# East Asia Carbon-Neutral Cities Accelerator (2025 Edition) :

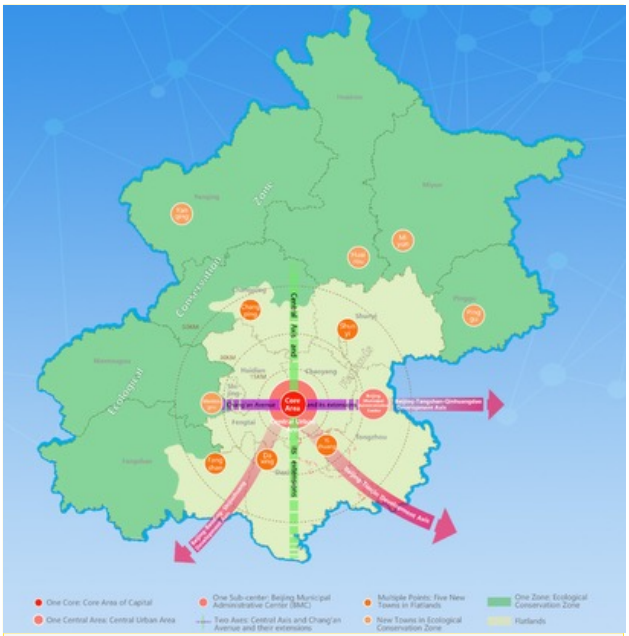
# Strengthening Precision VOCs Control through Innovative Approaches


## 1. Background

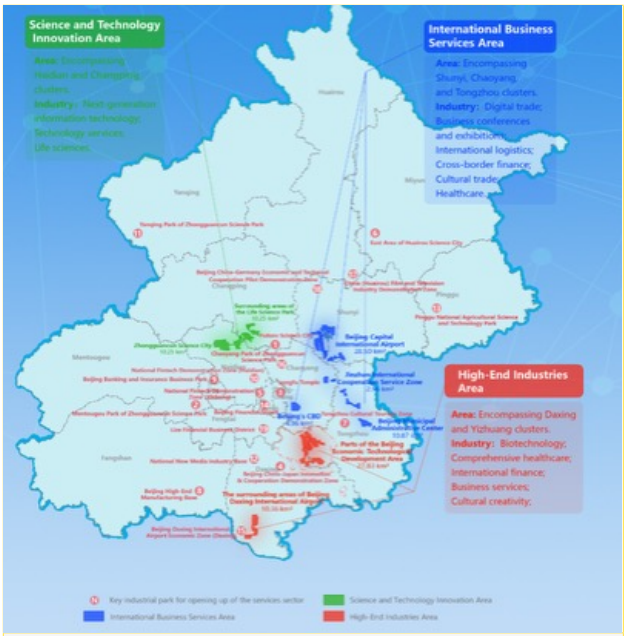
Beijing, the capital of the People's Republic of China, serves as the nation's political, cultural, and technological hub. As a megacity with over 21.8 million residents and a land area of 16,410 km$^2$, Beijing has experienced rapid urbanization and economic transformation in recent decades.

Beijing's economic structure has undergone significant adjustment over the past decades, transitioning from a secondary industry-dominated economy to a tertiary industry-dominated economy. According to Beijing's statistical bulletins on national economic and social development in 2024, the tertiary sector accounted for 85.3% of the city's GDP. Nowadays, finance, information technology, scientific research and development, cultural and creative industries, and professional services serve as Beijing's key growth drivers.

The secondary sector, which encompasses manufacturing and construction, continues to decline and now accounts for less than 15% of Beijing's economic output. Specifically, industrial activities have been gradually relocated out of the central urban area since the 2000s, especially those associated with high pollution and high energy consumption.



Beijing Industrial Master Plan (2016-2035)



