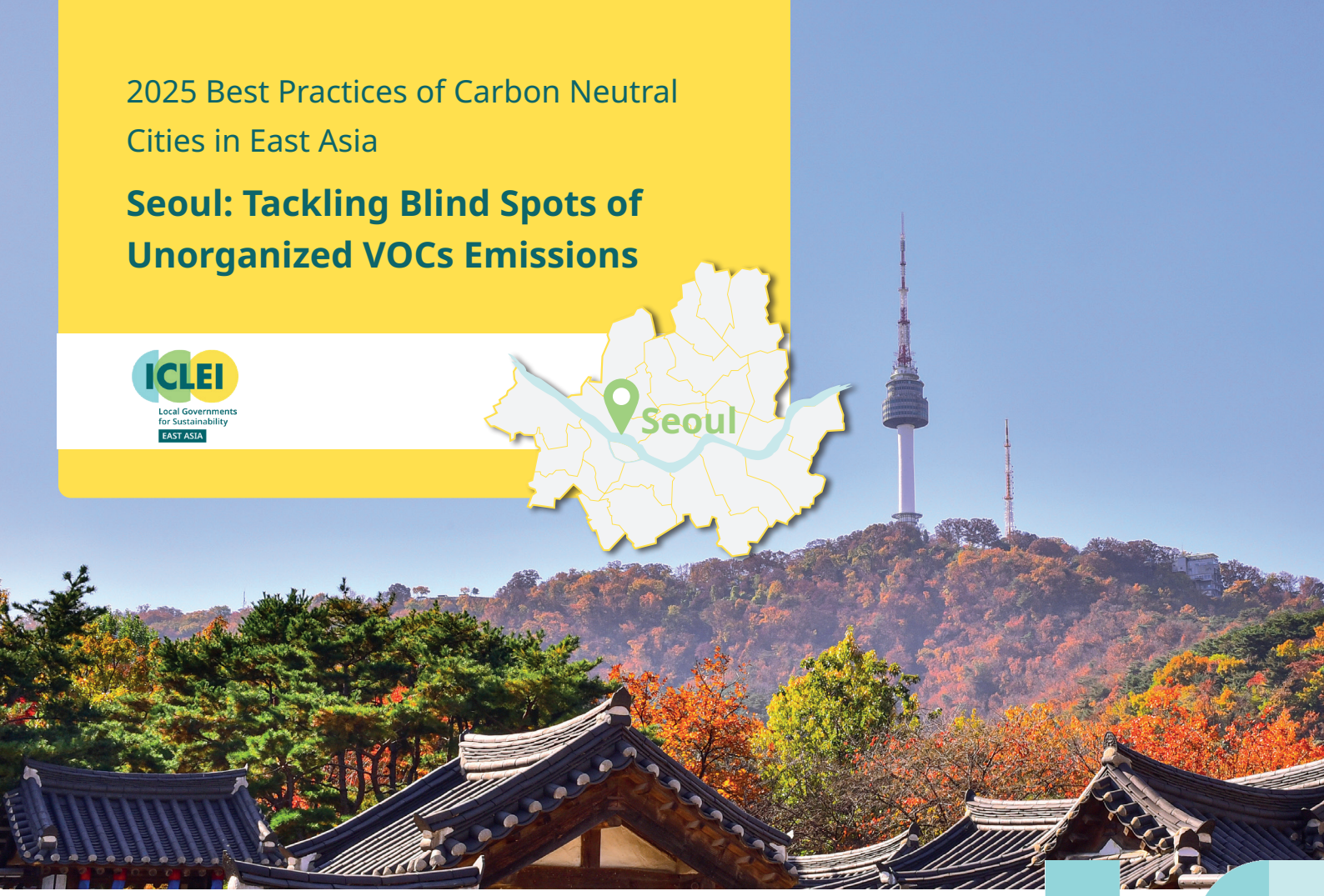
2025 Best Practices of Carbon Neutral Cities in East Asia

Seoul: Tackling Blind Spots of Unorganized VOCs Emissions



1. Background

Seoul, the capital of South Korea, is a densely populated metropolis with 9 million residents within just 605.2 km^2. The city envisions becoming a world-class city in all fields, including culture, environment, welfare, and economy. Its vision is to build a warm and people-centered city, a green city inspired by nature, a vibrant city and a historical and cultural capital. To realize this, Seoul has implemented a wide range of strategic projects.

To address the air quality challenges posed by dense urbanization and rapid industrialization, Seoul has taken multiple initiatives over the past two decades to reduce and prevent air pollution. Seoul's air quality improvement policy has been evolving in a more integrated manner for Seoul's long-term sustainable development. A key moment in this shift was the enactment of the **Special Act on Air Quality Improvement for the Capital Region** in 2003, which fostered collaborative air governance encompassing Seoul, Incheon, and Gyeonggi Province.

