# REduction of Brake weaR Emissions in the Transport sector "RE-BREATH"

## *Deliverable 5.3*
## *After-Life conservation plan*

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# Executive summary

The LIFE RE-BREATH project has tackled a key but often overlooked contributor to urban air pollution: non-exhaust particulate emissions from vehicles, with a primary focus on brake wear. Through the integration of industrial innovation, environmental monitoring, and urban design, the project has delivered four principal outcomes: a novel low-emission braking system, a robust methodology for measuring non-exhaust emissions, a set of demonstration vehicles equipped with the new technology, and targeted green infrastructure improvements.

The purpose of this After-LIFE Conservation Plan is to ensure that these achievements continue to deliver environmental and societal value beyond the formal end of the project. It provides a structured, realistic framework for preserving and promoting the project's results in the long term, based on the strengths and opportunities identified through an internal SWOT analysis. It sets out clear post-LIFE objectives, defines the key outputs to be conserved, and details the roles and responsibilities of each partner in sustaining these outputs.

The conservation strategies are tailored to the nature of each output. Brembo will continue industrial development and commercial exploration of the braking system. CNR will promote the monitoring methodology as a replicable tool for urban air quality management. Arriva will retain and operate the demonstration vehicles as part of its regular fleet. The Municipality of Bergamo will maintain the installed green areas.

The implementation plan balances specificity with flexibility, assigning responsibilities while respecting the voluntary and adaptive nature of post-project commitments. Monitoring and reporting will be carried out informally by each partner, while financial sustainability relies on ongoing integration into industrial strategies and institutional workflows. Overall, the After-LIFE Conservation Plan ensures that LIFE RE-BREATH will leave a lasting legacy—not only through its technical outputs, but by influencing how cities and public transport operators address the challenge of non-exhaust emissions in the coming years.

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# 1 Introduction

The LIFE RE-BREATH project has addressed a critical and still under-regulated dimension of urban air pollution: non-exhaust particulate emissions from vehicles, with a specific focus on brake wear. By advancing both technical solutions and monitoring methodologies, the project has produced concrete outcomes that not only demonstrate the feasibility of emission reduction but also provide replicable models for future application. As the project approaches its conclusion, it is essential to ensure that these results are not only preserved but actively integrated into broader strategies for air quality improvement and sustainable mobility. This is the fundamental purpose of the After-LIFE Conservation Plan.

The After-LIFE Conservation Plan is a strategic framework that articulates how the main results of the LIFE RE-BREATH project will be sustained, developed, and transferred beyond the lifetime of EU funding. It outlines the actions, responsibilities, and structures needed to preserve the project's most significant outcomes and ensure their future utility across diverse contexts—technical, institutional, and geographical.

Among the key achievements of the project are the development of novel braking systems designed to significantly reduce particulate emissions; the elaboration and validation of a monitoring methodology for non-exhaust emissions applicable to real urban environments; the successful deployment of demonstration vehicles equipped with these innovative systems; and the integration of green areas as part of a systemic approach to improving air quality at high-exposure locations such as bus stops.

Each of these achievements constitutes a valuable output with the potential for long-term impact. However, realizing this potential requires planning, commitment, and coordination beyond the timeframe of the project itself. Technological innovations must be scaled and industrialized; methodologies must be adopted by competent authorities and incorporated into policy frameworks; and the urban improvements implemented as part of the demonstration must be maintained, monitored, and potentially replicated.

The After-LIFE Plan addresses these needs directly: more than a procedural requirement, it represents a continuation of the project’s mission. It ensures that the LIFE RE-BREATH project does not end with the publication of its final deliverables, but instead serves as a launching point for long-term improvements in air quality, public health, and environmental innovation across European cities and beyond.

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# 2 Methodology

The methodology for the implementation of the After-LIFE Plan aims at ensuring the long-term conservation, replication, and exploitation of the LIFE RE-BREATH project's key results, to continue the project's impact well beyond the funding period, ensuring its findings, technologies, and strategies remain available, actionable, and relevant for future implementation and scaling.

