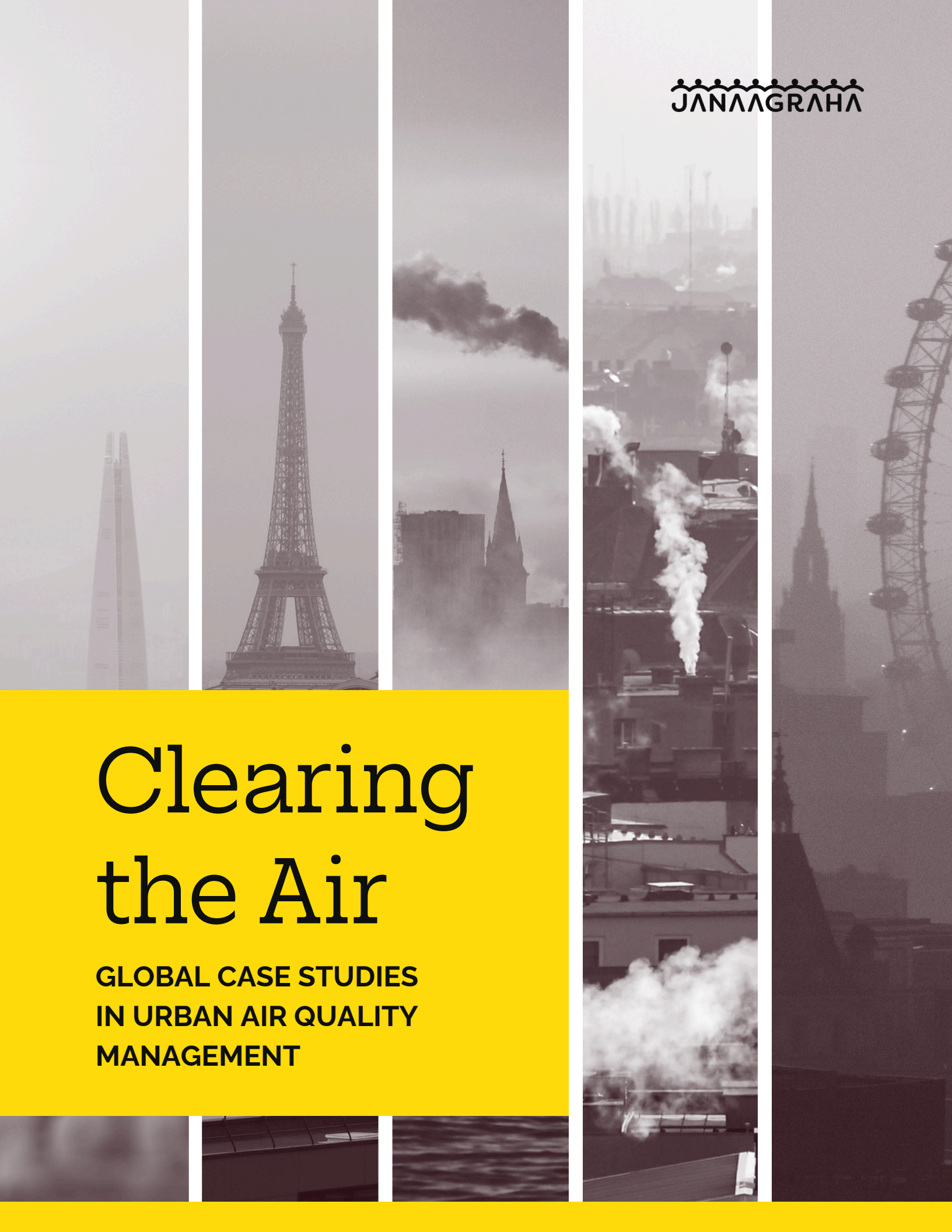

JANAAGRAHA

Clearing the Air

GLOBAL CASE STUDIES IN URBAN AIR QUALITY MANAGEMENT

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These case studies were compiled as part of Janaagraha's broader study, Air Quality in Indian Cities: An Assessment of Outcomes of XV Finance Commission Funding for Cities with Learnings and Recommendations. While the main report synthesises the key findings and recommendations from the overall study, this document presents the detailed case studies of five global cities, highlighting their approaches, governance mechanisms, and policy interventions for improving urban air quality.

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We hope these case studies contribute to a deeper understanding of urban air quality governance and support future research and policy discussions on improving air quality in cities.

Contents

01 Beijing

China

1. Introduction and Context

1.1 Background

The case of Beijing as a model city that has been able to tackle the issue of air pollution has been a journey of sustained efforts. It was in the late 1990s when the Chinese government started to give greater attention to the issue of air pollution. Beijing's journey of cleaning its air can be categorised into three distinct phases; 1998-2008, 2009-2012 and 2013-2017.

By the 1990s the air quality in Beijing had started to deteriorate, with annual average concentrations of CO, SO2 and NO2 in Beijing reaching 3.3 mg/m3, 120µg/m3 and 74µg/m3 respectively. This was the period when the Chinese economy was growing rapidly. It was in 1998, that the Beijing Municipal Government issued an Announcement of Urgent Measures to Control Air Pollution of People's Government of Beijing Municipality[1]. The Beijing Summer Olympics acted as a catalyst for Beijing's war on air pollution control.

A turning point was Beijing's 'Airpocalypse' in 2013[2], when the Chinese communist party faced severe backlash from the public. The public anger was expressed through social media on Chinese platforms like Weibo. The event forced the local and federal government to action.

1.2 Major Policy Response

Triggered by the crisis the Chinese government launched the Air Pollution Prevention and Control Action Plan, 2013. The 2013 action plan was backed by a $270 billion budget[3]. It was the first national strategy with the prime objective of controlling air pollution. The Action Plan specified targets along with time frames to be achieved and focused on three regions, i.e., the Beijing-Tianjin-Hebei (BTH) area, the Yangtze River Delta (YRD), and the Pearl River Delta (PRD) (Feng et al., 2024)[4]. Beijing came up with Beijing Clean Air Action Plan 2013–2017, under the larger umbrella[5].

[1]United Nations Environment Programme. (2019). A review of 20 years' air pollution control inBeijing. https://wedocs.unep.org/bitstream/handle/20.500.11822/27645/airPolCh_EN.pdf?sequence=1&isAllowed=y
[2]Silver, B., Reddington, C. L., Chen, Y., & Arnold, S. R. (2025). A decade of China's air quality monitoring data suggests health impacts are no longer declining. Environment International, 197, Article 109318. https://doi.org/10.1016/j.envint.2025.109318
[3]Kumar, A. (2024, November 19). How China won its deadly smog battle. Is it possible for India too? Business Standard. https://www.business-standard.com/india-news/how-china-won-its-deadly-smog-battle-is-it-possible-for-india-too124111900882_1.html
[4]Leung, F. (2024, June 6). How China is winning its battle against air pollution. Earth.Org. https://earth.org/how-china-is-winning-its-battle-against-air-pollution/
[5]United Nations Environment Programme. (2019). A review of 20 years' air pollution control in Beijing.https://wedocs.unep.org/bitstream/handle/20.500.11822/27645/airPolCh_EN.pdf?sequence=1&isAllowed=y

In 2014, Premier Li Keqiang declared a "war against pollution"[6]. Beijing's three-year action plan promoted green industrial growth, stricter control of unregulated emitters and vehicular pollution, increased railway freight, and strengthened regional cooperation to combat severe air pollution (Ministry of Ecology and Environment of the People's Republic of China, 2018).

The central government too showed fiscal support with direct outlays around RMB 52.8 billion (US$ 7.81 billion) for the period between 2013 and 2017[7].

2. Policy Framework and Planning

2.1 Five Year Plans and National Strategies

The 11th Five Year Plan (2006-2010) was the first time when mandatory targets for energy and environment were introduced. Under the plan energy intensity was to be reduced by 20% by 2010 from the 2005 levels[8]. In the early 2010s, the country managed to create a comprehensive and reliable system for air pollution monitoring and emissions reporting covering the entire country, making it possible to track progress and hold policymakers accountable. This included even making real-time emission data from individual power plants and factories available online[9].

In 2013, triggered by the PM2.5 crisis, the well-known Air Pollution Prevention and Control Action Plan (hereafter the Action Plan) was released by the Chinese government as the first national strategy on air pollution control. For the first time, the Action Plan charted the roadmap for China's air quality improvement by defining specific quantitative targets and clear time nodes, focusing in particular on three key regions, i.e., the Beijing-Tianjin-Hebei (BTH) area, the Yangtze River Delta (YRD), and the Pearl River Delta (PRD)[10]. Beijing was given a target of reducing mean annual concentrations of PM2.5 to around 60 μg/m3 by 2017[11].