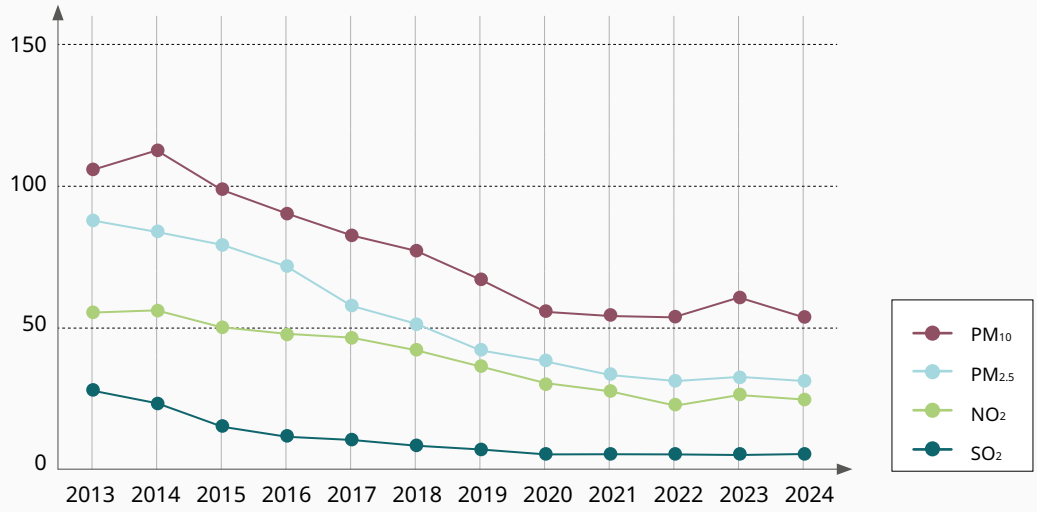

Beijing Industrial Map issued in 2024

Source - Beijing Municipal Commission of Development and Reform

Despite the transformation, legacy sources of emissions, including construction activities, transportation, residual small-scale industrial operations in peri-urban areas, as well as other non-restricted emissions, continue to pose challenges to environmental management, particularly with regard to air quality control.

Beijing has made significant efforts to improve its air quality in recent years, especially since the launch of **Beijing's 2013-2017 Clean Air Action Plan** in 2013, with specific annual clean air plans developed each year. In 2014, Beijing enacted **Regulations of Beijing Municipality on the Prevention and Control of Atmospheric Pollution,** which is the first local regulation in China setting the control of fine particles ($PM_{2.5}$) as the primary objective. From 2016 to 2017, two key documents were introduced to outline Beijing's strategies to combat air pollution in the Beijing-Tianjin-Hebei Region, namely **Implementation Plan for Beijing Municipality on the Implementation of the Enhanced Measures for Air Pollution Prevention and Control in the Beijing-Tianjin-Hebei Region (2016-2017)** and the **Detailed Implementation Plan for Beijing Municipality on the Action Plan for Comprehensive Air Pollution Control during the 2017-2018 Autumn and Winter Season.** These plans focus on reducing emissions from various sources, including industrial activities, transportation, and residential heating. With urban operations and daily life activities becoming the primary sources of air pollution, the city developed the **Three-Year Action Plan for the Blue Sky Protection Campaign in Beijing** in 2018, outlining a comprehensive roadmap for air pollution control in Beijing. Based on the progress made in the previous years, the city's air pollution control efforts have been upgraded from the "1 microgram" campaign to the "0.1 microgram"

**Trend of Annual Average Concentrations of Major Air Pollutants from 2013 to 2024**




According to the Ambient Air Quality Standards (GB3095-2012), the Grade II limit values for six major air pollutants are as follows : $PM_{2.5}$: 35 μg/m³; $SO_2$: 60 μg/m³; $NO_2$: 40 μg/m³; $PM_{10}$: 70 μg/m³; CO (24-hour average): 4 mg/m³; $O_3$ (8-hour average): 160 μg/m³.

Source - 2024 Beijing Municipal Environmental Protection Bulletin

campaign, requiring more scientific measures and more meticulous control.

Key strategies are in place across multiple sectors with tangible outcomes. In the industrial sector, over 2,600 polluting enterprises have been closed or relocated out of the city since 2013, particularly in the cement, chemical, and metallurgy sectors. In the transportation sector, the city has implemented increasingly strict emission standards for in-use vehicles, while actively promoting new energy vehicles and phasing out older high-emission vehicles. As of April 2025, the number of new energy vehicles in Beijing has exceeded one million. In the construction sector, real-time monitoring and stricter compliance inspections significantly contributed to the reduction of fugitive dust emissions from construction sites and roads. Meanwhile, the city also put a lot of effort into transitioning the energy structure. By the end of 2023, approximately 1.38 million households in the city will have implemented the “coal-to-clean energy” program, with 93% of villages and 96% of rural households achieving clean heating with cleaner alternatives, such as electricity and natural gas.

Following the implementation of multi-sectoral strategies, the city’s air quality has improved significantly, with a notable reduction in multiple air pollutants. According to the 2024 Beijing Municipal Environmental Protection Bulletin, $PM_{2.5}$ has dropped by 65.9% since 2013. Specifically, annual concentrations fell from nearly 90 μg/m³ in 2013 to around 30.5 μg/m³ in 2024, meeting China’s national standard for the first time in 2021. Other

pollutants have also decreased significantly: $PM_{10}$ by 50%, $NO_2$ by 57.1%, and $SO_2$ by approximately 88.7% between 2013 and 2024 .

With significant improvements achieved in controlling $PM_{2.5}$ and other major air pollutants, governance of Volatile Organic Compounds (VOCs) emissions, which lead to ozone formation and severe public health challenges, has gained substantial attention in recent years. Initially, Beijing's efforts in VOCs governance have been focused on key industries, such as the industrial sector, the transportation sector, and several solvent-intensive industries. Particularly, the city has actively promoted industrial upgrading and restructuring, and the construction of end-of-pipe treatment facilities. Subsequently, with a significant reduction in organized emissions, measures have been gradually expanded to include the control of unorganized emissions. Through these comprehensive sector-targeted measures, Beijing has achieved a significant reduction in VOCs emissions. According to the preliminary analysis released by Beijing Municipal Ecology and Environment Bureau, anthropogenic VOCs emissions in 2023 in Beijing decreased by 64.6% compared to 2013.