In the years that followed, Seoul made continuous efforts to reduce air pollution to meet different priorities. In 2007, Seoul launched the **Clear Seoul 2010 Plan** which focused on mobile sources by converting diesel buses to compressed natural gas (CNG) ones, achieving diesel-free public buses. Seoul also actively promoted the installation

of emission-reduction devices on old diesel vehicles. In 2019, Seoul implemented emergency measures to reduce fine dust emissions, alleviating concentrations through centralized management over a short period of time. The Low Emission Zone in the Green Transport Zone was introduced to permanently restrict grade 5 diesel vehicles. In addition, aged vehicles were restricted during periods of high fine dust concentration through **Emergency Reduction Measures for High Fine Dust Concentration.** Recognizing the seasonal nature of air pollution, Seoul has introduced the **Seasonal Fine Dust Management System**, implemented annually from December to March since 2020. This Seasonal Management System includes targeted winter actions such as construction site special inspections and further restrictions on older vehicles. Most recently, from 2022, Seoul has been pushing forward the **Clearer Seoul 2030 Roadmap** with an ambitious target to reduce annual $PM_{2.5}$ concentrations to 13 μg/m³ by 2030.

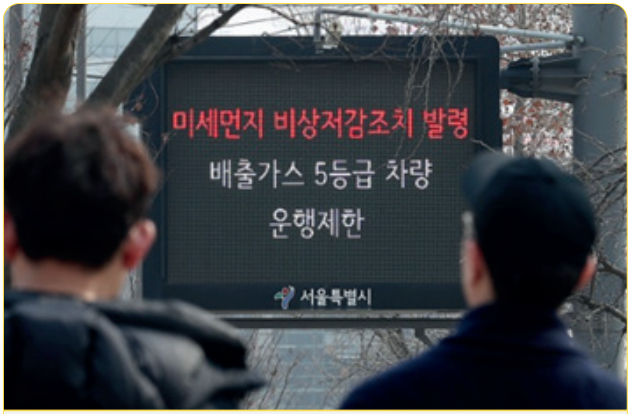
These efforts have delivered tangible results. Between 2008 and 2024, Seoul's annual average $PM_{2.5}$ concentration dropped from 26 μg/m³ to 17.6 μg/m³ —the lowest level recorded since monitoring began. Additionally, other pollutants like NO_X and sulfur oxide (SO_X), have consistently decreased, reflecting improvements across both stationary and mobile emission sources.

With steady reductions in major air pollutants including $PM_{2.5}$, NO_X, and SO_X, ozone and Volatile Organic Compounds (VOCs)became primary concerns of air pollution in Seoul, particularly during the summer months when sunlight accelerates photochemical reactions.

According to Seoul's official data in 2024, Seoul's main source of VOCs emissions is solvent use, accounting for nearly 85% of Seoul's total VOCs emissions—significantly higher than in other major cities such as Busan (77.8%) and Incheon (51.9%). In addition to large-scale solvent use in industrial processes, small-scale solvent use for laundry, printing and painting holds a significant share of VOCs emissions. These activities are mainly concentrated in older neighborhoods like Jung-gu, Euljiro, and the Sewoon District. These

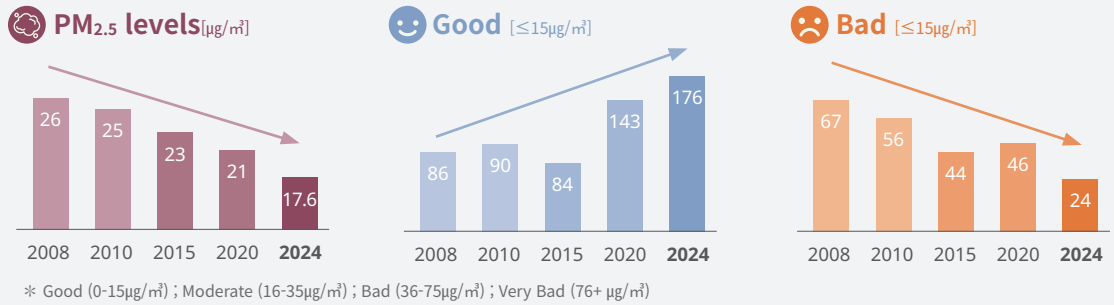


Seoul's Clear Sky
Source - Seoul Metropolitan Government



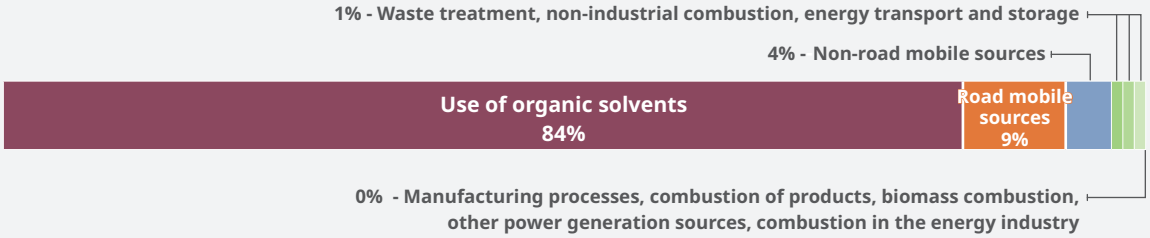
Emergency Reduction Measures for High Concentrations of Fine Dust Source - Seoul Metropolitan Government

$PM_{2.5}$ Levels in Seoul 2008–2024 Source - Seoul Metropolitan Government



* Good (0-15㎍/㎥) ; Moderate (16-35㎍/㎥) ; Bad (36-75㎍/㎥) ; Very Bad (76+ ㎍/㎥)

VOCs emissions by Source in Seoul Source - The Seoul Institute



areas host dense clusters of small and medium-sized enterprises (SMEs) engaged in printing, metalworking, surface treatment, and dry cleaning, many of which are located near residential zones.