During the "12th Five-Year Plan" period, the number of cities under ambient air quality assessment were increased from 113 to 333 cities across the country[12]. In the 13th FYP Plan targets were further tightened, aiming to reduce national total SO2 and nitrogen oxides (NOx) emissions by 15% in 2020 from their 2015 levels[13].

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[7] Huang, D., Narain, U., Nygard, J., Sall, C., Sanchez-Triana, E., & Siegmann, K. (2020, October 29). Clearing the air: A tale of three cities (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/521491604042907160

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[9] Cgtn. (2023, December 12). China's new air pollution plan injects momentum into cleaning the air and reducing coal use. CGTN. https://newseu.cgtn.com/news/2023-12-12/China-s-new-air-pollution-plan-injects-momentum-into-cleaning-the-air-and-reducing-coal- use-1ptR5FFKOE8/index.html

[10] Zhang, Q., Zheng, Y., Tong, D., et al. (2019). Drivers of improved $PM_{2.5}$ air quality in China from 2013 to 2017. Proceedings of the National Academy of Sciences, 116(49), 24463–24469. https://doi.org/10.1073/pnas.1907956116

[11] Huang, D., Narain, U., Nygard, J., Sall, C., Sanchez-Triana, E., & Siegmann, K. (2020, October 29). Clearing the air: A tale of three cities (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/521491604042907160

[12] Ministry of Ecology and Environment of the People's Republic of China. (2016). The 13th Five-Year Plan for the Protection of Ecological Environment [PDF]. https://english.mee.gov.cn/Resources/Plans/National_Fiveyear_Plan/201706/P020160601356854927248.pdf

[13] Zheng, H., Cai, S., Wang, S., Zhao, B., Chang, X., & Hao, J. (2019). Development of a unit-based industrial emission inventory in the Beijing–Tianjin–Hebei region and resulting improvement in air quality modeling. Atmospheric Chemistry and Physics, 19, 3447–3466. https://acp.copernicus.org/articles/19/3447/2019/

3. Sectoral Interventions

3.1 Transport

Beijing has formed an integrated "Vehicle-Fuel-Road" framework in order to tackle vehicular emissions. Beijing was the first city in China to implement China 1 emission standards for light- duty vehicles in January 1999. In 2011 Beijing restricted purchase of new vehicles by introducing monthly quota limits on new license plates for passenger cars. It was limited to just 20,000 new license plates. In 2014 it was further tightened from 2,40,000 annually to 1,50,000. In February 2013, Beijing initiated the adoption of Beijing 5/V emissions regulations, which are comparable to Euro 5/V emissions standards.[14] To promote cleaner transport, the administration provided subsidies for new energy vehicles (NEVs); for instance, individuals could receive RMB 22,000 (US$ 3,254) from the city in addition to RMB 44,000 (US$ 6,509) in national subsidies when purchasing an electric vehicle (Huang et al., 2020)[15]. Between 2014 and 2017, individuals in Beijing received subsidies covering up to 60% of the purchase price for electric passenger vehicles, and during the 2013–2017 plan period, the city removed 1.7 million old vehicles from its roads.[16] At present, a total of over 3 million high-pollution vehicles has been phased out, and more than 1 million New Energy Vehicles were adopted.[17]

In 2015, the Chinese government introduced the Plan for the Coordinated Development of the Beijing-Tianjin-Hebei Region to strengthen regional cooperation on environmental governance[18]. As part of this effort, Hebei Province launched its Action Plan for Controlling Agricultural Non- Point Source Pollution (2015–2018) to reduce emissions from crop stubble burning[19].

3.2 Coal

Among the measures taken to control pollution were shifting from using low sulphur coal, retrofitting of coal boilers, and shifting from "coal to gas". Standards for controlling emissions from coal-fired boilers were first introduced in 1998 with subsequent revisions in 2002, 2007, and 2015 respectively. By the end of 2015 Beijing was almost coal free in core urban areas. In 2017, Beijing had imposed a total ban on coal use by households for cooking and heating within city limits, including in peri-urban villages[20].

Between 2006 and 2015, over 100 GW of small, inefficient coal plants were closed[21]. Beijing's coal consumption declined sharply from 21.8 million tonnes in 2012 to under

[14]United Nations Environment Programme. (2019). A review of 20 years' air pollution control in Beijing. https://wedocs.unep.org/bitstream/handle/20.500.11822/27645/airPolCh_EN.pdf?sequence=1&isAllowed=y
[15]Huang, D., Narain, U., Nygard, J., Sall, C., Sanchez-Triana, E., & Siegmann, K. (2020, October 29). Clearing the air: A tale of three cities (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/521491604042907160
[16]United Nations Environment Programme. (2019). A review of 20 years' air pollution control in Beijing. https://wedocs.unep.org/bitstream/handle/20.500.11822/27645/airPolCh_EN.pdf?sequence=1&isAllowed=y
[17]Xinhua. (2025, June 9). From smog to sunshine: Beijing's decade-long clean air campaign pays off. Qiushi English Edition. https://en.qstheory.cn/2025-06/09/c_1099081.htm
[18]United Nations Environment Programme. (2019). A review of 20 years' air pollution control in Beijing. https://wedocs.unep.org/bitstream/handle/20.500.11822/27645/airPolCh_EN.pdf?sequence=1&isAllowed=y
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[20]United Nations Environment Programme. (2019). A review of 20 years' air pollution control in Beijing. https://wedocs.unep.org/bitstream/handle/20.500.11822/27645/airPolCh_EN.pdf?sequence=1&isAllowed=y

6,00,000 tonnes in 2024, representing less than 1% of the city's total energy consumption, while green electricity rose to 26% of the energy mix[22]. Nationally, coal's share in China's energy mix dropped from 68.5% in 2012 to 57.7% by 2019, while clean energy sources (natural gas, hydropower, nuclear, and wind) increased to 23.4% over the same period[23].

At the city level, Beijing reduced coal consumption from 23 million tons in 2012 to less than 5 million tons in 2017. Nearly 3,00,000 coal-fired heating stoves were replaced with gas or electric systems, and about 2,000 heavy industrial enterprises were either shut down or relocated[24]. By 2015, 99% of coal-fired power generation units were equipped with desulfurisation and 92% with denitrification facilities[25].

3.3 Air Pollution Monitoring

Monitoring air quality forms a crucial component of China's air pollution control strategy. In Beijing, a dense PM2.5 monitoring network with over 1,000 sensors was established to improve spatial resolution of pollution data and support targeted interventions.[26], while the number of national monitoring stations nearly tripled from 661 in 2012 to 1,800 in 2020[27]. To strengthen dust control, more than 1,700 construction sites and 155 concrete mixing plants were placed under video surveillance (United Nations Environment Programme, 2019)[28]. Additionally, China centralised its air quality monitoring system under the China National Centre for Environmental Monitoring (CNEMC), effectively addressing issues of data manipulation by local governments[29].

3.4 Implementation and Governance

Although China's environmental governance is majorly based on command-and-control regulation inherited from China's previous planned economy. But at the same time the local governments have great authority over financial resources needed for environmental protection and other such affairs[30]. Local authorities are the key actors responsible for enforcement in their respective jurisdictions. This contrasts with the period of 2000s, when central government ministries led the charge of policy implementation[31].

