Deliverable 1.6 Intervention Conclusions:

Wroclaw




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1 Executive Summary

Funded by the European Commission, GrowGreen explores the ways investing in nature based solutions (NbS) can help cities adapt a changing climate. Led by Manchester City Council (MCC) , GrowGreen includes developments in Manchester (UK), Valencia (ESP) and Wroclaw (PL). This report presents the challenges and results from the work in Wroclaw, where NbS interventions were undertaken in eight locations in the Ofbin area, south of the city. A key objective was to determine if a combination of NbS interventions would have a greater impact than a single one.

The baseline diagnostics for the area explored climate, air and water quality, health indicators, water management, noise, green space, soil contamination along with social and economic indicators. Baseline diagnostics within the project looked at climate, air and water quality, health indicators, water management, noise, green space and soil contamination, alongside social and economic indicators. This baseline was used to provide a robust evidence base and develop a set of Key Performance Indicators (KPIs).

The key threats to Wroclaw are increasing temperatures, intense rainfall and high winds. The projections for 2030 indicate these will continue to worsen. The project also looks at the potential to deliver co-benefits. For example, how green space can improve biodiversity and also impact on the social health and wellbeing of local people.

Community engagement was high on the agenda, with participatory planning seen as an important element within it. Recognising that engagement of the local community was vital with participatory planning a key element. The locations were determined by the residents through their participation alongside local climate parameters, air circulation, spatial constrains and ownership.
Post construction, the Wroclaw University of Environmental and Life Sciences (WUELS) led a process of monitoring and evaluation. This assessed the impact and effectiveness of the NbS interventions. The data is drawn from three areas:

- **Environmental** – to what extent the solutions are able to improve air temperature averages, air humidity, air quality, rainwater retention and increased biodiversity.
- **Social** – can NbS be a vehicle for community involvement, improve the quality of life, sense of security and increase social cohesion as well as environmental awareness.
- **Economic** - estimate the economic benefits, develop business models and create green jobs.

The Wroclaw demonstrator is made up of a series of pocket parks bounded by a green street located within 200 m of one of the area's main streets. The areas have trees, shrubs, swales and raingardens, each unique and tailored to the needs of the residents. The common denominator is the NbS interventions which create green oases in the densely built areas of Olbin. Together they create:

- A green street
- A green tram stop
- Six blue-green courtyards - including vegetable/ herb gardens and a dog exercise park

Monitoring was undertaken pre (2018-19) and post greening (2020 – 2022). The Park was developed as a "Living Lab" with research outcomes on the following areas: climate and water resilience, biodiversity, water quality, participatory planning, social cohesion, health and wellbeing

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and economics outcomes. Outcomes also include the lessons learnt, replication and scaling at a city and regional level, the implications for maintenance and future research.

The total costs of the project were **€1,572,655**. This is based on the capital costs as incurred in specific years and does not include ongoing maintenance (this will transfer to the City of Wroclaw's mainstream budget).

Improved hydrological performance The management systems are designed to encourage on-site infiltration through the use of NbS by encouraging infiltration and attenuating water originating from hard surfaces. As a result of the introduction of 14,993m^2 of biologically active surfaces and 2,544m^2 of semi-permeable surfaces in the project demonstration area, the retention of rainwater in this area increased. The average rainwater retention increased by about 54 m^3, i.e. 54,000L in the periods of precipitation. An average hydrological performance of NbS features deployed in the area of project demonstrator in Wroclaw provides runoff volume reduction at the level of 70%. A runoff coefficient calculated for the Wroclaw demonstration area increased from av. 0,87 to 0,29.

The project has also made a contribution to CO2 sequestration and storage. The newly planted trees (112) in their second year after the planting. provided carbon storage at the level of 600kg/y and carbon sequestration at the level of 142kg/y. It is important to note that the performance of young trees (i.e. with a breast height trunk diameter in the range of 5-7cm) regarding CO2 removal is incomparably smaller than of mature trees and will gradually grow overtime.
Biodiversity net gain has been a **success with a significanlty enchanced biodiversity**. The results show the biodiversity indexes of all vegetation categories have increased. Even though trees were already growing in the demonstration areas, the tree species diversity index increased by 8.6% and in the green street by 4.1%. 6862 shrubs (56 species) and 19,414 herbaceous plants (75 species), including 902 climbing plants (10 species) were introduced after the intervention:

Social impacts were measured with more than 600 people participating in the 30 meeting and events. **All stakeholders reported an increase in knowledge and expertise in NbS, at both individual and institutional level. Significantly, there was a positive impact on citizen learning with an increase in interest levels**. There is also evidence showing how **NbS can enhance the senses, imagination and thought processes.** 63% of the respondents involved in the creation of new green areas believe this project is an example that officials / decision makers can cooperate with residents in introducing changes to housing estates

Health and wellbeing measures showed improvements in these areas with the number of people using green space located in the demonstration areas (i.e. number of adults observed walking in target outdoor spaces) increased from 43% to 83%. The introduction of greenery also contributed significantly to the increase in the number of children playing in these spaces (an increase from 10 to 13%).

Learning about NbS and SuDs have been a key element. The Park provides opportunities to inform future city developments and what was previously parking areas and a busy street have been transformed to created green spaces. **The lessons learnt include the need for specialist knowledge and skills.**

GrowGreen has been a unique opportunity for Wroclaw. For the future, NbS is about changing behaviour in city council departments and with other partners to recognise that NbS is part of the response to the challenges of urban environments. Alongside this is the positive impact on citizens and their appreciation of the value of green infrastructure.

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2 Introduction

Nature based solutions (NbS) demonstration projects were carried out in each of the three GrowGreen Front Runner Cities: Manchester, Valencia and Wroclaw. This deliverable looks at the activities which were work co-designed and implemented in Wroclaw, along with the outcomes, key messages and lessons learned.

The city of Wroclaw has over 642,700 inhabitants. This is the fourth most populous city in Poland and the administrative capital of the Lower Silesia Province. Wroclaw is a heart of a wider agglomeration of more than 1m inhabitants. It is also academic centre with ca. 30 public and private universities and more than 130,000 students. The city has good business competencies, infrastructure, people, educational basis, innovation background, and an entrepreneurial attitude.

The Olbin district is an area of approximately 0.8 km^2, over a length of ca. 1 km. The area is characterised by a dense layout, built at the end of the 19th / beginning of the 20th centuries. There are mostly tenement houses, SMEs, independent shops, bars, cafes and restaurants at street level. Some new multi-storey housing buildings have been constructed recently. There are also number of universities and schools as well and administrative service buildings. The area is divided in two distinct parts in terms of social groups – the south-east part is more affluent and with a higher standard of education (university employees and professionals). In the north-west, the population is more socially disadvantaged.

The area is a local urban heat island, exposed to heat waves and frequent rainfall.

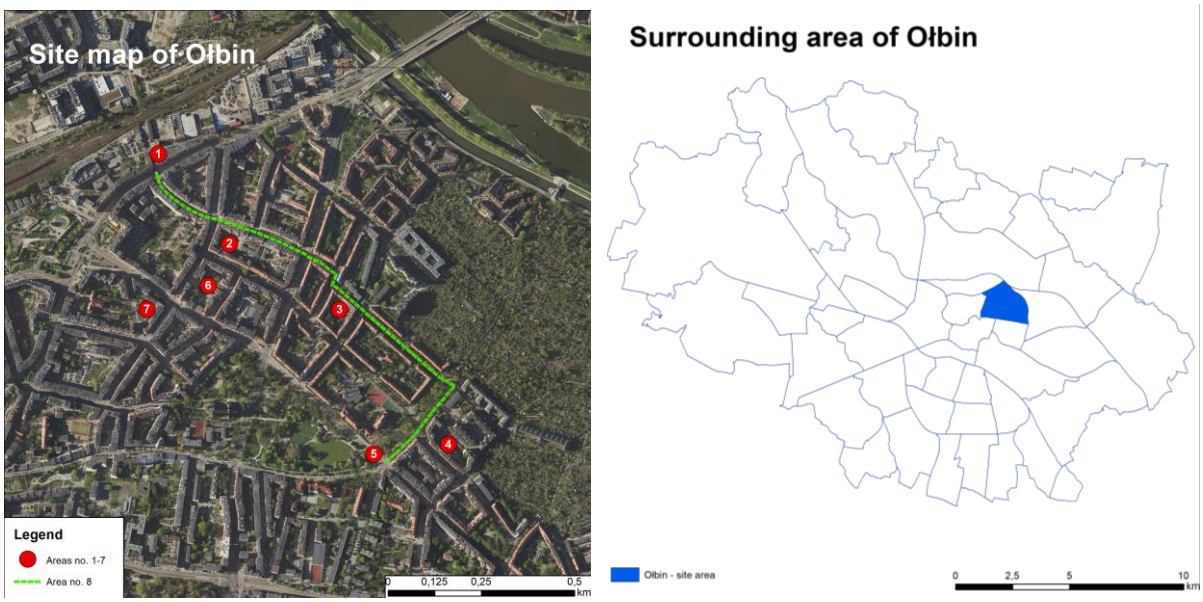

Figure 1 Location map, Olbin district, Wroclaw

The Wroclaw demonstrator is made up of seven pocket parks and/or green walls bounded by a green street (the 8th). The seven are a combination of green walls, pocket parks and other interventions (green parklets[1], thematic gardens, etc), located within 200 m of one of the area's

[1] A parklet is a pavement extension providing more space and amenities for people using the street.

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main streets. The locations were determined by the residents needs as a result of their participation along with inputs on local climate parameters, air circulation, spatial constrains and ownership.

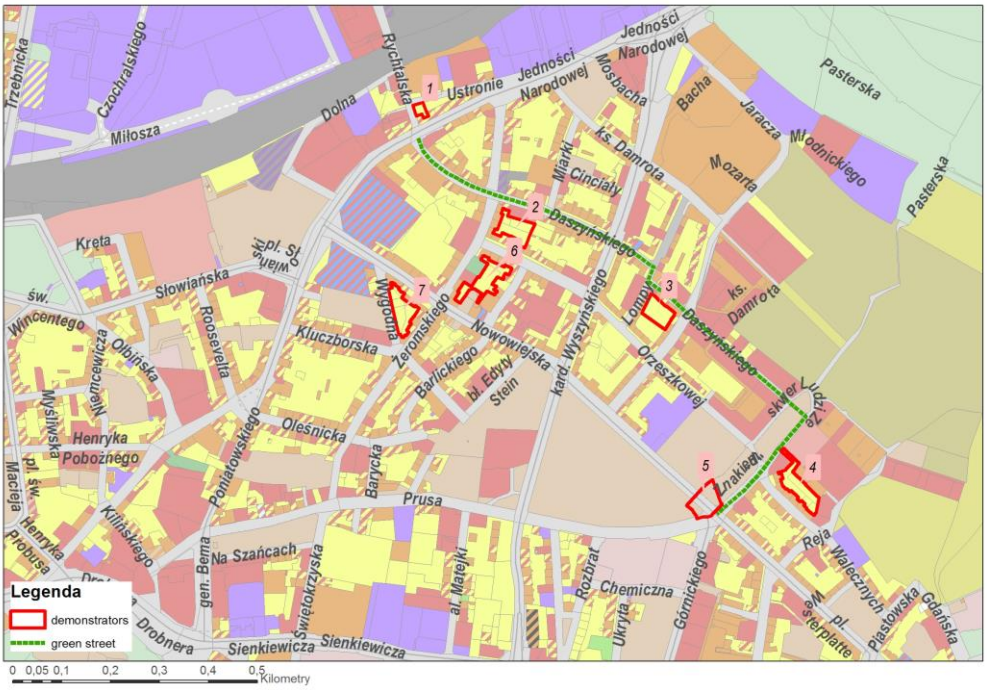

Figure 2 Location map of demos, Olbin district, Wroclaw

The locations include Daszyńskiego Street and the surrounding seven areas in Ołbin. For the purposes of the project the following names were adopted:

- **Area 1 - courtyard between streets**: Jednosci Narodowej, Rychtalska and Ustronie;
- **Area 2 - western part of the courtyard**: between Daszyńskiego, Stanislawa Zeromskiego and Elizy Orzeszkowej streets.
- **Area 3 - courtyard inside the quarter** between Daszyńskiego, Lompy, Elizy Orzeszkowej and Jaracza streets.
- **Area 4 - courtyard inside the building block** between Walecznych, Boleslawa Prusa and Mikolaja Reja streets.
- **Area 5 - squares at the intersection** of Nowowiejska and Boleslawa Prusa streets.
- **Area 6** - **courtyard between streets** Nowowiejska, Zeromskiego, Orzeszkowej and Barlickiego Streets;
- **Area 7 - a backyard inside the building quarters** between Wygodna, Nowowiejska and Zeromskiego streets.
- **Area 8** - **green street**, Daszyńskiego Street together with an adjacent green areas and front gardens.