To tackle seasonal peak emissions and emissions from scattered, often under-regulated sources, Seoul is proactively adopting targeted and seasonal inter-ventions, such as focused **inspections in high-emission districts, support for SMEs to adopt low-emission equipment and eco-friendly solvents**, and the promotion of low-VOCs products across industries. As a result, between 2018 and 2022, Seoul successfully reduced VOCs emissions by 25%, from 73,118 tons to 54,677 tons.



Euljiro Printing Alley
Source - Seoul Metropolitan Government

2. Policy Analysis

2.1 Evolution of VOCs Control Policies and Regulatory Frameworks

Seoul's approach to managing VOCs has evolved from broad, industry-wide regulation to more localized and sector-specific strategies. This shift reflects Seoul's deeper understanding of VOCs' role in ozone formation, their health impacts in dense urban areas, and the growing need to control emissions from diverse and diffuse sources. This transition laid the groundwork for a more adaptive framework to address localized emission hotspots and seasonal pollution peaks effectively.

Rather than relying solely on traditional end-of-pipe controls, Seoul turned to preventive strategies such as encouraging the use of substitute materials e.g., low-VOCs alternatives, conducting targeted seasonal inspections, and localizing enforcement.

• Phases of VOCs Control Policy Evolution

Phase 1 **Monitoring & Regulation on Major Sources** 1997-2006

- **Key Actions** Designated air quality control zones; specified the responsibilities of businesses (e.g., gas stations, dry cleaning facilities) on VOCs pollution prevention and control
- **Shift** From passive responding to VOCs pollution to active reduction through abatement requirements

Phase 2 **Expansion to Urban SMEs** 2007-2016

- **Key Actions** Extended VOCs regulations to small businesses (e.g., printing, drying); introduced vapor recovery systems at gas stations; and established specific standards for VOCs content in printing
- **Shift** From major industrial sources to diffuse urban emitters

Phase 3 **Enhanced Standards & Localized Management** 2017-Present

- **Key Actions** Expanded the supply and dissemination of low-VOCs products; urged the establishment of a VOCs management system for consumer products
- **Shift** From end-of-pipe control approach to proactive and localized management

2.2 Governance and Control Measures

Building on its evolving policy framework, Seoul has developed a comprehensive set of implementation strategies to translate regulatory intent into tangible outcomes. These strategies are structured around three main pillars: seasonal control measures in summer, routine interventions, and capacity-building programs, especially when

the likelihood and frequency of ozone pollution are higher.

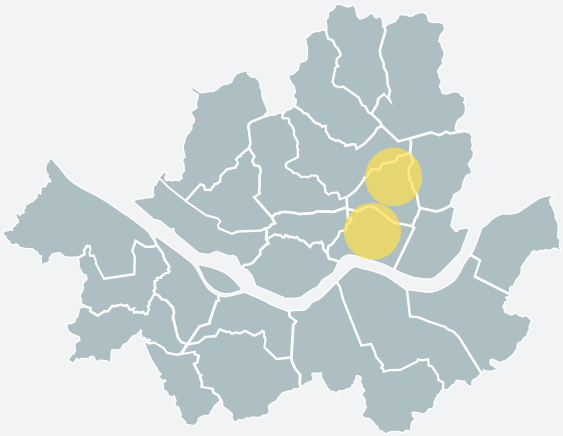
1) Seasonal Control Measures (May-August): Policies in the Industrial, Transportation, and Construction Sectors

In summer, the warmer temperature in Seoul increases the evaporation of VOCs from various sources and accelerates photochemical activities, leading to higher VOCs and ozone pollution. Thus, from May to August each year, Seoul undertakes targeted activities to reduce VOCs emissions and prevent ozone pollution across three major sectors : industry, transportation, and construction. Strict regulatory enforcement is complemented with technical and financial support, especially in high-risk areas where emissions tend to concentrate.

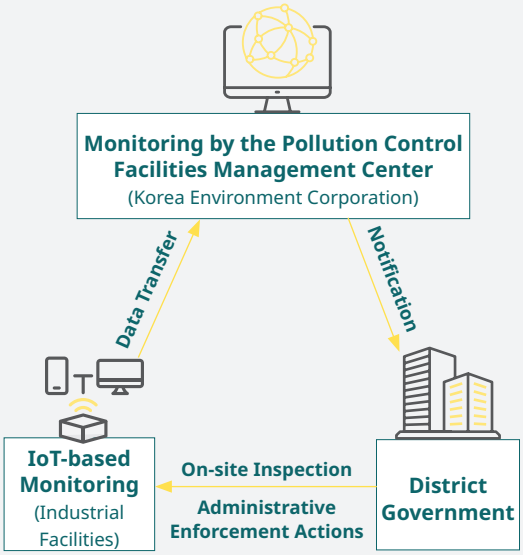
Industrial Sector: Targeting VOCs from both Formal and Informal Sources through Technical and Financial Support

In districts like Jung-gu and Gangseo-gu, small-scale emitters such as dry cleaners, printers, and automobile repair shops, are responsible for a substantial share of VOCs emissions. Since many of these SMEs lack the capacity to implement advanced abatement systems on their own, Seoul employs a dual approach of supervision and targeted support to address VOCs emissions from both formal and informal sources.