# 2. Policy Analysis

## 2.1 Evolution of VOCs Control Policies and Regulatory Frameworks

Over the past decade, Beijing has gradually strengthened its efforts to control VOCs, in response to growing public health concerns and the urgency of controlling ozone pollution. The National 12th Five-Year Plan for Environmental Protection (2011-2015) proposes to implement comprehensive control of multiple air pollutants and strengthen the control of VOCs emission at the national level. In response to the national plan, Beijing has formulated and updated the **List of Key Monitored Enterprises in Beijing during the 12th Five-Year Plan Period** to strengthen supervision of key pollution sources in the early 2010s. The list included a total of 418 key monitored enterprises, with 64 enterprises emitting VOCs. From 2015 to 2017, Beijing Municipal Ecology and Environment Bureau organized the drafting of **local VOCs emission standards** targeting various industries, in accordance with the requirements of the Beijing Clean Air Action Plan. In this stage, VOCs control in Beijing mainly focused on large industrial sources, especially in sectors like printing, furniture manufacturing, and painting.

Following these initial efforts, the policy frameworks of VOCs governance became more detailed and included a wider range of industries, particularly with the introduction of national plans like the 13th Five-year Plan for Economic and Social Development (2016-2020) and local Clean Air Action Plans. Beijing also clearly defined its **emission reduction targets** for this period, aiming to reduce $NO_X$ and VOCs by 20% by 2020 compared to 2017 levels. To achieve the specific target, the city implemented a series of measures across multiple sectors. Measures for this phase include implementing classified control of VOCs emissions, formulating or revising a set of **stricter emission standards** for pollutants, e.g., limits on VOCs content in products, as well as **monitoring methods and technical specifications,** and actively promoting the inclusion of VOCs in the scope of taxation. In addition to restrictive measures, Beijing is also actively providing technical and financial support to encourage various industries to take proactive measures to reduce VOCs emissions.

Since 2021, the city has focused on building a more comprehensive VOCs management system and has also set a clear emission reduction goal in accordance with the requirements listed in the national Action Plan for Continuous Improvement of Air Quality, aiming to cut total VOCs emissions by 10% by 2025 compared to 2020 levels. This requires a combination of mandatory measures and voluntary efforts, such as real-time monitoring at major facilities, regular inspections for strict compliance, and purchasing low-VOCs products in daily life. What's more, with the support of advanced low-VOCs technologies, districts and industrial parks have strengthened their capacity to control VOCs emissions, showing a shift toward full-process control, actively addressing unorganized and fugitive emissions.

Overall, Beijing's VOCs policies have evolved from basic industrial regulation to a more integrated approach, combining standards, monitoring, and technological improvements to address diverse and diffuse emission sources.

In the following section, Beijing's progress in reducing VOCs emissions in different sources will be analyzed, mainly focusing on the combination of strict local standards with active supervision and behavioral guidance.

## 2.2 Policy Governance and Control Measures

### 1) Industrial Sources

Beijing's VOCs governance in the industrial sector primarily targets the petrochemical industry, printing sector and other high-VOCs emission industries.

**Petrochemical Industry**

The **petrochemical industry** is a major source of VOCs emissions in Beijing. The emissions mainly come from the storage, transport, processing, and leakage of raw materials and products. Since the early 2010s, Beijing has continuously strengthened VOCs control measures in this industry. First of all, it requires that the enterprises enhance the maintenance of all types of facilities involved to ensure that organized emissions meet standards. Second, for those processes prone to unorganized emissions, such as storage and transportation, enterprises should promptly replace valves, pumps, compressors, and other devices easily leading to leakages. Concurrently, dynamic leak detection and repair (LDAR) programs are implemented to control leakage at all sealing points.


Emission Standards of Air Pollutants for Petroleum Refining and Petrochemicals Manufacturing Industry (DB11/447-2015)


Emission Standards for Air Pollutants of Miscellaneous Organic Chemicals Manufacturing (DB11/1385-2017)

Source - Beijing Municipal Ecology and Environment Bureau

For instance, the Beijing Municipal Environmental Protection and Ecological Construction Plan for the 13th Five-Year Plan Period(2016-2020) set strict control requirements on unorganized emissions and limiting leakage rates at all sealing points to below 1%. Besides, to prevent and avoid abnormal emissions, the management systems are continuously improving to control VOCs emissions during startup, shutdown, maintenance, and abnormal operations of petrochemical production facilities.

The **Summer Campaign on VOCs Control** launched in 2024 further strengthened the reduction of unorganized emissions from key enterprises in the petrochemical industry, focusing on storage tanks and deep treatment of exhaust gas. In addition, Beijing has introduced stricter air pollutant emission standards built on national standards, in line with its stringent emission reduction targets and advanced capacity. These local standards include the **Emission Standards of Air Pollutants for Petroleum Refining and Petrochemicals Manufacturing Industry (DB11/447-2015) and the Emission Standards for Air Pollutants of Miscellaneous Organic Chemicals Manufacturing (DB11/1385-2017)**. DB11/447-2015 stipulates that for refining and petrochemical industry equipment, the leakage detection value for pumps or compressors handling VOCs gases or liquids is 1,000 μmol/mol, which is significantly lower than the national standard (GB 31570-2015) of 2,000 μmol/mol.

