D 3.2

Tailor-made Plans for Operation of Sensing System at Demonstration Cities

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Executive Summary of Deliverable

Purpose and Scope

The purpose of this deliverable to describe the background, features and way of tailoring, elaborating a tailor-made sensing plan in the UPSURGE demonstration cities based on the sensing system framework elaborated in D3.1.

Based on the tailor-made sensing plans, demonstration cities are able to procure sensing systems that will be able to monitor the impact of the demonstration NBS projects by using the combination of low-cost sensor technologies with non-conventional, novel sensing methodology to verify conventional and non-conventional pollutants.

The deliverable contributes to the combination of unique set of technology- and nature-based sensing, includes verification of non-conventional pollution factors (e.g. airborne heavy metals, pesticides etc.) and presents an adapted sensing approach to be tested in each NBS demonstration location.

Intended Readership/Users

The deliverable is intended to serve as a guidance to the practitioners of demonstration cities and other European cities, researchers and relevant stakeholder groups, who intend to set up

LCS environmental monitoring system to monitor impact of NBS, or interested in the topic in general.

Contribution to Other WPs and Deliverables

The tailor-made sensing plans are based on the sensing framework elaborated in D3.1. The content of the sensing plans, the sensing systems will be implemented and their experience will feed into the D3.3 report. The information from the sensing plan elaboration process fed into the D5.2 and D5.2, because the sensing network is monitoring the impact of the demonstration NBS through conventional and non-conventional pollutants in the demo area.

The realized sensing network's environmental data will feed into the T6.1 (D6.1) activities.

Summary of Key Findings and Recommendations

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The demonstration cities utilized the sensing framework (Deliverable 3.1) to set up their own tailor-made sensing plan adapted to their NBS investments and the city characteristics to measure the NBS impact and contributing to the previously determined KPIs.

The tailor-made planned sensing system are lower in technical complexity that originally planned in the GA. However, they will provide sufficient scientific data to be able to assess the impact for various KPIs near the NBS investment locations.

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Acronyms and Abbreviations Table

Acronym / Abbreviation	Meaning
E-Institute	E-ZAVOD, ZAVOD ZA PROJEKTNO SVETOVANJE, RAZISKOVANJE IN RAZVOJ CELOVITIH RESITEV
UNIPASSAU	UNIVERSITAT PASSAU
ICS	INSTITUTE OF COMMUNICATION STUDIESSKOPJE
LEITAT	ACONDICIONAMIENTO TARRASENSE ASSOCIACION
GCE	UNIVERSITEIT ANTWERPEN
PATRAS	DIMOS PATREON
POR	POR CONSULT DOO ZA POSLOVNO SAVJETOVANJE
PRATO	COMUNE DI PRATO
AITIIP	FUNDACION AITIIP
OC	OPENCONTENT SOCIETA COOPERATIVA
Belfast Council	Belfast City Council
BURST	BURST NONPROFIT KFT
ICLEI	ICLEI EUROPASEKRETARIAT GMBH
RRA-PODRAVJE	REGIONALNA RAZVOJNA AGENCIJA ZA PODRAVJE – MARIBOR
BOKU	UNIVERSITAET FUER BODENKULTUR WIEN
BP18	BUDAPEST FOVAROS XVIII. KERULET PESTSZENTLORINC-PESTSZENTIMRE ONKORMANYZATA
BREDA	GEMEENTE BREDA
BeeoDiv	BEEODIVERSITY
QUB	THE QUEEN'S UNIVERSITY OF BELFAST
OPERATE	FONDAZIONE OPERATE
UniLeeds	UNIVERSITY OF LEEDS
IETU	INSTYTUT EKOLOGII TERENOW UPRZEMYSLOWIONYCH
Katowice City	KATOWICE - MIASTO NA PRAWACH POWIATU

EC	European Commission
GA	Grant Agreement
M no.	Month, e.g. 1 of project implementation
NBS	Nature Based Solutions
EU	European Union
KPI	Key Performance Indicator
QCG	Quality Control Group, a group of internal reviewers presented in Upsurge deliverable D1.2 Quality Assurance Plan.
LCS	low-cost sensors
UAV	unmanned aerial vehicles

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1 INTRODUCTION

To measure pollution and pollutants coming from different sources efficiently, UPSURGE developed a multi-component pollution measuring approach as a reference holistic sensing and monitoring network comprised of several elements specially targeting particular pollution and environmental-monitoring problems. UPSURGE Deliverable 3.1 on the Sensing System Framework defined the fundaments of the sensing system framework, the types and scope of sensing technologies and approaches that can be implemented in the 5 demonstration cities. Moreover, the D3.1 serves as a guidance to concretise sensing system for each demonstration project by following the phases of framework implementation in Task 3.2 for optimal deployment. The Work Package 3 leader, OPERATE assisted the city partners in defining their sensing system based on their needs in terms of providing technical specifications too.

This deliverable describes the planned sensing system of the 5 demonstration cities (Belfast, Breda, Budapest District 18, Katowice and Maribor)

Moreover, D3.2 encircles the challenge for which the cities planned the NBS for intervention, as well as the adapted monitoring or sensing system that is able to follow-up the impact of the NBS investments and compare them at a scientific basis despite the differing urban settings and interventions. The sensing plan of the cities incorporates the compulsory environmental and the site-specific parameters to be measured by the sensing devices. Furthermore, the sensing plan provides guidance about the specification for the sensors, roadmap for procurement, and other necessary considerations for the installation.

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1.1 The Originally Planned tailor-made sensing plans

UPSURGE's environmental monitoring networks are designed for the (scientific) environmental verification of NBS implemented in 5 demonstrator cities comprising of stationary and supplementary mobile LCSs. Due to the prohibitive cost of the conventional static sensing devices, clean mobility vectors and citizens e.g. bicycles, no emission public transportation vehicles and UAV were planned to be used as vectors for the sensors and thereby increase the low spatial resolution of conventional environmental monitoring. Beyond measuring standard air pollutant, the UPSURGE sensing system puts emphasis on rarely measured pollutants too that are not considered normally at environmental verification such as airborne heavy-metals.

Although currently, most LCS have finite lifetimes and they may experience other manageable issues, larger networks of sensors may be able to discern long-term trends and can be an important complementary source of information for the existing accredited systems, provided that the appropriate sensor system is used, and calibration and quality control routines are in place. Clear benefit of complementary mobile monitoring applications is the increase in the spatial density of measurements as small and portable LCSs, enable access where conventional instruments simply cannot be practically deployed. Citizen involvement is another key factors, as LCSs place measurements in the hands of local communities who may take a greater ownership of issues related to local air quality this way influencing behavioural change of individuals.

Based on the sensing framework in D3.1, sensing plans are being elaborated for each demonstration city describing an optimal, feasible, adapted sensing system that they would realize within UPSURGE at the demonstration sites. The sensing plans react on the identified urban challenges, and aim to follow the environmental impact of new NBSs to tackle the challenges.

The sensing framework set diverse way of collecting information about the environmental parameters that were originally foreseen in the grant agreement in all demonstration cities. This original approach planned the following ways of data collection:

1) At least 2 stationary sensors per demonstration site, but depending on more precise pre assessment of the sites, the number of static sensors might differ from;
2) 5 mounted sensors on unmanned aerial vehicles will be used to increase low spatial and temporal resolution compared to static sensors;
3) Mobile sensing:
   a) At least 100 citizens are planned to be involved with wearable sensors, whose exposure in their daily lives to air pollutants are being connected to the NBS demonstration solutions;
   b) 5 clean transport-based sensing units are planned in each demo location with installed sensing devices. These units are periodically moving transport modes geographically connected to implemented NBS locations with careful consideration to their properties in order not to distort the results (e.g., they do not exhaust gases);
4) Bee-based sensing solution (or beeomonitoring) will be deployed at each site. Local beekeepers will be provided sampling equipment with instructions and the analysis of the pollen samples will occur at project partner providing quantitative and qualitative indicators of biodiversity and pollution in the respective locations.

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Figure 1 - UPSURGE's air quality sensing system network
(Source: UPSURGE D3.1)

1.2 ENVIRONMENTAL PARAMETERS

UPSURGE experts identified and defined compulsory and optional parameters to be measure the key environmental parameters and to be able to make the demonstration sites comparable and to ensure adaptability to the local needs and circumstances. The demonstration city partners selected the appropriate environmental factors for their case and then searched for devices being able to satisfy their needs and to fulfil project requirements such as reflected in Figure 1.

The following environmental factors, pollutant types are planned to be measured in the demonstration cities:

Air quality parameters:

Compulsory	Optional
• PM2.5 • PM10 • NO_2 • O_3 • CO • CO_2 • Pesticides • Heavy metals • Polycyclic aromatic hydrocarbon (PAH)	• SO_2 • PM1 • Black Carbon

Table 1 - Air quality parameters to be measured

Weather parameters:

Compulsory	Optional
• Air temperature, • Air relative humidity, • Solar radiation, • Atmospheric pressure, • Rain gauge, • Wind direction, • Wind speed	• UV • sunlight

Table 2 - Weather parameters to be measured

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Other environmental factors (soil, water run-off, noise, biodiversity)

Compulsory	Optional
• plant diversity	• Runoff time, • Soil water content, • Soil temperature, • Noise • surface water quality • surface water level • groundwater level • groundwater pollution • infiltration capacity • soil pH • nutrient level

Table 3 - Other environmental parameters to be measured

1.3 Key Performance Indicators

To monitor the impact of the NBS demonstrations projects locally, the project partners and cities identified and selected a list of key performance indicators based on elaborate research on KPIs (See D 2.2.). The demonstration partners, selected the KPIs that are the most appropriate to the challenges they face. Several KPIs, esp. the ones based on environmental parameters have data sources coming from the cities' sensing systems located near the demonstration NBSs. All cities measure pre-defined compulsory air quality and climate data. These data feed into general project KPIs. Some cities have specific challenges identified for which they have to install sensors to measure optional parameters such as noise.