Given the multifaceted nature of the project—spanning brake system innovation, air quality measurement, policy development, and stakeholder engagement—the methodology has been devised to allow for comprehensive analysis and strategic planning across technical, policy, and institutional dimensions. The process begins with an evaluative assessment of the project's overall performance and outcomes through a **SWOT analysis**, continues through a stage-wise formulation of **post-LIFE objectives**, proceeds to the identification of **key outputs**, and culminates in the development of a detailed **conservation strategy** and a fully articulated **implementation plan**.

The first step in our methodology is the execution of a SWOT analysis. This will serve as the foundational diagnostic tool to assess the internal and external factors affecting the project's capacity to generate long-term impact. The SWOT analysis will critically reflect on the Strengths, such as the technical robustness of the innovative braking system and the empirical validation of the monitoring protocols; the Weaknesses, including any limitations encountered during the demonstrations or dissemination phases; the Opportunities, such as alignment with emerging EU policy trends or market interest in low-emission technologies; and the Threats, like regulatory inertia, limited market uptake, or technological obsolescence. The SWOT analysis will be conducted using insights gathered throughout the project, supplemented by consultations with project partners, advisors, and relevant institutional stakeholders. It will not only summarize the internal performance and external context of the project, but also establish a clear basis for subsequent planning phases by identifying enabling conditions and risks.

Following the SWOT analysis, the next step in our methodology involves the definition of Post-LIFE Objectives. These objectives will provide the overarching vision and direction for the continuation of RE-BREATH's mission beyond the formal end of the LIFE programme funding. The objectives will be guided by the strengths and opportunities identified in the SWOT analysis, while accounting for the risks and limitations flagged in the same process. The formulation of the post-LIFE objectives will be both realistic and forward-looking. Rather than simply restating the project's original aims, the objectives will be refined to reflect future-

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oriented goals, such as the mainstreaming of non-exhaust emission monitoring into urban air quality strategies, the commercial upscaling of low-emission braking systems, or the use of project methodologies to inform standardization or policy reform at national and European levels.

With the post-LIFE objectives defined, the next phase will focus on the identification of key outputs. These outputs represent the tangible and intangible assets generated by the LIFE RE-BREATH project, which will serve as the building blocks for future action. Key outputs may include technical deliverables such as the brake emission monitoring protocol, the validated prototype braking systems, the dispersion modelling tools, or the health exposure risk maps. Other outputs may be institutional in nature, such as the knowledge and experience accumulated by project partners, the policy recommendations outlined in Deliverable 5.4, or the stakeholder networks activated through the project. Each key output will be analysed in terms of its maturity, usability, replicability, and relevance to various stakeholder groups. This step will allow for an informed and selective approach to the conservation phase, recognizing that different outputs may require different strategies to ensure their continued relevance and impact.

The fourth methodological step involves the development of a conservation strategy for each key output. This strategy will provide a tailored approach for sustaining, scaling, or transferring each major result of the project. For instance, for a technical tool such as the air quality monitoring protocol, the conservation strategy may focus on integrating the protocol into municipal air quality action plans, or aligning it with emerging CEN/ISO standards. For a policy-oriented output, the strategy may focus on ensuring its uptake by transport ministries, environmental agencies, or urban mobility working groups. The conservation strategy will address not only the immediate actions required to maintain the output's value, but also the long-term structural arrangements needed for sustainability. These may include institutional partnerships, financing mechanisms, legal arrangements, and knowledge transfer pathways. Special attention will be paid to ensuring that the conservation of outputs aligns with the roles and capacities of specific project partners, who may be best placed to take stewardship over particular deliverables.

The methodology also includes the creation of a comprehensive implementation plan, which will operationalize the conservation strategies into a concrete, time-bound, and accountable framework. Finally, based on the previous steps, the approach for monitoring, evaluation, and reporting is defined.

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# 3 Definition of post-LIFE objectives and key outputs for conservation

## 3.1 SWOT analysis

In order to define post-LIFE objectives and key outputs, a SWOT analysis of the project has been carried out. The SWOT methodology was adopted to ensure that the After-LIFE Conservation Plan is rooted in a realistic and forward-looking understanding of the project's long-term potential.

This internal assessment was designed to identify the main strengths and weaknesses of the project from a technical and operational perspective, while also exploring external opportunities and potential threats that may influence the uptake, replication, or continuity of project outcomes after its official end. The SWOT analysis serves as a strategic bridge between the project's achievements and the formulation of its post-LIFE objectives. Indeed, the analysis of both internal and external factors supports a more targeted and sustainable approach to the conservation of key outputs, the allocation of responsibilities among partners, and the planning of follow-up activities.