[22] Xinhua. (2025, June 9). From smog to sunshine: Beijing's decade-long clean air campaign pays off. Qiushi English Edition. https://en.qstheory.cn/2025-06/09/c_1099081.htm
[23] Ministry of Ecology and Environment of the People's Republic of China. (2020, December 22). White paper on China's ecological and environmental protection and high-quality development. https://english.mee.gov.cn/Resources/publications/Whitep/202012/t20201222_814160.shtml
[24] Huang, D., Narain, U., Nygard, J., Sall, C., Sanchez-Triana, E., & Siegmann, K. (2020, October 29). Clearing the air: A tale of three cities (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/521491604042907160
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[26] ICLEI Sustainable Mobility. (2023). Clearing the skies: how Beijing tackled air pollution & what it means for urban monitoring. September 1, 2023. https://sustainablemobility.iclei.org/air-pollution-beijing/
[27] Hu, Q., & Whitney, M. (2021, February 10). How China is tackling air pollution with big data. World Economic Forum. https://www.weforum.org/stories/2021/02/china-tackling-air-pollution-big-data/
[28] United Nations Environment Programme. (2019). A review of 20 years' air pollution control in Beijing. https://wedocs.unep.org/bitstream/handle/20.500.11822/27645/airPolCh_EN.pdf?sequence=1&isAllowed=y
[29] Silver, B., Reddington, C. L., Chen, Y., & Arnold, S. R. (2025). A decade of China's air quality monitoring data suggests health impacts are no longer declining. Environment International, 197, Article 109318. https://doi.org/10.1016/j.envint.2025.109318
[30] Liu, L., Zhang, B., & Bi, J. (2012). Reforming China's multi-level environmental governance: Lessons from the 11th Five-Year Plan. Environmental Science & Policy, 21, 106–111. https://doi.org/10.1016/j.envsci.2012.05.001
[31] Ren,X. (2020). From a comparative gesture to structured comparison:An analysis ofair pollution control in Beijing and Delhi. Cambridge Journal of Regions, Economy and Society, 13(3), 461–473. https://doi.org/10.1093/cjres/rsaa017

In China local city officials are held responsible for meeting pollution control targets under the Targeted Responsibility System. Air pollution reduction carries "veto power," local officials are denied promotion if pollution targets are not met, regardless of their achievements in other areas[32]. "The "Target Responsibility System", where the promotion of the local officials and enterprise managers, was tied to the achievement of pollution control and energy saving targets[33]. The Assessment Program for the Implementation of the Air Pollution Prevention Action Plan also allocated a certain weightage to reduction of PM2.5 concentration as a mandatory indicator in performance in Beijing-Tianjin Hebei region[34].

In 2014, the revised Environmental Protection Law (EPL) introduced stricter penalties for polluting industries. Also, it made local officials criminally liable if they failed to act against defaulters (Kostka & Zhang, 2018)[35]. The plan stated that the Ministry of Environmental Protection (MEP) would intensify random inspections and oversight, while promoting public supervision of regional governments where excessive emissions were common. It also proposed establishing a regional cooperation mechanism for the Beijing-Tianjin-Hebei region[36]. Increased onsite inspections helped deter violations, with over 10,000 individuals penalized for environmental breaches between 2016 and 2017, and around 400 officials in Hebei punished for misconduct in environmental data management in 2016[37]. Local Environmental Protection Bureaus (EPBs) serve as the main supervisory and enforcement bodies for environmental regulations, but their financial and administrative dependence on local governments often limits their effectiveness, as enforcement largely reflects local priorities[38].

4. Impact

The annual average concentration of PM2.5 in Beijing decreased from 89.5µg/m3 in 2013, to 58µg/m3 by the end of 2017. Over a period of 20 years (1998-2018), Beijing has shown a significant improvement of air quality. The annual concentrations of SO2 , NO2 , and PM10 decreased by 93.3%, 37.8%, and 55.3% respectively. In the period 2013 to 2017 the concentrations of SO2 , CO, NO2 , PM2.5 and PM10 fell by 70.4%, 38.2%, 17.9%, 35.6% and 22.2% respectively.

[31] Ren,X. (2020). From a comparative gesture to structured comparison:An analysis ofair pollution control in Beijing and Delhi. Cambridge Journal of Regions, Economy and Society, 13(3), 461–473. https://doi.org/10.1093/cjres/rsaa017
[32] Ibid.
[33] Jargad, S., & Ramamurthi, P. (2024, December 18). Making air less toxic: Why has Delhi failed and Beijing succeeded? The Indian Express. https://indianexpress.com/article/opinion/columns/air-less-toxic-delhi-failed-beijing-succeeded-9732292/
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[36] Ministry of Ecology and Environment of the People's Republic of China. (2017). The 13th Five-Year Plan for Ecological and Environmental Protection [PDF]. https://english.mee.gov.cn/Resources/Plans/National_Fiveyear_Plan/201706/P020170605420340944828.pdf
[37] Kostka, G., & Zhang, C. (2018). Tightening the grip: Environmental governance under Xi Jinping. Environmental Politics, 27(5), 769–781. https://doi.org/10.1080/09644016.2018.1491116
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In the period 2013 to 2017 the concentrations of SO2 , CO, NO2 , PM2.5 and PM10 fell by 70.4%, 38.2%, 17.9%, 35.6% and 22.2% respectively. However, Beijing continues to suffer from heavy pollution episodes during autumn and winter[39]. According to the Energy Policy Institute at the University of Chicago, air pollution in the city dropped by 42.3 per cent between 2013 and 2021 (Kumar, 2024)[40]. The number of days with good air quality increased from114 days in 2013 to 290 in 2024.the number of heavily polluted days dropped from 58 in 2013 to just two in 2024, which was a reduction of 96.6 percent[41]. China has cleaned up its air twice as fast as the UK did after the Great Smog of post- war London[42].

Between 2013 and 2017, China reduced its total coal consumption by over 300 million tons, lowering coal's share in primary energy use from 67.4% to 60%. Key regions such as the Beijing- Tianjin-Hebei (BTH) area even recorded negative growth in total coal consumption[43]. During the same period, Beijing's PM2.5 concentration dropped from about 90 μg/m³ in 2013 to 58 μg/m³ in 2017[44]. Measures implemented by the city contributed to a 20.6 μg/m³ decline in PM2.5 levels accounting for 65% of the overall reduction. By 2017, emissions of PM2.5, SO_2, and NO_x had decreased by 97%, 98%, and 86%, respectively, compared to levels two decades earlier[45].

Over two decades, Beijing achieved major air quality improvements. From 2013 to 2017, emissions of SO_2, NO_x, VOCs, PM2.5, and PM10 declined by 83%, 43%, 42%, 55%, and 52%. The city's average PM2.5 concentration dropped from 89.5 μg/m³ in 2013 to 58 μg/m³ in 2017, while SO_2, NO_2, and PM10 levels fell by 93.3%, 37.8%, and 55.3% over 20 years[46].

5. Analysis

A key distinction between China and India's is their approaches to air pollution control. In China, it follows a territorial logic, driven by local institutions and authorities such as municipal governments and officials. In contrast, India's approach is shaped by an associational logic that relies on coalition building among diverse actors, including civil society groups, the judiciary, government agencies, and private industries[47]. "Target Responsibility System" is a critical factor behind the success of the pollution control strategy.Mandatory targets are allocated to each level of government from provincial to municipal and county levels.

[39] United Nations Environment Programme. (2019). A review of 20 years' air pollution control in Beijing. https://wedocs.unep.org/bitstream/handle/20.500.11822/27645/airPolCh_EN.pdf?sequence=1&isAllowed=y
[40] Kumar, A. (2024, November 19). How China won its deadly smog battle. Is it possible for India too? Business Standard. https://www.business-standard.com/india-news/how-china-won-its-deadly-smog-battle-is-it-possible-for-india- too124111900882_1.html
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[44] Huang, D., Narain, U., Nygard, J., Sall, C., Sanchez-Triana, E., & Siegmann, K. (2020, October 29). Clearing the air: A tale of three cities (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/521491604042907160
[45] United Nations Environment Programme. (2019). A review of 20 years' air pollution control in Beijing. https://wedocs.unep.org/bitstream/handle/20.500.11822/27645/airPolCh_EN.pdf?sequence=1&isAllowed=y
[46] United Nations Environment Programme. (2019). A review of 20 years' air pollution control in Beijing. https://wedocs.unep.org/bitstream/handle/20.500.11822/27645/airPolCh_EN.pdf?sequence=1&isAllowed=y
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The binding targets are part of responsibility contracts of local officials and important criteria for promotions[48]. The approach which the Chinese adopted might be difficult to try in democracies around the world. The Chinese action on controlling air pollution was driven by concerns about international reputation [short term action around major sporting events (Beijing 2008 Olympics, Shanghai 2010 World Expo, Nanjing 2014 Youth Olympics) and global economic meetings (APEC 2012)], citizen activism and political will[49].

6. Challenges

At the national level, ozone concentrations have been rising between 2021 and 2024, with an average annual increase of 2.06 μg/m³[50]. This trend underscores the need for a territorial or regional "airshed" approach to air quality management, as pollution often transcends administrative boundaries. Meanwhile, China's energy mix has seen a renewed dependence on coal, returning to its pre-pandemic share of 60% in 2017 after previously declining to 57.7% in 2019. In response to widespread electricity shortages in 2021, coal imports were further increased[51]. Balancing economic growth with environmental commitments thus remains a complex public policy challenge that demands strong political will, sustained financial investment, and broad public participation[52].