	No.		GROUP KPIs name	KPI/indicator	Parameters measured by sensors
Air quality	1	1.1.1	Air pollutant concentrations	Air pollutant concentrations	+ Air pollutant concentration
	2	1.2.1	Concentration levels limits	Concentration levels limits (number of days with exceedances)	+ Air pollutant concentration
	3	1.3.1	Air quality index	Air quality index	+ Air pollutant concentration
	4	1.5.1	Ambient pollen concentration	Ambient pollen concentration	+ Ambient pollen concentration

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Climate vulnerability	5	2.5.4	Flood	Flooded area	+ Rainfall intensity; Rainfall duration
	6	2.7.1	Soil	Soil temperature	+ Temperature
	7	2.7.2	Soil	Soil sealing	
	8	2.10.1	Climate policy	Degree of development of climate resilience strategy	
	9	2.10.3	Climate policy	Adaptation of local plans and regulations to include NB	
UHI Effect	10	3.1.1	Urban Heat Island (UHI) effect	Urban Heat Island (UHI) effect	+ Temperature
	11	3.3.3	Mean or peak daytime local temperatures / Air temperature - mean, peak	Mean or peak daytime local temperature	+ Temperature
	12	3.4.1	Heat waves incidences (hot days, tropical nights)	Heatwave risk (days)	+ Temperature
	13	3.4.2	Heat waves incidences (hot days, tropical nights)	Heatwave risk (tropical nights)	+ Temperature
Water pollution	14	4.1.1	Water quality	Pollutant discharge to local waterbodies	
	15	4.1.2	Water quality	Basic water quality (pH, temperature, EC, DO, flow rate)	+ Temperature; pH; Flow rate; Electrical conductivity etc.
Soils	16	5.1.2	Soil organic matter	Soil organic matter content	
	17	5.2.1	Carbon in soil	Measured soil carbon content	
	18	5.2.3	Carbon in soil	Soil carbon to nitrogen ratio	
	19	5.11.1	Derelict land reclaimed for NBS	Derelict land reclaimed for NBS	
Water	20	6.1.1	Water balance	Infiltration capacity	+ Water level; Volume of water; Substrate capacity
	21	6.3.1	Water slowed down	Volume of water slowed down	+ Water flow

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	22	6.4.2	Irrigations	Rainwater or greywater use for irrigation purposes	+ Water level; Volume of rainwater/greywater; The amount of water used
Biodiversity	23	7.1.2	Biotope area factor - BAF	BAF - Biotope Area Factor	
	24	7.5.3	Pollinator species changes	Pollinator species presence	
	25	7.5.5	Pollinator species changes	Density and seasonal spread of floral resources for pollinators	
	26	7.7.1	Increase of plants and animals species	Plant species richness	
	27	8.6.1	Community garden area	Community garden area	
	28	8.7.1	Ratio of open spaces to built form	Ratio of open spaces to built form	

Ecosystem connectivity	29	8.10.1	Ecosystem benefits of NBS	Benefits provided pre and post interventions	
	30	8.15.1	Total vegetation cover	Total vegetation cover	
Gender	31	9.1.1	Diversity of participants in the process around the NBS	Involvement of citizens from traditionally under-represented groups	
	32	9.2.1	Consciousness of citizenship	Consciousness of citizenship	
Age vulnerability	33	10.1.2	Children vulnerability	Exploratory behaviour in children	
	34	10.2.1	Quality of life	Quality of life for elderly people	
Socio-economic	35	11.1.2	Community involvement	Community involvement in planning	
	36	11.1.3	Community involvement	Diversity of stakeholders involved	
	37	11.2.3	NBS Management	Investment cost for NBS (construction and equipment)	

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Cultural racial	38	12.3.1	Access to cultural facilities	Access to cultural facilities	
	39	12.5.2	Recreational & cultural activities	Number of new activities in the tourism sector in the study area	
	40	12.5.4	Recreational & cultural activities	Number of visitors per day that is seen as fully or partially connected to the NBS	
Health	41	13.3.2	Influence of air quality	Proportion of population exposed to ambient air pollution	+ Air pollutant concentration
	42	13.4.1	Influence of noise	Noise	+ Sound level
	43	13.7.7	Quality of Life	Distribution of public green space – total surface or per capita.	
Housin(	44	14.2.1	Changes in economic opportunities and green jobs	Change in mean or median land and property value	
	45	14.3.1	Property betterment	Perception of property betterment	
	46	14.4.1	GENtryfication	GEN - Gentrification	
Jobs	47	15.2.1	Business development	Establishment of new businesses in the area surrounding NBS	
	48	15.2.3	Business development	Proportion of ground floor surface of buildings within a specified distance (300 m) from NBS used for commercial or public purposes	
Crime	49	16.1.1	Crime rates	CC - CRIME COUNTS	
	50	16.1.4	Crime rates	Crime reduction	
Mobility	51	17.1.1	Percentage of pedestrians and bicycle roads	Proportion of road network dedicated to pedestrians and/or bicyclists	
	52	17.3.2	Increase in walking and cycling after interventions	Increase in walking and cycling in and around areas of interventions	

Table 4 - UPSURGE identified and selected 52 KPIs (Source: UPSURGE D2.2)

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1.4 Adaptation of the sensing framework to the current circumstances

The UPSURGE project foresaw deployment of sensing systems at each demonstration project to monitor the change in the environmental conditions in a comparable way. This required a careful planning parallel to the planning and implementation of the NBS demonstration projects.

Each demonstration city followed the original approach described in D3.1. However, several issues arose throughout first period of the project, that made the cities deviate from the original plan more than just adapting the framework to the local circumstances. This decision was made at consortium level.

COVID pandemic caused unforeseen changes throughout the world, and the UPSURGE project proposal could not foresee certain outcomes that influenced now the implementation of the project.

The conditions for which the project was planned turned out to deviate from what happened in reality, therefore the project team had to manage the changed circumstances in order to keep the project in the right track with the same planned resources though causing a delay in the delivery of the sensing plans. The encountered challenges have been tackled in a way to pursue the original goals, objectives.

The following challenges lead to the changes in the overall sensing framework:

1) Volatility of the market prices
2) Lack of service and market product providers
3) Planning for the unforeseen changes
4) UAV usability issues

1) Volatility of the market prices

   COVID-19 unexpectedly hit the whole world causing problems in the world market through the international supply chain in various fields of the economic sectors. The temporary closure of factories, imposed restrictions in trade triggered shortage in microchip supply, that affected the whole electrotechnical market, including sensors and related devices. This unreliable supply chain shortage caused extreme price shifts in certain product categories.

   The inflation hit European Union countries in 2021 – 2023 that further deteriorated the feasibility to carry out the planned sensing framework.

   This impact was further intensified by the impact of war on Ukraine causing further turbulence in the European energy prices affecting all aspects of life via increased inflation.

   The initial market mapping showed higher prices than the planned ones, that were justified by the UPSURGE partners.

   The estimated budget for each demonstrator city for buying sensor system at the time of proposal development was 66.000€. This turned out to be insufficient, therefore the consortium had to consider either investing more to realize the planned framework or to fulfil the original objectives with reduced sensing system content. Following several rounds of consultation within WP3 experts, for the proposal of the sensing expert of the WP3 leader, OPERATE, Alessandro Zaldei, the consortium decided to lower the technical content of the sensing network in a way that is will be still scientifically sound and meet the original objectives.

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2) Lack of service and market product providers
   The mapping of the market in the participating country turned out to be a useful experience for the demonstration cities. It was revealed, that there is a lack of service providers in the required set of LCS devices, either the sensors are clustered in another way in the sensing stations as the original project approach requires, or the sensors are sold only individually or due to limited sensor station capacities the monitoring activities require more sensing devices than planned. These conditions made cities face a limited or insufficient choice or products, if they existed on the market of the Member State. Some cities lack the competency to operate, maintain the sensing system properly during and beyond the project, therefore they require external service providers. The best way of doing market research was running market competition with the project specification provided by OPERATE (Review of the Performance of Low-Cost Sensors for Air Quality Monitoring, Atmosphere 2019, 10, 506; doi:10.3390/atmos10090506) and that was a clear answer of the market on UPSURGE needs. As an example, the experience of Maribor (RRA-PODRAVJE) with the first two competition showed the lack of service providers within Slovenia and at international level. Other cities had similar experiences, when looking for sensors based on the agreed specificities provided by OPERATE.
   Another example is the case of wearable sensors, that are not any more on sale or it turned out from user experience and scientific experiments that they do not really meet the requirements of the project in terms of data reliability or meeting all the required environmental parameters.
3) Planning for the unforeseen changes
   At the time of project development, initial market mapping proved the estimated €66,000 to be sufficient for setting the monitoring systems. However, the unforeseen changes rose the prices and this kind of risk was not well foreseen in the proposal development phase. Even though, the COVID-19 pandemics was happening parallel, no one could predict the spill-off effect of it, not even the intensified war with its impact on the EU between Russia and Ukraine.
4) UAV usability issues
   5 demonstration cities are located in different countries and 5 different UAV user conditions need to be kept to use UAVs or drones. Even though, there is an EU regulation for UAV usage, the exemplar case of the UPSURGE partner BP18 shows the strict regulation of near space of airport, as the Budapest Airport is located at the border of BP18. The drone flights are almost impossible in this area, so this is strictly ruled out from the sensing plan. Other cities' experiences are similar, the strict regulations may hinder the use of drones. The considerations, weighing the costs and benefit of the use of UAVs for monitoring made OPERATE to decide to exclude UAV from the planned sensing systems, this way focus on other, better-established ways of environmental sensing in cities. All in all, being a higher priced element in the sensing system, the UAV-mounted usage was taken out from the sensing systems at the demonstration cities.

All the abovementioned challenges made the UPSURGE consortium to rethink the originally planned sensing framework and elaborate a minimum set of sensing framework to be adapted to the cities' needs.

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2 SETTING COMMON REQUIREMENTS FOR THE SENSING SYSTEMS IN DEMONSTRATION CITIES

OPERATE's air quality experts on environmental sensing system provided the cities assistance to find appropriate sensors for the project requirements and to support the public procurement process. The LCS systems with proposed technical specifications make the systems at demonstration cities scientifically sound and comparable. Moreover, they set the communication compatibility requirements to the UPSURGE cloud-based system, that will collect, process and visualize all incoming data from the sensors.