The factors identified are listed in Table 1.

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*Table 1. SWOT analysis of LIFE RE-BREATH*

| | *Helpful* | *Harmful* |
|---|---|---|
| *Internal factors* | **Strengths**<br>Demonstrated effectiveness of the novel braking system in reducing particulate emissions under real-world urban conditions.<br>Development and field validation of a replicable methodology for measuring non-exhaust emissions (PM10) at high-exposure locations.<br>Integration of technological, environmental, and urban design approaches in a holistic air quality mitigation strategy.<br>Multidisciplinary consortium combining industrial innovation (Brembo), public transport operators (Arriva), scientific research (CNR), and municipal governance (MoBER).<br>Strong alignment with EU Green Deal objectives and upcoming regulatory focus on non-exhaust emissions (e.g., Euro 7).<br>Use of standard-compliant monitoring instruments and lab techniques, enabling comparability with external studies and inventories.<br>Inclusion of green infrastructure (green areas) to enhance local air quality and public space quality at bus stops.<br>High replicability of technical solutions across European cities with similar urban mobility challenges.<br>Engagement of end-users (e.g., bus drivers, maintenance teams) during demonstration, improving usability and practical relevance.<br>Generation of robust, real-world datasets that can support regulatory and scientific communities (e.g., EMEP/EEA, WHO, JRC). | **Weaknesses**<br>Limited duration of demonstration activities may restrict full evaluation of long-term durability and lifecycle performance.<br>Small-scale deployment (only a few retrofitted buses) may reduce perceived scalability by external stakeholders.<br>No formal certification framework exists yet for low-emission braking systems, potentially delaying market uptake.<br>Monitoring campaigns were limited to two cities and may not reflect all urban typologies or climatic conditions.<br>Limited direct engagement with national or EU-level regulators during the project (e.g., no formal policy pilot or consultation).<br>Green areas were implemented at a pilot scale, with limited post-project maintenance mechanisms currently defined.<br>Methodological complexity of PM source apportionment may pose challenges for adoption by non-specialist local authorities.<br>Braking system innovation remains pre-commercial; further industrial validation and homologation are required.<br>Stakeholder engagement was mainly internal to the project network; broader public or civil society awareness was limited.<br>The project's visibility within standardization bodies (e.g., CEN, UNECE) remains nascent and requires further outreach. |

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| | Opportunities | Threats |
|---|---|---|
| *External factors* | Growing EU policy momentum toward regulating brake and tire wear emissions through Euro 7 and complementary legislation.<br>Increasing interest from municipalities in cost-effective solutions for local air quality improvement in transport hubs.<br>High potential for transfer of the monitoring methodology to other pollutant sources or urban infrastructure projects.<br>Potential integration of green area concepts into broader urban regeneration or "15-minute city" strategies.<br>Availability of EU and national funding for sustainable transport innovation and retrofitting of public vehicle fleets.<br>Potential industrial partnerships for mass production and commercialization of the low-emission braking system.<br>Ongoing development of EU Green Public Procurement (GPP) criteria, where project outputs could be included.<br>Potential synergies with other EU projects or Horizon Europe clusters on urban health, mobility, or climate adaptation.<br>Expansion of policy influence via alignment with air quality planning (e.g., SUMPs, LEZs, air quality directives).<br>Scope to contribute to standardization processes under CEN, ISO, or UNECE by sharing project methods and data. | Regulatory delays or lack of enforcement in adopting standards for non-exhaust emissions could reduce market pressure.<br>High costs and complexity of brake system retrofitting may deter widespread adoption without policy incentives.<br>Municipal budget constraints may limit maintenance and expansion of green areas after the project ends.<br>Potential mismatch between technical readiness of outputs and the timeline of regulatory frameworks (e.g., Euro 7).<br>Risk of project findings being overtaken by faster-moving private sector R&D or proprietary systems.<br>Difficulties in harmonizing PM10 monitoring protocols across cities with diverse capacities and infrastructures.<br>Policy fragmentation across EU Member States may limit the replicability or adoption of guidelines.<br>Public and media focus remains predominantly on tailpipe emissions or climate impacts, reducing attention on NEEs.<br>Uncertainty around long-term vehicle fleet renewal strategies, particularly in light of electric vehicle transitions.<br>Limited institutional capacity in smaller cities may hinder uptake of complex monitoring and emission control strategies. |

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## 3.2 Definition of Post-LIFE Objectives

Building upon the internal analysis carried out through a SWOT framework, the project consortium has identified a set of post-LIFE objectives designed to consolidate the project's legacy and support the strategic continuation of its mission. These objectives reflect the combined insights of technical development, policy engagement, stakeholder feedback, and demonstration experience, and are designed to be both aspirational and actionable.