### Printing Industry

The printing industry is another key industry of Beijing that contributes substantially to VOCs emissions. In 2023, printing companies in the city generated over 24 billion RMB revenue. However, the industry involves extensive use of organic solvents, such as printing inks, adhesives, and cleaning agents, which emit significant amounts of VOCs during production.

In 2013, Beijing launched a special environmental protection campaign to rectify illegal emissions and safeguard public health, mandating enforcement inspections in the printing industry. The campaign strengthened environmental supervision of VOCs emissions from key controlled processes in the printing industry, focusing on the installation and operation of waste gas collection and treatment facilities, and strictly investigating unorganized waste gas emissions.

Since 2016, the use of raw materials with low-VOCs content has been actively promoted. The city and its printing enterprises conducted a wide range of clean production audits to ensure the use of low-VOCs materials in the production process, controlling VOCs from diverse sources. Concurrently, efficient solvent recovery and exhaust gas treatment systems have been installed, showing the efforts to manage VOCs emissions through end-of-pipe treatment.

Meanwhile, Beijing has made substantial efforts to establish a high-standard VOCs emission standard system. In May 2015, Beijing issued the local standard, **Emission Standards of Volatile Organic Compounds for Printing Industry (DB11/1201-2015)**, which primarily sets content limits for raw and auxiliary materials, process requirements, and management standards for VOCs emissions in this industry. This standard is one of the first industry-specific VOCs emission standards in Beijing. To expand the scope of control, Beijing Municipal Ecology and Environment Bureau and the Municipal Market Supervision and Administration Bureau jointly issued the **Emission Standards of Air Pollutants for Printing Industry (DB11/1201-2023)** in April 2023, replacing the previous one. This reflects stricter pollution control measures for the printing industry, covering not only VOCs but also

other air pollutants. The standard covers aspects from source control to end-of-pipe treatment, including both organized and unorganized emissions.


Emission Standards of Air Pollutants for Printing Industry (DB11/1201-2023)

Source - Beijing Municipal Ecology and Environment Bureau

### Coating and Manufacturing Industries

The city also focuses on those industries that extensively use VOCs-containing raw and auxiliary materials or emit large amounts of VOCs, such as industrial coating and manufacturing. The results of the Beijing VOCs pollution source census indicate that among industrial sources in Beijing, industrial coating accounts for a significant proportion of VOCs emissions from solvent-using pollution sources. Enterprises in Beijing that engage in coating processes primarily use solvent-based coatings. However, the application levels of low-VOCs content coatings, such as high-solid coatings, water-based coatings, and powder, are not high. What's more, the coating processes primarily involve low-efficiency air spraying and manual brushing, while efficient techniques such as immersion coating, flow coating, roller coating, and electrostatic spraying account for a minimal proportion. As a result, the production process inevitably generates a large amount of VOCs. To address these issues, Beijing has issued an industry-specific local standard **Emission Standards of Air Pollutants for Industrial Surface Coating (DB11/1226-2015)**, strengthening control over VOCs emissions from industrial coating enterprises and minimizing VOCs emissions from industrial coating processes. Essentially, the implementation of the standard guide industrial coating enterprises to adopt clean production processes, optimize coating processes and equipment, and install efficient and stable end-of-pipe treatment equipment.

According to the data released in 2022, the **automotive manufacturing industry** contributes approximately 20% of Beijing's industrial VOCs emissions, making it one of the city's primary focuses to control VOCs from industrial sources. Within this sector, vehicle assembly comprises over two-thirds of total VOCs emissions, while parts and accessories manufacturing, engine production, and vehicle modification collectively account for more than 30%. Since 2015, the vehicle manufacturing sector has implemented the **Emission Standard of Air Pollutants for the Painting Process of the Automobile Manufacturing Industry (DB11/1227-2015)**, while vehicle modification manufacturers and those producing parts and accessories with coating processes adhere to **DB11/1226-2015**. To consolidate previously fragmented control requirements for the automotive manufacturing industry, Beijing released the **Emission Standards of Air Pollutants for the Automotive Manufacturing Industry (DB11/1227-2023)** in


Emission Standards of Air Pollutants for Industrial Surface Coating (DB11/1226-2015)


Emission Standards of Air Pollutants for Automotive Manufacturing Industry (DB11/1227-2023)


Emission Standards of Air Pollutants for Wooden Furniture Manufacturing Industry (DB11/1226-2015)

Source - Beijing Municipal Ecology and Environment Bureau

2023, on the basis of DB11/1227-2015, national standards and its technological capacity. Taking effect on January 1, 2024, DB11/1227-2023 refines requirements for VOCs-containing raw and auxiliary materials, adjusts organized emission control indicators, and specifies unorganized emission control requirements. Its implementation supports automotive manufacturers in advancing source substitution, enhancing the collection and control of fugitive emissions, and standardizing the operation and maintenance of end-of-pipe treatment facilities.