The objective was to identify the potential to adapt the district to climate change using NbS and to determine if a combination of NbS interventions would have a greater impact than a single one. The components are:

- improving climate conditions (counteracting the urban heat island effect, local temperature reduction),

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- increasing the level of water retention in the soil (reducing water runoff into the sewage system, increasing the capacity of natural retention in the soil, managing rainwater on the land),
- increasing biodiversity (shaping stable ecosystems, improving habitat conditions for plants, increasing the number and diversity of native fauna species),
- improvement of air quality (reduction of pollutant emissions),
- improvement of acoustic environment quality (reduction of noise emission),
- social and economic aspects (increased satisfaction with the quality of public spaces and involvement of residents).

This report examines how these objectives have been achieved.

3 Diagnostic Report

The Wroclaw University of Environmental and Life Sciences (WUELS) produced an initial diagnosis and baseline report in May 2018 based on the Eklipse framework[2]. The report highlights the following:

4 Climate

Temperature - The average annual air temperature in Wrocław is 9.0 °C, the coldest month average air temperature (January) is -0.4 °C, and the warmest (July): 18.8 °C . The annual amplitude of temperatures, which is a measure of the degree of continental climate, is 19.2 °C. The weather in the city is mostly cloudy, without precipitation (141 days during a year). Only 26 days a year are sunny.

Due to its location within the city, the Olbin district, along with nature of the built environment (the vast majority of impermeable surfaces and a lack of greenery), suffers from being intense urban heat island. Differences in daily temperatures during heat waves, compared to the daily temperatures of suburbia, are among the highest in the city.

Precipitation - Wroclaw has low rainfall. Precipitation occurs approx. 167 days a year. However, in recent years, there has been an increasingly frequent occurrence of extremely heavy rainfalls, which cause problems such as sewage overflow, flooding of basements and low premises, periodic difficulties in traffic, water pollution of outflows. The area is particularly exposed to these issues due to a majority of impermeable surfaces and lack of green infrastructure. In recent years, strong winds and storms has also become more common (extreme weather events). The city experiences winds from the west and north as well as south westerlies.

5 Climate Change Adaption and Mitigation

Wroclaw has flood prevention measures, installed as part of the Modernization of the Wroclaw Floodway System. 40 km of riverbeds were adapted to create a flood wave flow of 3100 m^3/s. This work was in line with the Floods Directive and the Flood Risk Management Plan for the Central Odra River Basin. This sets out a series of measures to be completed by 2023. As a result, there is little or no risk of fluvial flooding in the area. The Odra River is located in the northern part of Olbin. Here the river has with levees and flood relief channels

[2] [2] Raymond, C.M. et al. (2017) A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas, *Environmental science & policy*, 77, pp. 15–24.

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In recent years periods of drought (up to 3-8 weeks without precipitation) were recorded during summer seasons, lowering river and groundwater levels. The consequences of urban heat island also need to be taken in to account. Heat waves are more frequent during the summer, with temperatures reaching 35-39°C and on single days even above 40°C. The district is also struggling with the problem of an intense urban heat island. Differences in daily temperatures during heat waves, compared to the daily temperatures of suburbia, are among the highest in the city.

The decrease in water levels and longer periods of drought require the introduction of measures to prevent fast drainage and evaporation of water and as a result a Mayoral order on rainwater management[3] is being implemented.

5.1 Water Management

The Wroclaw river system is considered one of the largest and most complex in Europe with a length of about 80 km. The city is located in the valley of the Odra River and tributaries and there are numerous reservoirs. The frequency of hydrological droughts, water scarcity and floods are decreasing, but at the same time rainfall intensity is increasing.

The state authorities play an important role in water management: the Ministry of the Environment, water management boards, regional boards, but also municipalities and citizens. In July 2001, a law was adopted, "Water Law". This introduced the management of water resources. As a result of Directive 2007/60 / EC on flood risk assessment and management, the following documents are applicable for the Central Odra River Water Region, on which the city of Wroclaw is located:

- terms of use of waters of the Central Water Region established by Regulation No. 9/2016 dated 14 July 2016 of the Director of the Regional Water Management Board in Wroclaw.
- flood risk management plan for the Central Odra River Water Region, along with specific activities in the time schedule.
- A water management plan in the Odra River basin.

5.2 Stormwater Management

In Wroclaw there are six rain basins and are 37 sewer transfer systems. In the rest of the city, there is a separate rain drainage system. Permeable pavements (parking lots), retention tanks (artificial and natural), green roofs, wells and gray water installations are also used.

[3] Mayoral Ordinance on rainwater management In Wroclaw: https://wp-mpwik-new.s3.eu-west-1.amazonaws.com/wp-content/uploads/2020/06/22111324/Zarz%C4%85dzenie-Prezydenta-wody-opadowe.pdf

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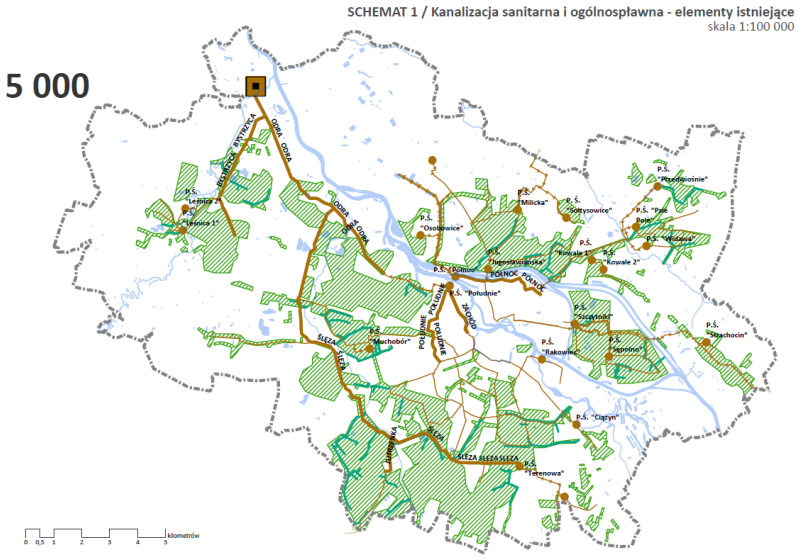

Figure 3 Combined sewage system in Wrocław – existing

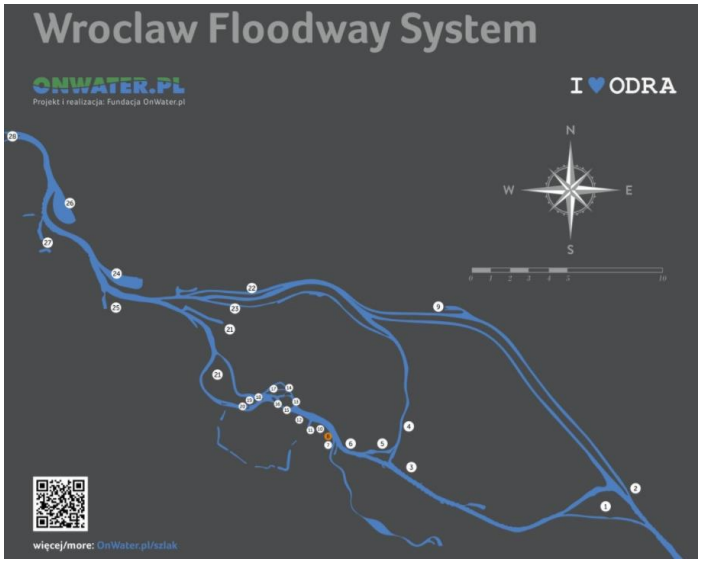

Figure 4 Wrocław floodway system

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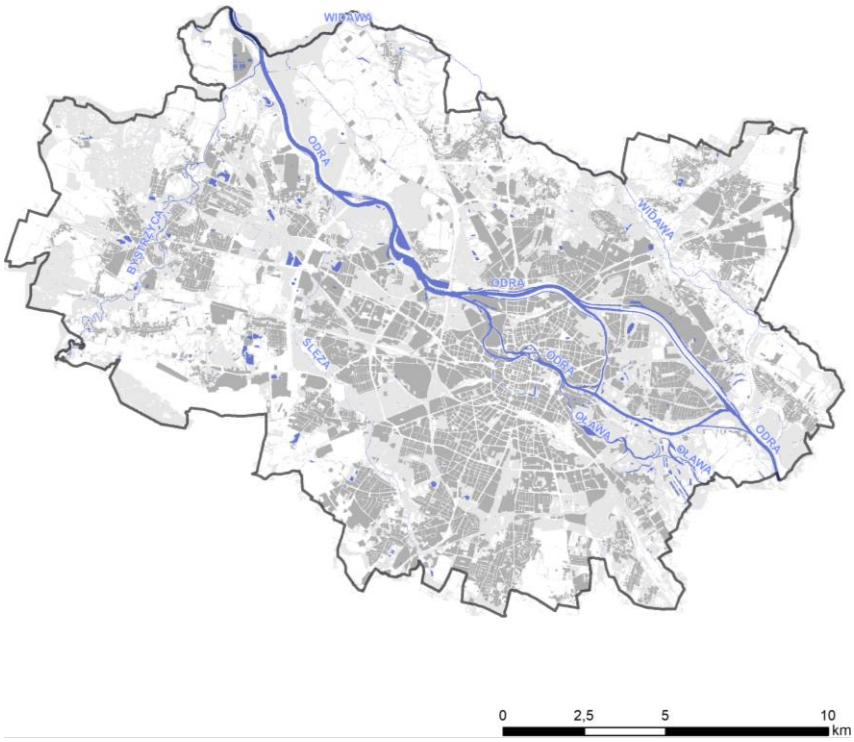

Figure 3 Waterbodies of Wroclaw

5.3 Air quality

Air quality in Wroclaw is impacted by residential coal fired heating. Annual air quality assessments carried out by the Regional Inspectorate for Environmental Protection and the air protection programs (POP) indicate that the emissions from the use of solid fuels (primarily coal) – so called "low emission", is the main source of high concentrations of PM10 and PM2.5 and benzo(a)pyrene in the city. The largest share of municipal buildings, heated by solid fuels is located in the Old Town (about 40%) and Downtown (30%) districts (Olbin is a part of the downtown district).

5.4 Water quality

The quality of the water resources has improved significantly in recent years. This is confirmed by the Water Management Plan for the Central Odra River Basin and the annual reports of the Regional Inspectorate for Environmental Protection.

The capacity of organic substances for the Wroclaw agglomeration is 1,050,000 PE and complies with the National Programme for Municipal Wastewater Treatment. The total load received of organic matter is currently 1029196 PE (2016). The system consists of Wroclaw Sewage Treatment Plant, 58 pump-rooms and confluent points. The length of the sewage system is 1462.34 km. The length of the sanitary sewage system is 520.57 km, the combined sewage system is 434.46 km. The rain drainage system is 145.23 km. 99% of sewage is discharged to the treatment plant. The water distribution network in Wroclaw has recently been upgraded.

5.5 Noise

Traffic noise is an issue in Olbin.This is mainly from road traffic along the Wyszynski Street as is one of the main arteries leading from the city centre to the north-east part of Wroclaw and to A1 highway (leading to Warsaw). A substantial source of traffic noise is also Jedności Narodowej and Nowowiejska Streets.

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The main areas exceeding the acoustic environment standards are along Wyszyńskiego and Jedności Narodowej Streets as well as Daszyńskiego Street.

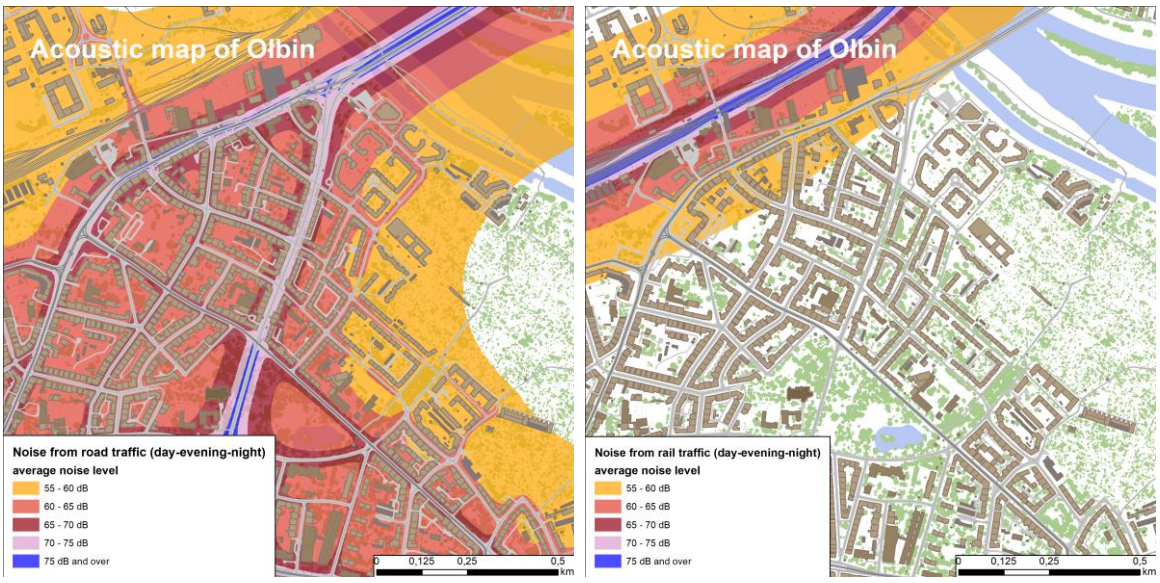

Figure 4 Focus on the Ołbin district– an acoustic map.