Unregistered Painting Facilities Concentrations Source - Seoul Metropolitan Government



IoT Real-time Monitoring System
Source - Seoul Metropolitan Government



For small size units emitting less than 10 tons/year, Seoul supports the deployment of real-time IoT-based monitoring systems which provide continuous data on VOCs release. To facilitate uptake, the city subsidizes up to 90% of installation costs, scheduling for deployment in all small-scale units in Seoul by December 2026.

Seoul also conducts targeted crackdown on **informal operations** such as unlicensed auto painting shops, where fugitive emissions are common.

These efforts are often triggered by citizen reports and play an important role in addressing uncontrolled emission sources that fall outside the



Unlicensed Painting Facility



Technical Support for VRS at Gas Station



Recovery Rate Inspection



Pressure Reduction, Leakage Inspection

Source - Seoul Metropolitan Government

formal regulatory system.

In addition, Seoul is actively tackling emissions from **regulated facilities,** particularly gas stations, which account for 94% of VOCs emissions facilities. Seoul, in collaboration with the Korean Environment Corporation (K-eco), provides technical assistance to underperforming stations, including leak detection, pressure testing, and staff training.

Transportation Sector: Strengthening Inspections to Reduce Mobile Emissions

To ensure the integrity of mobile source emissions control, the city conducts joint inspections of private emissions testing facilities to ensure accurate calibration and staff qualifications. These audits are especially important in dense districts where inaccurate testing could result in excessive emissions from noncompliant vehicles.



Roadside Monitoring & Idling Control

Source - Seoul Metropolitan Government

Construction Sector: Combining Mandatory Requirements with Voluntary Efforts

VOCs emissions from construction activities, particularly exterior painting and paving activities, account for a notable share of urban VOCs emissions. To address this, Seoul mandates the use of low-VOCs and eco-certified materials at

• Restrictions on the Use of Old Construction Machinery (5 types)

3 types of on-road use			2 types of non-road use	
Dump trucks	Concrete mixer trucks	Concrete pump truck	Excavators	Forklifts
				

Source - Seoul Metropolitan Government

large-scale construction sites (exceeding 100,000 m^2 in area), and is working to expand this requirement to all public-sector projects. These efforts will contribute to reducing VOCs emissions, particularly in Seoul's numerous redevelopment and reconstruction zones, aiming to reduce the risk of ozone formation. During the high ozone concentration period (May to August), on-site inspections are conducted at public construction sites, recommending the use of low-VOC materials, and imposing restrictions on outdated machinery and flexible working hours to avoid midday operations when ozone formation is most likely.

The five equipment types summarized in the table below are subject to restrictions on the use of outdated construction machinery. Reflecting Seoul's commitment to improving air quality, this policy aims to continuously enhance VOCs emission control in the construction sector through the management of material use and equipment operation.

2) Routine Measures: Policies Targeting Domestic Sources

While Seoul's seasonal control measures emphasize the efforts especially needed in the summer season, its routine control measures aim to address VOCs emissions from everyday and diffuse sources, which collectively contribute significantly to urban air pollution and require tailored and source-specific responses.

In Seoul, small dry cleaning businesses, especially those operating in mixed-use areas, remain a persistent yet under-regulated source of VOCs. Currently, only 0.5% of dry cleaners in Seoul are subject to VOCs regulations, leaving the vast majority of emissions unmanaged. To address this gap, Seoul is supporting the adoption of more than 90% high-efficiency solvent recovery systems, including solvent recovery dryers and integrated washer-dryer machines.

	
Eco-Washer	Solvent Recovery Dryer

Source - Seoul Metropolitan Government

This initiative not only contributes to lower local VOCs emissions and operational costs but also reduces odor-related complaints-delivering both environmental and socio-economic benefits. In addition to managing VOCs emissions resulting from solvent use from dry cleaning activities, Seoul actively promotes and mandates the utilization of low-VOCs ink for all public-sector publications, enforced through semi-annual compliance audits for continuous management of VOCs emissions.
Beyond efforts in the industrial and public sectors, Seoul also focuses on VOCs emissions from consumer goods such as sprays, air fresheners, and other household products. Although the VOCs content of these consumer products is relatively low, the widespread use of these consumer products in residential and commercial areas results in substantial cumulative emissions. However, despite being a primary source, this category has faced limited regulatory oversight.

As the need for safe product use and a market transition to address the regulatory blind spots increases, Seoul is proactively promoting public-private cooperation through partnership with the Consumer Chemical Safety Commitment Council, a multilateral body composed of the Ministry of Climate, Energy and Environment, Korean Environmental Industry & Technology Institute (KEITI), private companies and civic groups. The city plans to formalize their mutual efforts for the production and expanded use of low-VOCs products through a future Memorandum of Understanding (MOU). This partnership aims to increase the visibility and accessibility of low-VOCs alternatives across the entire consumer product market.

One of the initiatives is to provide support programs enabling citizens to select and use VOCs-safe consumer goods in their daily lives, thereby establishing a culture of practical application and encouraging voluntary participation in VOCs reduction activities.

