 which is going to be a challenge. The objectives of the ETS do not enlist reduction in annual caps on emissions which leaves out an important benefit. A switch from quarterly monitoring to real-time monitoring in Star Rating program is a requirement for ETS and it will also help get a quicker mitigation response from both MPCB and industry.

Chapter 3: Reforms For Results

REFORMS NEEDED IN RELATED POLICIES

Maharashtra being a large economy, and a key state in size, population and contribution to GDP, resources, skills and workforce will not prove to be a challenge in over-achieving NCAP goals, especially since NCAP in and by itself will not prove adequate to bring pollution levels below national permissible limits. As impacts on people's and economy's health increase every year, additional set of reforms become necessary for effective and decisive air quality governance -

1. Energy Planning

1.1 RE policies for rooftop and distributed generation to be strengthened through incentives, reforms and implementation experience. In parallel, state government needs to incentivise decentralised RE through feed-in-tariffs, smart grids, micro grids and tax benefits to divert from fossil energy. Bio-fuels promotion needs to be moderated for balance with food security, forest cover and energy consumption;

1.2 While TPPs need to be given immediate attention for emissions control systems, new thermal plant capacity such as in Koradi TPP needs to be avoided with alternatives in RE available;

2. Sustainable Mobility Planning

2.1 The risks to EV Policy and Urban Transport Policy from unabated expansion in private vehicle ownership need to be immediately addressed through effective measures;

2.2 Real-world emissions of diesel vehicles need to be made part of pollution checks;

3. Waste Management

3.1 Effective implementation of Waste Management Rules for segregation, collection and scientific landfill management has to be prioritised to reduce the menace of open waste burning and landfill emissions;

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3.2 Waste transport planning is also important to reduce emissions from diesel trucks and number of trips;

4. Household and Rural Energy Consumption

4.1 Household indoor pollution needs to be tackled through efficient, clean energy cookstoves and electrification for decentralised, non-recurring cost solutions, besides taking maximum mileage from PMUY scheme;

5. Brick Kilns

5.1 MEDA's Biogas Power financial assistance scheme on a prohibitive project cost reimbursement basis requires more accessible approach to suit the pocket of the project proponent and end-user including farmers and brick kiln owners;

5.2 While studies on emissions from clamp style brick kilns are needed, incentives and enforcement for shift to cleaner zig-zag technology are to be prioritised;

6. Governance Capacity

6.1 Recruitment for monitoring and enforcement agency such as MPCB and other grassroots entities needs to be streamlined in process and budget for quick hiring and enhanced access to skills and expertise;

6.2 A policy of rating the performance (and, thus, determining the career prospects) of NCAP stakeholder departments in-charge, city administrators, and state-owned enterprises leadership on meeting their allocated pollution targets is required to drive ambition and ownership;

6.3 The practice of self-audit, EIA, and self-certification by industry and brick kilns needs to be changed to random auditor assignment by state government.

7. Emergency Planning

7.1 Winter and emergency response plans need to be developed on the lines of GRAP for Delhi and informed to public. Since a big part of the effective implementation of NCAP city plans depends on cooperation from public and various sector stakeholders including other government departments identified in the NCAP, it is essential to engage them in planning stage.

CONCLUSION

Maharashtra, as the second-most populous sub-national state on earth and in India requires a campaign mode approach to air pollution crisis, steered at a level no less than that of Chief Minister to bring all stakeholders effectively onboard for impactful policy-making, governance and enforcement besides general public awareness. A good starting point seems to be on the ground as demonstrated by the successful approach of China who strengthened local level monitoring and governance agencies to regulate and implement anti-pollution policies.

The existing efforts such as the Star Rating program for industries can present a win-win approach to addressing air pollution and, thus, set off a chain reaction for the most important stakeholders to join the campaign towards over-achievement of NCAP goals. The program can aim to combine stringent measures such as denied financial access to polluting industries with supportive initiatives such as a peer learning platform.

ANNEXURE: TECHNOLOGICAL INNOVATIONS AS SOLUTIONS

1) Aurassure

Phoenix-Robotix, an Odisha-based IoTstartup designed an environment monitoring device 'Aurassure', a cloud-connected network of online air pollution monitoring systems for smart cities. The device captures various air quality parameters such as NO_2, O_3, $PM_{2.5}$ and Pm_{10} from different locations that industries can access over a mobile app in the form of high-resolution pollution data.