The purpose of these objectives is to provide a unifying vision for post-project actions, ensuring coherence between the conservation of technical outputs and the broader systemic goals of urban environmental improvement. They serve as the basis for defining the key outputs that require targeted conservation and will guide the implementation of governance, partnership, and monitoring strategies in the years following the conclusion of LIFE RE-BREATH.

Based on the SWOT analysis, the following post-LIFE objectives have been identified:

- Ensure the industrial scaling and commercial deployment of low-emission braking systems developed within the project.
- Promote the adoption of standardized methodologies for monitoring non-exhaust emissions in urban environments.
- Support the sustained use and maintenance of demonstration vehicles equipped with innovative braking technology.
- Preserve and replicate urban green infrastructure developed as part of the project’s air quality mitigation approach.
- Facilitate the integration of project findings into regional and European policy and standardization processes.

## 3.3 Identification of key outputs

In alignment with the post-LIFE objectives outlined above, the project has identified the principal results and deliverables that constitute its most valuable and impactful contributions. These key outputs are the tangible and intangible assets that will form the core of the project’s legacy and the focus of conservation efforts moving forward.

Each key output has been selected based on its relevance to future implementation, its transferability to other urban or institutional contexts, and its potential to catalyse continued innovation or regulatory development. While the project has generated a wide array of technical documents, datasets, and

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communication materials, the following outputs represent the most strategically significant elements to be preserved and expanded upon in the post-LIFE phase.

The key outputs identified are:

1. **Novel braking systems** developed and validated to significantly reduce particulate emissions from public transport fleets.
2. **A novel methodology for monitoring non-exhaust emissions**, including standardized protocols for sampling, analysis, and interpretation in real-world conditions.
3. **Demonstration vehicles** equipped with the innovative braking systems, serving as replicable models for sustainable fleet retrofitting.
4. **Green areas** installed at demonstration sites, designed to reduce local air pollution and enhance urban environmental quality through passive filtration and public space enhancement.

For each of this output, the next chapter provides a specific conservation plan

# 4 Conservation plan of key outputs

## 4.1 Novel braking systems

The innovative braking systems developed within the LIFE RE-BREATH project represent one of its most important and impactful technical outputs. These systems have been specifically designed to reduce particulate matter emissions originating from brake wear, thereby contributing to the broader goal of lowering non-exhaust emissions in urban environments. Following successful laboratory validation and field demonstration, the systems are now ready for further industrial scaling and commercial use.

The long-term conservation and exploitation of this output will be led by **Brembo**, the project's industrial partner and global leader in braking system technology. Brembo will integrate the developed solutions into its broader R&D and product portfolio, with the goal of bringing to market low-emission braking components that are compatible with both new vehicle platforms and retrofit applications. Commercial deployment will focus initially on the public transport sector but may expand to include other vehicle categories depending on regulatory developments and market demand.

**Arriva**, the project partner responsible for demonstration activities, will retain and continue to use the vehicles equipped with the new braking systems (loop 2 and Greenance product) in its operating fleet. The company will monitor the performance of the technology over time and provide valuable data that may

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inform future iterations, market positioning, or policy recommendations. Through this dual-track strategy—industrial integration by Brembo and operational deployment by Arriva—the braking systems will remain active and relevant well beyond the project's conclusion.

## 4.2 Novel methodology for monitoring non-exhaust emissions

The methodology developed and validated within LIFE RE-BREATH for monitoring non-exhaust emissions—particularly brake wear-related PM10—is a central innovation with strong potential for replication and policy integration. It consists of a coherent set of procedures covering site selection, instrumentation setup, sampling protocols, analytical methods (e.g., gravimetric and elemental analysis), and data interpretation techniques (e.g., source attribution using elemental fingerprints). The approach is tailored to the constraints and exposure profiles of urban environments, particularly in proximity to public transport stops.

