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*Identification of potential hotspots
and draft plan of greening intervention*

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Document information

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Abstract	This document describes briefly the process that led the Municipality of Bergamo to choose the green areas where to develop the local use case: to improve the green spaces with new plants which will help to reduce the particulate in the air.

Table of revisions

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1	Municipality of Bergamo	First draft	16/07/2024
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INTRODUCTION

Air pollution has been recognized as a serious problem in urban areas as it significantly affects human health. In particular, vehicular traffic emission is an important source of particulate matter (PM) in urban areas. In fact, PM is mainly originating from automotive internal combustion engines (exhaust emissions) as well as abrasion of brakes and tires and suspension of road dust (non-exhaust emissions) (De Kok et al., 2006). PM consists of a heterogeneous mixture of solid and liquid particles suspended in air that varies continuously in size and chemical composition in space and time (WHO, 2013). PM is of particular interest because it has a greater impact on health including premature death in people, aggravated asthma, and respiratory symptoms. Recently, Nature Based Solutions (NBS) have gaining popularity as they can provide a significant contribution to air quality improvement at feasible costs. NBS is defined by EU Commission as “solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience” (https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en). Many studies have demonstrated that plants can act as a porous barrier, altering local air dispersion patterns, by capturing PM on leaves and reducing PM pollution (Chen et al., 2017b; Shao et al., 2018; Song et al., 2015). Thus plants in urban environments can represent an effective solution to improve urban air quality and provide a valuable ecosystem service, especially in the vicinity of bus stops where there is a high accumulation of particulate concentrations due to the occurrence of both exhaust and non-exhaust emissions, which increase the exposure of passengers to particulates while waiting at the bus station.

RE-BREATH project focus on that topic, in particular Task no. 4.6 “Greening of the hot spots alongside the bus routes”.

This report is created to describe briefly the process that led the Municipality of Bergamo to choose the more suitable areas in the urban context where to improve the green spaces with new plants which will help to reduce the particulate in the air. These hotspots have been chosen next the bus stops where Arriva buses stops.

In the first phase of the process the Public Green Department of the Municipality of Bergamo coordinated with CNR (scientific support) in order to research and select the most optimal species that are the most suitable for the urban context of Bergamo, while the following phase has been the actual planting of the selected species in the flower bed.

In the following document there is:

- State of the art of the current species in the flower bed chosen;
- description of the species selected;
- evidences of the new flower bed.

SELECTION OF THE INTERVENTION AREAS

The areas of intervention were selected based on two different criteria: firstly, the proximity to the urban bus route where the new braking systems were tested, and secondly, their functionality in installing green areas and housing for long-term use.

Through shared work between the Public Green service and Mobility service of the Municipality of Bergamo and with the support of CNR the route of the urban line of interest was analyzed identifying the areas in which to implement green areas. Afterward, on-site inspections have been carried out. The proximity to the bus stop, the green space that complies with the measures identified in the project, the feasibility in terms of environment and efficiency, and the possibility of fixing these areas even after the end of the project were evaluated. The selection process involved selecting green areas that were visible and marked with a plaque about the project.

The selection process has resulted in the identification of 5 areas:

- roundabout via Foro Boario angolo via Bono (close to the bus station);
- via Muraine angolo via Frizzoni;
- via Cesare Battisti - Piazzale Oberdan;
- via Baioni;
- via Ruggeri da Stabello.

These areas are distributed equally throughout the urban line. In all the identified green spots, shrubs have been planted in the existing flowerbeds or green spaces near the road. The municipality of Bergamo has entrusted the work, following the current Italian contract laws, overseeing the operations, and following the agreed-upon criteria for selecting tree species with the aid of CNR.

To ensure healthy and vigorous plant growth in Bergamo city's flower beds, planting operations were conducted following a series of fundamental steps that took into consideration the specific conditions of the urban soil:

1. Removing the Cotico Erboso

To ensure efficient and fast processing, the first step was to remove the turf using a mini excavator where possible. In areas that are more challenging or delicate, this has been done manually using tools like hoes and spades. The turf removal was crucial for eliminating surface vegetation and preparing the soil for the next processing phase.