[48] Wu, J., Xu, M., & Zhang, P. (2018). The impacts of governmental performance assessment policy and citizen participation on improving environmental performance across Chinese provinces. Journal of Cleaner Production, 184, 227–238. https://doi.org/10.1016/j.jclepro.2018.02.056

[49] Jargad, S., & Ramamurthi, P. (2024, December 18). Making air less toxic: Why has Delhi failed and Beijing succeeded? The Indian Express. https://indianexpress.com/article/opinion/columns/air-less-toxic-delhi-failed-beijing-succeeded-9732292/

[50] Silver, B., Reddington, C. L., Chen, Y., & Arnold, S. R. (2025). A decade of China's air quality monitoring data suggests health impacts are no longer declining. Environment International, 197, Article 109318. https://doi.org/10.1016/j.envint.2025.109318

[51] Huang, Y. (2024, April 24). China's battle against air pollution: An update. Council on Foreign Relations. https://www.cfr.org/blog/chinas-battle-against-air-pollution-update

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02 Mexico City

Mexico

1. Introduction and Context

With a population exceeding 21 million, it is one of the world's largest megacities and the most populous metropolitan area in North America[53]. Mexico City is one of the most populous urban areas with a population of 9.2 million. The Metropolitan Area of the Valley of Mexico (ZMVM) is composed of three entities: Mexico City (16 territorial delegations), part of the State of Mexico (59 of its 125 municipalities) and a part of the State of Hidalgo (one municipality). The Metropolitan Area of the Valley of Mexico (ZMVM) is in central Mexico within a high-altitude basin ranging from 2,200 to 2,800 meters above sea level and is encircled by mountains rising above 5,000 meters[54].

The location of Mexico City, encircled by mountains play a role in accumulation of pollutants. Emissions from Popocatepetl volcano also play a role in the nature of air quality of the region. Industrial activities are primarily cantered in the northern and eastern areas of the city, where factory density is high[55.]

Mexico City faced severe air pollution during the 1980s and 1990s, as a byproduct of rapid population growth and increasing industrialisation[56.] The population of the valley of Mexico metropolitan region rose from 3.1 million in the 1950s to 14 million by the 1980s. The result was deteriorated air quality. Mexico City was labelled world's most polluted city by the United Nations in 1992[57].

The first air quality management program, the Comprehensive Program Against Air Pollution in the MCMA (PICCA), was launched in 1990. It was later replaced in 1996 by the Program to Improve Air Quality in the Valley of Mexico (PROAIRE 1995–2000). In 2002, a ten-year program, PROAIRE 2002–2010, was introduced, followed by PROAIRE 2011–2020, implemented in 2010[58].

[53] Molina, L. T., Velasco, E., Retama, A., & Zavala, M. (2019). Experience from integrated air quality management in the Mexico City Metropolitan Area and Singapore. Atmosphere, 10(9), 512. https://doi.org/10.3390/atmos10090512
[54] International Transport Forum. (2017, May 16). Strategies for mitigating air pollution in Mexico City. OECD/ITF. https://www.itf-oecd.org/strategies-mitigating-air-pollution-mexico-city
[55] Flores Vidriales, M. del P. (2023). Tracking the evolution of air pollution disparities in Mexico City: A spatial and statistical analysis [Master's thesis, Università Ca' Foscari Venezia]. Venice Institutional Repository. https://unitesi.unive.it/retrieve/302a3743-ce10-445e-b197-40fd13b560f1/890766-1282017.pdf
[56] World Bank. (2020). Clearing the air: A tale of three cities. World Bank. https://documents.worldbank.org/curated/en/521491604042907160/pdf/Clearing-the-Air-A-Tale-of-Three-Cities.pdf
[57] Davda, K. (2024, June 12). What are the effects of air pollution in Mexico City? Oizom. https://oizom.com/what-are-the-effects-of-air-pollution-in-mexico-city/
[58] Molina, L. T., Velasco, E., Retama, A., & Zavala, M. (2019). Experience from integrated air quality management in the Mexico City Metropolitan Area and Singapore. Atmosphere, 10(9), 512. https://doi.org/10.3390/atmos10090512

In 2017, the Secretariat of Environment and Natural Resources released the "Federal Program to Improve Air Quality in the Megalopolis: PROAIRE of the Megalopolis 2017 2030."[59]

2. Policy Framework and Planning

2.1 Institutional Evolution

The Metropolitan Environmental Commission (CAM) was established by a Presidential Decree to strengthen coordination between federal and local government agencies in the year 1992. CAM brought officials from ministries of environment, health, transport and the federal government, also from the federal district (now Mexico City) and the State of Mexico. It faced several challenges in the initial years hindered by frequent staff turnover, absence of independent budget, limited enforcement authority and an unclear organisational structure[60].

The CAM evolved into the Megalopolis Environmental Commission (la Comisión Ambiental de la Megalópolis, "CAMe") in 2013, to cover a greater geographic area. CAMe's geographical coverage included Mexico City and a total of 224 municipalities in the surrounding states of Hidalgo, Mexico, Morelos, Puebla, and Tlaxcala. In addition, CAMe had a more comprehensive governance structure that included a high level government body (with Mexico's Minister of Environment and Natural Resources, the five state governors, and the Chief of Mexico City's Government), an Executive Commissioner, and a Scientific Advisory Committee[61] [62].

In 1994, the Metropolitan Environmental Commission (Comisión Ambiental Metropolitana, CAM) was created. The CAM coordinated air quality improvement efforts for nearly two decades and developed the Air Quality Improvement Programmes (Programas para Mejorar la Calidad del Aire, PROAIRE) for the ZMVM. In 2013. It was restructured into the Environmental Commission for the Megalopolis (Comisión Ambiental de la Megalópolis, CAMe)[63].

An Environmental Trust Fund for the Valley of Mexico was established to finance CAM projects using revenue from a gasoline surcharge in the MCMA. Additional financial and technical support came from international environmental agencies, academic institutions, and foreign governments, including the World Bank and JICA[64].

2.2 Early Programs (1990-2000)

In 1990, the Mexican government introduced its first multi-year air quality management strategy to tackle deteriorating air quality. Mexico City was a Federal District administered

[59] World Bank. (2020). Clearing the air: A tale of three cities. World Bank. https://documents.worldbank.org/curated/en/521491604042907160/pdf/Clearing-the-Air-A-Tale-of-Three-Cities.pdf
[60] Ibid.
[61] Ibid.
[62] Molina, L. T., Velasco, E., Retama, A., & Zavala, M. (2019). Experience from integrated air quality management in the Mexico City Metropolitan Area and Singapore. Atmosphere, 10(9), 512. https://doi.org/10.3390/atmos10090512
[63] International Transport Forum. (2017, May 16). Strategies for mitigating air pollution in Mexico City. OECD/ITF. https://www.itf-oecd.org/strategies-mitigating-air-pollution-mexico-city
[64] Molina, L. T., Velasco, E., Retama, A., & Zavala, M. (2019). Experience from integrated air quality management in the Mexico City Metropolitan Area and Singapore. Atmosphere,10(9), 512. https://doi.org/10.3390/atmos10090512

by a Chief of the Federal District back then. An Integrated Program against Atmospheric Pollution in the Mexico City Metropolitan Area (PICCA) for 1990-1994 was developed as part of the process of the strategy[65].

The achievements of PICCA were improvement in fuel quality (phasing out lead in gasoline). A maximum limit of 500 PPM for sulphur was introduced in diesel. Strict vehicular emission norms were introduced. A maximum limit of sulphur content of 500 PPM in diesel was brought in. technologies like three-way catalytic converters, electronic fuel injection was introduced and made to install in vehicles. PICCA was followed up by the Program to Improve Air Quality (PROAIRE) 1995-2000. For the first time air quality improvement targets were included in the programme. A major thrust of the programme was to reduce concentrations of ozone. A next phase of PROAIRE was launched in 2002-2010. In 2004, for the first time a national standard for PM2.5 concentrations was introduced[66].

2.3 Industrial Measures

Beginning in 1986, power plants and major industrial facilities were shifted from heavy fuel oil to cleaner natural gas, and by 1990, this effort was reinforced by gradually relocating large industries to areas outside the MCMA[67].