The following technical specifications for the low-cost sensors were proposed:

2.1 STATIONARY SENSOR STATIONS FOR AIR QUALITY MONITORING

Sensor	Type	Units	Range	Resolution	Accuracy
Air temp	Solid state	°C	-40 – 80	0.3	5%
Air Hum	Solid state	%	0 – 100	1.0	5%
NO2	MOS-type gas sensors	µg/m³	0-5000	5.0	20%
O3	Semiconductor	µg/m³	0-1000	1.0	15%
CO	MOS-type gas sensors	mg/m³	0-30	0.03	15%
PM10	Optical particle counter	µg/m3	0-1000	1.0	10%
PM2.5	Optical particle counter	µg/m3	0-1000	1.0	10%
CO2	NDIR	ppm	0-2000	1.0	10%

Description	Expected lifespan	Notes
External DC power supply unit	>5 years	Switching power supply unit 12Vdc@2A
Optional solar power pack	>5 years	Internal backup lead-acid battery

Table 5 - Technical specification for stationary sensors

2.2 MOBILE SENSOR STATIONS FOR AIR QUALITY MONITORING

Sensor	Type	Units	Range	Resolution	Accuracy
Air temp	Solid state	°C	-40 – 80	0.3	5%
Air Hum	Solid state	%	0 – 100	1.0	5%
NO2	MOS-type gas sensors	µg/m³	0-5000	5.0	20%
O3	Semiconductor	µg/m³	0-1000	1.0	15%
CO	MOS-type gas sensors	mg/m³	0-30	0.03	15%
PM10	Optical particle counter	µg/m3	0-1000	1.0	10%
PM2.5	Optical particle counter	µg/m3	0-1000	1.0	10%
CO2	NDIR	ppm	0-2000	1.0	10%

Description	Expected lifespan	Notes
Waterproof battery bank 10.000mAh	>3 years	Switching battery charger

Table 6 - Technical specification for mobile sensors

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2.3 STATIONARY SENSOR STATIONS FOR AIR QUALITY MONITORING WITH METEOROLOGICAL SENSORS

Sensor	Type	Units	Range	Resolution	Accuracy
Air temp	Solid state	°C	-40 – 80	0.3	5%
Air Hum	Solid state	%	0 – 100	1.0	5%
NO2	MOS-type gas sensors	µg/m3	0-5000	5.0	20%
O3	Semiconductor	µg/m3	0-1000	1.0	15%
CO	MOS-type gas sensors	mg/m3	0-30	0.03	15%
PM10	Optical particle counter	µg/m3	0-1000	1.0	10%
PM2.5	Optical particle counter	µg/m3	0-1000	1.0	10%
CO2	NDIR	ppm	0-2000	1.0	10%
Wind speed	Cup anemometer	m/s	0-45	0.1	±0.5
Wind direction	Wind vane	deg	0-359	1°	1%
Solar radiation	Pyranometer	w/m2	0-1800	1	2%
Rain gauge	Tipping bucket	mm	-	0.2	3%
Barometer	Solid state	Kpa	0 – 120	0.15	1%

Description	Expected lifespan	Notes
External DC power supply unit	>5 years	Switching power supply unit 12Vdc@2A
Optional solar power pack	>5 years	Internal backup lead-acid battery

Table 7 - Technical specification for stationary sensors with meteorological sensors

Regardless the low-cost sensors selected for NBS monitoring activity, the sensors should housed in a waterproof case, connected to power supply, at the correct height (3.5/4 meter for air quality measurement), and protected from any disturbance. The sensor location that should take in account the features described above and provide proper condition for the operation of the devices.

UPSURGE determined the basic physical attributes and data access and communication requirements for the stations and communication devices incorporated:

2.4 SENSOR STATIONS PHYSICAL ATTRIBUTES

Enclosure	Environmental	Mounting	Size & weight
ABS, waterproof	Temperature range: -30°C to +70°C Humidity range: 15 to 100% RH	Aluminum mounting bracket for walls / posts	Weight: less than 1kg

Table 8 - Technical specification sensor station physical attributes

2.5 DATA ACCESS AND COMMUNICATION REQUIREMENTS

Communications	Measurement period	Transmission frequency	Server software	Data access
Raw data sent to remote server via 4G modem connection (2 years data transmission included)	1 second, moving average 120 seconds	2/5 minutes	Web browser based, real time data visualization, database storage on secure server	Raw data and calibrated data download available via API (Json and CSV format)

Table 9 - Technical specification for data access and communication requirements

All measurement data collected throughout the duration of the contract will be stored within the data platform. The demonstration cities should have full access to all such measurement data by contract.

The UPSURGE set the following requirements in terms of communication in the public procurement specifications:

- Data shall arrive to the platform via API

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- Use of standard for the transmission and communication of data.
- Technical integration of the Sensors to the UPSURGE Platform.
- Relayed data has to be in line with the set requirements (accuracy, sampling frequency etc.)

For the smooth UPSURGE monitoring data flow and processing, the procured systems need to be able to follow the steps below:

1) The information, **data is collected** at a minimum frequency by the sensor groups and it is being **transmitted to the IoT** of the service/sensor provide.
2) This **information** is being **relayed** in near real-time **to the UPSURGE** Cloud Platform through API.
3) The raw data are being saved in the **ingestion step** into the data lake layer.
4) The **data** is also **normalized**, and invalid outliers are eliminated, which can sometimes arise from sources such as uncalibrated or faulty monitoring stations.
5) Raw **data** can be **enriched** with third-party data to make the data provision, processing more comprehensive
6) Following normalized and enriched data, **data aggregation** occurs to organize data insights and data time series into layers.
7) Processed data, aggregated layers are being visualized and exposed to various frontends for the users.

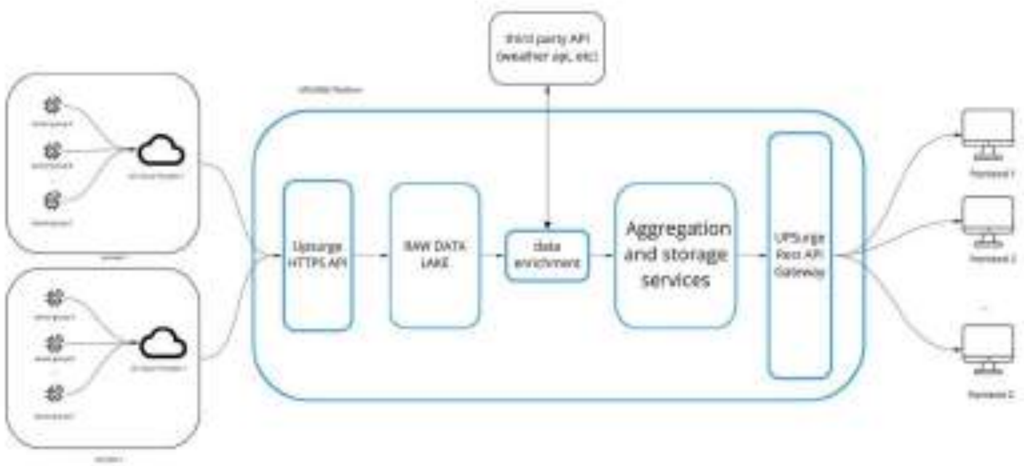

Figure 2 - Overview of the dataflow pattern (Source: UPSURGE D3.1)

2.5.1 DATA INPUT

<u>Specification of transmission (data schema)</u>

Data has to be sent according to a data schema of the UPSURGE Platform provided in a specific technical documentation.

Field	Type	Description	Example

parameter	String	The measured parameter; acceptable values are	*"pm25"*
Station	String	Unique station identifier	*"School B-19"*
City	String	City containing location	*"Maribor"*
Country	String	Country containing location in two letter ISO format	*"SI"*
Value	Number	Recorded value	*10.2*
Unit	String	Unit of measurement	*"ppm"*
Date	Object	Time of measurement in UTC time	*{"utc":"2015-10-*
Mobile	Boolean	Indicates whether the measuring station is stationary	*false*
coordinates	Object	Location of measurement	*{"latitude": -22.087,*
averagingPeriod	Object	Information about the time resolution of the	*{"value": 1, "unit":*

Table 10 - Technical specification for data transmission

<u>How to broadcast (transmission protocol)</u>

UPSURGE platform exposes a set of API to the web so any Contractor can send data from their sensors or from our platforms.

<u>Transmission Protocol:</u>

HTTPS, REST API (ApiKey authentication)

<u>Other specifications</u>

GNSS: GPS, BeiDou, Galileo and GLONASS

2.5.2 INSTALLATION AND MAINTENANCE

All the systems should be Plug & Play to permit an easy installation following instructions given by the supplier and the data transmission must be automatic, with a 4G modem, and with at least two years of data traffic included.

For fixed sensors cities should find some location with power supply and a pole, wall or other equipment that permit to put the sensor at a height of 3 / 4 metres.

Maintenance will be managed remotely, checking the correct functioning of the station. In case of malfunction not solvable by remote, the city should only remove and send the station for substitution.

2.5.3 Co-location and Calibration of low-cost sensors

All LCS must be supplied pre-calibrated in an accredited laboratory with a calibration certificate received during the production process. Furthermore, they must be optimized for the local settings in which they will operate to reach the most precise measurements.

The co-location and calibration will follow the next steps as depicted in Figure 3 - Process flow for in field co-location (Source: UPSURGE D3.1).

Step 1: Co-location phase: Air Quality Station (stationary and mobile stations) will be deployed next to the reference station to collect data for up to 1 month. This is needed in order to calibrate Air Quality nodes against scientific reference stations.

Step 2-3: Data from the Reference station will be sent to Cloud through a CSV file. Meanwhile, all data gathered by Air Quality Station has been collected in the cloud.

Step 4: Then the calibration process starts in the Model Factory section from our Cloud. This is where Artificial Intelligence takes part, allowing the user to start predictive models.

Step 5: Once the Air Quality Station node has been calibrated and trained it is ready to be deployed.

This calibration will be carried out by using the closest, relevant EAI station in the city and satellite models. Depending on the distance of the EAI station, sensor could be put on the EAI station for few weeks before installation and periodically for calibration. However, LCS monitoring stations have to be periodically recalibrated, preferably remotely. In particular to provide fast and cost-effective periodical calibration, needed to maintain good sensors performance, the project will use the Copernicus virtual reference station network (10x10km grid) already tested in other projects (such as UIA Prato Urban Jungle), running seasonal calibration of the whole network deployed in each demonstration city.

Copernicus virtual reference air quality stations can be reached here:
https://ads.atmosphere.copernicus.eu/cdsapp#!/dataset/cams-europe-air-quality-forecasts

The EAI stations and air-quality statistics can be reached here: https://www.eea.europa.eu/data-and-maps/dashboards/air-quality-statistics

The overview chart below from D3.1 shows this process.