5.6 Biodiversity

There was no data on biodiversity in Olbin due to the lack of greenery in the area. Courtyards with residual greenery are mostly covered with compacted soils and a lack of greenery along the streets.

5.7 Social, Health and Economic

Participatory Planning and Governance Olbin was one of the most active districts submitting projects to the Wroclaw Participatory Budget. Projects submitted by the residents include:

- increasing the number of renovations of tenement houses;
- increasing the number of green spaces, street greenery, places separated from traffic, etc.;
- increasing the amount of street lighting;
- increasing the budget for elimination of solid fuel stoves
- introduction of mechanisms to support building insulation;
- new cycle routes;
- improved safety at crossings and extended infrastructure.

5.8 Social Cohesion

Poland is a mono-ethnic state. Wroclaw, like the vast majority of Polish cities and regions, have few national minorities. Olbin district, compared to other districts has a relatively large group from the Romani community (about 0.5%). The cultural aspect of the city of Wrocław, as the European Capital of Culture 2016, fits into the complex and multi-layered history of the city as a multicultural capital of Lower Silesia Region. In recent years, Wroclaw has created open, dynamic, and friendly spaces that serve to support the interest in culture, art and beauty, cultural heritage, multicultural heritage, as well as awareness of innovation and the need for sustainable development. This has transformed the city. However, there were some negative perceptions of the Olbin district. These include high

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rates of crime and high levels of alcohol dependency. There is no specific data to evidence these perceptions and they were explored during the co-design process.

5.9 Health and Wellbeing

There was no local data available on the health and wellbeing of residents in the district.

5.10 Economy

In May 2018 the price per square meter of an apartment in the Olbin district in Wroclaw was €1,824 and the average value of an apartment in Olbin €103,000. The price per square meter of a plot or land in Wrocław was approx. €93 and the average value of a plot in Wroclaw was €444,143. There is no data available on unemployment levels specifically in the Olbin district. The Central Statistical Office gives the unemployment level as 1.8% for Wroclaw (March 2022).

6 Determining Co-Benefits

The main objective of the project was to adapt the demonstration area to climate change using NbS. Working with WP2 (Monitoring and Evaluation), measurement methodologies were agreed for each main benefit and selected co-benefits and a list of key performance indicators (KPIs) were agreed (Table 1 Wroclaw KPIs).

Olbin KPIs	
Challenge 1: Climate mitigation & adaptation	**Challenge 2: Water resilience**
Humidity	Run-off coefficient in relation to precipitation quantities
Air temperature	**Challenge 3: Water Management**
Insolation	Reduction on runoff peak discharges
Heatwaves Carbon sequestration in vegetation and soil	Reduction on runoff volume rates
Challenge 4: Green Space Management	**Challenge 5 : Air Quality**
Green area per capita Structural connectivity Accessibility to greenspace Diversity of trees and shrubs Diversity of vegetation strata	Pollution levels (PM2,5, PM25, BaP) Pollution levels (PM10)
Challenge 8: Social Justice and Social Cohesion	**Challenge 7 : Participatory Planning and Governance**
Percentage of individuals with access to at least 2 hectares of green space within 300 metres of home, percentage of individuals with access to at least one 20 hectare site within 5 kilometers of home, number of nature reserve/conservation areas per 1000 population	Noise (LAFma1, Lday) No. meetings with citizens to explain the progress of the project Number of persons (on average) involved in the activities carried out under the project Percentage of women involved in project activities
Percentage of households in full-time employment, percentage of households earning less than the national and regional average, percentage of households classified as deprived	Percentage of older/younger people (on average) involved in project activities
Percentage of people who feel safe in their neighbourhood, number of people using green space.	Number of civil society entities representing community members.
Percentage of people taking notice of their environment.	Number of civil society entities that have participated in the execution of the project in relation to the total of entities with presence in the neighbourhood
Percentage of people who feel integrated into their local community	Number of initiatives proposed and implemented by the public in the framework of the project.
Percentage of people interacting with each other in an outdoor space.	Percentage of population that has faith in decision-makers
Percentage of people with an attachment/sense of belonging to the neighbourhood	Percentage of population that has positively changed his/her opinion of decision makers
Percentage of people of who feel able to trust one another within the neighbourhood.	Percentage of population that believes in the value of procedures
Challenge 9: Public Health and Well-being	Percentage of the population that believes that their participation in the project has served something.
Percentage of people who are happy in their daily lives.	
Percentage of people undertaking forms of physical activity	

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Percentage variation in activity levels by age-group, gender and ethnicity	
Percentage variation in levels of activity	Percentage of community which attach significant value to nature based solutions, rankings of preferred nature based types.
Challenge 10: Potential of economic opportunities, green jobs and business models	Degree to which organisations have enhanced their knowledge and understanding of nature-based solutions
One-off construction costs	Degree to which organisations are able to respond in the context of nature-based solutions
Recurring / maintenance costs	
Property betterment	
Direct jobs & local economy	
Indirect jobs & local economy	
Avoided cost of run-off treatment	

Table 1 Wroclaw KPIs

The implementation of the project was also preceded by a number of studies. For example, The Study of Good Practices indicated actions and examples of solutions that determined the direction of work at the stage of development of conceptual, construction and execution projects.

6.1 Actions for Improvement of Climate, Air Quality and Biodiversity

A number of actions were identified to improve habitat conditions:

- reduction of the number of treatments in green areas,
- mulching and mycorrhization,
- loosening of soil structure and soil replacement,

The use of planting:

- flower meadows and urban amenity meadows (implemented on area no.1, 3, 4, 5)
- ruderal4 plant beds,
- climbers on facades and support structures (Green Daszyńskiego Street, area no. 1,3, 4, 7),
- eco-efficient and low-maintenance “biogroups”
- restoring trees in road lanes structures (Green Daszyńskiego Street)

The planting beds were not included in the final designs due to negative public perception concluded from the public consultations. In several areas, ruderal plants were allowed to partially grow into the edges of the beds. In Area 4 they were allowed to colonise space in paved areas. Creating a food base and habitat for birds and insects was part of the project. Special attention was paid to melliferous (pollinators for bees) plants, which were introduced in larger groups and at the edges of yards. Elements such as insect houses and birdhouses were built along with natural features (trunks of native tree species) left as habitats.

6.2 Water Management

Systems were put in place for capturing and collecting rainwater and snowmelt. These include collecting rainwater into rain barrels for watering plants and collection in raingardens, swales and infiltration into the ground.

Water drainage and infiltration within sealed surfaces has been addressed by the installation of permeable and semi-permeable surfaces on internal routes and parking lots. Rainwater barrels were

[4] Ruderal plants inhabit lands altered by humans, especially the urban environment – roads, roadsides, railroads, parking lots

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installed in Areas 1,2,6 and 7. Water collection and infiltration through raingardens, swales, also infiltration within permeable pavements.

The introduction of native vegetation resistant to dry conditions was included along with planting in the lowest parts of the area where rainwater accumulates. A community garden maintained by residents was also included.

6.3 Recycling Materials

Recycling of materials was a requirement. Attention was given to the reuse of items from demolition. Following options for the use of recycled materials were identified:

- aggregate and crushed concrete from edging - addition of pedestrian pathway and waste shelter substructure provided the required substructure parameters are maintained.
- segregated sand from troughing - addition to the road base and used for grading of terrain;
- granite slabs from demolitions - roadsides, finishing of lowered flowerbeds, pedestrian routes in greenery, development of community gardens.
- granite slabs from demolition of sidewalks - roadsides, green walkways, development of community gardens;
- demolition bricks - finishing of waste shelters;
- wood from cuttings - separating playgrounds and zones in green areas, edging flowerbeds;
- biomass, compost - addition to fertile soil;
- water barrels – reusing tanks.

7 Design Overview

7.1 Demonstrator Design

Area 1 - courtyard between the streets: Jednosci Narodowej, Rychtalska and Ustronie

A neglected courtyard was transformed into pocket park. New paving, trees and shrubs, and structures covered with climbing plants were installed. Rainwater from parking places, garbage sheds and roofs of the tenement houses is redirected and collected. An important element the creation of shade for areas used by residents. A hedge and climbing plants board the park from the streets.

Figure 8 Development concept and visualisation

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Figure 5 Demo no.1 site - before

Figure 6 Demo no.1 site - after

Area 1 - Key aspects

Greenery and biodiversity enhancement:

- more than 1,100 plants - groups of shrubs and beds maintained extensively,
- numerous climbing plants on special constructions for them, which serve as screens separating the interior from the traffic and covering the garbage shed - 32 RMT
- planting of hawthorns, birches, cherry plums and field maples - 16 new trees
- installation of 2 birdhouses

Rainwater retention:

- management of water from the roof of the garbage shed and the roofs of the tenements - installation of 4 rain barrels;
- water management in the swale along the parking places about 10 m2,
- water management in the rain garden of about 5 m2,
- maintenance treatment (replacement of topsoil, mycorrhization and mulching) was performed on the existing tree.

Internal roads and paths:

- construction of a paved square of semi-permeable surface - approximately 186 m^2,
- construction of permeable walking path - 218 m^2,
- construction of a pedestrian passage made of concrete cubes - 103 m^2.

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Area 2 - western part of the courtyard between Daszynskiego, Stanislawa Zeromskiego and Elizy Orzeszkowej Streets

The development design was prepared for the whole interior, with the western part of the courtyard was selected for the first phase. This part had the most of greenery and free space for new planting. The remaining part of the interior, including internal roads and garbage sheds will be delivered during the second stage of the project (June 2022 onwards).

The design works started from locating the parking space in the center of the courtyard near the entrance gate, allowing access to the garbage sheds. This limits the area of internal roads leaving free space next to the buildings for gardens or other forms of development dedicated to residents.

Figure 7 Development concept and visualisation

Figure 8 Demo no.2 site - before

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Figure 9 Demo no.2 site - after

Area 2:- Key aspects

Greenery and biodiversity enhancement:
- new trees planted - 7
- shrubs in front gardens - 111 m^2,
- low greenery - approx. 910 m^2,
- biodiversity enhancement installation - 27m^2,
- houses for pollinators – 5

Rainwater retention:
- creation of 3 rain gardens,
- 3 new rain barrels,

Internal roads and paths:
- internal route with paved square with semi-permeable surface - 143 m^2,
- sidewalk - 172 m^2,

Planned activities in the second phase (June 2022 onwards):

Greenery and biodiversity enhancement:
- lawns - 1254 m^2,
- flower meadow - 144 m^2,
- 11 new trees,
- planting shrubs, grass and perennials and climbers - 1443 m^2,

Rainwater management:
- swale of approx. 8 m^2,
- rain garden with an area of approximately 13.5 m^2,

Internal roads and paths:
- internal routes with squares paved with semi-permeable surface - about 3850 m^2,
- sidewalk of concrete blocks - 851 m^2.

Area 3 - courtyard inside the quarter between Daszyńskiego, Lompy, Elizy Orzeszkowej and Jaracza Streets

The buildings surrounding the courtyard were built in 1924 for postal workers with the centre of the courtyard featuring a fountain with a clock. The project wanted to respect to the historical character of the site and restore the modernist look whilst increasing the biodiversity of the area. To achieve this, the garbage shed was relocated to restore the view of the courtyard through the oldest gate

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from Stefan Jaracza Street. The center of the courtyard is emphasised by a new stone flowerbed filled with tavula and other low shrubs. The landscaping details use a historical material - brick, is exposed on the surrounding buildings.

Figure 10 Development concept and visualisation

Figure 11 Demo no.3 site - before

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Figure 12 Demo no.3 site - after

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Area 3 - Key aspects

Greenery and biodiversity enhancement:

- gardens for residents were created - 130 m^2,
- greenery composition in the central part of the yard - 64 m^2,
- recreation glade - 63 m^2,
- low greenery - 513 m^2,
- climbing plants by the waste and bicycle shed - 25 RMT,
- installation of 5 pollinator houses,
- installation increasing biodiversity - green willow wigwam,

Internal roads and paths:

- pedestrian routes - 50 m^2,
- gravel surface - access to green areas - 18 m^2,

Activities delivered in stage two - construction of an internal route with rainwater management and sidewalks:

- traffic route from semi-permeable surface - about 1140 m^2,
- pedestrian passage made of concrete cubes - about 649 m^2,
- rain gardens - 109,50 m^2.

Area.4 - a courtyard inside the building block between Walecznych, Boleslawa Prusa and Mikolaja Reja Streets

The key challenge was to manage the rainwater and level the outflow to the storm water drainage system. The landscaping was designed to direct the water to the center of the courtyard, away from the tenement houses, which had previously flooded during heavy rain falls.