3. Sectoral Interventions

3.1 Transport

Mexico City undertook several major initiatives to curb vehicular emissions and improve air quality. Expanding the metro, trail bus systems; a program to replace aging taxis; introducing cleaner, more efficient buses and phasing out old buses and freight vehicles. The city rolled out the bus rapid transit system (Metrobus) in 2005 and promoted non-motorized travel options such as cycling and walking. Oxygenated gasoline was adopted in 1989, followed by the introduction of unleaded gasoline in 1990 and the full phase-out of leaded fuel by 1997. The mandatory "No Driving Day" (Hoy No Circula) program was launched in 1989 and later refined. Starting in 1992, vehicles began transitioning to alternative fuels such as LPG and CNG encouraged by the authorities. In 1999, the city strengthened these efforts by implementing the Comprehensive Pollutant Emission Reduction Program (PIREC)[68].

Mexico City has been ahead of the national schedule, proactively implementing tighter emissions standards, similar to European and U.S. regulations (Euro VI or U.S. EPA 2010), through its voluntary inspection and maintenance program. In the early 2000s, the greater metropolitan area had several old taxis, contributing to NOx, CO, VOC, and PM emissions numbering approximately 110,000.

[65] World Bank. (2020). Clearing the air: A tale of three cities. World Bank. https://documents.worldbank.org/curated/en/521491604042907160/pdf/Clearing-the-Air-A-Tale-of-Three-Cities.pdf
[66] Ibid.
[67] Molina, L. T., Velasco, E., Retama, A., & Zavala, M. (2019). Experience from integrated air quality management in the Mexico City Metropolitan Area and Singapore. Atmosphere, 10(9), 512. https://doi.org/10.3390/atmos10090512
[68] Ibid.

The PROAIRE 2002–2010 program established a target to retire roughly 80 percent of outdated taxis by 2007. In January 2006, a regulation was introduced restricting the sulphur content in premium gasoline to a maximum of 80 parts per million (PPM) by October 2006[69].

Since 2015 Mexico City has run a pilot programme to retrofit diesel particulate filters for buses[70]. Under Mexico's vehicle inspection program "Programa de Verificación Vehicular Obligatoria", each vehicle's emissions are inspected semi-annually at authorized verification centres. Vehicles are given a hologram with a number associated with different driving restrictions[71].

"Programa de Verificación Vehicular Obligatoria" program

Hologram	Weekday Restrictions	Saturday Restrictions
00 and 0	Exempted	Exempted
1	Unable to drive one day between Monday and Friday	Unable to drive two Saturdays per month
2	Unable to drive one day between Monday and Friday	Unable to drive on Saturdays

The city administration has worked on improving the public transportation and consolidation of an Integrated Mobility System, by adding new BRT Metrobus corridors, expanding and rehabilitating Metro lines[72]. During the PROAIRE 2002–2010 implementation period, a new bus rapid transit system (BRT) was introduced, known as the Metrobus, to replace informal buses locally known as colectivos. Since its introduction the Metrobus network has expanded to seven lines, serving nearly 800,000 passengers per day[73].

3.2 Eco-bibi Bike Sharing Scheme

Mexico City has promoted a successful bike sharing initiative, known as Eco-bibi. It has been promoted as an alternative for individual transport, as a sustainable mode of mobility. The initiative was started in 2010, with 1,000 bicycles and 85 docking stations. It has grown to 6,000 bicycles and over 400 docking stations. The Eco-bibi programme is the largest in the region and has been replicated in several Latin American cities. Studies show that it has been successful in reducing use of taxis by 8% and that of private cars by 5%[74].

[69] World Bank. (2020). Clearing the air: A tale of three cities. World Bank. https://documents.worldbank.org/curated/en/521491604042907160/pdf/Clearing-the-Air-A-Tale-of-Three-Cities.pdf
[70] International Transport Forum. (2017, May 16). Strategies formitigating airpollutioninMexicoCity.OECD/ITF.https://www.itf-oecd.org/strategies-mitigating-air-pollution-mexico-city
[71] World Bank. (2020). Clearing the air: A tale of three cities. World Bank. https://documents.worldbank.org/curated/en/521491604042907160/pdf/Clearing-the-Air-A-Tale-of-Three-Cities.pdf
[72] Flores Vidriales, M. del P. (2023). Tracking the evolution of air pollution disparities in Mexico City: A spatial and statistical analysis [Master's thesis, Università Ca' Foscari Venezia]. Venice Institutional Repository. https://unitesi.unive.it/retrieve/302a3743-ce10-445e-b197-40fd13b560f1/890766-1282017.pdf
[73] World Bank. (2020). Clearing the air: A tale of three cities. World Bank. https://documents.worldbank.org/curated/en/521491604042907160/pdf/Clearing-the-Air-A-Tale-of-Three-Cities.pdf
[74] von Ritter Figueres, N. (2017, December 20). What can the rest of the world learn from Mexico City's EcoBici bike-sharing scheme? LSE Latin America & Caribbean. https://blogs.lse.ac.uk/latamcaribbean/2017/12/20/what-can-the-rest-of-the-world-learn-from-mexico-citys-ecobici-bike-sharing-scheme/

3.3 "Hoy No Circula" (No Driving Day)

The programme was introduced first in 1987 as part of a citizen initiative to participate voluntarily to avoid using cars once a week. In 1989 it was made mandatory for the winter months and permanent in 1990. Several revisions were made over the years. Taxis and public transport were also included in the following years[75]. The programme limits the use of vehicles depending on the last digit on the vehicle's registration plate[76]. A consequence of the policy was families buying an extra vehicle, often older, increasing the overall vehicular fleet during the early years of the program. Following a severe ozone episode in March 2016, authorities revised the program and required the vehicles to have on-board diagnostics systems (OBD II), along with exhaust emissions and visual inspection tests[77].

3.4 Air Pollution Monitoring

Mexico City has been monitoring air quality data since the 1970s with a manual network of 22 stations for SO2 and Total Suspended Particulates (TSP). Automatic air-quality monitoring networks were introduced in the late 1980s.In 1994, Mexico established its first ambient air quality standards for ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), lead (Pb), and PM 10. These standards were updated in 2014 for O_3, PM_{10}, and $PM_{2.5}$ and in 2010 for SO_2, while those for Pb, CO, and NO_2 have remained unchanged since their introduction[78]. The Atmospheric Monitoring System (SIMAT) conducts continuous measurement of major air pollutants in Mexico City. Nearly 44 monitoring stations are distributed across the metropolitan region, covering areas in both Mexico City and the adjoining urban areas of the State of Mexico[79].

3.5 Implementation and Governance

Mexico's air pollution management is supported by a strong legal framework. It is grounded in the Federal Constitution's provisions on environmental protection and further detailed in the General Law of Ecological Equilibrium and Environmental Protection. At the local level, the Mexico City Constitution also establishes specific environmental protection mandates, reinforcing the city's authority to address air quality issues. Several key institutions oversee air quality governance in the Megalopolis region. The Megalopolis Environmental Commission (CAMe) coordinates regional environmental policies, while each member jurisdiction is responsible for enforcing its own environmental laws and programs. At the national level, the Secretariat of Environment and Natural Resources (SEMARNAT) manage natural resources and enforces federal environmental regulations. The National Institute of Ecology and Climate Change (INECC) supports air quality monitoring and conducts research on air pollution and its health impacts. In addition, each state within the Megalopolis has its own

[75] Molina, L. T., Velasco, E., Retama, A., & Zavala, M. (2019). Experience from integrated air quality management in the Mexico City Metropolitan Area and Singapore. Atmosphere, 10(9), 512. https://doi.org/10.3390/atmos10090512
[76] René, P.-M. (2016, April 1). How Mexico City slashed air pollution levels by half. Dialogue Earth. https://dialogue.earth/en/pollution/8786-how-mexico-city-slashed-air-pollution-levels-by-half/
[77] Molina, L. T., Velasco, E., Retama, A., & Zavala, M. (2019). Experience from integrated air quality management in the Mexico City Metropolitan Area and Singapore. Atmosphere, 10(9), 512. https://doi.org/10.3390/atmos10090512
[78] Ibid.
[79] Flores Vidriales, M. del P. (2023). Tracking the evolution of air pollution disparities in Mexico City: A spatial and statistical analysis[Master's thesis, Università Ca' Foscari Venezia]. Venice Institutional Repository. https://unitesi.unive.it/retrieve/302a3743-ce10-445e-b197-40fd13b560f1/890766-1282017.pdf

environmental secretariat to implement and manage local environmental initiatives[80]. In Mexico, the right to clean air and a healthy environment is upheld across multiple levels of legislation. Article 4 of the Mexican Constitution recognizes the right to a healthy environment. Similarly, the Mexico City Constitution reinforces this in Article 16, which guarantees the right to a healthy environment and mandates the creation of public policies for environmental protection, including atmospheric quality. To address air pollution, the Mexican government reinforced its legal framework through the General Law of Ecological Equilibrium and Environmental Protection (LGEEPA), which demarcated the federal, state, and local government responsibilities[81].