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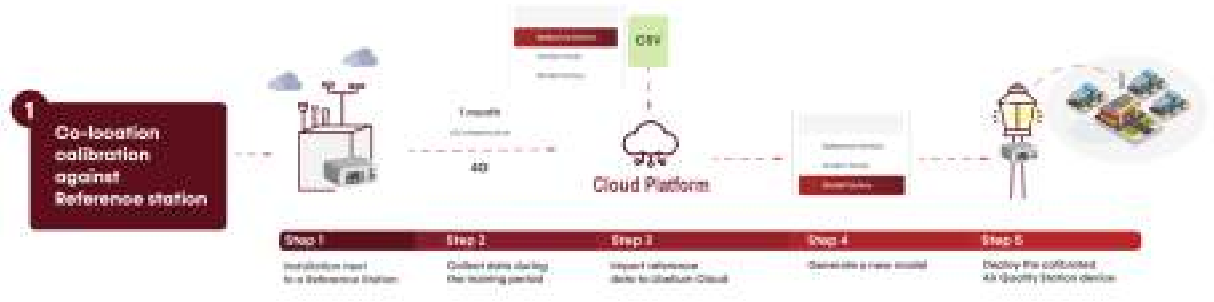

Figure 3 - Process flow for in field co-location (Source: UPSURGE D3.1)

2.6 WEARABLE SENSOR TECHNICAL SPECIFICATIONS

The wearable sensors represent an important tool to involve citizens in air quality monitoring and a way to increase the data density collected and to extend the analysis. Following market research, there are many types of wearable sensors, so it is relevant to select the best model according to these following requirements:

- Easy to wear and to use - people should have the opportunity to wear the sensor easily.
- Each sensor should be
  - light (less than 150 grams),
  - small (h<100mm, w<60mm, d<30mm)
  - with a long battery lifespan (up to 10 days with a single charge).
  - pre-calibrated and perform automatic calibration over time.
  - ready to communicate through open API with the UPSURGE platform for data relay.

The wearable devices shall measure the following parameters with the sensors included:

  - PM1, PM2.5, PM10,
  - Volatile Organic Compounds (VOCs);
  - Temperature, humidity, barometric pressure

OPERATE conducted market research on available wearable sensors. It turned out, that only few sensors match fully or partially the requirements and standards suitable for the UPSURGE. They may not be available in each country; therefore, the option of joint procurement was raised within the consortium with its benefits and drawbacks.

2.7 SENSORS MOUNTED ON UAVS

Considering the high cost for drones suitable to carry a sensing system and the limitations for flight coming from regulatory issues in the majority of the areas of the demo sites (urban areas) we proposed to exclude this type of measurement.

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3 PLANNED SENSING SYSTEM FOR BELFAST

3.1 INTRODUCING THE CASE IN BELFAST

3.1.1 ABOUT BELFAST

Belfast is the capital city of Northern Ireland and is a maritime city located along the River Lagan and the mouth of the Belfast Lough. The local government district had a population of 345,418 in the 2021 census but the metropolitan area is much larger than this, containing 37.1% of Northern Ireland's population according to 2011 figures. It is one of the youngest cities in Europe with young people up to the age of 21 making up nearly a third of the city's population, while a fifth of the city is under 15 years old. Belfast has 24.88 persons per hectare, compared with the average for Northern Ireland of 1.34 (Census 2011) making it the densest local government district, however, there is an ambition to densify and grow the population of the city by 66,000 more people by 2035 (Belfast Agenda, 2018).

Belfast city accounts for 18% of the population of NI and 30% of all jobs amounting to over 220,000 people. 93% of jobs are in the services sector, with almost one-third in the public sector. The median gross weekly pay in 209 was £575. The city is growing older, with 15% of the population being 65 and older. By 2035 this will rise to 20%. Life expectancy for males is 75.9 years, whilst for females it's 81.1 years. However, the gap between the 10 percent most deprived and least deprived areas of NI is 10.7 years for males and 7.7 years for females.

Belfast has a high number of physical barriers, largely located in the inner city, which causes issues for active travel, and sustainable service provision and contributes to carbon emissions through more people using a private car for transport. It is a very car-dominated city despite around 40% of households having no access to a car or van and has several Air Quality Management Areas shown below.

Belfast has 66 parks, totalling an area of 946.6 hectares, 38 growing spaces, totalling 1.8 ha, and overall, a total of 2388.4ha of open spaces including playing fields, play areas, amenity space, civic spaces and cemeteries as well. The city has several statutory designations including the Belfast Lough SPA and RAMSAR site (428.64ha), Belfast Lough Open Water SPA (5,591.73ha), 17 priority habitats and several important wetlands, one Area of Scientific Interest, 3 Nature Reserves, and Lagan Valley Area of Outstanding Natural Beauty, and six areas of Earth Science Interests and Assets, among other local natural designations.

Belfast is a city that has undergone significant transformation in recent years, having emerged from a sectarian conflict that impacted on relationships, investment, policy and the shape of the city. Many Belfast neighbourhoods remain disconnected, and a number of 'peace walls' which were erected to prevent violence between communities during the conflict continue to separate local areas – a stark reminder that much work is still needed to repair and reshape both relationships and the city itself. The peacebuilding programme of work is ongoing and will be assisted by the diverse benefits derived from UPSURGE, which will enable participants to look outwards to other city partners, and forwards, developing sustainable approaches to living.

Belfast has developed a strategic framework for the city known as 'The Belfast Agenda' that is delivered through city community planning structures and is coordinated by Belfast City Council, working closely with city partners. Within the community planning framework, the

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Belfast Resilience and Sustainability Board is responsible for creating the Belfast Resilience Strategy and the Belfast Climate Plan. The UPSURGE project will directly link to these plans through the Belfast City Council Belfast Resilience Unit. Other city plans that will align with the project include the Smart Belfast plan, the Green and Blue Infrastructure Plan, Belfast Open Spaces Strategy and the Belfast Biodiversity Plan.

Lower Ormeau is characterised as a nationalist area with a mixture of students and ethnic minorities among local residents. Ballynafeigh is characterised as an area with a wide mix of citizens and was one of the few mixed areas of Belfast throughout the conflict, the Holyland area is characterised as an area with a major student population, living alongside a small group of long-term residents and a range of ethnic minorities. Stranmillis is characterised as a more affluent area, again with a large student population. These local communities provide a rich and diverse mix for the project to engage with, alongside opportunities to build social cohesion, learning and neighbourhood approaches to sustainable urban agroecology. In addition to focusing on inter community and intra community relationships we will develop programmes specifically aimed at females, ethnic minorities and asylum seekers, groups traditionally under represented within such programmes.

The primary site will act as a learning base and hub for coordination and activity, linking to a number of satellite sites across Belfast. These will also be underused and derelict sites with potential for increased community involvement in their development, with a focus on generating multiple benefits including increased biodiversity, local sustainable food production, skills development, and rewilding. These satellite sites are integral to developing community and political support for a citywide approach, with the primary site at the core of the project.

Northern Ireland has a stable climate due to the moderating effect of the Atlantic Ocean, resulting in mild winters and cool summers. The temperate oceanic climate of Belfast is reflected in the narrow range of temperatures and rainfall throughout the year.

The indented shape of the coastline and the presence of high ground introduce localised differences in weather, whereas the Gulf Stream make Belfast's climate milder than most other locations at a similar latitude. July is normally the warmest month with average temperatures varying from 17.5 °C to 20 °C. The wettest months are between October and January. The average annual temperature in Belfast is 9.2°C. The predominant average hourly wind direction in Belfast varies throughout the year.

3.1.2 Challenges

Developed through a city-wide assessment, the Belfast Resilience Strategy (2020) identified several shocks and stresses facing the city (see Figure below). Existing and potential future shocks facing the city area include infrastructure capacity, public health, cyber resilience, the condition of existing housing stock, flooding and extreme weather events and the UK Exit from the EU. The stresses facing the city are its economic recovery capacity, climate change, mental ill health, poverty and inequality, housing supply, use of prescription drugs, population change, segregation and division, governance and financing of risk and carbon-intensive systems.

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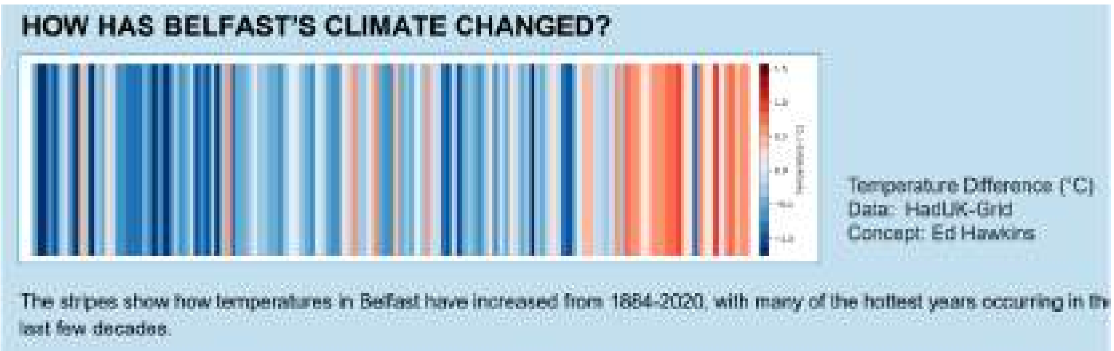
a)



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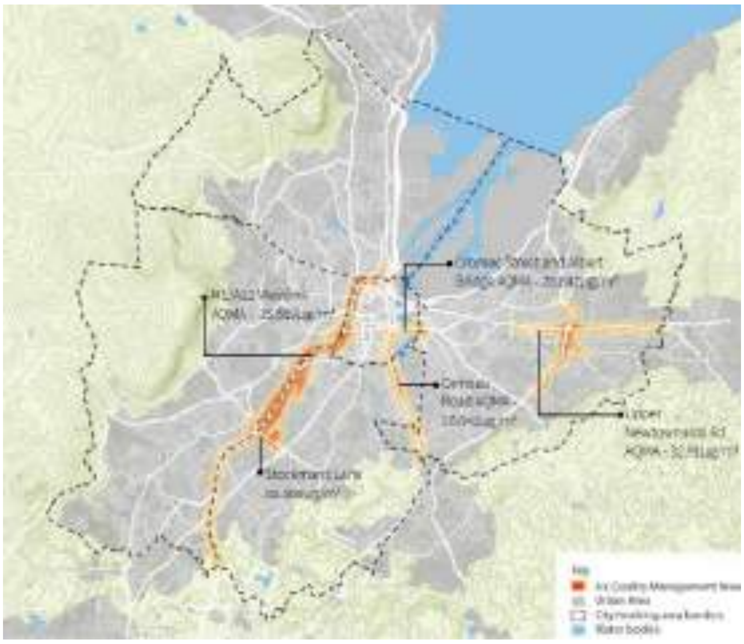