2. Adding Organic Compost

The soil was enriched with organic compost after removing the turf. It was crucial to take this step because the city soil often lacks the nutrients necessary for plant growth. Compaction, pollution, and the absence of natural organic materials lead to impoverished soil in urban environments. Organic compost, which is rich in essential nutrients like nitrogen, phosphorous, and potassium, has enhanced soil structure, increased its water retention capacity, and ensured a constant supply of nutrients to plant roots.

3. Positioning of Plants

After the soil has been prepared and enriched, it is possible to place the plants. A landscape design was used to arrange the plants in the flower beds, taking into account their specific needs in terms of light exposure, growth space, and compatibility with other plants. In order to promote rooting and development, special attention was paid during this phase to maintaining the root systems and positioning the plants at the right depth.

4. Coat with wood chips

The final step was to cover the soil with a layer of wood chips. Wood chips consist of small pieces of shredded wood and offer numerous advantages.:

- A. By storing moisture, the evaporation of water from the soil can be reduced, which keeps the roots of plants moist for a longer period of time.
- B. Weed control: Hindered weed growth by reducing competition for nutrients and water.
- C. Increased soil fertility: As the wood chips decomposed, they released nutrients into the soil, further improving its quality.
- D. Thermal insulation: It has protected the roots of plants from extreme temperature changes, both in summer and winter.

SELECTION OF PLANT SPECIES

- Flower bed in via Cesare Battisti - Piazzale Oberdan

Species used inside the flower bed:

		
Pyracantha "Navaho"	Prunus lauracerusus otto luken	Hedera Helix

Pyracantha "Navaho" is an evergreen shrub belonging to the Rosaceae family, characterized by a vigorous and compact growth. It has oval leaves, of a glossy dark green color, and produces abundant white flowers in late spring, followed by showy red berries in autumn that persist until winter. These berries not only add a decorative element to the landscape, but also provide food for birds during the colder months. The Pyracantha "Navaho" is native to the range that includes the regions of southern Europe, western Asia and China. It is particularly appreciated for its ability to resist air pollution, thanks to its foliar structure that captures polluting particles and improves air quality. Despite not being an autochthonous species of Italy, it is well adapted to the Italian climates, harmoniously integrating into the gardens and urban spaces of the country. Its ability to survive and thrive in harsh environmental conditions, along with its ecological and ornamental function, makes it an ideal choice for urban reforestation and for the creation of green barriers against pollution.

The Prunus laurocerusus "Otto Luyken" is an evergreen shrub belonging to the Rosaceae family, known for its compact and dense growth, reaching a maximum height of about 1-1.5 meters and a similar width. It has leathery, lanceolate and shiny dark green leaves, which offer an elegant and decorative look all year round. In spring, it produces abundant small white flowers, collected in upright clusters, which give off a delicate scent and attract pollinating insects. Subsequently, in autumn, the flowers are followed by shiny black berries, which may persist until winter, adding additional visual interest and providing food for birds.

Native to south-eastern Europe and Asia Minor, the Prunus laurocerusus "Otto Luyken" adapts perfectly to the temperate and humid climates of Italy, integrating well in the gardens, public parks and urban landscapes of the country. This shrub is particularly effective in combating air pollution thanks to its dense crown, which serves as a natural filter for polluting particles, such as fine dust and harmful gases, thus improving air quality. The leathery leaves and compact structure allow you to capture and retain these particles, helping to create a healthier environment.

In addition, the *Prunus laurocerasus* "Otto Luyken" is resistant to many diseases and pests, making it a robust and easy to maintain plant. Its ability to tolerate harsh environmental conditions, such as drought, frost and exposure to air pollutants, along with its ecological and ornamental function, makes it an excellent choice for urban reforestation and the creation of green barriers. These barriers not only improve the aesthetics of urban spaces, but also provide an important ecological function, contributing to the mitigation of pollution and the improvement of the general well-being of the community.