To ensure the long-term conservation and uptake of this methodology, it has been formally documented and codified in **Deliverable D5.4**, which serves as a set of technical guidelines for public authorities, environmental agencies, and mobility planners. The guidelines are designed to be modular and adaptable, allowing for application in a wide range of urban contexts while maintaining scientific rigor and comparability.

The conservation strategy for this output will be led by **CNR**, the project partner responsible for environmental monitoring and analytical protocols. CNR will promote the guidelines among municipalities and regional environmental protection agencies (ARPAs), with the aim of facilitating their integration into Urban Air Quality Action Plans, Sustainable Urban Mobility Plans (SUMPs), and Low Emission Zone (LEZ) management strategies. Outreach will take place through technical workshops, bilateral cooperation initiatives, and participation in national and European expert working groups.

CNR will also explore synergies with ongoing standardization efforts at the EU level. The methodology is compatible with emerging CEN and ISO discussions related to real-world PM monitoring, and could serve as a reference model for future technical standards. Moreover, the availability of empirical data and documented field experience strengthens the case for policy recognition and institutional adoption.

By embedding the monitoring methodology within policy instruments and technical networks, LIFE RE-BREATH ensures that the tools needed to quantify and manage non-exhaust emissions will remain available and applicable beyond the scope of the project.

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## 4.3 Vehicles with the new braking system

The buses equipped with the innovative low-emission braking systems constitute a key demonstration asset of the LIFE RE-BREATH project. These vehicles provided the necessary real-world testbed to assess the operational viability and environmental benefits of the braking technology under daily traffic conditions and urban mobility patterns.

**Arriva**, the project partner and public transport operator, will continue to use and maintain the demonstration vehicles within its regular fleet operations (REBREATH loop 2 and Greenance). The vehicles will remain in service along routes where high passenger exposure and frequent deceleration make them particularly relevant to air quality strategies. Maintenance procedures for the new braking systems will be integrated into routine depot workflows, ensuring their continued performance over time.

Through this sustained use, the vehicles will serve as a living example of how retrofitting existing fleets with environmentally improved components can generate tangible air quality benefits. Their continued operation will also provide long-term feedback on durability, maintenance needs, and cost-effectiveness, thereby supporting future decisions about broader fleet adoption or public procurement strategies.

## 4.4 Green areas

The green infrastructure installed at selected demonstration sites, particularly at high-exposure areas such as bus stops, represents a complementary output of LIFE RE-BREATH. These installations aim to passively reduce local air pollutant concentrations while enhancing the environmental and aesthetic quality of urban public spaces.

The conservation and maintenance of these green areas are addressed in detail in **Deliverable D4.5**, which outlines the technical specifications, plant selection criteria, irrigation and maintenance needs, and potential co-benefits (e.g., thermal comfort, biodiversity). The deliverable also includes recommendations for replication, scalability, and integration into broader urban green planning efforts.

The local partner **municipality of Bergamo** will continue maintaining these installations as part of regular urban upkeep. Municipality staff in charge of green spaces management have been involved in the project and are very committed in keeping alive the LIFE Re-breath activities. In parallel, the project's visibility and dissemination actions will promote the green area concept to other cities as an effective, low-cost intervention in air quality improvement strategies, especially in

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areas where non-exhaust emissions are concentrated due to frequent braking and passenger turnover.

# 5 Implementation Plan

## 5.1 Roles and Responsibilities

The After-LIFE Conservation Plan of the LIFE RE-BREATH project is designed to ensure that the project's key outputs are preserved, applied, and further developed well beyond the end of the funded period. Its implementation will follow a decentralized and pragmatic approach, building upon the established competencies of the project partners, the operational contexts in which the outputs were developed, and the strategic alignment of each output with ongoing activities or institutional mandates. The aim is to provide a realistic roadmap for continuity, without imposing over-structured governance that might hinder flexibility or scalability.