2) Pariyayantra

Researchers from Manav Rachna Educational Institutions based in Faridabad devised an air filter unit that can be mounted on the roof of any vehicle - buses, cars, auto-rickshaws and two-wheelers – and as the vehicle moves, the filter traps the pollutants through its holes and cleans the air. The observations made during experiments suggest that filters can trap up to 98% of the particulate matter.

3) Kurin City Cleaner and Smog Tower

The Kurin city cleaner machine has a capacity of cleaning 32 cubic meters of air per day in the radius of 3-km using solar energy. It cleans out 99.99% pollutants such as RSPM, volatile organic compounds (VOCs) and scents/smells. China had setup a smog tower which sucks air into a glass house of filters and runs on solar energy. It showed 15% reduction in PM2.5 level during heavy pollution.

4) ChakrShield

Chakr Innovation, founded by IIT Delhi alumnus, developed Chakr Shield that collects around 90% of PM emissions from the exhaust of diesel generators and converts into inks and paints. It ensures safe disposal of the pollutants.

5) Absolut Street Trees, Mexico City

The Absolut Street Trees initiative involves artists painting giant murals in the city using Airlite paint, which purifies polluted air in a process similar to photosynthesis. When the paint is exposed to sunlight, the surrounding air is oxygenated through a chemical reaction. The murals aim to neutralize the equivalent of pollution created by around 60,000 vehicles a year. The paint lasts about 10 years.

6) Aditya

NavAlt Solar and Electric Boats launched in Kochi, Kerala solar-powered ferries that emit zero CO_2 as compared to diesel ferries emitting 90 tonnes/year.

7) Multi-pot cookstove modification

Researchers from VNIT, Nagpur and St Vincent Palotti College, Nagpur have modified a multi-pot cookstove popular in rural Maharashtra to reduce energy consumption and emissions.

Bibliography

Executive Summary
https://www.teriin.org/sites/default/files/2019-06/Air_Quality_Report.pdf
http://www.urbanemissions.info/india-emissions-inventory/emissions-in-india-household-cooking-heating/
http://www.ebeijing.gov.cn/feature_2/AirPollutionControl/ReviewandOutlook/t1580469.htm
https://www.greenpeace.org/eastasia/Global/eastasia/publications/campaigns/Climate%20and%20Energy/Analysis%20of%20air%20quality%20trends%20in%202017.pdf

State Profile on Pollution
https://mahades.maharashtra.gov.in/files/publication/ESM_18_19_eng.pdf
http://ncrb.gov.in/StatPublications/CII/CII2016/pdfs/Crime%20Statistics%20-%202016.pdf
https://indianexpress.com/article/india/india-news-india/delhi-air-pollution-most-polluted-city-air-quality-index-aqi-3830971/
https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(18)30261-4/fulltext

Health Impacts and State's GDP Loss
https://theicct.org/sites/default/files/RKumar_0.pdf
https://openknowledge.worldbank.org/bitstream/handle/10986/25013/108141.pdf?sequence=4&isAllowed=y

Status of NCAP in Maharashtra
http://mpcb.gov.in/ereports/env_qualityReport_air.php
https://www.greenpeace.org/india/en/airpocalypse-iii_28jan19/
http://cerca.iitd.ac.in/files/reports/NCAP%20Report%20Full.pdf
http://amrut.gov.in/content/cities_list.php
http://citizenmatters.in/pune-bus-rapid-transit-brts-shortcomings-13365
https://timesofindia.indiatimes.com/home/environment/pollution/mumbai-and-bengaluru-among-10-polluted-cities-yet-to-submit-air-action-plan-centre-asked-to-modify-ncap-target/articleshow/70766049.cms