Hedera helix, commonly known as common ivy, is an evergreen climbing plant belonging to the Araliaceae family. It is characterised by lobed, dark green leaves with a leathery texture and a glossy surface. Ivy can grow up to 20-30 meters tall if it finds adequate supports, thanks to its aerial roots that allow it to adhere to walls, trunks and other surfaces. The flowers, inconspicuous and yellow-green, bloom in autumn, followed by black berries that ripen in winter, providing food for numerous birds. Native to Europe, the Caucasus and the regions of Central Asia, the *Hedera helix* is native to Italy, where it is widely spread both in natural and urban environments.

This plant is particularly appreciated for its exceptional properties in contrast to air pollution. Its dense foliar cover is capable of capturing and retaining fine dust, heavy metals and other pollutants in the air, significantly contributing to improving urban air quality. In addition, *Hedera helix* is effective in absorbing carbon dioxide and releasing oxygen, helping to mitigate the greenhouse effect. Her ability to grow in a variety of environmental conditions, including poor soils and shaded areas, makes her an extremely versatile and easy-to-maintain plant.

Being autochthonous in Italy, the common ivy is perfectly integrated in the local ecosystems, supporting the indigenous biodiversity. Its presence in gardens, parks and urban areas not only enhances the aesthetics of the landscape, but also provides shelter and food for many species of wildlife, helping to create a more sustainable and healthy environment. The combination of its ecological properties and its robustness makes *Hedera helix* an ideal choice for urban reforestation and the creation of green barriers, playing a crucial role in the fight against air pollution.

Evidences of the new green area:



- Flower bed in Via Ruggeri da Stabello

Specie used inside the flower bed:

	
Myrtus communis	Thymus vulgaris
	
Thymus vulgaris varietà "Aureus"	Helichrysum italicum

Myrtus communis, commonly known as myrtle, is an evergreen shrub belonging to the Myrtaceae family. Characterized by a compact and dense posture, it can reach a height of 2-3 meters. Its leaves, opposite, are small, oval, leathery and of an intense green, emitting an aromatic scent when rubbed. In summer, myrtle produces white or slightly pink flowers, with a delicate and pleasant scent, followed in autumn by blue-blackish berries, edible and used for the production of traditional liqueurs. Native to the Mediterranean basin, myrtle is native to Italy, where it grows spontaneously in spots and garrigues, especially in coastal regions.

Myrtle is appreciated not only for its aesthetic and aromatic qualities, but also for its properties in combating air pollution. The leaves, thanks to their structure and waxy coating, are effective in capturing fine dust and other pollutants in the air, thus helping to improve air quality in urban areas. In addition, myrtle absorbs carbon dioxide and releases oxygen, helping to mitigate the greenhouse effect.

Being autochthonous in Italy, myrtle adapts perfectly to the Mediterranean climates of the country, showing a remarkable resistance to drought and poor soils. This adaptability makes it an ideal plant for urban reforestation and the creation of green barriers, as well as for the recovery of degraded areas. The presence of myrtle in gardens and public spaces not only improves the aesthetics of the landscape, but also supports local biodiversity, providing habitats and food for different species of insects and birds. Its combination of beauty, robustness and ecological functionality makes *Myrtus communis* a valuable resource for the environment and public health.

Thymus vulgaris, commonly known as thyme, is a perennial aromatic plant belonging to the Lamiaceae family. This dwarf shrub, which reaches a height of 20-30 cm, has woody stems at the base and small, linear and greyish-green leaves, characterized by a slightly hairy surface and an intense and distinctive aroma. In spring and summer, the thyme produces small pink or

lilac flowers, arranged in inflorescences, which are very attractive for bees and other pollinating insects. Native to the Mediterranean region, *Thymus vulgaris* is autochthonous in Italy, where it grows spontaneously on calcareous and well drained soils, often in arid and sunny environments.

Thyme is known not only for its culinary and medicinal properties, but also for its ability to combat air pollution. Its aromatic leaves contain essential oils that have antibacterial and antifungal properties, helping to purify the surrounding air. In addition, due to its dense foliar structure, thyme is effective in capturing fine dust and other pollutants in the air, thereby improving air quality in urban areas.