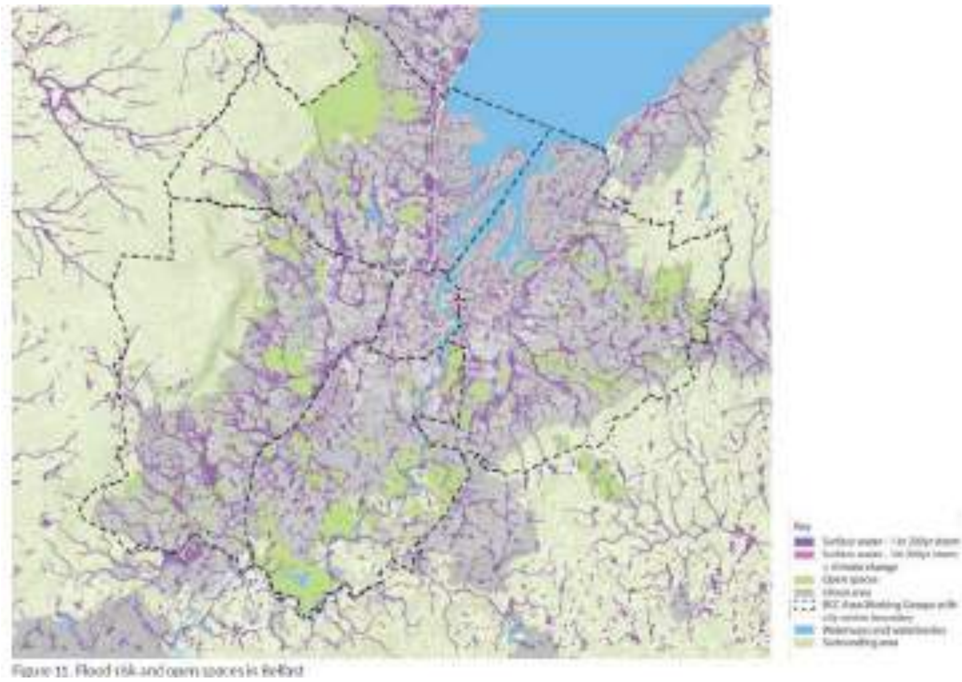

Figure 4 – Key City Challenges of Belfast a) Belfast's changing Climate (Source: Belfast City Pack, Met Office, 2022) b) Air Quality Management Areas in Belfast (Source: Belfast Green and Blue

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Infrastructure Plan), and c) Flood risk and open spaces in Belfast (Source: Belfast Open Spaces Strategy)

This historical site has had many iterations over the last 150 years but it has generally been contaminated with industrial waste over that period, up until the 1950's. The site has never been developed further, and in recent years has been a venue for concerts and sporting events. As the site currently stands, there is considerable amounts of soil and water contamination, as well as the site suffering from poor drainage, causing areas of standing water in poor weather conditions. There is only one small section which could be classed as Bio-diverse. The aim would be to increase bio-diversity, address contamination through NBSs, as well as addressing drainage and useability.

Concerning soil and water analysis, a contamination survey has been undertaken, by QUB, which demonstrates consistent historical ground contamination. This has led to some changes in the final design plan for the site and sensor locations.

Test	Method	Acc	LOD	Units							
Metals - Soil											
Arsenic	TP137	M	0.5	mg/kg	93.0	16.4	8.9	6.3	8.0	11.5	33.3
Cadmium	TP137	M	0.1	mg/kg	1.25	0.44	0.36	0.40	0.45	0.53	2.67
Chromium	TP137	M	1	mg/kg	29	30	43	49	28	37	38
Chromium, hexavalent	TP040	N	0.3	mg/kg	< 0.3 [d]	< 0.3 [d]	< 0.3 [d]	< 0.3 [d]	< 0.3 [d]	< 0.3 [d]	< 0.3 [d]
Copper	TP137	M	1	mg/kg	111	69	35	43	122	115	294
Lead	TP137	M	1	mg/kg	536	138	80	105	236	198	851
Mercury	TP137	M	0.1	mg/kg	0.71	0.22	< 0.10	0.21	0.64	0.95	0.59
Nickel	TP137	M	1	mg/kg	86	43	60	69	78	65	80
Selenium	TP137	U	0.5	mg/kg	< 0.50	0.52	0.57	0.57	< 0.50	< 0.50	0.87
Zinc	TP137	M	0.5	mg/kg	328	158	114	166	162	215	997
Chromium, trivalent	TP040	U	0.3	mg/kg	28.9	30.4	42.9	48.7	27.7	37.0	38.2

Table 11 - Presentation of existing data that justifies/illustrates the problem at the Belfast NBS location

The soil contamination was detected during series of larger soil analysis and focusses on metal contaminates on the demonstration site.

3.1.3 DEMONSTRATION SITE

The site is located in the south of the city and is considered part of the Botanic Gardens, which is a designated Historic Park, Garden and Demesne given its history and character. Whilst not within the conservation area, the site sits adjacent to Queen's Conservation area, the first to be designated in Belfast in 1987. It is also recognised as a Local Landscape Policy Area and sits adjacent to the Lagan Valley which is a Special Protected Area and a RAMSAR site of European importance.

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Figure 5 - Location of the NBS investment within Belfast (Source: QUB)

The UPSURGE demonstrator site is known locally as Lower Botanic and runs along the Stranmillis Embankment facing into the River Lagan to the east. To the north, it joins the Botanic Gardens and Queen's University, whilst to the west it sits adjacent to some housing and the Lyric Theatre.

The Lower Botanic site is easily accessible by bike, car and by walking from all sides, however, access through the Botanic Gardens is usually limited to daylight hours. It sits within the larger Queen's Quarter of South Belfast which is an area of the city with a large student population and a large university estate. The Holylands is a residential area with a large number of Houses of Multiple Occupation which is a short walk along the embankment from the site.

The former Botanic Gardens, later adapted as a public park (14.3ha), lie on the western bank of the River Lagan, some 1.5km directly to the south of Belfast City Centre. Botanic Gardens today is a heavily used public park and thoroughfare, which has excellent features and planting. It was established in 1828 by the Belfast Botanic and Horticultural Society in response to demands for a botanic garden for Belfast and was open to Society members (Fig. 6.5.5 a). Belfast Corporation purchased the property in 1895 and they were opened to the public. The park contains historical buildings of European significance such as the Palm House and Tropical Ravine. The Lower Botanic site for a period housed the Jaffe Memorial Fountain, erected by Otto Jaffe, Belfast's first Jewish Lord Mayor, in commemoration of his father who funded Belfast's first synagogue. This has since been restored and returned to its city centre location.

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Figure 6 - Belfast demonstration site (Source: QUB)

Throughout the history of Botanic Gardens, the location has been used as an events space, hosting garden fetes, flower shows and private events. It hosted the first Irish balloon ascent, as well as the Great International Fruit and Flower Show of August 1874. The area where the UPSURGE site is located was an additional piece of ground acquired along the River Lagan, which was less developed than the formal gardens but also used for growing.

From 1946, during the post second world war housing shortage the site housed temporary prefabricated huts for use as accommodation. They were known as Botanic bungalows. These were present until clearance of the site for use as the Ulster 1971 Convention, a large festival held from May to September, originally conceived to mark the 50th anniversary of the establishment of Northern Ireland.

The site has remained undeveloped and is identified on historical maps as playing fields. It has more recently been used for events such as music concerts and circuses. There is evidence of asbestos, and waste materials from previous use have been found in recent site investigations.

The site, known locally as Lower Botanic, has been chosen as it is an underutilised piece of open space currently within the Council's estate that is close to a range of surrounding and diverse communities. The site is linked and part of the Botanic Gardens, a designated Historic Park and Demesne with a rich history of botany, growing, civic and community uses. The park already benefits from a local group of community interests, the Friends of Botanic and has a substantial operation of park staff that currently maintain, develop, and act as stewards for the park itself. The site has significant potential for contamination due to its previous uses over many years and so offers a unique opportunity to test soil decontamination through growing and other nature-based solutions. Lower Botanic is close

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to Queen's University Belfast and so offers a high level of access for research activities to take place on the site.

3.1.3.1 Research Plots

A designated research area will be created within the demonstration site in conjunction with Queen's University Belfast (QUB). The objectives of the research site are 1) to measure bio-accessibility values from soils and vegetables grown onsite in non-amended and biochar-amended soils, and 2) to measure carbon and nitrogen isotope values from soils (and potentially vegetables) grown onsite in non-amended, biochar, basalt and biochar+basalt amended soils in conjunction with QUB and Antwerp University. This research contributes to the city's challenges around health and Brexit, identifying ways in which a more sustainable food system might be achievable in Belfast through food growing, and remediation on contaminated land. A sustainable food system is one of the ambitions of the Belfast Resilience Strategy (2020).

3.1.3.2 Rewild and boarded nature walk

Areas of the site will be 'rewilded' in order to encourage biodiversity and increase ecosystem services in the area. This will also encourage more wildlife habitats and provide pollination and food to support improving biodiversity in the city and citizens will be encouraged to help record, monitor and track how these changes across the site as the NBS is established.

3.1.3.3 Agroecology community garden & community education space

This space will provide growing opportunities for groups and residents to engage with the site. Various health benefits are known from shared growing and engaging in urban green spaces in a city, and this will also provide a space to overcome segregation and division that is built into the physical layout and residential makeup of the city. It is also hoped that this space will also help tackle poverty and inequality by developing opportunities for social enterprise through making, growing, creating etc. Giving young people and older people a space to work alongside one another too will help create more inclusive, age friendly environment.

3.1.3.4 Communal tree nursery

Brexit has created challenges for the sustainable and bio-secure supply of trees to Northern Ireland. There is also the need to develop an awareness of the climate benefits of trees and the value that they bring to the city. This tree nursery will engage citizens in seed collection, planting of native species, growing, looking after and understanding the resource requirements in growing in a climate resilient way, and help provide a stock of native and bio-secure trees for planting as part of the One Million Trees project and explore issues around urban production of tree stock.