Figure 13 Development concept and visualisation

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Figure 14 Demo no.4 site - before

Figure 15 Demo no.4 site – after

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Area 4 - Key aspects

Greenery and biodiversity enhancement:

- shrubs in front gardens - 450 m^2,
- low greenery and climbing plants near bike and waste shelters - 210 m^2,
- low greenery (water dedicated) along the swales - 121 m^2,
- biodiversity enhancement constructions - 5,
- climbing plants on the walls of garages together with a frame - 20 RMT,
- reclamation of soil area - 695 m^2,
- installation of pollinator houses - 3,

Rainwater retention:

- creation of three rain gardens (10, 7 and 5 m2) and swale along the green area about 70 m^2,

Internal roads and paths:

- internal route with semi-permeable surface - approx. 78 m^2,
- main square of semi-permeable surface - about 18 m^2,
- pedestrian tracts - 50 m^2 and sidewalk - 28 RMT,
- gravel surface - access to green areas - 18 m^2.

Area 6 - courtyard between Nowowiejska, Zeromskiego, Orzeszkowej and Barlickiego Streets

The design was developed for the entire courtyard with the main focus on the central part. The biggest challenge was to unseal the surface and bring in greenery instead of parked cars. The remaining works are planned as part of the second stage.

Figure 16 Development concept and visualisation

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Figure 17 Demo no.6 site – before

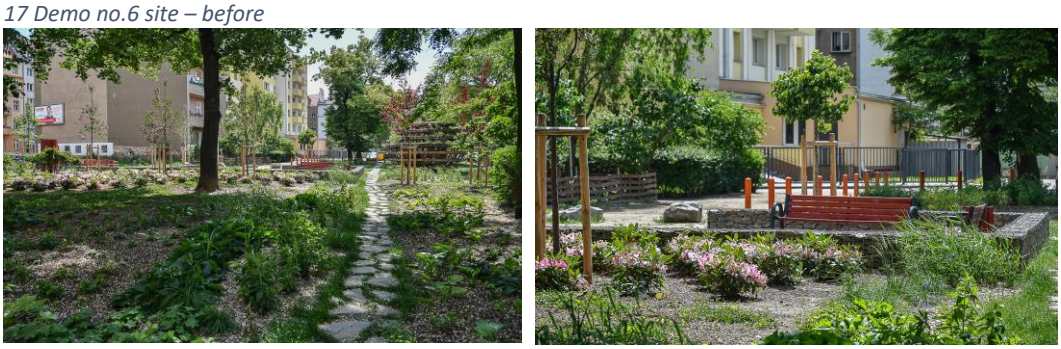

Figure 18 Demo no.6 site - after

Area 6 - Key aspects

Greenery and biodiversity enhancement:

- low greenery - approx. 1200 m2, including planting plants - 4230 pieces and 580 bulbs,
- new planting of trees - 15 pieces,
- establishment of flower meadow - 28 m^2,
- herbal garden for citizens – 9m^2,
- installation of 7 birdhouses,

Rainwater retention:

- swale along the green area about 36 $m^2$and 2 rain gardens,
- increase of absorption surface by unsealing of the surface- 76 m^2

Internal roads and paths:

- paved square with semi-permeable surface - about 162 m^2,
- pedestrian path - 85 m^2 and stone path - 54 RMT;

The following works are planned (June 2022 onwards) as a part of stage two:
Greenery and biodiversity enhancement:

- planting of shrubs, grasses, perennials and climbers - 966 m^2,
- lawn - 156 m^2,

Internal roads and paths:

- traffic route with semi-permeable surface - about 840 m^2,
- pedestrian path - 428 m^2.

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Area no.7 - a backyard inside the building quarters between Wygodna, Nowowiejska and Zeromskiego Streets

This courtyard, due to its open character, also plays the role of a square and is visited by residents walking their dogs. A small "dog playground" was created, open towards the sidewalk and surrounded by bushes. In the central part of the interior there is also a playground for children and recreational space. The existing greenery was supplemented with new planting.

Figure 19 Development concept and visualisation

Figure 20 Demo no.7 site – before

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Figure 21 Demo no.7 site – after

Area 7 - Key Aspects

Greenery and biodiversity enhancement:

- installation of 5 new birdhouses,
- maintenance work on 15 trees,
- trunks of 2 dead trees were secured and planted with climbers – serve as biodiversity enhancement structures,
- low greenery - about 700 m^2,
- sodded area - 506 m^2.

Rainwater retention:

- management of water in 3 rain gardens,
- installation of a rainwater barrel;

Internal roads and paths:

- construction of a permeable pedestrian route - 218 m^2,
- construction of a pedestrian passage - 32.5 m^2,
- reconstruction of sidewalk of concrete cobblestones - 3.5 m^2

Greenery and biodiversity enhancement
The following were delivered in phase 2.

- Planting of shrubs, grasses, perennials and climbers – 52m2
- Internal roads and paths:
- planting of shrubs, grasses, perennials and climbers - 52 m2,
- internal route of semi-permeable surface - about 475 m2
- pedestrian passage - 111 m2.

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Area 8 and 5 - green street and squares at the intersection of Nowowiejska and Boleslawa Prusa Street

Area 5 includes the square and the part of Tolpa Park located by the tram stop on Nowowiejska Street. The sites were maintained using lawn mowers so it was proposed to introduce ground cover plants to improve biodiversity. Low maintenance groundcover of creeping shrubs or perennials were used places too shady to sustain grass. A green waiting area was located in the tram stop area under the crown of a large beech tree.

Figure 22 Development concept

Figure 23 Demo no.5 site – construction increasing biodiversity and green tram stop

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Area 5- Key Aspects

Greenery and biodiversity enhancement:

- planting 3 trees,
- shrub and perennial planting - 460 m^2,
- planting a forest meadow - 115 m^2,
- anemone glade - 41 m^2,
- lawn enriched with bulbous plants - 132 m^2,
- installation of 3 birdhouses,
- installation of a structure increasing biodiversity
- creation of a green “waiting area”.

The Area 5 with green squares and “waiting area” is where the green street begins – Daszynskiego Street and focuses on the following criterial:

1. Plants in the sun, cars in the shade.
2. Meeting places and new functions at intersections.
3. Pedestrians are the most important - they have access to shade and places to rest.
4. The street regains its local function - cars drive slower.
5. We activate residents, involve local business, and stimulate service development.

The challenge was to reorganise parking space in the street and introduce greenery. The easiest solution was planting trees and shrubs, but the biggest challenge was to test trees in pavement conditions where there is infrastructure in the ground. The solution was to narrow the sidewalk and to unseal the surface to create living conditions for plants in half width of it and plant the trees in pots. Other solutions were climbing plants on the walls, lamp posts and big parklets at the intersection of the streets. Boxes for swifts were installed on green facades.

Introducing greenery along the pavement meant reducing parking space for cars. This required discussions with residents. With the support of the Council it was agreed a paid parking zone would be created.

The parklets also forced drivers to slow down, raising discussions on safety. Creating parklets helped to regain the street and enforce the pace 30 zone, not previously observed.

Figure 24 Daszynskiego Street – before

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Green Street - Key Aspects

Greenery and biodiversity enhancement:

- planting of 41 new trees and around 100 shrubs,
- approx. 1500 new perennials and 1100 ground-cover perennials,
- bed grass - approx. 900 m^2,
- approx. 360 new climbers.

The planting was installed:

- green modules along the sidewalk,
- 5 large parklets and 7 small parklets.

Figure 25 Daszynskiego Street – after

7.2 Participatory Planning and Governance

The initial work to identify seven demonstrators was based on scientific analysis, local conditions and citizens expectations. The local residents were asked to identify where they would like to have green interventions. The next step was to establish the municipal codesign team in cooperation with ARAW (Wroclaw Agglomeration Development Agency) and WUELS.

A first meeting with the district council representatives was organised, followed by a meeting with residents. During this meeting residents learnt about the project, the goals and NbS. A schedule of the work was presented, including future meetings for the designing and implementing process of the courtyard interiors.

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Figure 26 Designing workshops

In the following year, 2018, two sets of residents codesign workshops were held. The first was in June - eight meetings - one for each area, the second phase in September and October, another eight meetings. The June meetings were attended by residents, representatives of the Olbin District Council, Wrocław City Hall, the University of Life Sciences and designers, the assumptions of the project were discussed and examples of NbS were presented.

Residents then had the opportunity to tell how they imagined the future development of the area, what is most important to them and supported visualize their aspirations. The topics of parking and waste shelters were the most emotive. Some of the residents wanted more greenery and recreational areas at the expense of reducing the space for parking, but others wanted only parking. One idea was to extend the parking zone in Olbin as an alternative to parking in the courtyard. The location of waste shelters and their service was another hot topic. Residents were open to new solutions - green waste and bicycle shelters, rain gardens, community gardens and as a result, designers created concepts for each of the interiors, with solutions tailored to the needs of the residents in each courtyard.

The October and November meetings were used to present the first concepts, incorporating the findings from June with the opportunity to make amendments. The course of these consultations and the conclusions were presented in reports prepared by the EcoDevelopment Foundation. The outcome was an exhibition in the premises of the public library for two weeks in January 2019[5].

Figure 27 Exhibition in the library

In October 2019 more residents meetings were held. These were scheduled during the implementation of the courtyard interiors in order the residents could ask questions to the

[5] https://www.wroclaw.pl/growgreen/przedstawiamy-koncepcje-zielonego-zagospodarowania-olbinskich-podworek

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designers, contractors, managers, representatives of the City Office and the WUELS. The workshop closed with joint planting.

The next series of workshops took place in September/October 2020. The aim was to educate residents on how to take care of interiors - how to use rainwater barrel and cultivate vegetable gardens. More plants were planted together with the residents with various, green-themed games and activities were provided for the children.

Figure 28 Workshops in september 2020

7.3 Social Cohesion

The revitalisation of the courtyards has had an impact on creating social ties, especially where a community garden and herb garden have been created (Area 4 and Area 6). There are special events planned in fall on different courtyards to sum up the project. There will be outdoor film screening, cooking together, neighbourhood picnic, all building and maintaining social ties.

7.4 Public Health and Wellbeing

Each of the courtyards has a relaxation area. Others have playgrounds for children and a dog park. On two courtyards there are community gardens to grow vegetables and herbs. They are used both by the elderly and young people with children. Older people treat is as a form of outdoor entertainment, for younger it is an opportunity to grow some vegetables together with children and socialise.

Greening the courtyards had brought back the interiors to residents. Instead of serving as a car park space, now it is used by citizens. They could sit, relax and spend time surrounded by nature, in the densely built area.

8 Monitoring and Evaluation

Monitoring of the project areas is divided into two stages:

- Pre-greening - carried out before the introduction of selected NbS (i.e. before the introduction of pocket parks, green areas and parklets), was carried out from September 2018 to August 2019.
- Post-intervention - carried out for 2.5 years after the introduction of the NbS. The final monitoring commenced in February 2020 and will last for 2.5 years, ending September 2022.

Monitoring for both stages was then divided into three sections – environmental, social and economic.

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1. Environmental –to indicate whether, and to what extent, the solutions are able to improve:

    - A reduction of average air temperature, especially in relation to daily temperatures in summer,
    - Air humidity increase,
    - Air quality / pollution reduction, including PM concentrations reduction, particularly in heating season),
    - Increase the efficiency of rainwater retention and increase biodiversity.
    - Impact on the quality of environmental parameters in the whole city, and on increasing the city's climate resilience (i.e. reducing the negative effects of climate change and preventing them).

2. Social – to show if and to what extent, the introduction of NbS as vehicle for community involvement and participation can:

    - Improve the quality of life and increase the sense of security amongst residents.
    - Increase the level of social cohesion,
    - Increase environmental and climate protection awareness.
    - Assess how the demonstrators are being used

3. Economic - to examine / estimate:

    - Potential economic benefits,
    - Business models,
    - The creation of green jobs.
    - Savings, e.g. avoided costs of runoff treatment.

9 Evidence Based Outcomes

This section provides a precise of the datasets, along with analysis of the Challenges determined by the co-benefits process in. A detailed analysis can be found in the following:

- D2.2 Monitoring and Evaluation of Climate and Water Resilience.
- D2.3 Monitoring and Evaluation of Environmental Objectives.
- D2.4 Monitoring and Evaluation of Social Benefits and Participatory Planning.
- D2.5 Monitoring and Evaluation of Economic Objectives.

9.1 Climate and Water Resilence (Challenge 1 and 3)

See D2.2 Monitoring and Evaluation of Climate and Water Resilience.

The drainage scheme was implemented on the principle of gravity flow of water by drainage devices. The surfaces were water-permeable surfaces and the surface drained by infiltration along with longitudinal and transverse slopes to the adjacent terrain. The runoff coefficient was calculated according to the surface. For the catchment area, individual pavement surfaces are taken into account together with the runoff coefficient. The values of the coefficient were adopted on the basis of the PN-EN 752 standard.

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Type	The Value of the Runoff Coefficient Ψ
Impervious surface - asphalt roads, concrete roads and building roofs	Ψ = 0.90–1.00
Semi-impervious surface - surfaces were EcoGrid and gravel surfaces.	Ψ = 0.80–0.90
Biologically active surface - ground surfaces, lawns, gardens, parks and wood chip surfaces	Ψ = 0.00–0.10

Table 2 Surface runoff coefficient in accordance with PN-EN 752.