Being autochthonous in Italy, the *Thymus vulgaris* is perfectly adapted to the Mediterranean climates, demonstrating a remarkable resistance to drought and poor soil conditions. This adaptability makes it ideal for urban reforestation, greening of degraded areas and creating sustainable gardens. Its presence in gardens and public spaces not only improves the aesthetics of the landscape with its compact appearance and colorful flowers, but also contributes to supporting local biodiversity, providing habitats and resources for pollinating insects. The combination of beauty, robustness and ability to purify the air makes *Thymus vulgaris* a valuable plant for the environment and public health.

Helichrysum italicum, commonly known as helichrysum or Italian helichrysum, is a perennial plant belonging to the Asteraceae family. This small shrub, which reaches a height of 30-50 cm, is characterized by thin stems and linear and silvery leaves, covered by a thick white down that gives the plant a gray-silvery appearance. During the summer, the helichrysum produces bright yellow peeping buds, which give off a characteristic curry scent. Native to the Mediterranean regions, the *Helichrysum italicum* is autochthonous in Italy, where it thrives in arid and sunny environments, on poor and well drained soils, often in rocky soils and maritime coasts.

Helichrysum italicum is known for its aromatic and medicinal properties, but also for its ability to combat air pollution. The furry leaves and stems of the plant are effective in capturing polluting particles, such as fine dust and heavy metals, helping to improve air quality. In addition, the plant emits volatile compounds that possess antibacterial and antifungal properties, further contributing to the purification of the surrounding air.

The Italian helichrysum shows a remarkable resistance to drought and salinity. This adaptability makes it ideal for urban reforestation, the greening of degraded areas and the creation of sustainable and resistant gardens. Its presence in gardens, public parks and urban areas not only enhances the aesthetics of the landscape with its silvery appearance and bright yellow flowers, but also contributes to supporting local biodiversity by providing habitat and resources for pollinating insects. The combination of beauty, strength and ability to purify the air makes the *Helichrysum italicum* a valuable plant for the environment and public health.

Evidences of the new green area:



- Flower bed in Via Baioni

Species used inside the flower bed:

	
<p>Hedera helix</p>	<p>Geranium x cantabrigiense 'Karmina'</p>
	
<p>Thymus vulgaris</p>	<p>Thymus serpyllum</p>

Geranium x cantabrigiense 'Karmina' is a perennial plant belonging to the Geraniaceae family, known for its abundant flowering and decorative foliage. This variety has webbed, deeply lobed, bright dark green leaves, which tend to turn red in autumn, adding a touch of color to the landscape. The flowers of 'Karmina' are of a delicate intense pink color, which bloom from spring to summer, forming dense floral carpets.

Native to the mountainous regions of northern Spain and the Cantabrian regions, the Geranium x cantabrigiense 'Karmina' is suitable for temperate and cool climates, finding an ideal environment even in the highest areas of the Alps and the Apennines. In Italy, this species has naturalized mainly in the northern and central regions, where it finds well drained soils and sufficient humidity.

From an ecological point of view, the Geranium x cantabrigiense 'Karmina' contributes positively to the contrast of air pollution. Its leaves act as natural filters, capturing fine dust and other pollutants in the air, thus improving the quality of the urban environment. The plant is also appreciated for its resistance and ease of cultivation, requiring little care and adapting well to private gardens, public parks and urban green spaces.

Geranium x cantabrigiense 'Karmina' is therefore not only an aesthetically pleasing addition to Italian gardens with its vibrant flowers and attractive foliage, but also an important ecological resource in the fight against air pollution, helping to make cities healthier and more sustainable.

Thymus serpyllum, commonly known as thyme serpyllo or serpyllo, is a perennial plant belonging to the Lamiaceae family. Characterized by small creeping stems and small, oval and aromatic leaves, the wild snake grows in dense and carpeted bushes. During the summer, it produces flowers in the shape of a corolla of pink-purple color, which attract bees and other

pollinating insects. Native to the temperate regions of Europe, Asia and North America, the *Thymus serpyllum* is autochthonous in Italy, where it is commonly found in the arid meadows, on the calcareous cliffs and along the margins of the woods.

From an ecological point of view, the measles is known for its properties in contrast to air pollution. Its aromatic and resistant leaves are able to capture fine dust and other pollutant particles, helping to improve air quality. In addition, the snake is a resilient plant that thrives in harsh environmental conditions, such as poor soils and exposed to the sun, making it ideal for soil stabilization and erosion prevention.