3.1.3.5 RHS growing space

This space will encourage development of horticultural skills among groups such as the Friends of Botanic and a growing volunteer base for Botanic Gardens. Accredited courses could be run to help enable skills growth and stewardship of Belfast's natural and green spaces.

3.1.4 Stakeholder management

Stakeholder management activities for Belfast are outlined in a plan (D8.1) how to manage stakeholder engagement and what steps need to be taken to ensure expectations are met.

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Co-design has been at the heart of the project, with potential caretaker stakeholders identified early in that process. QUB and Belfast Council supported a series of co-design and consultation workshops to formalise concepts for the final site design. These where as follows:

- Workshop 1 – 29 April 2022
- Workshop 2 – 27th May 2022
- Workshop 3 – 16th Sep 2022
- 100+ participants across the 3 workshops

Figure 7 – Co-design workshops in Belfast

Conversations continued following workshops, with relationships with local stakeholders, residents, community sector, being developed and maintained. As part of this ongoing engagement, the project will identify longer term sustainable stakeholders, to work alongside existing Council departments to maintain the site, allowing it to transform, post UPSURGE, to a site that will continue to educate, innovate and welcome citizens of Belfast for years to come.

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3.2 TAILOR-MADE SENSING SYSTEM FOR BELFAST

Having learnt the general sensing framework approach, the location of the NBS demonstration projects of the City of Belfast for which the sensing system will be installed and adapted, this chapter introduces the planned sensing system in the city.

3.2.1 PLANNED SENSORS

3.2.1.1 AIR QUALITY

Belfast will measure air concentrations of the following parameters with LCS:

- PM_{10}
- $PM_{2.5}$
- NO_2
- O_3
- CO
- CO_2

3.2.1.2 WEATHER

Belfast will measure air concentrations of the following parameters

- Air temperature,
- Air relative humidity,
- Wind speed,
- Wind direction,
- Solar Radiation,
- Rain gauge,
- Atmospheric pressure.

3.2.1.3 OTHER ENVIRONMENTAL FACTORS

'Bee monitoring'

Novel tool for monitoring the environment is the analysis of pollen collected by bees. By means of the analysis of these natural bioindicators, qualitative and quantitative data about plant species, biodiversity, as well as certain parameters of indirect industrial and agricultural air- and soil pollution can be obtained.

Belfast will have at least one hive at a pre-selected location covering 1.5 km circle around it. The samples are being collected at a regular bases from April to October. The collected samples will be grouped into 4 periods and analysed in laboratory such as DNA and chemical analyses.

The following analysis will be carried out at the UPSURGE partners within BeeOmonitoring:

- Plant diversity
- Pesticides
- Heavy metals
- Polycyclic aromatic hydrocarbon (PAH)

Belfast will learn the identification, origin (such as heating, mobility, airport, recycling plant, etc.) and impact of heavy metals and pesticides. Moreover, identify the different plant diversity (quality and quantity, such as invasive species).

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The results will be made available on an online dashboard and will be published in the project reports.

Figure 8 – Planned bee-hive location in Belfast

Bees are being locally sourced through the Belfast & District Bee Keepers Society, which will prodominantly provide hives, using native Irish Black Bees.

Urban heat island effect

The intensity of the urban heat island effect is best measured by the difference in temperature and humidity between urban and non-urban areas, therefore no other specific element will be measured for this purpose.

Noise

The City of Belfast will monitor, analyze and record noise levels at the demonstration sites with LCS sensors.

3.2.2 Planned sensing stations

Sensors are often being located in the sensing units or stations, that have limited number of slots for sensors. The adaptation of the sensing framework based on the local circumstances

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and the changes reflected in section resulted in the following number of sensors and sensor stations under the current conditions:

Type of sensors	Static station	Mobile station	Wearable sensors	UAV sensors	Bee monitoring
Originally planned	2	5	100	5	1
Planned in Belfast	2	5	50	-	1

Table 12 - Number of sensors and sensing stations in Belfast

3.2.3 LOCATION OF THE SENSORS

The sensing stations will closely follow the location of the demonstration sites, following the features described in 3.3, but their exact location is still under planning. The first plan for sensors within the demonstration area is described below:

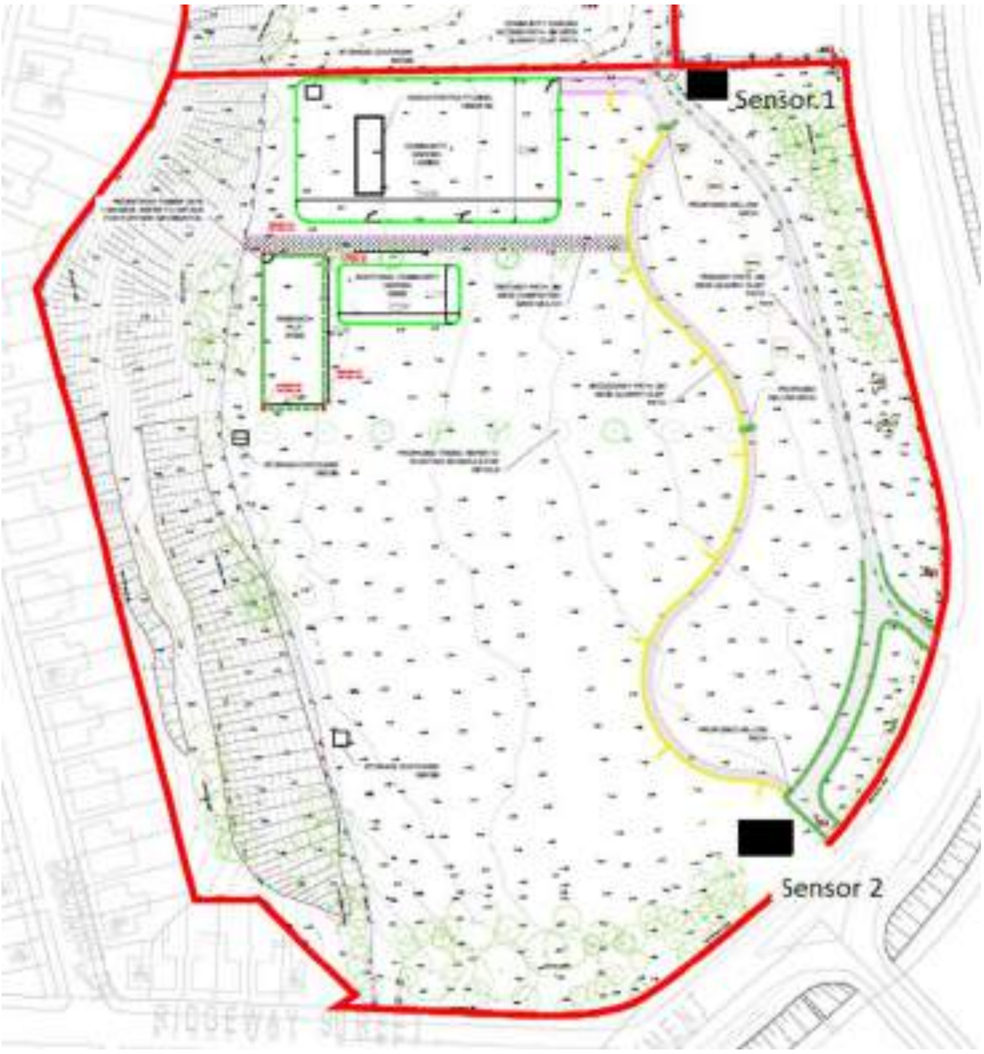

Figure 9 – Location of the sensors within the demonstration site in Belfast

	PM10	PM2.5	NO2	O3	CO	CO2	Air temperature	Air relative humidity	Wind direction	Wind speed	Solar Radiation	Rain gauge	Atmospheric pressure	Noise
Sensor #1	X	X	X	X	X	X								X
Sensor #2	X	X	X	X	X	X	X	X	X	X	X	X	X	

Table 13 - Distribution of the type of sensors at NBS locations in Belfast

3.2.4 KPIs MEASURABLE BY THE SENSING SYSTEM

	No.		GROUP KPIs name	KPI/indicator	Parameters measured by sensors
Air quality	1	1.1.1	Air pollutant concentrations	Air pollutant concentrations	+ Air pollutant concentration
	2	1.2.1	Concentration levels limits	Concentration levels limits (number of days with exceedances)	+ Air pollutant concentration
	3	1.3.1	Air quality index	Air quality index	+ Air pollutant concentration
UHI Effect	10	3.1.1	Urban Heat Island (UHI) effect	Urban Heat Island (UHI) effect	+ Temperature
	11	3.3.3	Mean or peak daytime local temperatures / Air temperature - mean, peak	Mean or peak daytime local temperature	+ Temperature
	12	3.4.1	Heat waves incidences (hot days, tropical nights)	Heatwave risk (days)	+ Temperature
	13	3.4.2	Heat waves incidences (hot days, tropical nights)	Heatwave risk (tropical nights)	+ Temperature

Table 14 – Measurable KPIs in Belfast

3.2.5 INSTALLATION OF SENSORS

As described in Phase IV of the sensing system framework, cities need to identify the place of the static sensing stations at the demonstration sites. It is recommended to install static sensors at a height of three to four meters from ground level. This could work well mounting

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on existing infrastructure or setting up new infrastructure element. Both may require permission and has to go through an authorization process.

3.2.5.1 STATIC SENSORS

Each demo site has to be thoroughly examined before the installation whether they are suitable for accommodating the static sensing stations. The city has to consider:

- **the ownership** of the site is clear and the owners officially let the sensors to be installed. Permissions might be need.
- if there is **sufficient space** for installing the container station
- the operation of the station, if it is easily **accessible for maintenance**
- the **orientation and placement** of the station if the location is ideal for continuous monitoring
- **connection to power and communication utilities**. Cable connection is evidently the easiest, but solar power supply with battery or wireless communication is a viable option too.
- if the installed station **fits into the environment**. Some city regulation might require a permission if the static station is in line with the cityscape or not.
- the **security** of the device, if it is protected against vandalism or cannot be easily stolen.
- capturing additional information during the installation and continuously about the surroundings or device itself. It is highly recommended to **document auxiliary information** in a log the maintenance, calibration process, as well as the temporary activities in the area, that might impact the results of the monitoring such as car-free day, construction activities etc.