In addition to the automotive manufacturing industry, Beijing has also made efforts in controlling air pollutants such as VOCs and paint mist generated from the **wood furniture manufacturing industry.** As of 2015, Beijing had over 1,000 wood furniture manufacturers. To regulate the environmental practices of wood furniture manufacturers, the city established the **Emission Standards of Air Pollutants for Wooden Furniture Manufacturing Industry (DB11/1226-2015)**.

According to regulations, the use of oil-based coatings will be completely banned in Beijing's furniture manufacturing industry after 2017. This local industry-specific standard sets limits on VOCs content in raw and auxiliary materials used in the industry, along with process measures and management requirements, to control VOCs emissions at the source.

### 2) Transportation Sources

Among the anthropogenic VOCs emission sources in Beijing, transportation is another major emission source. Through optimizing motor vehicles' structures, Beijing has achieved a reduction in VOCs emissions from transportation over the past decade. The city has also made efforts targeting other major sources in the transportation sector, with a particular focus on fuel distribution and asphalt-related activities.

### Fuel Distribution Industry

The fuel distribution industry involves sites and facilities such as gasoline stations, storage depots, and tanker trucks. VOCs are easily evaporated during storage, loading, and refueling processes. To address this issue, Beijing has been developing and updating its local emission standards focusing on this industry in recent years. In 2003, Beijing, the first city in China, implemented three local standards for oil vapor emissions from storage depots, gasoline tankers, and filling stations. Since then, Beijing has effectively promoted comprehensive management of VOCs emissions throughout the entire process. According to official data, the oil recovery efficiency has exceeded 80% in 2024 compared to the level in 2003, achieving significant emission reduction benefits.

In 2023, Beijing revised the three standards for the third time to meet the city's updated air quality goals and to align with technological advancements. The newly released standards are **Emission Control and Limits of Vapor for Bulk Petroleum Terminals (DB11/206-2023)**, **Emission Control and Limits of Vapor for Road and Rail Tankers (DB11/207-2023)**, and **Emission Control and Limits of Vapor for Gasoline Filling Stations (DB11/208-2023)**. These standards feature tighter emission limits, enhanced leak detection protocols, and new requirements for online monitoring. Considering that high temperature accelerates the release of VOCs, corresponding measures have been adopted. Gas stations and oil storage facilities are requested to stagger fuel loading and unloading times during the summer and encouraged to refuel during night time.

### Asphalt-related Industry

Asphalt is widely used in urban operations and requires high-temperature conditions for handling. Its production, transportation and paving processes all contribute to a high level of VOCs emissions. Recognizing these challenges, the city has developed several targeted measures to


Emission Control and Limits of Vapor for Bulk Petroleum Terminals (DB11/206-2023)


Emission Control and Limits of Vapor for Road and Rail Tankers (DB11/207-2023)


Emission Control and Limits of Vapor for Gasoline Filling Stations (DB11/208-2023)

Source - Beijing Municipal Ecology and Environment Bureau


Technical Guide for Green Evaluation of Asphalt Mixture in Beijing (BJJT/ 0066-2022)

Source - Beijing Municipal Commission of Transport


Technical Requirement and Evaluation for Green Production of Asphalt Mixing Plants (DB11/T 2424-2025)

Source - Beijing Municipal Administration for Market Regulation

control emissions from asphalt-related activities. In 2022, Beijing issued the **Technical Guide for Green Evaluation of Asphalt Mixture in Beijing (BJJT/ 0066-2022)** , which guides the green evaluation and labeling of asphalt mixtures in the city. Accompanied by newly released local standards **Technical Requirement and Evaluation for Green Production of Asphalt Mixing Plants (DB11/T 2424-2025)**, this industry-specific guide stipulates various measures for VOCs emissions reduction in the asphalt sector, covering different processes. They facilitate overall upgrading of asphalt mixing equipment, promote green logistics of asphalt concrete and encourage the use of low-emission warm-mix asphalt to replace traditional hot mix methods, which is prone to more VOCs emissions. At the same time, the city promotes the upgrade of pollution control facilities and advanced treatment technologies at the pilot sites, aiming to treat VOCs more efficiently. These actions reflect Beijing's broader shift toward source-specific, process-oriented VOCs control.

### 3) Domestic Sources

In addition to industrial and transportation-related sources, Beijing has also been focusing on VOCs emissions from everyday urban activities, particularly from catering and automotive repair.

#### Catering Industry

As a densely populated city with strong food services, cooking fume emissions from restaurants, street food stalls, and commercial kitchens have become a major component of total urban VOCs. The catering industry in Beijing is large, diverse, and often concentrated in mixed-use residential and commercial areas. Many small and medium-sized establishments operate with limited space and ventilation infrastructure, making the control of VOCs a significant challenge. Given this context in 2018, Beijing released the **Emission Standards of Air Pollutants for Catering Industry (DB11/1488-2018)**.

Based on the national standard GB18483,

this standard incorporates Beijing's unique requirements for air pollution management. It includes particulate matter and VOCs to the control list, targeting integrated removal of these two types of air pollutants. This is one of the first local standards in China to set clear limits on non-methane VOCs emissions for the catering industry, providing quantitative indicators for VOCs control.