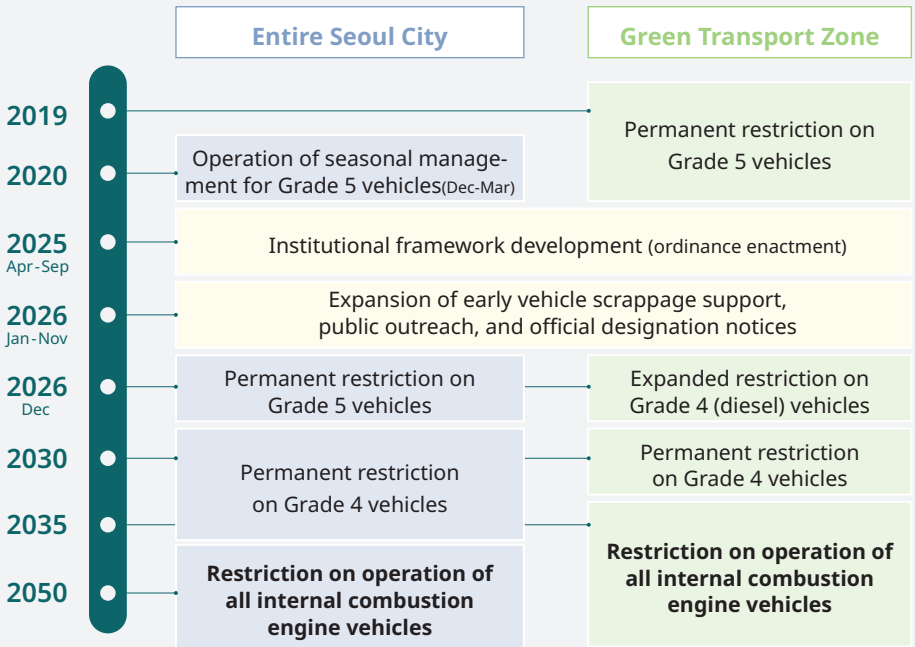
In addition, Seoul is pursuing a long-term transition away from internal combustion engine (ICE) vehicles, beginning with restrictions on grade 5 diesel vehicles in 2026 and culminating in a complete phase-out by 2050. Key actions include expanding Low Emission Zones (LEZ); providing financial incentives for electric vehicle (EV) adoption; and extending early scrappages. To further accelerate the shift to clean transportation, Seoul is increasing support for EVs, with a focus on delivery services, taxis, and public fleets. Support includes expanding EV charging and hydrogen fueling infrastructure and offering preferential treatment for zero-emission vehicles within LEZs.

3) Capacity Building

To ensure the long-term effectiveness of its VOCs governance strategies, Seoul is investing in building its scientific, institutional, and international capacities. These efforts aim to reinforce evidence-based policymaking, strengthen interregional cooperation, and promote global partnerships to address the complex challenges of ozone and VOCs pollution.

Seoul is expanding its understanding of the formation and transport of ozone and its precursors—VOCs and NO_X—by improving regional monitoring and conducting emissions modeling.

Seoul City's Roadmap for ICE Vehicle Phase-Out (Draft)



According to the 2025 Action Plan under **Special Measures for High-Concentration Ozone Management**, a citywide ozone source analysis will be launched to refine Seoul's emission inventory and support more targeted control measures in the near future.

Recognizing that air pollution transcends administrative boundaries, Seoul is deepening collaboration with Gyeonggi Province and Incheon City. Through the Capital Region Air Quality Council, the three governments hold regular policy dialogues and implement joint ozone seasonal controls to address shared air quality challenges.

Seoul is also expanding its global engagement by partnering with peer cities e.g. Beijing to exchange best practices through joint research and peer learning at international forums. These collaborations help Seoul stay at the forefront of innovation and policy development in urban air quality.

Through these capacity-building initiatives, Seoul is laying the foundation for sustained and scalable air quality improvements. By enhancing data accuracy, strengthening regional coordination, and fostering international cooperation, the city is reinforcing its ability to respond to emerging air pollution challenges—and positioning itself as a global leader in clean air governance.

3. Case Study:
Promoting the Reduction of VOCs from Unrestricted Emission Sources

3.1 Background and Objectives

In Seoul, there are a total of 2,389 air emission facilities. Among these, 50 facilities fall under Class 1 to 3, while 2,339 facilities are classified as Class 4 and 5. Facilities classified as Class 4 and 5, which generate less than 10 tons of air pollutants annually, constitute the majority.

• Classification of Air Pollutant-emitting Facilities in Seoul

Total Facilities	Class 1 (≥80t)	Class 2 (20-80t)	Class 3 (10-20t)	Class 4 (2-10t)	Class 5 (<2t)
2,389	17	12	21	786	1,553

Facilities subject to emission controls are designated and managed under the Enforcement Decree of the Clean Air Conservation Act, with specific VOCs facilities designation and public notification by the Ministry of Environment. Specifically, regulated business facilities are managed through support programs that replace aging facilities, and through compliance checks that ensure vapor recovery systems for solvents and that pollution prevention facilities are operating normally.

However, a challenge Seoul faces in VOCs emission control is that the city possesses numerous facilities that fall below the regulatory threshold. Specifically, small-scale organic solvent usage facilities (such as painting, printing and dry cleaning) are largely excluded from official regulatory oversight, which complicates effective management and inspection. This situation necessitates a proactive response targeting these non-regulated units.