Being autochthonous in Italy, the *Thymus serpyllum* adapts perfectly to the Mediterranean climates of the country, demonstrating a remarkable resistance to drought and summer heat. This adaptability makes it an ideal choice for urban reforestation, reclaiming degraded land and creating sustainable gardens. The presence of the snake in urban gardens not only improves the aesthetics of the landscape with its colorful flowers and aromatic foliage, but also contributes to supporting local biodiversity, providing shelter and nourishment for pollinating insects and other small organisms. In conclusion, the *Thymus serpyllum* represents a valuable resource for environmental health and quality of life in Italian urban communities.

Evidences of the new green area:



- Flower bed in via Muraine - Angolo Via Frizzoni

Species used inside the flower bed:

					
Ilex crenata		Iberis sempervirens "Snowflake"			

Ilex crenata, commonly known as Japanese holly, is an evergreen shrub of the Aquifoliaceae family. This plant is characterized by oval, shiny and dark green leaves, with serrated margins that give the plant a decorative look all year round. In spring, it produces small white flowers, inconspicuous but fragrant, which attract pollinating insects. The following berries are black or bluish and remain on the plant until the following spring, providing food for birds and other wildlife.

Native to the temperate regions of East Asia, the *Ilex crenata* has been introduced and has naturalized in many parts of Europe, including Italy, where it adapts well to temperate and subtropical climates. It grows preferably in fertile soils, well drained and with good exposure to sunlight, but is versatile enough to tolerate even more shady conditions and less fertile soils. The Japanese holly is known for its properties of improving urban air quality. The dense and leathery leaves act as natural filters, capturing polluting particles such as fine dust and harmful gases, thus helping to reduce air pollution. In addition, holly is a robust and easy to maintain plant, resistant to weathering and many diseases, making it an ideal choice for creating green barriers in urban areas.

The presence of *Ilex crenata* in the gardens, parks and streets of Italian cities not only contributes to improving the aesthetic environment with its bright green foliage and its colored berries, but also to promote local biodiversity, providing shelter and food source for wildlife. *Iberis sempervirens* "Snowflake", commonly known as perennial strawberry tree or perennial strawberry tree, is a perennial plant belonging to the Brassicaceae family. Characterized by narrow, oval and evergreen leaves, this variety of strawberry tree grows in compact bushes that can reach a height of about 20-30 centimeters. The flowers of "Snowflake" are small and gathered in clusters, pure white and extremely fragrant, which bloom abundantly in spring and continue to bloom for most of the summer.

Native to the mountainous regions of south-western Europe, in particular Spain, France and Italy, the *Iberis sempervirens* "Snowflake" is well adapted to the Mediterranean climates and is commonly found in the rocky areas, in the prairies and along the slopes of the hills. In Italy, the plant has naturalized and is easily found in many regions, especially in coastal areas and in the Maritime Alps.

From an ecological point of view, the *Iberis sempervirens* "Snowflake" plays an important role in combating air pollution. Its evergreen and dense leaves act as a natural filter, capturing

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dust particles and other pollutants present in the urban air. In addition, the plant contributes to soil stabilization and erosion prevention, thanks to its fibrous roots and its surface rooting system.

The presence of "Snowflake" in Italian urban gardens not only adds aesthetic value with its bright white flowers and bright green foliage, but also supports local biodiversity, providing habitat and food source for pollinating insects and other small organisms.

Evidences of the new green area:



- Roundabout in Via Foro Boario - angolo Via Bono

Species used inside the flower bed:

		
<p>Cornus stolonifera "Kelsey"</p>	<p>Hedera helix</p>	<p>Osmanthus heterophyllus "Aureomarginatus"</p>

Cornus stolonifera 'Kelsey', commonly known as red dogwood, is a deciduous shrub belonging to the Cornaceae family. This variety is distinguished by its erect and branched stems, which can reach a height of 1.5-3 meters. The leaves are opposite, oval-shaped elliptical, bright green in spring and summer, turning to red and purple shades in autumn before falling. During spring, the dogwood produces small and white flowers, grouped in flat inflorescences, followed by small bluish white drupes in summer, which attract birds.