Sources of Pollution, Drivers and Policy Loopholes
https://www.hindustantimes.com/mumbai-news/tiny-toxic-particles-linger-in-mumbai-s-air-longer/story-G0CDMEesc2JUjS7F28SGiI.html
https://epaper.timesgroup.com/Olive/ODN/TimesOfIndia/shared/ShowArticle.aspx?doc=TOIM%2F2019%2F03%2F06&entity=Ar00510&sk=2228275F&mode=text#
https://www.hindustantimes.com/pune-news/puneites-breathe-air-that-is-4x-more-dangerous-than-normal/story-gAw1WuKh1Z5ZnswPtMsGtK.html
http://citizenmatters.in/mumbai-delhi-air-pollution-particulate-matter-aqi-environment-12940
https://www.hindustantimes.com/pune-news/more-vehicles-on-pune-roads-has-residents-breathless/story-89PWXf76KXxWrlQWXVRaeL.html
https://indiaclimatedialogue.net/2017/06/05/what-are-you-breathing-today-in-maharashtra/
https://www.hindustantimes.com/mumbai-news/mumbai-grows-pollution-soars-construction-dust-ups-risk-of-stroke-shows-data/story-HuTyYtoMgwpx8TB7aooaK2K.html
https://www.hindustantimes.com/pune-news/number-of-people-vehicles-are-equal-in-pune-pmc-s-environment-status-report/story-pOQpoB2VW1jYaWZQPWW8bI.html
https://www.hindustantimes.com/mumbai-news/27-lakh-new-vehicles-hit-roads-of-maharashtra-in-a-year/story-rPNWp7bNT0hfnBfz9oG1uJ.html
http://www.urbanemissions.info/india-emissions-inventory/emissions-in-india-household-cooking-heating/
http://www.ghgplatform-india.org/EnergyAnalytics-Maharashtra
https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?view=map
https://mahades.maharashtra.gov.in/files/publication/ESM_18_19_eng.pdf
https://timesofindia.indiatimes.com/city/navi-mumbai/fumes-from-brick-kiln-turn-turbhe-air-toxic/articleshow/64129252.cms
https://timesofindia.indiatimes.com/city/mumbai/to-cut-emissions-state-tells-brick-kiln-units-to-run-only-one-furnace-at-a-time/articleshow/65585951.cms
https://timesofindia.indiatimes.com/city/pune/winds-bring-pollutants-from-afar-add-to-pune-delhis-bad-air-study/articleshow/67875732.cms
http://www.urbanemissions.info/india-apna/aurungabad-india/
http://www.indiaairquality.info/wp-content/uploads/docs/2003_CPCB_Guidelines_for_Air_Monitoring.pdf
https://www.thehindubusinessline.com/economy/logistics/shipping-industry-jittery-over-fuel-cost-as-deadline-for-new-emission-norms-nears/article26297320.ece
http://www.cea.nic.in/reports/monthly/executivesummary/2019/exe_summary-06.pdf
https://www.mahagenco.in/index.php/fly-ash-utilization
https://www.businesstoday.in/current/economy-politics/mumbai-car-density-traffic-congestion-delhi-mumbai-is-indias-most-car-congested-city-with-510-cars-per-km/story/330734.html
http://www.urbanemissions.info/india-air-quality/india-ambient-monitoring-data/
http://www.cea.nic.in/reports/monthly/installedcapacity/2019/installed_capacity-06.pdf
https://timesofindia.indiatimes.com/city/mumbai/mumbai-indias-most-car-congested-city/articleshow/68554703.cm
https://www.hindustantimes.com/mumbai-news/pollution-control-board-shuts-down-cement-plant-in-aarey/story-R8zdkHqlOVz8sPBxlJtJNP.html
https://www.hindustantimes.com/mumbai-news/we-are-promoting-public-transport-to-reduce-air-pollution-in-mumbai-mpcb-chief/story-rur8ms2nt2LHixyKkDjP4M.html
http://www.urbanemissions.info/india-emissions-inventory/emissions-in-india-household-cooking-heating/
https://economictimes.indiatimes.com/news/environment/pollution/ngt-notice-to-centre-on-air-pollution-caused-by-ships/articleshow/59645151.cms?from=mdr
https://indianexpress.com/article/cities/mumbai/monitor-4-major-air-polluters-mpcb/
https://www.indiatimes.com/technology/news/pune-deploys-25-electric-buses-for-7-routes-across-the-city-with-same-fares-as-for-the-ordinary-ones-362120.html
https://www.sciencedirect.com/science/article/pii/S0269749119315799
http://www.urbanemissions.info/india-apna/mumbai-india/
http://www.cea.nic.in/reports/monthly/broadstatus/2019/broad_status-05.pdf
https://www.greenpeace.org/international/press-release/23819/global-so2-air-pollution-hotspots-ranked-by-greenpeace-analysis/
http://www.urbanemissions.info/india-air-quality/india-ambient-monitoring-data/
https://maitri.mahaonline.gov.in/PDF/Electric_Vehicle.pdf
https://www.maharashtra.gov.in/site/Upload/Acts%20Rules/Marathi/Notification%20UDD.....pdf
https://indianexpress.com/article/cities/mumbai/maharashtra-revises-township-rules-unlocks-more-green-land-for-construction-5456416/
https://www.esa.int/spaceinimages/Images/2018/07/Nitrogen_dioxide_from_Sentinel-5P