To facilitate the implementation of the standard, specific operational requirements are also outlined to provide scientific guidance for the selection of purification facilities in the catering industry, with economically reasonable maintenance and inspection requirements clearly defined. In addition, Beijing actively provides guidance and assistance to catering establishments in the processes of planning, construction, restaurant site selection, leasing, registration, renovation, pre-opening and so on, improving the environmental management level of the catering sector.


Emission Standards of Air Pollutants for Catering Industry (DB11/1488-2018)

Source - Beijing Municipal Ecology and Environment Bureau

**Automotive Repair Industry**

Among domestic VOCs sources, the automotive repair sector in Beijing represents another significant contributor due to its widespread use of solvent-based coatings and auxiliary materials. By the end of 2023, there are 4,890 registered auto repair businesses in the city. Emissions inventories over the past five years show that the auto repair industry in Beijing emits approximately 2,000 tons of VOCs annually, accounting for 3.3% of domestic sources. Therefore, this area requires high attention in Beijing's domestic pollution prevention and control efforts.

In response, the city has developed a series of specialized local standards, including the **Emission Standard of Air Pollutants for Vehicle Maintenance and Repair Industry (DB11 1228-2025), Technical Guidelines for Environmental Impact Assessment - Vehicle Maintenance Industry and Repair Industry (DB11/T 2058-2022), Technical Specifications for Pollution Prevention and Control of Vehicle Maintenance and Repair Industry (DB11/T 1426-2017), and Assessment Indicator System of Cleaner Production for Motor Vehicle Repair and Dismantling (DB11/T 1265-2015)**. These standards regulate emission limits, VOCs content in raw materials, purification equipment requirements, and operational practices like record keeping. The government has also published the **Beijing Municipal Handbook on Pollution Prevention and Control in the Automobile Repair Industry** and **Technical Guidelines for On-Site Inspection**, providing guidance to operators and officers for on-site enforcement and inspection. In


| Emission Standard of Air Pollutants for Vehicle Maintenance and Repair Industry (DB11 1228-2025) | Technical Guidelines for Environmental Impact Assessment - Vehicle Maintenance Industry and Repair Industry (DB11/T 2058-2022) | Technical Specifications for Pollution Prevention and Control of Vehicle Maintenance and Repair Industry (DB11/T 1426-2017) | Assessment Indicator System of Cleaner Production for Motor Vehicle Repair and Dismantling (DB11/T 1265-2015) |
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Source - Beijing Municipal Ecology and Environment Bureau, Beijing Municipal Administration for Market Regulation, and Beijing Municipal Administration of Quality and Technology Supervision

addition to setting rules, Beijing applies graded supervision and performance-based regulation. The **Implementation Rules for the Assessment of Pollution Prevention Performance Ratings in the Motor Vehicle Maintenance Industry of Beijing (Trial)** was developed to support the identification of green enterprises and the emergency emission reduction enterprise list during heavy-air-pollution warning days. Lastly, innovative technologies are adopted to ensure accurate enforcement and data-driven actions. Mobile VOCs monitoring vehicles, infrared sensors, and power usage analytics are applied to identify pollution hotspots, trace sources, and verify the synchrony of pollution control equipment with actual production activity.

Furthermore, the city also promotes the replacement of raw and auxiliary materials with low (or zero) VOCs content in both public and private sectors with various measures. In 2018, the **Beijing Action Plan for Important Measures to Deepen Reform and Expand Opening Up** limited VOCs-containing materials that are used in building coatings and controlled organic solvent pollution at the source. Following the green procurement policy updated in September 2018, new construction projects and maintenance projects using public funds must apply low-VOCs-content coating materials and adhesives, starting in 2019.

Additionally, strictly enforcing VOCs content limit standards is implemented by conducting random inspections across different stakeholders, such as supermarkets, building material markets, and manufacturing enterprises. The government regularly exposes on its website products that fail to meet standards along with their manufacturers and sales locations. For products with two or more batches failing inspections, manufacturers are legally traceable and held accountable. Besides, for those industrial enterprises with high annual VOCs emissions (1 ton or more), the government

encourages them to conduct clean production assessments and simultaneously address VOCs-related issues identified during the assessment.

### Architectural Industry

Apart from the measures above, Beijing has established standards to set clear limits on the VOCs content of architectural coatings and adhesive products to reduce VOCs emissions. Unlike traditional industrial sources that can employ end-of-pipe treatment facilities for VOCs reduction, the application of architectural coatings and adhesives typically occurs in open spaces, generating fugitive emissions that can hardly be captured or treated. Reportedly, the VOCs emissions generated from architectural coatings and adhesives, particularly with the usage of solvent-based products, exceed 8,000 tons per year.

To align with national standards, address Beijing's VOCs reduction requirements, protect the environment, and safeguard public health, the **Beijing Municipal Standard for Volatile Organic Compound Content Limits in Architectural Coatings and Adhesives** refines VOCs content limits for these products. This initiative promotes the development and adoption of low-VOCs products within the architectural coatings and adhesives manufacturing sector, thereby reducing VOCs emissions during their application. **Limit Standards of Volatile Organic Compounds of Architectural Coatings and Adhesives** (DB11/ 1983-2022) has been revised based on DB11/3005-2017 to align with national standards and meet the evolving requirements of Beijing's goal on VOCs reduction.