The responsibility for the conservation and post-LIFE continuation of each output will rest with the project partner most closely aligned with its technical development, implementation, or long-term operational use:

- **Key Output 1 – Novel Braking Systems:** The responsibility for further development, industrial upscaling, and market exploitation of the low-emission braking systems lies with **Brembo.** As the technological lead for WP2, Brembo will evaluate opportunities to integrate the developed solutions into its commercial portfolio and continue to explore technical refinements in line with emerging regulatory standards and client needs.
- **Key Output 2 – Methodology for Monitoring Non-Exhaust Emissions:** The methodological framework developed under WP4 will be maintained and promoted by **CNR**. CNR will engage with technical agencies, local governments, and standardization bodies to support the dissemination and potential institutional adoption of the monitoring protocol. Deliverable D5.4 will serve as the primary reference for transferability and training.
- **Key Output 3 – Demonstration Vehicles:** The buses equipped with the novel braking systems will remain in use by **Arriva**, the operating partner responsible for the demonstration campaigns in WP3. Arriva will retain full operational responsibility for the vehicles, including their maintenance, performance monitoring, and evaluation for potential broader fleet applications.
- **Key Output 4 – Green Areas:** The small-scale green infrastructure interventions deployed at bus stops will continue to be maintained by the

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**Municipality of Bergamo**, which coordinated their design and installation. As detailed in Deliverable D4.5, the municipality will integrate maintenance actions into regular urban management routines, ensuring the continued presence and visibility of this component.

## 5.2 Monitoring Program

The monitoring of post-LIFE activities will be based on a lightweight, partner-led model. Each partner will be responsible for tracking the progress and outcomes related to their respective outputs. The purpose of this monitoring will be to support learning, identify opportunities for follow-up action, and allow for voluntary reporting in institutional or technical fora.

Monitoring activities may include:

- Informal progress updates during sectoral meetings or collaborative initiatives;
- Internal tracking of technology performance (e.g., brake system wear rates or PM emission profiles);
- Observation of the uptake or use of the monitoring methodology by external actors;
- Routine maintenance logs or visual inspections of green areas.

While no binding reporting structure is foreseen, opportunities for informal sharing of insights—e.g., through conference presentations, technical workshops, or updates to the project's website or network—will be encouraged. This approach ensures that monitoring remains useful and proportionate to the scale and resources of the post-LIFE context.

## 5.3 Financial Sustainability

The financial sustainability of post-LIFE actions will depend on a mix of industrial strategy, institutional budgeting, and potential funding opportunities. Specific revenue models, cost-benefit analyses, and scaling strategies—particularly in relation to the braking system—have been addressed in detail in **Deliverable D5.2**.

For the monitoring methodology and green areas, financial sustainability is anticipated through integration into existing institutional workflows and budgets (e.g., environmental monitoring activities for CNR; routine urban maintenance for MoBER). Demonstration vehicles will be maintained under Arriva's standard operating and fleet renewal procedures. In general, no additional EU funding is required for the continued use or preservation of the project's key outputs.

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However, project partners will remain open to participating in follow-up projects, calls, or partnerships where the RE-BREATH experience and results can be further leveraged.

# 6 Conclusions

The LIFE RE-BREATH project has demonstrated that the challenge of non-exhaust particulate emissions—particularly those generated by brake wear—can be addressed through a combination of targeted technological innovation, empirical environmental monitoring, and practical urban interventions. The project's results are timely, relevant, and scalable, aligning with the broader trajectory of EU air quality policy, sustainable urban mobility planning, and environmental innovation.

The project has taken meaningful steps to ensure that its most valuable outputs do not end with the project itself. Each output has been linked to a conservation strategy that is credible, proportionate, and embedded within the core competencies of the project partners. Brembo, CNR, Arriva, and the Municipality of Bergamo each have clearly defined roles that reflect their contribution to the project and their capacity to sustain its results.

The After-LIFE Conservation Plan avoids rigid or prescriptive commitments, recognizing that future developments—whether regulatory, technological, or institutional—will shape the pathways for exploitation and replication. Instead, it offers a roadmap for continuity that is grounded in the experience of the consortium, the lessons learned from implementation, and the shared ambition to contribute to cleaner, healthier urban environments.

By planning for the long term, LIFE RE-BREATH ensures that its legacy is not limited to the scope of the project, but continues to support the transformation of urban mobility systems toward more sustainable and health-conscious practices. Through this forward-looking strategy, the project positions itself as a relevant and credible actor in the European transition to cleaner urban transport and improved air quality management.

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