3.6 Citizen Participation

Mexico City uses an air quality forecasting system, altering the public twenty hours prior to high pollution events (Molina, Velasco, Retama, & Zavala, 2019).[82] Authorities in Mexico have used social platforms to disseminate hourly bulletins to raise awareness and also gain input from stakeholders. Since 2020, authorities have introduced a new federal standard (NOM-072-SEMARNAT-2019) that mandates the use of a new color-coded Air and Health Index, to communicate about air quality and enable individuals to take steps to reduce their exposure to air pollution[83].

4. Impact

Mexico City has achieved substantial improvements in air quality[84]. Mexico City has been successful in reducing the pollutant concentrations as result of better fuels and stricter emission standards between 1990 and 2002. Key measures included phasing out leaded gasoline, lowering sulphur content in diesel, substituting fuel oil and diesel with natural gas in power plants, introducing catalytic converter technology in 1993, and implementing vapor-recovery systems in 1995[85].

Pollution concentrations have declined since 1990, however annual concentrations of PM2.5 and PM10 have risen slightly after 2015 and remain above the national standards. Ozone levels have also dropped substantially since the 1990s, however still remain a persistent challenge[86]. The city wide average annual PM2.5 concentration was nearly 40 μg/m³ in the early 1990s. By 2015, levels had fallen below 25 μg/m3 throughout the city, while ambient ozone levels fell from over 130 ppb to around 80 ppb over the same period.

[80] Molina, L. T., Velasco, E., Retama, A., & Zavala, M. (2019). Experience from integrated air quality management in the Mexico City Metropolitan Area and Singapore. Atmosphere, 10(9), 512. https://doi.org/10.3390/atmos10090512
[81] Ibid.
[82] Ibid.
[83] World Bank. (2020). Clearing the air: A tale of three cities. World Bank. https://documents.worldbank.org/curated/en/521491604042907160/pdf/Clearing-the-Air-A-Tale-of-Three-Cities.pdf
[84] Secretaría del Medio Ambiente (SEDEMA). (n.d.). Health benefits from improved air quality in Mexico City 1990–2012 [PDF]. http://www.data.sedema.cdmx.gob.mx/beneficios-en-salud-por-la-mejora-de-la-calidad-del-aire/descargas/analisis-ingles.pdf
[85] Silva Rodríguez de San Miguel, J. A. (2019). Management of air pollution in Mexico. Management of Environmental Quality: An International Journal, 30(3), 578–592. https://doi.org/10.1108/MEQ-05-2018-0099
[86] World Bank. (2020). Clearing the air: A tale of three cities. World Bank. https://documents.worldbank.org/curated/en/521491604042907160/pdf/Clearing-the-Air-A-Tale-of-Three-Cities.pdf

PM10 levels have significantly reduced by 60% between 1990 and 2015, dropping from 110 µg/m3 to below 45 µg/m3[87]. During ProAire III (2002–2010), estimated annual emission reductions included 5,078 tons of PM_{10}, 506 tons of SO_2, 8,17,132 tons of CO, 64,779 tons of NO_x, and 85,706 tons of VOCs (Centre for Public Impact, n.d.)[88]. In its third phase, the Proaire reforms cut Mexico City's Metropolitan Air Quality Index (Imeca) levels from about 300 in the 1980s to under 150 in 2016, while ozone levels dropped from around 500 ppb to roughly 120–150 ppb[89].

The results of "Hoy No Circula" are debatable. Many people have resorted to purchasing a second vehicle, often older, higher-emitting models to circumvent the restrictions[92]. There is insufficient evidence to prove that licence-plate-based restriction policies reduce traffic congestion and air pollution. Several studies have indicated that driving restriction policies have only limited impact in air pollution reductions. Also, these measures raise equity concerns; it has resulted in displacement of old polluting vehicles to lower income neighbourhoods[93].

The number of days with severe levels of pollution fell from 344 days in 1994 to 118 days in 2012[90]. Mexico City also achieved a reduction of 7.7 million tons of carbon emissions between 2008 and 2012 surpassing its target of 7.0 million tons[91].

[87] Secretaría del Medio Ambiente (SEDEMA). (n.d.). Health benefits from improved air quality in Mexico City 1990–2012 [PDF]. http://www.data.sedema.cdmx.gob.mx/beneficios-en-salud-por-la-mejora-de-la-calidad-del-aire/descargas/analisis-ingles.pdf
[88] Centre for Public Impact. (n.d.). Mexico City's ProAire programme. https://centreforpublicimpact.org/public-impact-fundamentals/mexico-citys-proaire-programme/
[89] René, P.-M. (2016, April 1). How Mexico City slashed air pollution levels by half. DialogueEarth. https://dialogue.earth/en/pollution/8786-how-mexico-city-slashed-air-pollution-levels-by-half/
[90] Bhatt, A. (2019, October 15). Mexico City can show us the way in tackling increasing air pollution. Hindustan Times. https://www.hindustantimes.com/cities/mexico-city-can-show-us-the-way-in-tackling-increasing-air-pollution/story-fqUTmjSx3tLEfnnCYSOiiN.html
[91] Centre for Public Impact. (n.d.). Mexico City's ProAire programme. https://centreforpublicimpact.org/public-impact-fundamentals/mexico-citys-proaire-programme/
[92] World Bank. (2020). Clearing the air: A tale of three cities. World Bank. https://documents.worldbank.org/curated/en/521491604042907160/pdf/Clearing-the-Air-A-Tale-of-Three-Cities.pdf
[93] Flores Vidriales, M. del P. (2023). Tracking the evolution of air pollution disparities in Mexico City: A spatial and statistical analysis [Master's thesis, Università Ca' Foscari Venezia]. Venice Institutional Repository. https://unitesi.unive.it/retrieve/302a3743-ce10- 445e-b197-40fd13b560f1/890766-1282017.pdf

03 Accra

Ghana

1. Introduction and Context

Airpollution is one of the significant environmental costs in Ghana, amounting to 4.2% of GDP Between 2006–2015 PM_{10} concentrations exceeded the limits set under Ghana and WHO guidelines.[94] Air pollution levels in Ghana are influenced by seasonal variation. During the dry season (November to March) the levels are high due to desert dust.[95] Harmattan winds play a significant role, transporting Saharan dust to Accra adding to air pollution. These winds result in episodes of extremely high PM2.5 and PM10 levels[96]. The Greater Accra Metropolitan Area is home to over four million people and experiences a daily influx of 2.5 million business commuters. Accra, serves both as the country's commercial centre and capital of the country. Approximately 40% of Accra's $PM_{2.5}$ concentrations are linked to emissions from the road transport. In 2019, Ghana's annual average $PM_{2.5}$ concentration was eleven times higher than WHO's 2021 recommended guideline level. Nearly 3,000 premature deaths were attributed to air pollution in 2019. Across the country, numbers related to air pollution exceeded those caused by malaria, tuberculosis and HIV/ AIDS for the year 2019[97].

2. Policy Framework and Planning

The Government of Ghana has collaborated with the World Health Organisation (WHO) and other international organisations to implement the Urban Health Initiative, aimed at reducing deaths due to air and climate pollutants (Ambient Air Pollution and Health in Accra, Ghana, 2021)[98]. Ghana became a founding member of the Climate and Clean Air Coalition (CCAC) in 2012, a program within the United Nations Environment Programme initiative focused on reducing short-lived climate pollutants. In 2015, a National Gas Master Plan (2015) was brought to expand the use of natural gas for transportation and electricity generation[99].