Limit Standards of Volatile Organic Compounds of Architectural Coatings and Adhesives (DB11/ 1983-2022)

Source - Beijing Municipal Ecology and Environment Bureau

This limit standard further refines VOCs content limits for architectural coatings and adhesives, thereby reducing VOCs emissions during the use of these products. The establishment also promotes the development and application of low-VOCs products within the manufacturing industry.

By introducing enforceable emission standards across sectors and strengthening both supervision and support, Beijing is gradually transforming all these sectors into more regulated ones and providing best practices for other cities pursuing low-VOCs urban development strategies.

# 3. Case Study:
## Mobile Monitoring of VOCs in Auto Repair Parks

### 3.1 Background and Objectives

In Beijing, the auto repair and spray-painting sector is a substantial VOCs emission source, particularly in clustered auto repair parks located in urban and suburban areas. The three major processes leading to significant VOCs emissions include vehicle maintenance and repair, painting, and the storage of hazardous waste. First, during vehicle maintenance and repair activities, VOCs are emitted when vehicle parts are cleaned using organic solvents. Second, the painting process, which involves steps such as paint mixing, spraying, drying, and cleaning, is reported as the primary source of VOCs emissions in the auto repair industry. Last, VOCs emissions can occur during the hazardous waste storage process if the sealing is inadequate. Given the multiple emission points and operational steps involved, VOCs management in the auto repair industry remains particularly complex and challenging. In addition, auto repair parks often house dozens to hundreds of small workshops, many of which operate with limited environmental controls, making emissions diffuse, complex, and difficult to supervise through traditional means.

Traditional offline monitoring methods involve periodic manual sampling using various external monitoring instruments, followed by analysis of the collected samples in a laboratory. Offline monitoring analysis offers advantages such as high accuracy and sensitivity of analytical results. However, the analysis process is time-consuming and labor-intensive, with stringent requirements for the operating environment, and restricts the monitoring of real-time changes in VOCs concentrations in a given area.

Manual Sampling for
Traditional Offline VOCs Monitoring
Source - Beijing Municipal Research Institute of Eco-Environment Protection

To address this challenge, as a complement to traditional VOCs monitoring methods, Beijing has actively explored and adopted mobile monitoring to strengthen real-time, spatial resolution supervision of VOCs emissions from the auto repair parks. The goal is to transition from passive, periodic enforcement to proactive, data-driven environmental management.

Mobile monitoring of VOCs mainly uses mass spectrometry methods. Compared with sensor and optical methods, mass spectrometry features accurate response, high sensitivity, and strong interference resistance. Meanwhile, its data resolution is comparatively higher than that of chromatography. The specific technical routes are divided into soft ionization and hard ionization

routes. However, each technical route has its own limitations and shortcomings, and there is an urgent need for standardized guidelines and regulatory frameworks to address these issues.

The updated technical specifications for mobile monitoring of VOCs should standardize various aspects, including instrument performance parameters, quality assurance and control, and evaluation analysis, to achieve a standardized mobile monitoring system. This will enhance the comparability and applicability of data, thereby providing a solid foundation for precise VOCs control in Beijing.

### 3.2 Implementation

In the past five years, Beijing has organized multiple rounds of municipal-level targeted enforcement campaigns, focusing on VOCs emissions from the auto repair industry and other sources. Mobile monitoring can directly obtain the specific concentration of each VOC substance, and categorizes VOCs concentrations into seven levels. The lowest level, with concentrations ranging from 0 to 200 μg/m$^3$, is displayed in green on real-time maps. The highest level, with concentrations exceeding 1,200 μg/m$^3$, is indicated in purple. From the lowest to the highest level, the color progresses from green, light yellow, yellow, orange, red, pink, to purple. This color-coded concentration display method facilitates monitoring agencies in mapping VOCs concentration and identifying areas with high pollutant concentrations.

For example, in the Laiguangyingxiang township of Chaoyang District, 28 auto repair businesses have gathered here, forming a relatively large auto repair cluster. In 2023, according to mobile monitoring results, the Laiguangyingxiang auto repair cluster area had an average of one high-value point every 2.6 km, with peak concentrations reaching several thousand μg/m$^3$, significantly impacting the daily lives of surrounding residents. Accordingly, multiple monitoring points in this area are marked as red bubbles on the map. After identifying key areas with high-VOCs emissions using mobile

Pollution Distribution Map that was generated based on data provided through VOCs mobile monitoring