Consideration	#1	#2
Ownership	X	X
Sufficient space	X	X
Accessibility	X	X
Orientation	X	X
Power utility connection (cable)		
Communication utility connection (cable)		
Fitting into the environment	X	X
Security	X	X
Auxiliary documentation	X	X

Table 15 - Installation aspects for the demonstration sites in Belfast

3.2.5.2 MOBILE SENSORS

The installation of mobile sensors is considered easier than in the case of static sensors. These sensors stations will be mounted in an undisturbed position on non-combustions engine run vehicles, such as electric car, bus or bicycle. They need permission from the owner of the vehicle, proper attachment to install securely the sensor case not to fall off

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during operation or not to be easily stolen. The mobile sensors have off-grid power supply and wireless communication connection and shall operate soundly following a calibration step.

3.2.5.3 WEARABLE SENSORS

Wearable sensors belong to a specific category of mobile sensors, that can be mounted on humans, on clothes or accessories. These light, hardly noticeable sensor devices shall be installed, turned on easily (plug-and-play for laymen users) following the first calibration and utilized regularly mapping the air-quality related few parameters (due to limited size and weight of the device) in which the users were exposed to. The challenge in installing and using wearable sensors lays in the consent of the users to register their location as geolocation of the air-quality mapping is necessary. All demonstration cities, including Belfast shall make sure that the users are aware of what information will be collected and how, and they are fully aware of the GDPR declaration details for which they have to give their consent before start using the wearable sensors. Data collected from wearable sensors will be recorded and stored as anonymous devices with no link with registered user.

3.2.5.4 BEE MONITORING

The sensors of the bee monitoring are the bees. They are based in their home, their hives where from they cover an area of about 1,5km^2 with sampling. The location of the hives in urban environment requires careful planning. The City of Belfast agrees on a location with local bee-keepers based on the localization conditions to deploy a hive.

3.2.5.5 UAV SENSORS

The UPSURGE partnership made decision to exclude the use of UAV-mounted data collection.

3.2.6 CO-LOCATION AND CALIBRATION

In the process of calibration to the local circumstances is essential that sensors show reliable values. Belfast plans to seasonally recalibrate the low-cost sensor monitoring stations, preferably remotely, following the initial recalibration and co-location as described in the recommendations of D3.1 that is mix of on-site and virtual activities.

This calibration will be carried out by using the closest, relevant EAI station in the city and satellite models. Depending on the distance of the EAI station, sensor could be put on the EAI station for few weeks before installation and periodically for calibration. However, LCS monitoring stations have to be periodically recalibrated, preferably remotely. In particular to provide fast and cost-effective periodical calibration, the project will use the Copernicus virtual reference station network (10x10km grid) already tested in other projects (such as UIA Prato Urban Jungle), running seasonal calibration of the whole network deployed in each demonstration city.

The closest and relevant EAI reference station in Belfast are the followings:

	EAI reference station #1	EAI reference station #2
Station name	Stockman's Lane	Belfast Centre
Link to location	https://aqicn.org/map/belfast/	https://aqicn.org/map/belfast/

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Link to data	https://aqicn.org/city/united-kingdom/northenireland/belfast-stockmans-lane/	https://aqicn.org/city/united-kingdom/belfast-centre/
Sampling point		
Type	Urban - Traffic	Urban - Background

Table 16 – EAI reference stations in Belfast

This way, calibrations shall be part of the public procurement process in which cities do not only buy the products, but service for the maintenance of the monitoring stations.

After each deployment and calibration, the contractor shall make available a report with the results of the initial calibration checks of the sensor systems deployed at the air quality monitoring station.

3.2.7 Budget/cost estimation

Based on the information coming from market research, the estimated total budget for the purchase is expected to be in the range of €40-45.000 (net).

CONFIGURATION	Sensor	Costs		
	Type	Estimated Cost / item in EUR	Number of items	Total estimated cost
REFERENCE STATION	FIX STATION	€ 45,000	0	€ -
STANDARD - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2	FIX STATION	€ 4,500	0	€ -
MOBILE - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2	MOBILE STATION	€ 4,500	5	€ 22,500
WEATHER - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, Wind direction, Wind speed, Solar radiation, barometric pressure, rain gauge	FIX STATION	€ 5,500	1	€ 5,500
SOIL + HIDROS21 - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, n°1 soil sensor Hidros21 soil water depth, soil temperature, soil conductivity, rain gauge	FIX STATION	€ 6,000	0	€ -
SOIL - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, n°2 soil water content, n° 2 soil temperature, rain gauge	FIX STATION	€ 5,500	0	€ -
AIR - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, SO2, NOISE	FIX STATION	€ 5,500	1	€ 5,500
AIR BLACK CARBON - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, SO2, NOISE, Black carbon sensor AETS AE51 with system integration	FIX STATION	€ 6,000	0	€ -
WEARABLE	WEARABLE	€ 200	50	€ 10,000
Other additional costs (VAT, technical fees, city costs for installation, etc.)				€ 22,500
			SUM	€ 66,000
			Available budget	€ 66,000

Table 17 – Budget/cost estimation

3.2.8 Procurement process and challenges

Belfast City Council's procurement policies and procedures, will create the framework for the sensor procurement and are cognisent of UK and EU policies.

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This requires an open tendering public procurement process. The Belfast City Council will be applying the Council's Social Value Procurement Framework in this exercise which has award criteria based on living wage, reducing carbon emissions, use of local expertise. Identifying expertise locally will be challenging but important for managing the ensuring the sensors operate effectively for the duration of the project.

Rising costs in the UK are causing challenges for the budget. Council is currently trying to identify additional funding to maximise sensors that can be installed in the required quality.

Attempts to integrate a sensor system with other council departments/functions are complex and the discussion on that are continuous.

The procurement/tender documents for the full site are yet to be signed off and published, it is envisaged that the current timeline for this is November 2023. QUB research plots will have localised low cost sensors associated with them, which will be installed, upon completion of the current stage of works.

- The preparation entails the entire process entails the use of the framework's (D3.1) Phase I – III. Defining the objectives of the sensing system, mapping and assessing the background conditions, identifying needs and selecting the sensors with the sensing expert and the UPSURGE partners. This step finishes with the formulation call for public procurement including the technical specifications for the sensing system. This step takes about 3 months.
- The estimation of the public procurement process may differ from the reality, as there are many legal and technical aspects that may prolong the process. However, a successful tender process may take at least 3 months in the best case if proper device and service provider is found in the first tender process.

1) The installation of sensors is possible only after selecting the contractor and signing the contract with them. The modification of the condition on the demonstration site, installation with calibration may take 4-6 months.

Figure 10 – Planned timeline in Belfast

3.2.9 PROJECT AFTER-LIFE

Maintenance of the sensing equipment, during the project lifetime, has been factored into the procurement process. Test equipment will be monitored and serviced on a regular basis to ensure affective recording of data.

In the longer term, it is hoped that, Belfast Council will adopt a responsibility for the equipment, although, this will rely on the ability of the project to secure future funding.

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4 Planned Sensing System For Breda

4.1 Introducing the case in Breda

4.1.1 About Breda

Breda is a lively city in the Dutch province of North Brabant with 185,000 inhabitants within 128 km^2 on the North-South axis between the metropolitan areas of Rotterdam (Netherlands) and Antwerp (Belgium). The city of Breda has a medieval urban core and various expansions surrounding it. Breda is known as the most important 'Nassau' city and for its beautiful old town. The Nassau family was responsible for Breda's prosperity and nine members of the Nassau noble family as well as the first Prince of Orange buried in the city. The House of Nassau-Orange also includes the Dutch royal family. Many monuments and green areas reflect this royal influence.

The climate of the Netherlands is influenced by the North Sea and the Atlantic Ocean, so it's cool, cloudy and humid for most of the year. The rains are not so abundant, ranging between 750-850mm (29-33 inches) per year, but they are frequent throughout the year. Winter, from December to February, is cold but not freezing, with daily average temperatures ranging from 2.5 °C (36.5 °F) in the North (see Groningen) to 4 °C (39 °F) on the south-western coast (see Rotterdam, Vissingen). In summer, from June to August, the temperatures are generally pleasant, but the sun does not shine very often. Cool and rainy days are quite frequent, with maximum temperatures below 20 °C (68 °F), however, they alternate with warmer days, with the sun peeping through the clouds and the temperature exceeding 25 °C (77 °F) in the early afternoon. The predominant wind directions are easterly in summer, and southwest directions in winter

4.1.2 Challenges

Breda covers 12,868 ha, of which 107 ha are covered by railways and 2,338 ha by residential buildings. Semi-built-up areas (construction areas) occupy 224 ha and sports grounds 278 ha of Breda. Additionally, there are 115 ha of greenhouses and 1,347 ha of forests and nature.[1] There is a great variety of biotopes in the municipality, making Breda rich in different animal and plant species. The municipality is actively involved in protecting the various biotopes and this is bearing fruit.[2] The Municipality of Breda has mapped out the possible climate effects by carrying out stress tests.