Native to the northern and temperate regions of North America, the Cornus stolonifera 'Kelsey' has been introduced in Europe and has adapted well in Italy, especially in mountainous and humid regions. It is particularly common along watercourses, in humid woods and in areas with well-drained soils and rich in humus.

From an ecological point of view, the red dogwood 'Kelsey' offers several benefits in combating air pollution. The dense leaves and the branched structure of the plant act as natural filters, capturing polluting particles and fine dust in the air. In addition, the roots of the dogwood are effective in fixing the soil, preventing soil erosion and contributing to the stability of river ecosystems.

The autoctonicity of the Cornus stolonifera 'Kelsey' in Italy makes it an ideal choice for reforestation, recolonization of degraded areas and the creation of natural barriers against air pollution in urban areas. Its presence in gardens and public parks not only improves the aesthetic appearance with its bright colors and elegant structure, but also contributes to supporting local biodiversity, providing shelter and habitat for insects, birds and other small animals.

Osmanthus heterophyllus "Aureomarginatus" is an evergreen shrub of the Oleaceae family, known for its decorative foliage and its small but fragrant blooms. This variety is distinguished by the leathery and lanceolate leaves, of a bright dark green color, with notched margins and edged with yellow or cream, which give the plant a variegated and lively appearance throughout the year. In autumn, the leaves can turn to shades of bronze or red, adding additional aesthetic interests to the landscape.

Native to the subtropical regions of East Asia, including China and Japan, *Osmanthus heterophyllus* "Aureomarginatus" has been successfully introduced and cultivated in other parts of the world, including Italy. It is adaptable to a variety of climatic conditions, preferring well-drained soils and partial exposure to the sun or partial shade.

Ecologically, *Osmanthus heterophyllus* "Aureomarginatus" contributes to the quality of urban air thanks to its dense leaves and shrub structure that act as natural filters, capturing fine dust and other polluting particles. The plant is also valued for its ability to provide shelter and habitat for local wildlife, including pollinators and birds.

The autoctonicity of the *Osmanthus heterophyllus* "Aureomarginatus" in Italy makes it an ecologically sustainable choice for urban gardening projects, reforestation and conversion of degraded areas. Its presence in city parks, private gardens and public green spaces not only improves the aesthetics of the landscape with its varied foliage and its delicate blooms, but also contributes to promoting biodiversity and creating healthier and more sustainable environments for local communities.

Evidences of the new green area:



RESULTS

This work examines the effectiveness of two different shrubs (*Prunus laucerus* and *Pyrachanta Navajo*) in abating PM (and contaminants associated with PM) by monitoring in flower bed close to a bus station in the city of Bergamo, Italy (Figure 1). The monitoring campaign started on the 15th of January and ended on the 14th of February 2024. To evaluate the potential beneficial effects of plants on human health, the study wants to assess:

- PM concentration in ambient air measured in the presence of shrubs and at the adjacent area, where plants were not present;
- the concentrations of heavy metals and polycyclic aromatic hydrocarbons associated to ambient PM;
- the total mass and number density of PM deposited on leaves of the shrubs and its elemental composition.

The following evidences of the Monitoring PM and organic and inorganic contaminants associated to PM in the presence of shrubs (evidence A) and in the adjacent area, where plants were not present in a flower bed close to a bus station in the city of Bergamo, Italy (evidence B).

Evidences A



Evidences B



This project has received funds by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Climate Infrastructure and Environment Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

CONCLUSIONS

The results of this document show that potential hotspots have been identified and the draft plan has been implemented.

These outputs are an intermediate product, however they are particularly important for achieving the final objectives of the project. Indeed, greening interventions have the potential of significantly improve local air quality. This will help achieving the REBREATH target to reduce citizens exposure to atmospheric pollution at the bus stop. On a broader perspective, greening interventions can also enhance thermal comfort and improve the microclimate, thus improving the life quality of users.

The plant species were selected to reach these targets, while preserving biodiversity and avoiding invasive species. Intervention sites were selected to maximise the impact, considering both number of citizens/users and baseline concentration/expected air quality improvement.

In the next tasks, the effect of greening interventions will be assessed, in integration with the effects of the novel braking system.