Source - Beijing Municipal Ecology and Environment Bureau

**Main Working Progress to Develop the Technical Specifications for Mobile Monitoring and Evaluation of Volatile Organic Compounds**

| | | |
|---|---|---|
| 2022 | March | • Initiated the development of the technical specifications and established a working group. |
| | April to July | • Reviewed domestic and international standards and literature, assessed the current state of mobile VOCs monitoring technologies in China, and established the technical route and structure of the specifications. |
| | August to September | • Conducted field research on existing manufacturers of vehicle-mounted VOCs monitoring instruments, performed technical testing, identified key monitoring parameters, and evaluated differences in instrument performance while developing quality assurance and control protocols. |
| | October to December | • Drafted the initial version of the specifications, refined the content under the guidance of the Monitoring Division of Beijing Municipal Ecology and Environment Bureau, and conducted data analysis and experimental validation. |
| 2023 | January 10 to 20 | • Held internal expert consultation to gather professional feedback and finalized a draft for public comment based on feedback. |
| | April 27 to May 26 | • Released draft specification released for public comments to finalize the specification. |
| | December 25 | • Officially approved. |

monitoring, other measures are implemented to pinpoint auto repair companies, such as using the micro-scale atmospheric pollutant dispersion model. For companies identified, the government employs a combination of infrared remote sensing, electricity consumption monitoring, portable monitoring devices, and other investigative tools to conduct thorough on-site assessments. These methods enable inspectors to find out unreported operations, malfunctioning VOCs control systems, and other irregularities. Based on these diagnostics, the government develops tailored "one-enterprise-one-policy" action plans for each non-compliant enterprise, providing professional technical guidance.

VOCs Mobile Monitoring

Source - Beijing Daily Group

On the other hand, following the growing demand for standardized mobile monitoring in VOCs governance, Beijing Municipal Ecology and Environment Bureau initiated the development

of the **Technical Specifications for Mobile Monitoring and Evaluation of Volatile Organic Compounds** in March 2022. This local standard **DB11/T 2174-2023** came into force on April 1, 2024, marking a significant step in standardizing high-resolution, data-driven VOCs supervision.

### 3.3 Outcomes

The mobile monitoring technology and the released standards have driven the refined management of VOCs pollution in the auto repair industry, resulting in a noticeable improvement in air quality in the areas surrounding auto repair clusters.

In addition to monitoring and analysing the collected data itself, Beijing has integrated the mobile data captured with existing emissions inventories, power usage records, and enterprise production schedules to identify unregulated activities. For example, if VOCs levels remain high at times when facilities report no activity, it may indicate unreported or illegal operations.

Taking the high-VOCs area in the Laiguangyingxiang township as an example, the authorities use mobile monitoring to visualize and identify high-VOCs hotspots for targeted on-site investigations and source tracing. Based on the results, they conducted an in-depth investigation, established 36 hotspot monitoring grids covering an area of 22 $km^2$, and defined a total of 6 categories and over 40 typical pollution issues in the auto repair industry, including problems from paint mixing, spray painting, pollution control facilities, and hazardous waste management.

Through refined control of VOCs emissions, upgrading and enhancing the efficiency of treatment facilities, and strengthening the standardized management of hazardous waste, as of October 2024, the number of high-value red-bubbles in the North Fifth Ring Road auto repair cluster has significantly decreased, along with a lower frequency of occurrence. The number of high-value points that is detected per mobile monitoring session has reduced from an average of three to one, with a peak concentration reduction exceeding 80%. Residents have also reported that unpleasant odors are now rarely noticed when passing by.


Vehicle-mounted Mobile Monitoring

Source - Beijing Municipal Ecology and Environment Bureau

## 4. Reflections and Recommendations

Beijing's VOCs governance offers several valuable lessons for other megacities which are experiencing a similar urban transition.

### 1) Develop Stricter Local Standards Based on the City's Own Capacity

Building upon the foundational framework of national regulations and standards, Beijing has consistently advanced its VOCs governance by establishing more stringent local instruments. The city leverages its strong institutional and technical capacity, effectively raising the threshold for compliance while keeping the requirements technically attainable.

### 2) Adopt a Phase-based, Source-targeted Approach

An effective approach to VOCs reduction and management involves a phased and source-targeted deployment of resources. Beijing has initially focused on regulatory stringency on sectors with the highest emission impact, such as fuel distribution, printing, and industrial coating. Following the successful mitigation in these key areas, measures have been gradually extended to cover more complex, dispersed emission sources like catering, auto repair, and small-scale manufacturing.

### 3) Invest in Technical Capacity-building for Precision Enforcement

Equipped with advanced technologies, regular inspections can enable more effective targeted enforcement of stricter local standards. Vehicle-mounted VOCs monitoring serves as an example to show how technological applications can significantly improve enforcement. Authorities are able to track down the sources of pollution more effectively by mapping emissions hotspots in real time, especially within clusters of small businesses. Furthermore, when mobile monitoring data is integrated with other operational data, like energy consumption records, abnormal and underreported operations can be uncovered and identified. This increases the credibility and data-drivenness of compliance checks.

### 4) Promote Low-VOCs Products across Sectors and Strengthen Behavioral Change

Promoting the application of low-VOCs products in both public and private sectors is a practical and effective strategy to control the source of VOCs emissions. Measures such as mandating low-VOCs products application in public projects and promoting private sector adoption through certification and labeling, can reduce VOCs emissions from sources. In addition, regularly disclosing non-compliant products publicly and conducting random consumer goods inspections can significantly increase market pressure for compliance. Lastly, public involvement is essential for long-term VOCs reduction. Encouraging citizens to consume low-VOCs products can shape low-emission behavior and promote voluntary compliance.

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