In 2016 a pilot project was launched in Accra to strengthen the health sector's role in tackling air pollution. Awareness campaigns were conducted regarding climate change and

[94] Frimpong-Boateng, K., & Pwamang, J. (2018). National action plan to mitigate short-lived climate pollutants. Republic of Ghana.
[95] Ambient air pollution and health in Accra, Ghana. (2021). World Health Organization.
[96] Frimpong-Boateng, K., & Pwamang, J. (2018). National action plan to mitigate short-lived climate pollutants. Republic of Ghana.
[97] Accra and air pollution – Clean Air Fund (2025, September 12). Clean Air Fund. https://www.cleanairfund.org/clean-air-africas-cities/accra/
[98] Ambient air pollution and health in Accra, Ghana. (2021). World Health Organization.
[99] Greater Accra Region air quality management plan. (2024). Climate & Clean Air Coalition. https://www.ccacoalition.org/resources/greater-accra-region-air-quality-management-plan

air pollution[100]. Industrial and manufacturing activities account for a significant share of Accra's air pollution (11%). Biomass fuels used in power generators add to the PM2.5 concentration. Moreover, nearly 60% of the households in Ghana rely on charcoal and wood as their primary cooking fuels, contributing to air pollution levels both indoors and outdoors.[101] About 70% of Ghana's population rely on solid fuels such as fuelwood, charcoal and dung for cooking and heating. As per a 2015 report of Ghana Statistical Service, more than half of urban households and 90 percent of rural households continue to use solid fuel for cooking. Nevertheless since 2005 Ghana has reduced by 20 percent the proportion of population using solid fuels.[102] The Ghanaian government, through the Energy Commission in partnership with the Global Alliance for Clean Cookstoves and the Ghana Alliance for Clean Cookstoves (GHACCO), set a national target to provide clean cooking solutions to 50 percent of the population by 2020 .The access to electricity among the population of Ghana doubled in 1990 and 2012, access to non-solid cooking fuels improved significantly. By 2021, 96.1% of households in the Greater Accra Region used electricity as their primary lighting source and about 68.2% used LPG for cooking.[103]

3. Sectoral Interventions

3.1 Transport

About 70% of daily commuters in Ghana rely on private minibuses locally known as 'Tro-tros', which are mainly older high-emitting vehicles. Due to a network mainly of unpaved and dusty roads in Accra, contributes to high PM2.5 concentration levels. The Ghana Urban Mobility and Accessibility Project was launched to enhance public transport services. Key measures of the project included regulation of Tro-tros and expansion of the metro and public bus network. Additionally, in 2024 import duty on electric vehicles for commercial transportation until 2032 was proposed under the policy initiatives, to reduce vehicular emissions[104].

The Urban Transport Project funded by the World Bank was launched in 2007, aimed at reducing vehicular emissions through improved public transport regulation, introduction of a Bus Rapid Transit (BRT). After the successful phase out of lead from gasoline, EPA Ghana collaborated with the National Petroleum Authority (NPA) to reduce the sulphur content in fuel. In 2014, the maximum sulphur content in diesel was reduced from 5,000 parts per million (ppm) to 3,000 ppm.[105]

3.2 Air Pollution Monitoring

The air quality monitoring network in Ghana is operated by the Environment Protection Agency, measuring PM10 and, to a more limited extent, PM2.5, across up to fifteen sites in

[100] Ambient air pollution and health in Accra, Ghana. (2021). World Health Organization.
[101] Accra and air pollution – Clean Air Fund (2025, September 12). Clean Air Fund. https://www.cleanairfund.org/clean-air-africas-cities/accra/
[102] Frimpong-Boateng, K., & Pwamang, J. (2018). National action plan to mitigate short-lived climate pollutants. Republic of Ghana.
[103] Greater Accra Region air quality management plan. (2024). Climate & Clean Air Coalition. https://www.ccacoalition.org/resources/greater-accra-region-air-quality-management-plan
[104] Accra and air pollution – Clean Air Fund (2025, September 12). Clean Air Fund. https://www.cleanairfund.org/clean-air-africas-cities/accra/
[105] Greater Accra Region air quality management plan. (2024). Climate & Clean Air Coalition. https://www.ccacoalition.org/resources/greater-accra-region-air-quality-management-plan

Accra and its surrounding areas. Several studies have been carried out over the past fifteen years to assess air pollution levels from particular emission sources. A low cost PM sensor network was deployed across Accra in 2018, to complement the existing network of monitoring infrastructure and enhance local air quality management capacity[106].

Air quality monitoring in Ghana is limited to only a few locations, mostly concentrated in the capital city. Ghana Urban Air Quality Project (GHAir) was launched in 2019, with an aim to bridge Ghana's air pollution data gaps. The project aims were to establish a dense network of low-cost air quality sensors across urban areas to generate real-time, high-resolution air quality data that can inform policy interventions.[107] In 2023, Ghana collaborated with the Clean Air Fund to review the air quality laws and identify best practices to strengthen air quality in urban centres such as Accra. Also,the Environmental Protection Agency of Ghana introduced the Air Quality Management Plan (AQMP), to steer efforts to improve air quality across the Greater Accra Region.[108]

3.3 Institutional Mechanism

The Environmental Protection Agency of Ghana works with various government bodies and other institutions both international and national to control emissions.[109] The Environmental Protection Council, now Environmental Protection Agency (EPA) was created in 1974 bringing regulation of environmental issues under a single body and to implement Environmental Impact Assessments (EIA).The Environmental Protection Agency Act, 1994 (Act 490) was complemented with legislations like the Hazardous and Electronic Waste Control and Management Act, 2016 (Act 917) and the Environmental Assessment Regulations.[110]

EPA Ghana joined hands with the World Bank in 1997 to monitor key air quality indicators - sulphur dioxide, carbon monoxide, black carbon PM_{10}, and total suspended particulates under a program that ended in 2001. In 2004, an Air Quality Management Capacity Building Programme was jointly by USAID, the US EPA, and EPA Ghana, involving installation of air quality monitors across residential, commercial, industrial and roadside sites throughout Accra.[111]

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[106] Ibid.
[107] Sewor, C., Obeng, A. A., & Amegah, A. K. (2021). Commentary: The Ghana Urban Air Quality Project (GHAir): Bridging air pollution data gaps in Ghana. Clean Air Journal, 31(1). https://doi.org/10.17159/caj/2021/31/1.11172
[108] Romanello, M., Walawender, M., Hsu, S., Moskeland, A., Palmeiro-Silva, Y., Scamman, D., Ali, Z., Ameli, N., Angelova, D., Ayeb-Karlsson, S., Basart, S., Beagley, J., Beggs, P. J., Blanco-Villafuerte, L., Cai, W., Callaghan, M., Campbell-Lendrum, D., Chambers, J. D., Chicmana-Zapata, V., … Springmann, M. (2024).The 2024 report of the Lancet Countdown on health and climate change: Facing record-breaking threats from delayed action. *The Lancet, 404*(10465), 1847–1896.https://doi.org/10.1016/S0140-6736(24)01822-1
[109] Greater Accra Region air quality management plan. (2024). Climate & Clean Air Coalition. https://www.ccacoalition.org/resources/greater-accra-region-air-quality-management-plan

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3.4 Legal Framework

Ghana's 1992 Constitution provides the right to sound environment and assigns responsibility of sustainable use of Ghana's natural resources to both the state and citizens. Article 36(9) of the constitution states" the State shall take appropriate steps needed to protect and safeguard the national environment for posterity; and shall seek cooperation with other states and bodies for purposes of protecting the wider international environment for mankind." The National Environmental Policy adapted in 1991 was the first comprehensive policy that provided the framework to implement the National Environmental Action Plan (NEAP).[112]

The Renewable Energy Act,2011 (Act 832) was passed by the parliament of Ghana with the motive to expand the share of renewable energy in the electricity generation mix. The act provides fiscal incentive to ensure adequate returns on energy investments.[113]

4. Impact

Despite the various laws and policies that exist in Ghana related to improving the air quality and reducing GHG emissions, it lacks a unified national air quality management (AQM) framework. Air Quality Management was first outlined in the Environmental Protection Agency Act 1994 (Act 490) and the Environmental Assessment Regulations,1999. Subsequent policies like the National Environmental Sanitation Strategy and Action Plan (2010), to curb open burning of municipal waste and National Environmental Policy (2014), that called for stronger compliance and monitoring systems. In 2018 Ghana's National Action Plan was introduced to combat emissions of Short-Lived Climate Pollutants (SLCP).[114]

[110] Frimpong-Boateng, K., & Pwamang, J. (2018). National action plan to mitigate short-lived climate pollutants. Republic of Ghana.
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04 Paris

France

1. Introduction and Context

Transportation is the largest contributor to Paris's air pollution, contributing to approximately 45% of nitrogen oxide emissions. Apart from this, emissions from residential and commercial buildings add to the overall emissions. The pressure is compounded due to the high population density of the region, which has demands for heating, transportation etc. Beginning in 2025, all French cities with more than 1,50,000 residents will be required to establish Crit'Air low-emission zones[115].