3.2 Implementation

Recognizing the complexities and significance of regulating and controlling the VOCs emissions from unrestricted sources, Seoul adopts a complementary and targeted approach, particularly in the summer season. Seoul established and implemented a **VOCs Source Concentration Management Plan** from 2022 to 2024. The

• Non-regulated Sites emitting VOCs

Category	Total	Dry Cleaners	Printing Shops	Painting Facilities	Gas Stations
Total number of sites	**14,564**	6,286	6,801	1,013	464
Number of regulated sites	**1,069 (7.34%)**	27 (0.43%)	1 (0.01%)	591 (58.34%)	450 (97%)
Regulatory threshold	-	Processing capacity ≥ 30 kg/day	Total volume ≥ 1 m^3	Chamber volume ≥ 5 m^3	Storage volume ≥ 20 m^3

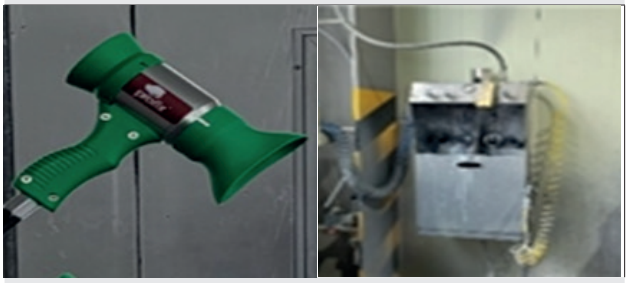
Source - Seoul Open Data Plaza, 2024, Places of business for Air Pollutant Emitting Business Sites (as of Dec 2024)

core emission sources managed under this plan included painting (automotive and architectural), printing and dry cleaning facilities.

In addition to technical support that improves equipment and abatement capacity, the government actively promotes the application of water-borne paints and eco-labeled inks, and raises citizens' awareness of their use. The detailed initiatives for each source are as follows.



Spray Gun(Printing Gun) Electronic Scale



Dryer Cleaner (Spray Gun)

Source - Seoul Metropolitan Government

Supporting Water-based Painting Equipment for Automotive Facilities

To facilitate the transition and expansion of water-based automotive repair coatings, in 2023, Seoul provided specialized equipment (spray guns, electronic scales and dryers) for water-based coating to comprehensive automobile maintenance facilities (1,000m^2 or more) and small automobile maintenance facilities (400m^2).

Using Eco-Label Paint in Public Const-ruction Sites

Since 2022, Seoul has continuously encouraged the use of eco-label certificated painting for coating work at construction sites of the city and its affiliated institutions, aiming to establish the public sector as a leader in low-VOCs product use. The certification criteria for these paintings are as follows:

• Eco-label Certified Standard

Category	General Painting Standard (g/L)	Eco-label Certified Standard (g/L)
Concrete (Oil-based Exterior)	≤ 400-450	≤ 200
Steel (Excl. Lacquer)	≤ 440-470	≤ 300
Wood (Excl. Oil/Lacquer)	≤ 450	≤ 300

Printing: Promoting Low-VOCs Inks in Public Printing

Regarding Low-VOCs ink, Seoul is pushing for the mandatory use of eco-friendly inks for publications subject to public relations material review, aiming to lead the use of low-VOCs products in the public sector. Eco-friendly ink types include soy-based ink, eco-label certified ink and solvent-free ink.

Dry Cleaners: Granting VOCs Reduction Equipment

In the cleaning and drying sector, Seoul is actively implementing a support program for the installation of VOCs reduction facilities in dry cleaners. Since 2023, the city has been supporting

the installation of eco-friendly washing machines and solvent-recovery dryers in small dry cleaners with a processing capacity under 30kg. The eco-friendly washing machine is an integrated washer and dryer with a solvent recovery rate of 90% or higher for dry cleaning solvents. In tiny shops where full machine replacement is not feasible, the recovery dryers are installed.

3.3. Outcomes

To assess the effectiveness of the policy measures and inform further policy improvement, the Seoul Metropolitan Government conducted a quantitative analysis in 2025 to evaluate the emission reduction effects from its VOCs reduction project targeting non-regulated facilities. This analysis evaluates changes in VOCs emissions and reduction effects by support type, and derives tangible policy outcomes. Detailed results are as follows.

Reduction in VOCs Emissions

The official analysis shows that following the support programs for water-based **painting equipment** in 89 repair shops in 2023, the annual VOCs emissions from oil-based coatings decreased from 12,503kg to 5,557kg. This represents an estimated 56% reduction, calculated based on VOCs content, conversion rate and equipment supply. Regarding construction painting facilities, a positive outcome was observed after the city mandated the use of eco-label certified painting in public construction projects. As the usage of eco-label painting increased from 81.3% in 2022 to 87.4% in 2024, the annual VOCs emissions decreased from 128,437kg to 98,450kg, achieving a reduction of approximately 23%. This is calculated based on construction area, printing usage and certified eco-label printing ratio.

In municipal operations, the proportion of eco-friendly ink used in **printing** has risen from 12.6% in 2022 to 31.9% in 2024, with further adoption after additional institutional reforms. Annual VOCs emissions were reduced from 4,040kg to 3,873kg.