Less water flows from impermeable surfaces (pavements, squares) into the sewage system. This contributes to an increase in the amount of water in the landscape, prevents the lowering of groundwater levels and local flooding during heavy rainfall. The excess of rainwater or meltwater flows into the earthen trough in the green area or to other water retention devices. The surface of the pedestrian route was drained through longitudinal and transverse slopes to the adjacent area. The outflow from the roofs is carried out using the downspouts drainage gutters.

Figure 29. Paving stones - eco-lattice the surface - concrete cubes and joints with soil and grass.

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Figure 30. Downpipes

The gutter collector has settings suitable for summer or winter, enabling collection of rainwater in the period of demand and closing the flow (drainage of water to the rainwater sewage system) in the winter. The rainwater collectors are installed in the downpipes. The water collector is adapted to the drain pipe so that it works irrespective of the manufacturer of the system and material (metal or PVC). The length of the pipe and its assembly must take into account the position of the lower socket of the drain pipe up to the height of the water collector connection and the height of the barrel with the raising plinth.

Figure 31. Rain garden.

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Figure 32. Drainage ditch of rainwater after rainfall.

Figure 33 Drain gutter and rainwater tank (left) and road gutter (right)

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9.1.1 Outcomes

The analysis focuses on the following storm events:

Date	Maximum intensity of precipitation over time period	Theoretical outflow from catchment m^3	Total amount of rainfall during event m^3	Average value of runoff from the event	Volume reduction %	Runoff coefficient pre greening	Runoff coefficient post greening
29 & 30 June 2022	7.15mm in 10 minutes	65,834	70.918	1,046mm/10min	92.8	0.87	0.07
4 July 2022	5.80mm in 10 minutes	39,624	39.624	1,007mm/10min	100	0.87	0.0
30 July 2022	5,60mm in 10 minutes	57,002	317,256	1,211 m/10min	17.9	0.87	0.82

Table 3 Storm Event Summary Analysis

As a result of the introduction of 14,993m^2 of biologically active surfaces and 2,544m^2 of semi-permeable surfaces in the project demonstration area, the retention of rainwater in this area increased. The average rainwater retention increased by about 54 m^3, i.e. 54,000L in the periods of precipitation. An average hydrological performance of NbS features deployed in the area of project demonstrator in Wroclaw provides runoff volume reduction at the level of 70%. A runoff coefficient calculated for the Wroclaw demonstration area increased from av. 0,87 to 0,29.

9.1.2 Air Quality

The following air quality parameters were identified:

- PM10 pollution levels,
- PM2.5 pollution levels,
- B(a)P [benzo(a)pyrene] in PM10 pollution levels.

The air quality parameters: PM2.5, PM10 and B(a)P in PM10 pollution levels [µg/m^3] data were gathered both within the pre-and post-greening monitoring periods in Wroclaw. Annual air quality assessments are carried out by the Regional Inspectorate for Environmental Protection in Wroclaw and the Lower Silesian Voivodship Board. These indicate that the emissions from residential heating with the use of solid fuels (primarily coal), is the main source of high concentrations of PM10, PM2.5 and benzo(a)pyrene in the city. The measures indicate the need to reduce emissions from coal burning by changing the heating systems. The majority of municipal buildings heated by solid fuels is located in the Stare Miasto (about 40%) and Srodmiescie (30%) districts. Ołbin is a part of the Srodmiescie district.

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Since 2017 the government implemented a programme to replace solid fuel heating systems in the residential buildings6. It was estimated that ten thousand dwellings will be affected. Many are located in the demonstrator area7. Those buildings selected for new heating systems replacement are shown in red. The area covered by the GrowGreen project is marked with a green square.

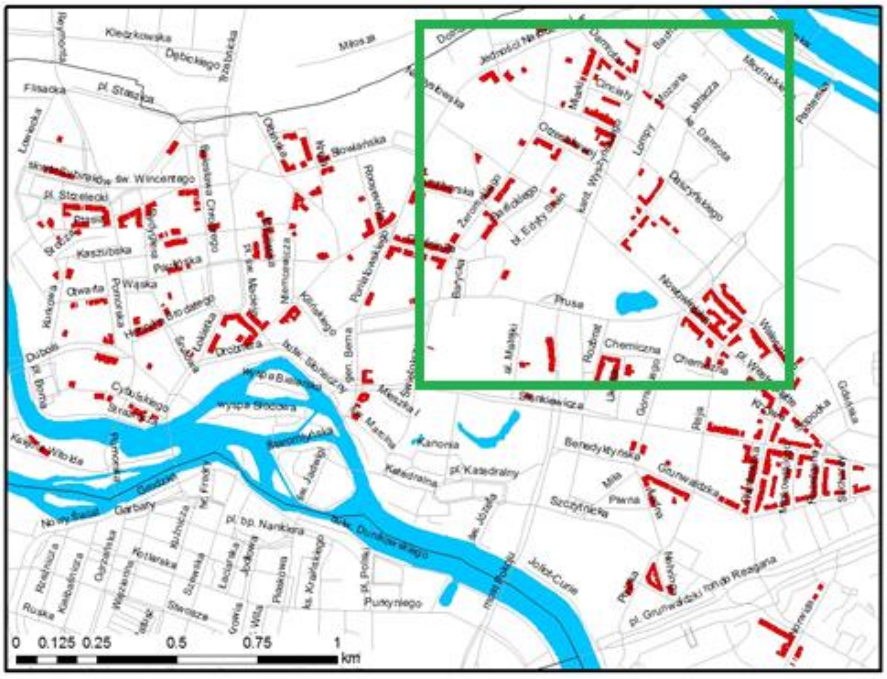

Figure 34 Buildings selected for heating systems replacement shown in red (demonstrator in green square).

The air quality data was obtained via the Regional Inspectorate of Environmental Protection in Wroclaw[8]. The Inspectorate is a government institution responsible for air quality monitoring across the country and manages a network of monitoring stations. One of the monitoring stations in Wroclaw located in close proximity to the area covered by the demonstrator.

The number of solid fuel heating systems in the residential buildings in the project area has a significant impact on particulate matter (PM) concentrations. The vegetation in the demonstrator is relatively immature. During the project period it has not been possible to reliably assess the impact of the NbS on the reduction of particulate matter. Further research will be required as part of the ongoing monitoring years when a new heating structure in this area is established.

9.1.3 Noise

The information on noise drawn from the Wroclaw City acoustic map 2017[9] provided a baseline for pre-greening monitoring. The acoustic maps for Wroclaw are published every 5 years and show noise levels exceeded thresholds in the categories of:

- traffic noise Lden[10]

[6] https://zmienpiec.pl/ (access: July 2022), https://www.wm.wroc.pl/program-kawka-dla-osob-fizycznych/ (access: July 2022)
[7] WP1 Wroclaw Demonstration Project Diagnosis and Baseline Report, December 2017
[8] https://www.wroclaw.pios.gov.pl/
[9] Wroclaw Spatial Information System
[10]

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- traffic noise Lninght[11]

Based on the comparison of the 2017 and 2022 acoustic maps (representing pre- and post-monitoring period), the evidence shows that in 2022 the traffic noise Lden category is no longer observed in "the green street demonstrator". This leads to the conclusion that traffic noise reduction has been influenced by the NbS introduction.

To investigate the subjective experience of residents, a survey was found 66% felt the introduction of new green areas in the courtyards / along the street made the area quieter. Therefore it can also be concluded that the NbS along the green street demonstrator reduced the perception of noise nuisance. One of the strengths of NbS is modifying soundscape (even when the noise levels are the same) with the natural elements contributing to enrich the sound atmosphere with natural and improve the general environmental experience.

9.1.4 Heat Stress Impact Assessment

Climate projections will contribute to increasing the Urban Heat Island Intensity (UHII) effect. The role of NbS solutions can play to adapt to this and contribute to more resilient cities depends on the scale of intervention. Meteorological parameters: air temperature, air humidity, wind speed were gathered both within the pre-and post-greening monitoring periods in Wroclaw as hourly measurements. However, due to the difficulties in maintaining the continuity of measurements in the selected location (the measuring stations were moved during the project), as well as the lack of a reliable reference station and historical city data it has not been possible to reliably assess the impact of the introduced NbS on the reduction of average daily temperatures during heat waves. Further research, mainly in the form of modeling will be required as part of the ongoing monitoring years when, i.e. new green areas will reach maturity.

9.1.5 CO_2 Sequestration and Storage

The calculation of CO_2 sequestration and storage (CSS) due to natural tree growing in urban environment is calculated using:

- On-field tree input data: species and key dimensions (trunk diameter, height, crown diameter)[12] and general site description.
- Reference weather data (temperature, wind speed/direction, HR, solar radiation)

The I-Tree Eco Field Guide [12] describes the key parameters as species, DBH (tree reference trunk diameter "at breast height", normalized height of 1.3 m), crown top / base height and width. To evaluate tree carbon sequestration and storage i-Tree Eco software was used. Tree measurements and field data are entered manually along with local weather and air pollution concentration data (from references weather data station). Carbon storage is estimated using:

- Species – to identify biomass equation
- Diameter at breast height (DBH) – to calculate tree biomass
- Total height – to calculate tree biomass
- Field land use – to assign biomass adjustment factor[13]

[12] I-Tree Eco Field Guide. https://www.itreetools.org/documents/274/EcoV6.FieldManual.2021.10.06.pdf

Carbon Sequestration (also referred to gross carbon sequestration) is estimated using:

- Species – to identify biomass equations
- Diameter at breast height (DBH) – to calculate tree biomass
- Total height – to calculate tree biomass
- Field land use – to assign biomass adjustment factor.
- Crown health (condition/dieback) – to adjust growth rates
- Crown light exposure (CLE) – to adjust growth rates

Note: Crown light exposure (CLE) indicates, from the 5 possible sides (upper part, front, behind, right, left), how many faces are free of obstacles for solar radiation. There are three different categories of CLE: 0-1 represents forest conditions with a closed, or nearly closed canopy, where none or one side of the tree is exposed to sunlight. CLE of 2-3 represents park conditions and 4-5 represents open-grown conditions. After three years of measurements, DBH measures indicated that best fitting was obtained with CLE=2-3. This result is typical for urban parks and street trees.

The newly planted trees (112) in their second year after the planting. provided carbon storage at the level of 600kg/y and carbon sequestration at the level of 142kg/y. It is important to note that the performance of young trees (i.e. with a breast height trunk diameter in the range of 5-7cm) regarding CO2 removal is incomparably smaller than of mature trees and will gradually grow overtime.

As a result of introduction of large amount of vegetation (112 trees of 27 species, 6862 shrubs of 56 species and 19 414 herbaceous plants of 75 species (including 902 climbing plants of 10 species)) within the project, as well as protection of mature trees and proper selection of plant species, all project demonstration areas noted significant biodiversity uplift. The results show the biodiversity indexes of all vegetation categories have increased. Even though trees were already growing in most of the demonstration areas, the tree species diversity index of the entire area covered by the project increased by 7.5%. There were no trees or other type of vegetation in the western part of "the green street" demonstrator and after the project intervention the tree species diversity index in this area is 1,0603874. For the entire project area the shrub species diversity index post-intervention is 2,06814525 and herbaceous plants diversity index: 3,71336485 (while entire project area was almost completely devoid of low greenery before the project).

In mid-2022 there was an evaluation and annual monitoring of trees, see Table 4 for the results.

	CO_2 Sequestration & Storage			
	Pre-Greening		**Post-Greening (2022)**	
Action	Co_2 Sequestration Vegetation (Trees) / Annual ton CO_2 per	CO_2 Storage Trees / ton CO_2	Co_2 Sequestration Vegetation (Trees) / Annual ton CO_2 per	CO_2 Storage Trees / ton CO_2

[13] . Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak, 2008). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8.
Nowak, David & Crane, Daniel & Stevens, Jack & Hoehn, Robert & Walton, Jeffrey & Bond, Jerry. (2008). A Ground-Based Method of Assessing Urban Forest Structure and Ecosystem Services. Arboriculture & Urban Forestry. 34. 10.48044/jauf.2008.048.

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	year		year	
Network of demonstrators: "Green System"	- (*)	- (*)	0.521	2.20

- (*) Pre-greening values can be considered zero as post-greening results are evaluated for new trees

Table 4: CO_2 Storage And Sequestration

9.2 Green Space Management – Biodiversity (Challenge 4)

See D2.3 Monitoring and Evaluation of Environmental Objectives.