Challenges to Emissions Norms Compliance by TPPs & Vehicles
http://cat.org.in/portfolio/55-of-77-coal-plants-in-maharashtra-flouting-pollution-norms/
https://www.downtoearth.org.in/news/air/mahagenco-koradi-to-install-fgd-55113
https://timesofindia.indiatimes.com/city/nagpur/mahagenco-repeatedly-tried-to-seek-koradi-fgds-waiver/articleshow/69364682.cms
https://www.moneycontrol.com/news/business/economy/maharashtra-approves-660-mw-coal-based-units-at-koradi-power-station-3612231.html
https://timesofindia.indiatimes.com/city/nagpur/cpcb-takes-action-against-ktps-but-doesnt-reveal-what/articleshow/62421068.cms
https://theicct.org/sites/default/files/publications/PV-in-use-emissions-testing-India_ICCT-consultant-report_20170329.pdf
http://www.indiaenvironmentportal.org.in/content/465374/order-of-the-supreme-court-regarding-environmental-norms-of-nox-for-coal-based-thermal-power-plants-05082019/
https://www.iisd.org/sites/default/files/publications/india-energy-transition-air-pollution-standards.pdf
http://www.cea.nic.in/reports/others/thermal/umpp/fgd_newnorms.pdf

Initiatives by the State Government
https://www.mcciapune.com/MahaIndustrialPolicy/
https://www.maharashtra.gov.in/Site/Upload/Acts%20Rules/Marathi/Notification%20for%20Transport%20Policy.pdf
https://drive.google.com/file/d/1HqRcRNFRdMwJlSVvPOdRTRXqWBWX9vJT/view

Potential of Industry Star Rating Program
https://indianexpress.com/article/cities/mumbai/monitor-4-major-air-polluters-mpcb/
https://epic.uchicago.in/wp-content/uploads/2019/06/City-star-rating-booklet-Maharashtra-Star-Rating-Program.pdf
https://epic.uchicago.in/maharashtra-star-rating-program-adds-ambient-air-ratings-cities/
https://epic.uchicago.in/project/developing-indias-first-emissions-trading-scheme-2/
https://mpcb.info/about-program/

Reforms Needed in Related Policies
https://thewire.in/environment/does-india-have-the-skilled-workforce-needed-to-fight-air-pollution
http://cerca.iitd.ac.in/files/reports/BreatheBooklet-%20Niti%20Aayog%20(consulting%20paper).pdf
https://www.mahaurja.com/meda/off_grid_power/bio_energy/biogas_power

Annexures: Technological Innovations
https://www.dnaindia.com/mumbai/report-mumbai-wayu-to-reduce-pollution-at-five-city-junctions-2139601
https://yourstory.com/2018/11/startups-solutions-air-pollution
https://inc42.com/startups/phoenix-robotix-aurassure-iot/
https://www.chakr.in/delhi-chakr-innovations-diesel-soot-ink/#
http://navaltboats.com/navalt-products-solar-electric-ferry/https://www.deccanchronicle.com/nation/current-affairs/160119/kerala-plans-mass-rollout-of-solar-powered-boats.html
https://www.thebetterindia.com/163770/delhi-air-pollution-solution-kurin-smog-tower-news/
https://in.one.un.org/blogs/five-indian-innovations-to-beat-air-pollution/
https://www.businessinsider.com/china-builds-worlds-biggest-air-purifier-2018-12?IR=T
https://www.unenvironment.org/news-and-stories/story/business-unusual-four-innovations-clear-air
https://mexiconewsdaily.com/news/murals-beautify-and-help-improve-air-quality/
https://link.springer.com/article/10.1007/s10668-018-0092-4