Between 2023 and 2024, 36 **dry cleaners** has installed VOCs emission reduction equipment such as eco-friendly dry-cleaning machines and solvent-recovery dryers, which resulted in a 58% annual VOCs reduction from 21,793kg to 9,192kg, calculated based on solvent purchased reduction and unit emission factors.

Reduction in Hazards and Health Risks

In addition, to evaluate the reduction effects and changes in toxicity resulting from switching to low-VOCs products for key items, Seoul conducted complementary analysis based on each product's **Material Safety Data Sheet** (MSDS). This included examining VOCs composition, toxicity information, and legal regulatory requirements.

First, in the aspect of VOCs' composition, traditional oil-based products showed high VOCs content, mostly ranging from 58% to 120%. Whereas the water-based products introduced through the support program had 21% to 43% of VOCs content, indicating a substantial reduction in unit emission per product.

In terms of hazard identification, oil-based products contained numerous substances associated with

oral, dermal and inhalation toxicity - up to nine such substances in construction paintings and four in printing inks. In contrast, the number of toxic substances identified under the same criteria was significantly lower in water-based products.

Moreover, most oil-based products are regulated under multiple regulations including Occupational Safety and Health Act, Chemical Substances Control Act, and Clean Air Conservation Act, whereas water-based products generally fall outside these scopes or contain fewer regulated chemicals.

In summary, this analysis indicates that converting existing oil-based products to water-based alternatives via the support programs is expected to yield highly positive environmental and health effects. It not only decreases the number of toxic and legally regulated substances with harmfulness but also reduces the total VOCs emissions significantly.

4. Reflections and Recommendations

1) Regulation and Incentive Policy for the Paint Business

Under the current Clean Air Conservation Act, VOCs content standards are primarily regulated at the supplier level, including paint manufacturers and sellers. However, Seoul has no direct legal sanctions for consumers of oil-based paints yet, which limits the effectiveness of on-site inspections and enforcement.

To improve administrative efficiency and strengthen compliance, it is recommended to implement institutional reforms that introduce consumer-side restrictions on VOCs use, mandatory training requirements and simplified sampling procedures during on-site inspections of painting facilities. These revisions should also include administrative measures for violations, such as suspension orders. Given that legal reform can be a long-term process, a short-term strategy should focus on inducing the transition to eco-friendly paintings through voluntary industry participation and incentives, such as awards for exemplary businesses, to enhance acceptance and rapid adoption.

2) Development of Practice-Oriented Education Materials for Small Businesses

Currently, on-site understanding of water-based paint conversion remains limited. Existing outreach and equipment-support programs are often theoretical or policy-centered, reducing their practical impact.

To address this gap, it is suggested to develop hands-on, practice-oriented training programs covering the installation and operation of air pollution control equipment, as well as practical workshops for water-based paint conversion.

3) Scale-up Support for Eco-friendly Equipment in Small Business

The current equipment support programs (e.g., for the auto repair business) have shown limited effectiveness due to insufficient demand and a restricted scope of support. To actively facilitate the transition to water-based paintings and maximize the effect of VOCs reduction, the city should establish a comprehensive and scalable support system that covers both high-cost equipment and small-scale tools. Such a system would make eco-friendly conversion more feasible across a wide range of businesses and facility sizes.

• Regulation Articles on Clean Air Conservation Act

Act	Violation	Penalty
Article 44 (2) 3-4	· Supply or sell paintings exceeding VOCs standards	· Order to halt supply or sale, or recall paintings
Article 91 (3) 2-5	· Supply or sell paintings exceeding VOCs standards · Violate the order to halt supply/sale or recall coatings.	· Imprisonment for up to 1 year or a fine up to 10 million KRW