Biodiversity monitoring aims *"to quantify the enhancements in biodiversity in each of the demonstration projects. Although each city will have country-specific methods and standards for assessing biodiversity, common attributes will be monitored across all demonstration projects to facilitate robust comparisons. These (…) may include species richness, habitat fragmentation, biomass, vegetation cover/area. In addition to identified attributes, the biodiversity assessment at each site will also assess whether species of conservation concern (e.g. spiders, beetles and butterflies) are present (i.e. those that appear on European or National Red Lists, European Habitats Directives or Biodiversity Action Plans)[14]".*

The biodiversity indices were calculated for each of the demonstration areas before and after the interventions. To express the measure of biodiversity, the Shannon (Shannon-Wiener) Diversity Index (H') is used. The Shannon Diveristy Index takes into account the number of species present within a given area or habitat - i.e. the richness, and their relative abundance with that area or habitat - i.e. the eveness. The equation was used:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where: *H'* - Shannon diversity index; *S* - number of species
p_i - Proportion of individuals of i-th species within the dataset

Developing biodiversity across the demonstrators was important. Many of the courtyards were neglected and used for parking. Pocket parks were created. Trees and shrubs, flower borders and groundcover plants were planted. Garbage container sheds and bicycle sheds were built with frames for climbing plants. Other NbS features included elements of blue infrastructure, i.e. rain gardens (small hollows in the ground, planted with vegetation resistant to both periodic drought and flooding, also called bioretention facilities), swales and barrels collecting rainwater (rainwater tanks allow to quickly drain some of the rainwater after rainfall), to be used for watering plants. The NbS also included permeable surfaces, in the form of a concrete grid that allows rainwater to infiltrate the ground[15]. Bird boxes, insect houses and flower meadows (especially valuable for pollinators) were also introduced in the pocket parks.

Initial monitoring biodiversity surveys were carried out during the summer / autumn of 2018, with final monitoring in the spring / summer of 2022. Due to the diverse nature of the Wroclaw project demonstrators, the post-intervention tree species diversity index (Shannon Diversity Index - H') were carried out for the individual demonstrator categories as well as the entire area covered by the project.

[14] Grant Agreement no. 730283 - Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environments (GROW GREEN)

[15] Siedlecka M., Suchocka M.: *Wodoprzepuszczalne nawierzchnie a zrównoważony rozwój terenów miejskich*, Drogownictwo nr 2 (2017), 60-67

Research on the diversity of tree species was carried out on the basis of a study containing a complete dendrological inventory of trees growing in the project areas[16]. The initial list of trees 51 species, a total of 361 trees (see Section 14).

The calculations of these pre-intervention tree species diversity index for the total area, as well as the individual categories of demonstrators are shown in Table 5 . It was not possible to calculate the species diversity index of shrubs as the dendrological inventory did not include data on the number of shrubs growing before intervention. Many were old and neglected with overgrown hedges making made it impossible to determine the number of individual plants forming a hedge. There was a scarcity of herbaceous plants in the project area before the intervention and hence calculation of the species diversity index of this vegetation category was not possible. In the study[17].

9.2.1 Interventions

The images below illustrate some of the interventions and their considerable impact on the urban environment. Demonstrator no. 5 and the green street had a row of trees planted with small hedges and flower borders and groundcover plants. Parklets were also used (wooden constructions in which trees and shrubs were planted and seating).

Figure 35 Demonstrator no. 2 before and after

[16] *„Inwentaryzacja dendrologiczna na potrzeby projektu Grow Green”*, Reda P., Budny M., Rymarowicz P., czerwiec 2018 r., maszynopis w zbiorach Biura Ochrony Przyrody i Klimatu Urzędu Miejskiego Wrocławia.
[17] *„Rozpoznanie uwarunkowań przyrodniczych na potrzeby projektu Grow Green”*, Reda P., Malkiewicz A., Lontkowski J., Gottfried T., czerwiec 2018, maszynopis w zbiorach Biura Ochrony Przyrody i Klimatu Urzędu Miejskiego Wrocławia

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Figure 36 Demonstrator no. 1 before and after.

Figure 37 Development concept and visualisation – Area 2

Figure 38 Demonstrator no. 4 before and after

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In the period between the initial and final monitoring, none of the trees already growing in the project area were removed. This enabled the calculation of the species diversity index of the trees before and after the intervention, as well the ability as to compare the indexes calculated before and after the NbS was introduced . The design documentation contains data on the number of each tree species introduced - 112 trees (27 species).

The selection of tree species introduced in the project areas was based on native tree species-cultivars, characterised by high resistance to urban conditions: salinity, compact ground, drought, difficult soil conditions, air pollution etc. (see Section 14 for full details of the species).

6862 shrubs (56 species) and 19,414 herbaceous plants (75 species), including 902 climbing plants (10 species) were introduced after the intervention:

- shrub species diversity index for the entire area covered by the project is: H' = 2,06814525;
- herbaceous plant species diversity index for the entire area covered by the project is: H' = 3,71336485.

The selection of shrubs and herbaceous plant species was based on native species, cultivars characterised by resistance to urban conditions as well as adaptation to habitat conditions.
The comparison of calculated biodiversity indexes for the vegetation categories by demonstrator are shown in Table 5.

Vegetation category	**Demonstration area categories**	**Species biodiversity index (H') pre-**	**Species biodiversity index (H') post-**	**Increase (%/value)**
Trees	Courtyards (demo areas no. 1, 2, 3, 4, 6 and 7)	3,06669462	3,35527335	+8,6%
	Area of Daszynskiego Str. along with the green space at Nowowiejska Str. (demonstrators no. 5 and "green street")	2,96993883	3,0974271	+4,1%
	Fragment of the "green street" demonstrator - section from Karola Miarki to the Jednosci Narodowej Streets	n/a (no trees or vegetation in this area)	1,0603874	1,0603874
	Area covered by the project	3,18553981	3,44366895	+7,5%
Shrubs	Area covered by the project	n/a	2,06814525	2,06814525
Herbaceous Vegetation	Area covered by the project	n/a (almost no herb. veg. in this area)	3,71336485	3,71336485

Table 5 Biodiversity indexes (H') for vegetation categories by demonstration areas.

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The results show the biodiversity indexes of all vegetation categories have increased. Even though trees were already growing in the demonstration areas, the tree species diversity index increased by 8.6% and in the green street by 4.1%.

The pre-intervention research work[18] also included a description of the fauna habitat conditions. Whilst this was not repeated as part of the post-intervention, it will be repeated in the next two years i.e. four years following the initial intervention.

9.2.2 Outcomes

The project led to the introduction of 112 trees of 27 species, 6862 shrubs of 56 species and 19 414 herbaceous plants of 75 species (including 902 climbing plants of 10 species) in the project areas (with additional wildflower meadows consisting of herbaceous plants of 58 species in 4 demonstration areas).

The city's Department of Sustainable Development estimates approximately 1ha of new green space has been created (this does not include the area occupied by the climbers). Blue-green infrastructure with biodiversity supporting elements were also added.

In the future research it will be important to observe how the introduced plant species cope without additional maintenance (when the contractors' guarantee period expires) and which are most suitable. The results of the fauna inventory of these areas will also be important to determine whether the introduction of NbS has also increased the number of animal species.

9.3 Social and Participatory Benefits (Challenges 7 and 8)

See D2.4 Monitoring and Evaluation of Social Benefits and Participatory Planning.

The research on the social and participatory benefits focuses on three challenges covering aspects of both NbS process and NbS provision. These are drawn from the EU EKLIPSE approach originally developed by Raymond et al., (2017)[19]. This seeks to promote an assessment framework for the evaluation of climate resilience measures in urban areas. The **three areas of challenge are:**

- Challenge 7: Participatory Planning and Governance
- Challenge 8: Social Justice and Social Cohesion
- Challenge 9: Health and Wellbeing.

Measurement parameters in the field of social monitoring were tested with the use of surveys, questionnaires and field observations in accordance with the Mohawk methodology (Method for Observing Physical Activity and Wellbeing) [20]. Data was also collected from various public institutions and research centres (including Statistical Office in Wroclaw and the Wroclaw Spatial Information System).

[18] *„Rozpoznanie uwarunkowań przyrodniczych na potrzeby projektu Grow Green"*, Reda P., Malkiewicz A., Lontkowski J., Gottfried T., czerwiec 2018, maszynopis w zbiorach Biura Ochrony Przyrody i Klimatu Urzędu Miejskiego Wrocławia

[20] MOHAWk is a systematic observation tool for assessing three levels of physical activity (Sedentary, Walking, Vigorous) and two other behaviours important for wellbeing (Take Notice and Connect), in urban spaces.

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30 meetings and events were organized with the residents of the areas covered by the project. The meetings were of a varied nature - some were aimed at discussing the course of work and progress in the project, some aimed at involving residents in the process of introducing nature-based solutions in their place of residence (by participating in the development of the spatial planning concept of the project areas). Some of them were aimed at encouraging participation in maintenance works and using the new green infrastructure. Each of the meetings was also educational - as part of the meetings, the inhabitants were provided with knowledge about the climate change adaptation in cities, green infrastructure, nature-based solutions and environmental protection.

In the region of 600 people participated in all the 30 meetings, of which

- approx. 53% were women and 47% men,
- approx. 11% - elderly people and approx.
- 1% - young people.
- The total number of persons involved in the activities: 152 people.
- Percentage of women involved in activities approx. 53,3%
- Percentage of older people involved in activities approx. 5,3%.

A key intention of the project was achieved i.e. to involve the inhabitants in the process of introducing NbS. As a result of the involvement of representatives of numerous institutions, companies and entities in project meetings, residents had the opportunity to develop their knowledge, not only about the benefits of NbS, but also the procedures necessary to implement these projects. The work was characterized by high openness of participatory processes - enabling public participation in the project implementation, where residents were allowed to access and participate in procedures related to the implementation.

Only a small number of people in the 60+ age category involved in the activities carried out under the project. This mainly due to the fact that most people in this age group are retired (the statutory retirement age is 60 for women and 65 for men in Poland).

While developing the spatial planning concepts, the opinions and the suggestions submitted by the residents were taken into account. As a result traffic calming was introduced, reducing traffic noise and providing places to rest along Daszyńskiego Street i.e. the "green street" demonstrator.

9.3.1 Outcomes

As part of the social monitoring research, a questionnaire survey was conducted in which, the respondents were asked if they were *„(…) involved in creating new green areas in Olbin (i.a. via workshops with residents in summer / autumn 2018, workshops in autumn 2019, autumn 2020, email / phone contact, conversation with the contractors in demo areas etc., other*)).

Over 56% of all respondents declared that they were involved in the creation of new green areas in the project area. They were then asked further questions on their subjective feelings about their participation, the value of procedures / faith in decision-makers. The results are as following:

- 30% of the surveyed population that believes that by participating in the project they had an impact on its final effect (their participation in the project has served something)
- 50% believe in the value of the procedures thanks to which the project was implemented.

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- 63% of the respondents involved in the creation of new green areas believe this project is an example that officials / decision makers can cooperate with residents in introducing changes to housing estates

On the basis of these results, it can be concluded that the active involvement of residents in the process of introducing changes in their place of residence contributes to building social trust in the processes and builds faith in the honesty and integrity of procedures and people in decision-making roles.

The area of green space per inhabitant of Wroclaw did not increase. However, the area of accessible green space in the proximity to the homes of people living in the project areas has increased. In 2017 there was approx. 31,7m^2 and in 2022, approx. 34m^2 of publicly accessible green space, per inhabitant (within a radius of approx. 400m from each project demonstrator).

As many as 93% of the respondents answered positively to the question "*Can you list nature-based solutions that have been introduced in the new green areas?*" and declared their willingness to list their favorite nature-based solutions. The ranking of the NbS by the respondents shows that the implementation of projects like GrowGreen where inhabitants of the project areas are actively involved in NbS, influences the perception of urban nature by city dwellers and makes the inhabitants attach significant value to natural elements.

As a result of many socio-economic factors taking place in Poland during the project period, the life circumstances of many people have deteriorated. Full time employment has fallen from 46% to 36%. For these reasons it is difficult to demonstrate that the implementation of the project as having a positive impact on the respondents' access to financial resources.

According to the results of surveys conducted in both campaigns (pre- and post-greening), the percentage of people who feel safe in their neighborhood, increased by 14% and 16% (depending on whether the question referred to walking outside alone during the daytime or after dark). Also the percentage of people who declare to feel unsafe in their neighborhood decreased. However, in order to be able to conclude whether the implementation of the project actually had a direct impact on the improvement of these parameters, more sociological research should be performed. Future research should, i.e. take into account the correlation of the respondents' answers with their demographic characteristics (such as age, gender, time of residence in the area, etc.).

97% of the respondents of the surveys believe that the introduction of new green areas in the courtyards / along the street make the area more visually pleasing. 70% of the respondents say that they visit the areas more often than before the introduction of new green areas. As many as 85% of the respondents said it is possible to observe birds and other animals (butterflies, pollinators) more often and as many as 93% of the respondents answered positively to the question "Can you list nature-based solutions that have been introduced in the new green areas?"

On the basis of this research, it can certainly be concluded that the people using the newly introduced green areas take notice of their environment and surroundings, express interest or even admiration towards the newly created green areas or the introduced nature-based solutions. Also that the implementation of projects like GrowGreen brings people closer to nature, influences their perception of urban nature and brings “a joy for the senses”.

According to the results of surveys conducted in both campaigns (pre and post-greening), the percentage of people who feel integrated into their local community increased by 24%, the percentage of people with an attachment / sense of belonging to the neighbourhood, increased by

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19% and the percentage of people who feel able to trust one another within the neighbourhood, increased by 26%.

The number of people using green space located in the demonstration areas (i.e. number of adults observed walking in target outdoor spaces) increased from 43% to 83%. Therefore, it can be concluded the implementation of projects like Grow Green increases the number of people using outdoor spaces. The introduction of greenery also contributed significantly to the increase in the number of children playing in these spaces (an increase from 10 to 13%).