Stoppollution, a campaign launched by Paris's City Hall, warned that living in Paris is equivalent to smoking eight cigarettes per day[116].

2. Policy Framework and Planning

In 2024, Paris came up with its Climate Plan 2024-2030, outlining the city's policy agenda towards 2050 sustainability targets. It is aimed at meeting the European Union's climate targets for 2030. The city has adopted strategies like expansion of cycling infrastructure, promotion of cycling as mode of transport, establishing low emission zones and traffic reduction measures[117].

Paris's strategy to combat traffic related air pollution includes improvements to the city's flagship self-service bike and electric car sharing schemes, Velib' and Autolib'. Free transportation and free access were provided to Vélib and Autolib (Rodriguez, 2016). Paris added 1,279 bicycle parking spaces in 2014 and planned the installation of 1,400 km of cycle lanes by 2020.Diesel fuelled motor vehicles contribute approximately 40% of total emissions[118]

Under Crit'Air vehicles in France are classified into six colour coded categories according to emissions of pollutant types. The sticker is displayed on the windscreen of the car and remains valid for the lifetime of the vehicle. It is already practiced across more than 300

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European cities. Higher polluting vehicles are denied access to certain areas and during episodes of elevated pollution levels (James, 2025). As per anti-pollution measures, motorists were required to display colour coded air quality certificates linked to their emission levels[119].

Trucks and cars with Crit'Air 5 registration, registered between 1997 and 2000 were banned from July,2017. More than half of the cars in the Paris region faced restrictions due to record heatwave conditions. The city council has plans to tighten these regulations, till 2030 with the objective of only electric and hydrogen-fuelled cars running on the Paris roads by that year[120].

3. Impact

IAirparif's latest assessment of the region's air quality indicates a 45% reduction in nitrogen dioxide levels between 2014 and 2024. These reductions have been possible due to lower emissions from road traffic, heating, and industrial activities[121]. As per Airparif, the fine particulate matter (PM2.5) levels have dropped by 55 percent since 2005, while levels of nitrogen dioxide have fallen by 50 percent. These reductions were credited due to regulatory measures and policies, including traffic reductions and banning polluting vehicles. Paris Mayor, Anne Hidalgo since assuming office in 2014 has led a series of green initiatives. As noted by The Washington Post, under her leadership 50,000 parking spots were eliminated[122].

As per 2022 study deaths attributed to air pollution declined from 10,350 to 6,220 between 2010 and 2019. The study further determined that alignment of air pollution levels as recommended by the WHO, could have prevented more than 7,900 deaths per year in the Île-de-France region[123].

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05 London

England

1. Introduction and Context

The 1952 London smog caused between 4,000 and 12,000 casualties, with daily fatalities higher than those seen at the time of Covid-19 in the UK. This led to the 1956 Clean Air Act, that targeted the reduction of domestic coal burning in London[124]. The Clean Air Act, 1956 established Smoke Control Areas in the city[125]. In 1952 coal accounted for 61% of the energy needs of London City, with household consumption making up 28% of this share. The United Kingdom government responded to the Great Smog with Clean Air Act 1956[126]. During the 1980s, unleaded petrol was introduced. A clean diesel programme was introduced in the 1990s and Euro emission standards were also introduced at the same time[127].

London introduced the Low Emission Zone (LEZ) as its emission control scheme. Initially heavy goods vehicles were charged a certain fee to decongest and reduce vehicular emissions. In subsequent revisions, it was extended to all commercial vehicles that did not meet Euro IV standards. Sadiq Khan, mayor of London, decided to expand the Ultra Low Emission Zone (ULEZ) to cover the whole of Greater London in 2022. Another policy adopted is low traffic neighbourhoods (LTNs), which has been successful in lowering car ownership, reducing NO_2 levels[128].

London has failed to meet the European Union (EU) air quality standards since 2010, largely due to the prevalence of diesel vehicles which contribute to high NO_2 emissions[129].

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2. Policy Framework and Planning

The Clean Air Act was passed in 1956, in response to the Great Smog of 1952. The act regulated domestic fireplaces and created smoke control areas[130]. Monitoring of sulphur Monitoring of sulphur dioxide was started in January 1954 as a consequence[131]. Ambient air quality standards were established for the first time under the Mayor's Air Quality Strategy in 1980. Subsequently, the Environment Act 1995 mandated the government to have a national air quality strategy, with certain objectives and measures to achieve them[132].

The London Air Quality Network (LAQN) was established in 1983 at King's College London by the Environmental Research Group (ERG)[133].

The city of London has been promoting clean air zones as a strategy to tackle air pollution. At a local level, measures like speed restrictions were introduced focusing on schools, hospitals, and other sensitive areas. Low Emission Zones were introduced throughout the whole of London from 2009 restricting heavy polluting vehicles. An Ultra- Low Emission Zone was introduced in 2019 covering the entire city[134] [135]. A Congestion Charging Scheme was also introduced in central London in 2003[136].

Emissions from vehicles are a major source in London, with over 97% of carbon monoxide emissions and around 75% of NOx emissions[137]. Diesel vehicles account for 40 per cent of all NOx emissions within London. A modelling study by King's College London suggested that by reducing diesel cars in inner London to just 5% of the vehicle fleet, could bring 99.96% of London into compliance with legal NO_2 limits[138].

London's fight is supported by the Mayor's £27 million Air Quality Fund, supplemented by over £20 million from boroughs and partners. A Breathe London programme was launched, under which 400 air quality sensors were installed to monitor pollution levels across the city. Installation of nearly 19,000 electric vehicle charging points was supported, helping transition to electric vehicles. Since 2019, £271 million has been provided to help residents scrap or retrofit non-compliant vehicles and shift to cleaner alternatives. Around 95% of vehicles driven in London on an average day meet ULEZ today[139].

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3. Impact

Air pollution levels in London have dropped since 2016 by 65% in central London, 53% in inner London, and 45% in outer London. Significant credit is given to the introduction and expansion of the ULEZ, first implemented in 2019 and extended in 2021 and 2023. Other measures like promoting electric and hybrid buses have added to the gains[140].

The number of air quality monitoring stations where the UK's annual legal limit for NO_2 dropped from 56 sites in 2016 to just five in 2023. The levels of nitrogen dioxide (NO2) have fallen significantly in London compared to the rest of the UK since 2016. The number of Londoners living in areas with high levels of nitrogen dioxide dropped by 94 per cent, between 2016 and 2020 along with reductions in air pollution across the city[141]. Between 1950 and 2000, annual average smoke and SO_2 in London declined by approximately 95% and 98%, respectively[142].

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Abbreviations

AQMP	Air Quality Management Plan
BRT	Bus Rapid Transit
BTH	Beijing Tianjin Hebei
CAM	Metropolitan Environmental Commission
CAMe	Environmental Commission for the Megalopolis
CNG	Compressed Natural Gas
CO	Carbon Monoxide
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
GHAir	Ghana Urban Air Quality Project
GHACCO	Ghana Alliance for Clean Cookstoves
INECC	National Institute of Ecology and Climate Change (Mexico)
JICA	Japan International Cooperation Agency
LGEEPA	General Law of Ecological Equilibrium and Environmental Protection (Mexico)
LPG	Liquefied Petroleum Gas
MCMA	Mexico City Metropolitan Area
NCAP	National Clean Air Programme
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides
OBD II	On Board Diagnostics II
OECD	Organisation for Economic Co operation and Development
PICCA	Comprehensive Program Against Air Pollution in the Mexico City Metropolitan Area
PIREC	Comprehensive Pollutant Emission Reduction Program
$PM_{2.5}$	Particulate Matter with aerodynamic diameter of 2.5 micrometres or less
PM_{10}	Particulate Matter with aerodynamic diameter of 10 micrometres or less
PPM	Parts Per Million
PRD	Pearl River Delta
PROAIRE	Program to Improve Air Quality
SEDEMA	Secretariat of the Environment (Mexico City)
SEMARNAT	Secretariat of Environment and Natural Resources (Mexico)
SO_2	Sulphur Dioxide
ULG	Urban Local Government
U.S. EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WHO	World Health Organization
YRD	Yangtze River Delta
ZMVM	Zona Metropolitana del Valle de México

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London

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