References

- Son, M., Jeon, H., & Kim, J. (2025) Analysis and Improvement strategies for VOCs emissions Source Management in Seoul: Focus on Industrial Facilities. Seoul, Republic of Korea: The Seoul Institute.
- Choi, Y., Baek, J., & Kim, J. (2023). (rep.). Analysis of Volatile Organic Compounds (VOCs) Characteristics and Sources in Seoul (pp. 1–121). Seoul, Republic of Korea: The Seoul Institute.
- Euljiro provides window into Seoul's industrial past - The Korea Times. koreatimes.co.kr. (2018, September 26). https://www.koreatimes.co.kr/southkorea/society/20180926/euljiro-provides-window-into-seouls-industrial-past
- Eun, D.-M., Han, Y.-S., Nam, I., Chang, Y., Lee, S., Park, J.-H., Gong, S. Y., & Youn, J.-S. (2024). Ambient volatile organic compounds in the Seoul metropolitan area of South Korea: Chemical reactivity, risks and source apportionment. Environmental Research, 251.
- Fifth seasonal PM management through 16 reduction measures in 4 areas -. Official Website of the Seoul Metropolitan Government. (2023a, December 1). https://english.seoul.go.kr/fifth-seasonal-pm-management-through-16-reduction-measures-in-4-areas/
- Hill, A. (2019, June 12). Profile: Sewoon –a city of making (in Seoul). Cities of Making Profile Sewoon a City of Making in Seoul Comments. https://citiesofmaking.com/cities-of-making-in-korea/
- Kim, H., Won, J., Choi, Y., & Lee, H. (2024). (rep.). Analysis of the impact of Seoul's air management policy on public health. Seoul, Republic of Korea: The Seoul Institute.
- Kim, S.-J., Lee, S.-J., Lee, H.-Y., Park, H.-J., Kim, C.-H., Lim, H.-J., Lee, S.-B., Kim, J. Y., Schlink, U., & Choi, S.-D. (2021). Spatial-seasonal variations and source identification of volatile organic compounds using passive air samplers in the Metropolitan City of Seoul, South Korea. Atmospheric Environment, 246.
- Kim, U., Sin, S., & Kim, J. (2018). (rep.). A Study for Developing an Integrated Air Quality (Ozone and $PM_{2.5}$) Management Framework in Seoul (pp. 1–142). Seoul, Republic of Korea: The Seoul Institute.
- Lee, J., Lee, M., Chang, L., Shin, S.-A., Kim, K., Choi, Y., Lim, H., Choi, S.-D., & Lee, G. (2024). Assessment of VOCs emissions inventory in Seoul through spatiotemporal observations using passive and online PAMS measurements. Atmospheric Environment, 338.
- Park, S.-Y., Jang, H., Kim, K., Ha, H., Choi, Y., Kwon, S., Choi, Y., Park, J.-S., & Lee, C.-M. (2025). Estimation of potentially toxic substances and health risks in vocs in Urban Areas of Seoul. Water, Air, & Soil Pollution, 236.
- Protecting citizens from ozone (O3)...Seoul Metropolitan Government announces 'Special Measures for Managing High Ozone Concentrations' | Press Release. Seoul Climate and Environment Headquarters "Zero Seoul": Naver Blog. (2025, April 2). https://blog.naver.com/zero_seoul_official/223819268857
- Record low $PM_{2.5}$ levels in Seoul for 3 consecutive years -. Official Website of the Seoul Metropolitan Government. (2023b, July 28). https://english.seoul.go.kr/record-low-pm2-5-levels-in-seoul-for-3-consecutive-years/

- Seoul achieved the lowest $PM_{2.5}$ level since the launch of the seasonal PM management -. Official Website of the Seoul Metropolitan Government. (2024, April 5). https://english.seoul.go.kr/seoul-achieved-the-lowest-pm2-5-level-since-the-launch-of-the-seasonal-pm-management/
- Seoul Administrative District Status. Korean Statistical Information Service. (2024, November 4). https://kosis.kr/statHtml/statHtml.do?sso=ok&returnurl=https%3A%2F%2Fkosis.kr%3A443%2FstatHtml%2FstatHtml.do%3Fconn_path%3DI2%26tblId%3DTX_315_2009_H1009%26orgId%3D460%26
- Seoul Metropolitan Government Air Quality Information. Seoul Air Quality Information - Air Pollutants - Fine Dust ($PM_{-2.5}$) Seoul Air Quality Information. (n.d.). https://cleanair.seoul.go.kr/information/info11
- Seoul Metropolitan Government. (2024). 为有效治理夏季臭氧重度污染 首尔市VOCs排放源重点治理政策. Seoul, Republic of Korea.
- Seoul Metropolitan Government. (2025). (rep.). Special Measures to Manage High Ozone Levels (pp. 1–34). Seoul, Republic of Korea.
- Seoul Registered Population Statistics. Seoul Open Data Square. (2025, April 24). https://data.seoul.go.kr/dataList/419/S/2/datasetView.do
- Seoul to reduce 408.5 tons of $PM_{-2.5}$ through constant air quality improvement programs -. Official Website of the Seoul Metropolitan Government. (2018, April 26). https://english.seoul.go.kr/seoul-reduce-408-5-tons-pm-2-5-constant-air-quality-improvement-programs/
- Seoulsolution. (2016, October 31). Air Quality Monitoring System : Real-time air quality monitoring system to protect citizens' health. Seoul Policy Archive Seoul Solution. https://seoulsolution.kr/en/content/air-quality-monitoring-system-real-time-air-quality-monitoring-system-protect-citizens%E2%80%99
- Seoulsolution. (2018a, February 1). Diesel vehicle emission control devices. Seoul Policy Archive Seoul Solution. https://seoulsolution.kr/en/content/6539
- Seoulsolution. (2018b, May 8). Changes in Seoul's Air Quality Control Policy. Seoul Policy Archive Seoul Solution. https://seoulsolution.kr/en/content/3496
- Seoulsolution. (2022, January 25). 1. Sewoon Plaza Revitalization Project Progress / The process of promoting the Sewoon Plaza revitalization project (eng / spa / KOR). Seoul Policy Archive Seoul Solution. https://seoulsolution.kr/en/content/9454
- Seoul's Industrial Structure. Seoul Research Data Service. (n.d.). https://data.si.re.kr/node/288
- Song, M., & Jeon, H. (2022). (rep.). Study on Characteristics of VOC Emission Facilities Generating Ozone in Seoul and Measures to Reduce Ozone (pp. 1–244). Seoul, Republic of Korea: The Seoul Institute.
- SPECIAL ACT ON THE IMPROVEMENT OF AIR QUALITY IN AIR CONTROL ZONES 2021 (KR1.)

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