9.4 Economic Objectives (Challenge 10)

See D2.5 Monitoring and Evaluation of Economic Objectives

A Cost Benefit Analysis (CBA) was carried out by Trinomics[21]. CBA is used in policy analysis to assess the overall benefits of a policy option compared to its costs and can also be used to assess the relative merits of alternative options available to decision-makers. CBA is a preferred policy tool in decision-making because it provides a 'decision rule' on whether an option can be justified for implementation, using the benefit-cost ratio (BCR). If a BCR is greater than 1, then the investment produces higher quantified benefits than the costs incurred to deliver them, and the investment is justified in economic terms. CBA can be used to compare benefits and costs that occur at different times over a long time period (say, 25 years), by discounting future costs and benefits to present day terms, allowing for options to be compared on a 'like for like' basis.

In public policy, the range of benefits and costs extend beyond purely financial items (expenditures and revenues) to consider a broader range of non-financial or non-market benefits, typically reflecting environmental or social outcomes, in what is referred to as 'social cost-benefit analysis'. This approach is applied here, using a discounted cash flow analysis over 25 years, discounting future costs and benefits using a real discount rate of 3% (as recommended by the EC's Better Regulation Toolbox[22]).

[21] Project partner - Trinomics B.V. is a consultancy firm offering bespoke policy advice related to energy, environment and climate change issues.

[22] https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how/better-regulation-guidelines-and-toolbox_en

9.4.1 Quantifying Costs

The total costs of design and build were **€1,572,655**. The breakdown is as follows:

Number	Location	Type	Cost
Pocket Park # 1	Area between Jedności Narodowej Street, Rychtalska Streat, Ustronie Streat	blue-green park	€159 165.62
Pocket Park # 2	Area between Daszyńskiego Street, Zeromskiego Street, Orzeszkowa Street	blue-green park	€158 651.49
Pocket Park # 3	Area between Daszyńskiego Street, Lompy Street, Orzeszkowa Street and Jaracza Street	blue-green park	€222 199.98
Pocket Park # 4	Area between Walecznych Street, Prusa Street, Reja Street	blue-green park	€218 329.28
Area # 5	Area of tram stop near Nowowiejska Streat (linear planting) and part of Tolpa park	green tram stop	€74 000.55
Pocket Park #6	Area between Nowowiejska Street, Zeromskiego Street, Orzeszkowa Street and Barlickiego Street	blue-green park	€233 459.72
Pocket Park #7	Area between Wygodna Street, Zeromska Street, Nowowiejska Street	blue-green park	€149 293,16
Area #8	Green space improvement along Daszyńskiego Street	green Street	€357 554.91
		Total	**€1,572,655**

Table 6 Construction Costs

9.4.2 Operating Costs

The project was implemented in areas with established maintenance. During the design phase, discussions were held to rationalize the work required. Those responsible for maintaining the areas anticipated the following problems:

- lack of consent of residents to not cut lawns or to have beds of ruderal plants;
- reports on the need for tree maintenance or more frequent mowing of lawns;
- lack of simple procedures for providing residents with access to areas for their own greenery management - formally this is only possible by leasing the land.

The maintenance will be delivered by the contractors for the next two years, according to the agreements (five-year maintenance in the agreements).

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9.4.3 Property Betterment

Analysis of real estate prices shows a slight increase in prices in the project area compared to the control area (Rychtalska Street).

Category	Year	Average property price in project area zone (<300m of site)	Average property price in control area
	2017	6333	6400
	2018	6978	7000
	2019	7892	8000
Property sales information- post construction	2020	8769	8400
	2021	9596	9333
	2022	10246	10000

Table 7 Estimated change in property prices in project area zone and control area[23]

9.4.4 Direct Jobs

The number of direct jobs created in the period 2017-2022 is shown in Table 8. Most direct jobs stem from the construction phase of the project, followed by overall project management. Labour time for design and maintenance represents a smaller proportion.

Job category	Estimated persons / month					
	2017	**2018**	**2019**	**2020**	**2021**	**2022**
Overall project management	4	24	35	4		
Labour time design	9.4	23.3	3.3			
Labour time construction			267.35	5.6		
Labour hours maintenance/ ongoing			0.07	0.27	0.27	0.19
Total	**13.4**	**47.3**	**305.72**	**9.87**	**0.27**	**0.19**

Table 8 Estimated number of direct jobs created, in persons / month.

9.4.5 Indirect Jobs

It has not been possible to estimate the number of indirect jobs created.

9.4.6 Avoided Run off

Error! Reference source not found. Table 9 shows the amount of run off avoided as a result of the NbS interventions in Wroclaw overall along with the financial value.

Description	2020	2021	2022	Estimated cost of wastewater treatment (€/m^3)

[23] Source: www.domipotra.pl

An overview of the changes in runoff volumes				
Runoff reduction (m^3/ yr.)	*m3*	*m3*	*m3*	€1.7/m^3
Street	814,03	814,03	814,03	1383,85
Demonstrator 1	*1845,58*	*1845,58*	*1845,58*	3137,49
Demonstrator 2	2533,96	2533,96	2533,96	4307,73
Demonstrator 3	*6535,34*	*6535,34*	*6535,34*	11110,08
Demonstrator 4	9727,56	9727,56	9727,56	16536,85
Demonstrator 5	*0*	*0*	*0*	0,00
Demonstrator 6	*2848,73*	*2848,73*	*2848,73*	4842,84
Demonstrator 7	*3259,07*	*3259,07*	*3259,07*	5540,42
	Total [Euro]			46 859,26

Table 9 Reduction in Run Off in Wroclaw

10 Sustainability and Maintenance

The areas designated for demonstrators were already managed by the municipal bodies and companies. After completion they were handed over to the existing municipal managing companies, i.e. Municipal Resource Management, Municipal Housing Company, Urban Greenery Management and Roads and City Maintenance Management. The areas were designed and constructed in such a way as to keep the costs of maintenance as low as possible. In Area. 3, at the request of residents, an area was prepared for vegetable gardens, to be maintained by the residents. In the other courtyards some of the gardens are under informal care of the residents. In Area 6 there is an herb garden. Some of the lawns were replaced by flower meadows, reducing maintenance.

The first five years of greenery maintenance (by the construction contractor) are funded from the construction budget.
Comparing maintenance before and after, the costs have increased, principally because previously there was practically no greenery and infrastructure previously. Green infrastructure solutions generate the highest costs at the beginning, before the plants reach maturity. After this they require less frequent watering or care as traditional solutions.

11 Innovation

Social innovation – the process of co-design, involving citizens and other stakeholders in the process of designing combined with education was new for Wroclaw. The normal process would have been to look at residents needs from the city point of view and then then a designer proposed a project to be followed up with public consultations. The process of inviting all stakeholders to the table from the beginning, including residents was a very different way of working.

Design innovation - the comprehensive approach to the design process and the solutions applied in the courtyards and on the street, all tailored to local conditions and residents' demands is innovative in Wroclaw. Each demonstrator is different, focusing on different aspects, although some solutions, using NbS, are common to all areas. The whole approach to NbS in the projects showing that NbS are not just add-on in the design, but the design is based on NbS

Technical innovation – a number of the solutions tested were innovative for Wroclaw conditions:

In the courtyards the permeable surface for the access road was tested made of special paving stone that as a grass covering , called " farmer's pavement", provides surface permeability.

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Figure 39 Parklets

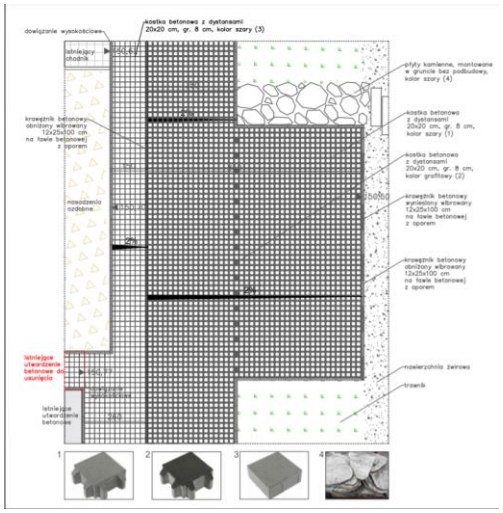

Figure 40 Permeable surface – details

Similar to the green street, a “rail" for greenery was designed in the pavement. This has the same qualities as a sealed based but is permeable. It also collects and directs rainwater from the sidewalk towards the trees. The success of the solution is the introduction of trees in the street with a sub infrastructure network. The selection of trees is based on native species, characterised by resistance to urban conditions: salinity, tight soil, drought, difficult soil conditions and air pollution.

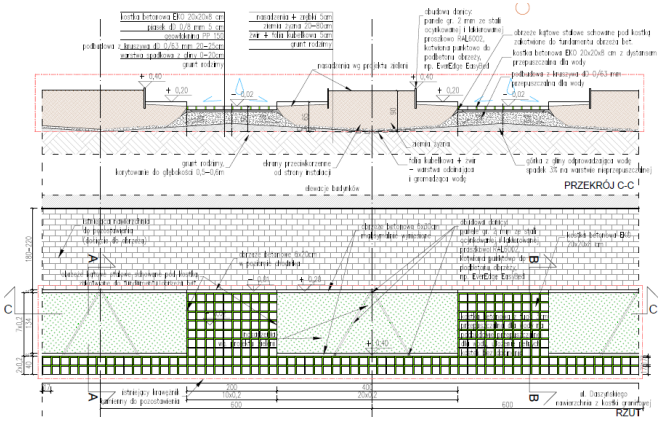

Figure 41 “Rail” for greenery - details

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12 Challenges and Lessons Learnt

12.1 Design

It was challenging to find the designer with NbS skills. It became our role to educate them, inspire them and co-design. Setting up the goals and people about the goals of the project, explaining why we were not going to spend the money on huge parking lots (even with permeable surface) was challenging.

12.2 Construction and capital costs

The city opted for the “design and build’ option because this option allows greater flexibility in terms of the solutions used. The parklets had to be revised because they were too large and the residents were not ready for such a bold solution. The construction works should have been finished in April or May, when everything is green and blooming, making easier to accept unconventional solutions.

12.3 Procurement

Public procurement was a challenge in terms of describing the requirements for NbS in public tender. The best approach was found to be to hire small, local companies instead of a large one. The small companies were more open to atypical/unusual innovative solutions.

The city decided to tender for "design and build". To prepare, two studies were commissioned via procurement procedures: *Recognition of conditions for the concept of experimental green areas within the framework of the scientific research project GrowGreen.* The main conclusions were used to in *Study of good practices for the implementation of the GrowGreen project*. These documents were then used in the tenders.

It is worth noting that the design documents were arranged via the Municipal Office, the investments are carried out by dedicated municipal companies, acting as a” substitute” investor. Under a delegation agreement, municipal company Wrocławskie Inwestycje (WI) handled the procedure for selecting the contractor for the design and build contracts. The city's aim was to encourage smaller, local companies to apply. Experience in design of blue-green infrastructure solutions, especially water management was a requisite.

12.4 Citizen engagement

Engaging citizens in the process of design is a way to involve and encourage them to take care of the demos. During public consultations numerous issues came up. These included parking and greenery (i.e. fewer parking places). Cooperation with the district council was invaluable as they helped convince residents of the benefits of greening the courtyards. A compromise solution was created – the introduction of paid parking zone in the area, to discourage casual drivers from parking and a subscription at favorable terms for residents. Whilst it was not a solution that satisfied everyone, the residents have now said they could no longer imagine cars parked in their backyards.

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Figure 42 Demo no.3 – playground and vegetable garden

There were some acts of vandalism in the first months after completion, along with parking in the green areas and plant thefts. The solution for the cars was temporary posts separating the road or pavement from the greenery. Workshops with residents were organised to replace the plants. It immerged that some had never done it before. One boy came with his grandmother, they brought their own tree to planted, an uplifting moment. The residents were also encouraged to take care of the plants and feel more responsible for the courtyards. Now the residents seem to feel safe and do take care of the courtyards and grow vegetables.

12.5 On-going management and maintenance

The project was implemented in areas with established maintenance. During the design phase, discussions were held to rationalise the work required. Those responsible for maintaining the areas anticipated the following problems:

- lack of consent of residents to not cut lawns or to have beds of ruderal plants;
- reports on the need for tree maintenance or more frequent mowing of lawns;
- lack of simple procedures for providing residents with access to areas for their own greenery management - formally this is only possible by leasing the land.

The maintenance will be delivered by the contractors for the next two years, according to the agreements (5 year maintenance in the agreements).

12.6 Political

Following the completion of work on the green street, particularly the parklets at the street intersection, issues were raised. There was a view that they slow traffic and take away parking spaces. There were also opposing views, that they introduce greenery in a space and that slowing down the traffic was intentional, increasing safety for pedestrians.

The opposition party to the mayor's held a press conference about the parklets. Many people, even those who had not visited the area, felt able to criticise the parklets. The discussion continued intermittently until April after which most of the negative voices quietened, especially as the plants began to grow and the area became greener.

12.7 Governance

NbS is embedded in Wroclaw Municipality strategic and urban planning documents. One of the first city's strategic documents referring to blue-green infrastructure is the Wroclaw City Masterplan. This is the key document shaping the spatial planning policy in the city. The new plan reflects the growing importance of greenery in the city.

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The masterplan was preceded by other regulations to protect and develop green infrastructure in 2016 (the new ordinance is from 2019) and the Ordinance of the Mayor of Wroclaw on rainwater management. There is also a city council resolution on greening/real estate tax decrease. The latest document (2019) is the Urban Climate Change Adaptation Plan for Wroclaw with a strong focus on nature-based solutions.

The blue-green infrastructure action plan, developed as a part of GrowGreen project links to the Urban Climate Change Adaptation Plan. As a result, Wroclaw Municipality has introduced the policy to include NbS in all municipal investment meaning NbS are a part of standard solutions that have to be considered in public tenders.

13 Replication and Impact

13.1 Financial and Business Case Development

The construction costs for each demonstrator is show Table 10. The overall total is ~€1.6m. This does not include ongoing maintenance.

Number	Location	Type	Cost
Pocket Park # 1	Area between Jedności Narodowej Street, Rychtalska Streat, Ustronie Streat	blue-green park	€159 165.62
Pocket Park # 2	Area between Daszyńskiego Street, Zeromskiego Street, Orzeszkowa Street	blue-green park	€158 651.49
Pocket Park # 3	Area between Daszyńskiego Street, Lompy Street, Orzeszkowa Street and Jaracza Street	blue-green park	€222 199.98
Pocket Park # 4	Area between Walecznych Street, Prusa Street, Reja Street	blue-green park	€218 329.28
Area # 5	Area of tram stop near Nowowiejska Streat (linear planting) and part of Tolpa park	green tram stop	€74 000.55
Pocket Park #6	Area between Nowowiejska Street, Zeromskiego Street, Orzeszkowa Street and Barlickiego Street	blue-green park	€233 459.72
Pocket Park #7	Area between Wygodna Street, Zeromska Street, Nowowiejska Street	blue-green park	€149 293,16
Area #8	Green space improvement along Daszyńskiego Street	green Street	€357 554.91
		Total	**€1,572,655**

Table 10 Demonstrator Construction Costs

Table 11 shows amount of run off avoided as a result of the NbS interventions in Wroclaw overall along with the financial value.The reduction in the estimated cost of annual discharge to the sewers is estimated to be ~€46K .

An overview of the changes in runoff volumes m3				Estimated cost of wastewater treatment (€/m3)	
Runoff reduction (m^3/ yr.)	2020	2021	2022		
Demonstrator 1 - Pocket Park # 1	1845.58	1845.58	1845.58	EUR	3,137.49
Demonstrator 2 - Pocket Park # 2	2533.96	2533.96	2533.96	EUR	4,307.73
Demonstrator 3 - Pocket Park # 3	6535.34	6535.34	6535.34	EUR	11,110.08
Demonstrator 4 - Pocket Park # 4	9727.56	9727.56	9727.56	EUR	16,536.85
Demonstrator 5 - Area #5	603.22	603.22	603.22	EUR	603.22
Demonstrator 6 - Pocket Park #6	2848.73	2848.73	2848.73	EUR	4,842.84
Demonstrator 7 - Pocket Park #7	3259.07	3259.07	3259.07	EUR	5,540.42
Area #8 - Green Street	814.03	814.03	814.03	EUR	1,383.85
	27,353.46	27,353.46	27,353.46	EUR	46,078.63

Table 11 Reduction in run off (m3) against the estimated cost of wastewater treatment

13.2 Strategic Impact

By embedding NbS in long term city planning, development and management there are new projects, programs and investments including NbS. All municipal investments must now include NbS, e.g. green tram trucks are now standard. There is a municipal program dedicated greening areas around schools and kindergartens called “Grey into Green”. The program is a part of climate change adaptation efforts by incorporating NbS into landscaping projects. Schools are encouraged not only to "unseal" concrete backyards, but to include solutions such as the rain gardens, flower meadows, climbing plants on fences to create natural green walls, rain barrels to water the garden. Small vegetable gardens are becoming increasingly popular as an educational element in healthy eating. Similar programs are part of cultural entities working with the city.

There green street has inspired district council to initiate works on next green street – adjacent to Daszynskiego Street. The public consultation was performed on green Daszynskiego Street.

Figure 43 Public consultation and concept design of Zeromskiego Street

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The city has also begun a cooperation with the European Commission funded project, Replication Cities[24] to share the knowledge and promote the best solutions. In May and June 2022 there will be a series of workshops dedicated to NbS for municipal workers, urban planners, landscape architects and civil engineers.

13.3 Living Lab Creation

Similar to the projects in the other project cities, Wroclaw has created a living lab, in this case a series of labs. The courtyards provide an exemplar for other developments. The solutions used have gained recognition and distinction, for example in the EcoCity Competition. The competition is organized by the French Embassy in Poland. Wroclaw was awarded for recognition of the importance of areas covered with vegetation (formal and informal green areas) as an equal material of the urban structure of the city and for the apt and interestingly planned educational and investment projects in the field of blue-green infrastructure in the GrowGreen project.

https://www.eco-miasto.pl/konkurs-dla-miast-2/konkurs-dla-miast/laureaci-minionych-edycji/2/

The work has also been recognized by the Friendly Public Space Competition organized by Polish Architects Association (SARP) as a part of DoFa Festival. It received a mention for revitalization of courtyard interiors no. 3 and no. 4 in the category Public and Semi-public space in areas co-created with the participation of the local community.

http://www.wroclaw.sarp.org.pl/pl/dofa/20/category/dofa-festiwale-20-wystawy-konkursowe

[24] https://replicate-project.eu/cities/

14 Appendices

List of tree species introduced pre-intervention

Ailanthus altissima	*Metasequoia glyptostroboides*
Prunus persica	*Larix decidua*
Betula pendula	*Prunus armeniaca*
Fagus sylvatica	*Morus alba*
Chamaecyparis lawsoniana	*Juglans regia*
Pseudotsuga menziesii	*Robinia pseudoacacia*
Quercus rubra	*Pterocarya fraxinifolia*
Quercus robur	*Pinus nigra*
Crataegus monogyna	*Pinus sylvestris*
Carpinus betulus	*Rhus typhina*
Pyrus communis	*Prunus cerasifera*
Malus domestica	*Prunus domestica*
Sorbus aucuparia	*Picea pungens*
Sorbus x intermedia	*Picea abies*
Fraxinus pennsylvanica	*Populus nigra*
Fraxinus excelsior	*Liriodendron tulipifera*
Abies x arnoldiana	*Ulmus laevis*
Abies koreana	*Salix babylonica*
Abies alba	*Salix alba*
Aesculus hippocastanum	*Salix x sepulcralis*
Acer pseudoplatanus	*Prunus serrulata*
Acer negundo	*Prunus cerasus*
Acer campestre	*Cerasus mahaleb*
Acer platanoides	*Thuja plicata*
Tilia cordata	*Thuja occidentalis*
Magnolia sp.	

List of tree species introduced post intervention

Betula pendula	*Aesculus x carnea*
Betula papyrifera	*Acer rubrum*
Betula utilis	*Acer pseudoplatanus*
Fagus sylvatica	*Acer campestre*
Quercus palustris	*Acer platanoides*
Quercus coccinea	*Tilia cordata*
Crataegus monogyna	*Tilia euchlora*
Crataegus x media	*Tilia tomentosa*
Carpinus betulus	*Alnus glutinosa*
Cercidiphyllum japonicum	*Alnus incana*
Malus pumila	*Prunus cerasifera*
Malus x purpurea	*Amelanchier x lamarckii*
Malus x zumi	
Sorbus aucuparia	
Sorbus x intermedia	

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List of shrub species introduced post intervention

Berberis thunbergii	*Kolkwitzja amabilis*	*Salix integra*
Buddleja daviddi	*Ligustrum vulgare*	*Salix purpurea*
Chaenomeles japonica	*Lonicera caerulea*	*Sambucus ebulus*
Colutea arborescens	*Lonicera nitida*	*Sambucus nigra*
Cornus alba	*Lonicera pileata*	*Spiraea cinerea*
Cornus mas	*Mahonia aquifolium*	*Spiraea japonica*
Cotinus coggygria	*Molinia caerulea*	*Spiraea nipponica*
Cotoneaster suecicus	*Morus alba*	*Spiraea vanhouttei*
Cotoneaster dammeri	*Philadelphus coronarius*	*Symphoricarpos chenaultii*
Deucia gracillis	*Physocarpus opulifolius*	*Symphroricarpos albus*
Deucia scabra	*Potentilla fruticosa*	*Syringa meyeri*
Euonymus europaeus	*Pyracantha coccinea*	*Syringa vulgaris*
Euonymus fortunei	*Rhododendron*	*Tamarix ramosissima*
Fagus sylvatica	*Ribes aplinum*	*Tamarix tetrandra*
Forsythia x intermedia	*Rosa canina*	*Viburnum lantana*
Hippophae rhamnoldes	*Rosa pimpinellifolia*	*Viburnum opulus*
Hydrangea macrophylla	*Rosa rugosa*	*Viburnum plicatum*
Hydrangea paniculata	*Rosa sp.*	*Weigela florida*
Juniperus communis	*Rubus caesius*	

List of herbaceous plant species introduced post intervention

Plantago lanceolata	*Silene vulgaris*	*Lavatera thuringiaca*
Plantago media	*Linaria vulgaris*	*Knautia arvensis*
Silene latifolia ssp. Alba	*Medicago lupulina*	*Astragalus glycyphyllos*
Centaurea cyanus	*Thymus pulegioides*	*Armeria elongata*
Centaurea scabiosa	*Papaver rhoes*	*Glebionis segetum*
Securigera varia	*Daucus carota*	*Leucanthemum vulgare*
Scabiosa ochroleuca	*Calendula arvensis*	*Echium vulgare*
Verbascum thapsus	*Solidago virgaurea*	*Festuca rubra*
Verbascum nigrum	*Consolida regalis*	*Festuca ovina*
Campanula rotundifolia	*Pastinaca sativa*	*Agrostis capillaris*
Anchusa officinalis	*Anthyllis vulneraria*	*Bromus erectus*
Dianthus carthusianorum	*Veronica spicata*	*Anthoxanthum odoratum*
Dianthus deltoides	*Galium verum*	*Poa bulbosa*
Ranunculus bulbosus	*Berteroa incana*	*Poa pratensis*
Agrostemma githago	*Anthemis tinctoria*	*Poa compressa*
Lotus corniculatus	*Anthemis arvensis*	*Poa pratensis*
Trifolium medium	*Agrimonia eupatoria*	*Lolium perenne*
Achillea millefolium	*Viscaria vulgaris*	*Festuca rubra*
Sanguisorba minor	*Salvia pratensis*	
Origanum vulgare	*Salvia verticillata*	

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List of herbaceous plant species introduced to create wildflower meadows (seed mixture).

Achillea millefolium	*Heuchera sanguinea*	*Salvia nemorosa*
Agastache sp.	*Heuchera sp.*	*Salvia officinalis*
Ajuga reptans	*Hosta sieboldiana*	*Salvia pratensis*
Astrantia major	*Hosta ventricosa*	*Sedum sp.*
Aegopodium podagraria	*Iris siberica*	*Sesleria heufleriana*
Alcea rosea	*Lamium maculatum*	*Sisyrinchium angustifolium*
Alchemilla mollis	*Lavandula angustifolia*	*Sporobolus heterolepis*
Anemone hupehensis	*Lobelia cardinalis*	*Stipa joannis*
Aquilegia vulgaris	*Lysimachia nummularia*	*Stipa pennata*
Asarum europaeum	*Lysimachia punctata*	*Symphtum grandiflorum*
Asperula odorata	*Lythrum salicaria*	*Thymus pulegioides*
Aster alpinus	*Matricaria chamomilla*	*Vinca minor*
Astilbe sp.	*Matteuccia struthiopteris*	*Viola odorata*
Athyrium filix-femina	*Miscanthus sinensis*	*Clematis mandschurica*
Bergenia cordifolia	*Nepeta x faassenii*	*Clematis sp.*
Brunnera macrophylla	*Origanum vulgare*	*Hedera helix*
Campanula poscharskyana	*Osmunda regalis*	*Humulus lupulus*
Carex elata	*Pachysandra terminalis*	*Hydrangea anomala ssp. petiolaris*
Deschampsia caespitosa	*Perovskia atriplicifolia*	*Parthenocissus inserta*
Echinacea purpurea	*Phragmites australis*	*Parthenocissus quinquefolia*
Festuca gautieri	*Phyllitis scolopendrium*	*Parthenocissus tricuspidata*
Festuca mairei	*Polygonum bistorta*	*Vitis coignetiae*
Geranium macrorrhizum	*Polygonatum humile*	*Vitis riparia*
Geranium sanguineum	*Polystichum setiferum*	
Glechoma hederacea	*Primula veris*	
Hemerocallis hybrida	*Pulmonaria saccharata*	

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