[1] StatLine 2018
[2] Gemeente Breda 2021

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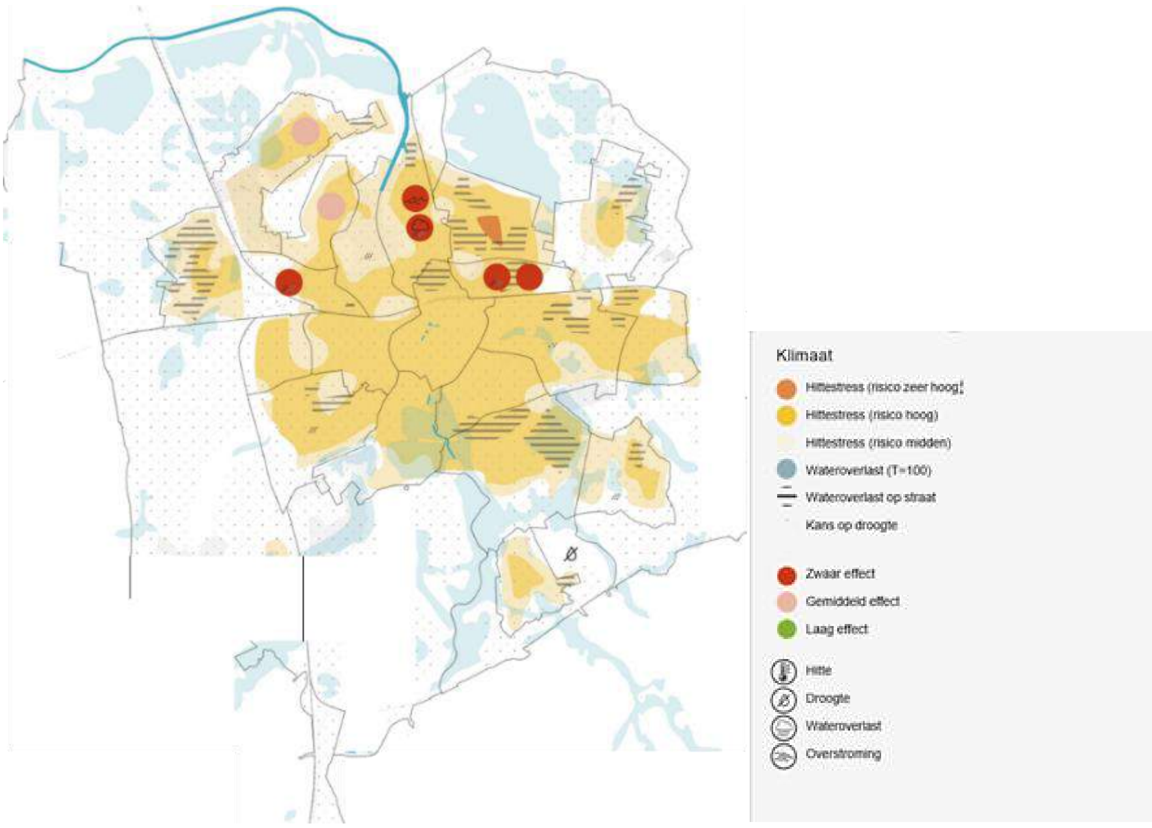

Figure 11 - Climate in Breda (Source: Gemeente Breda 2021)

The rural and urban area of Breda is confronted with various effects of climate change. In terms of drought, the heaviest effects are expected in the Ulvenhout forest and the higher sandy soils in the rural area. In terms of heat nuisance, the focus is on the residential areas of the city centre, Doornbos-Linie, Ginneken/IJpelaar and Tuinzigt. In addition, all large-scale work locations have to deal with adverse effects in the field of heat (Krogten, Steenakker, Emer, Hoogeind, Hazeldonk and Heilaar). The risk of flooding is highest in the northern neighbourhoods of Breda, especially the areas on both sides of the Mark (downstream) such as the Krogten, Haagse Beemden, Hagebeemd and residential areas as IJpelaar, Tuinzigt and Doornbos-Linie. So, the UPSURGE demo in Doornbos-Linie has to tackle heavy effects of heat stress and flooding.[3] Besides that, residents in Doornbos-Linie point out that the dumping of waste and litter is a thorn in the side of many residents.[4]

As part of the Groenkompas (green compass), the effects of green areas for the quality of life was determined for Breda. Most areas are perceived as rich green spaces. However, Doornbos-Linie is one of the districts which does not fall within the category of rich green space. The UPSURGE demo site is therefore focused on improving the quality of life of the Doornbos-Linie district. The Breda UPSURGE approach aims to contribute to Breda's aspiration of becoming the first European city within a park.

[3] Gemeente Breda 2021

[4] Wijkraad Doornbos-Linie 2022

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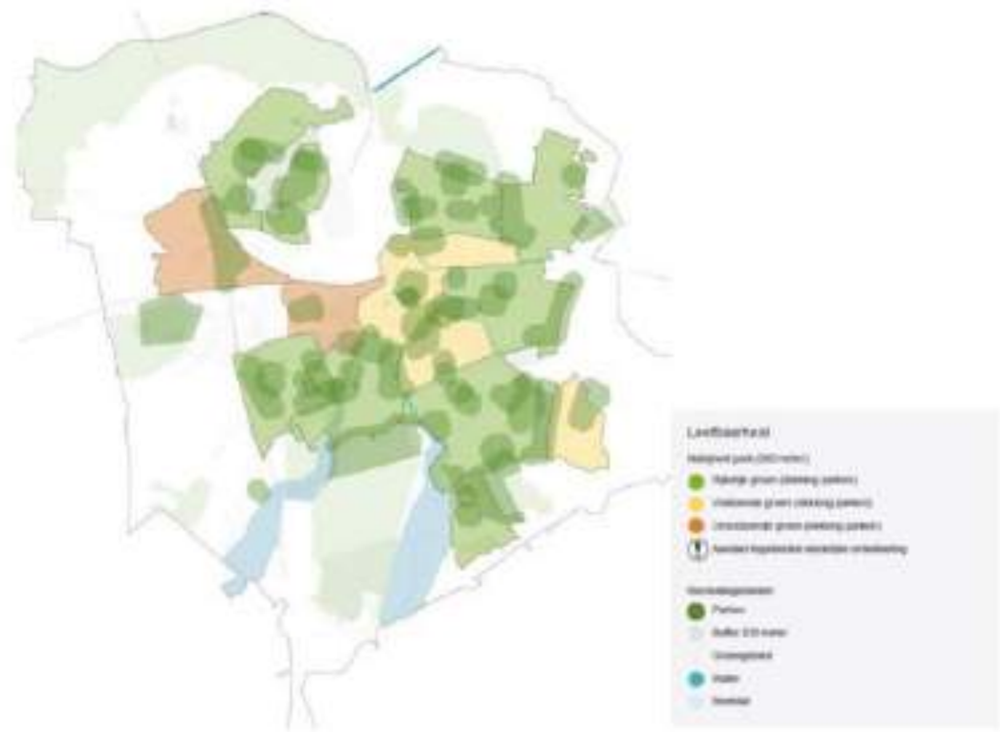

Figure 12 - Key City Challenges of Breda – Improvising Quality of Life in Breda (Source – Gemeente Breda 2021)

4.1.3 Demonstration site

The site is located between railways and the Northern ring road of the city within a socio-economically impoverished area.

Doornbos-Linie is mainly inhabited by low-income social groups and is an ethnic diverse population. There are language barriers of the multicultural residents and challenges due to a lack of environmental education and awareness. Both are necessary to tackle challenges, which are triggered by various effects of climate change. The UPSURGE demo in Breda tackles heavy effects of heat stress and flooding. Besides that, residents in Doornbos-Linie point out that the dumping of waste and litter is a thorn in the side of many residents. As indicated in the green compass, many residential areas, work locations and shopping areas are currently characterized by a high percentage of surfacing. Within Doornbos-Linie there are two public places, which are surrounded by housing and do have a high percentage of sealing. This is enhancing the heat island effect and low air quality. The demo sites are mainly used as parking spots right now. They are used by local residents as well as commuters as P+R. The Breda Municipality will introduce parking fees in the district soon. There is a general lack of parking spaces within the district and around the main train station. It is a challenge to make the area greener and to tackle the need for parking spaces. The surface sealing and parking is wounding the roots of old trees, which are in the centre of the square.

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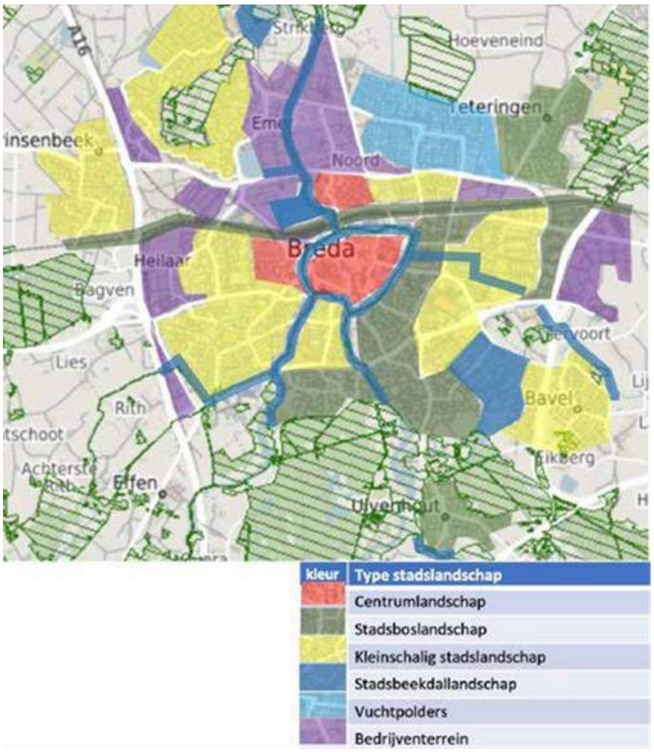

Figure 13 – Type of urban neighbourhoods in Breda

The district is well accessible by bus or bike on separate bike lanes. Residents in the district point out that the situation around the Northern ring road (safety, traffic pressure, particulate matter, noise) and the road safety in the neighbourhood in general (street layout, parking) require attention. They also point out that the entire district is a 30 km zone, but in a number of places it is not equipped for this. Besides these challenges, residents from Doornbos-Linie are currently experiencing various health problems. In this district the numbers are higher compared to other neighbourhoods in Breda. An increasing amount of public green spaces in these districts could tackle these issues since greenery contributes in particular to the quality of life in vulnerable neighbourhoods and improves the health prospects of the residents. The number of registered crimes in the Doornbos-Line district has been falling significantly since 2020, but criminal activities (e.g., property crime, traffic crime or drug crimes) and antisocial behaviour is still a challenge within the district.

The site is located between railways and the Northern ring road of the city within a socio-economically impoverished area. The UPSURGE demo site in Doornbos-Line is affected by heat stress and flooding. The urban jungles are designed to address the issues of heat stress and flooding and increase the overall environmental design through increased green spaces.

Breda 'City in a Park' will become a biodiverse green metropolis connected to the greenery surrounding the city. The Breda UPSURGE approach also contributes to this goal and uses urban jungles, which are high density re-designed areas immersed in the city to address the city challenges.

The Breda UPSURGE approach uses urban jungles, which are high-density green re-designed areas immersed in the city. The UPSURGE demonstration will be implemented in district "Linie" – located between the railways and the Northern ring road of the city. Doornbos-Linie can be characterized as a small-scale urban landscape.

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Figure 14 - Map of demonstration site in the district Doornbos-Linie. Source: Gemeente Breda 2021

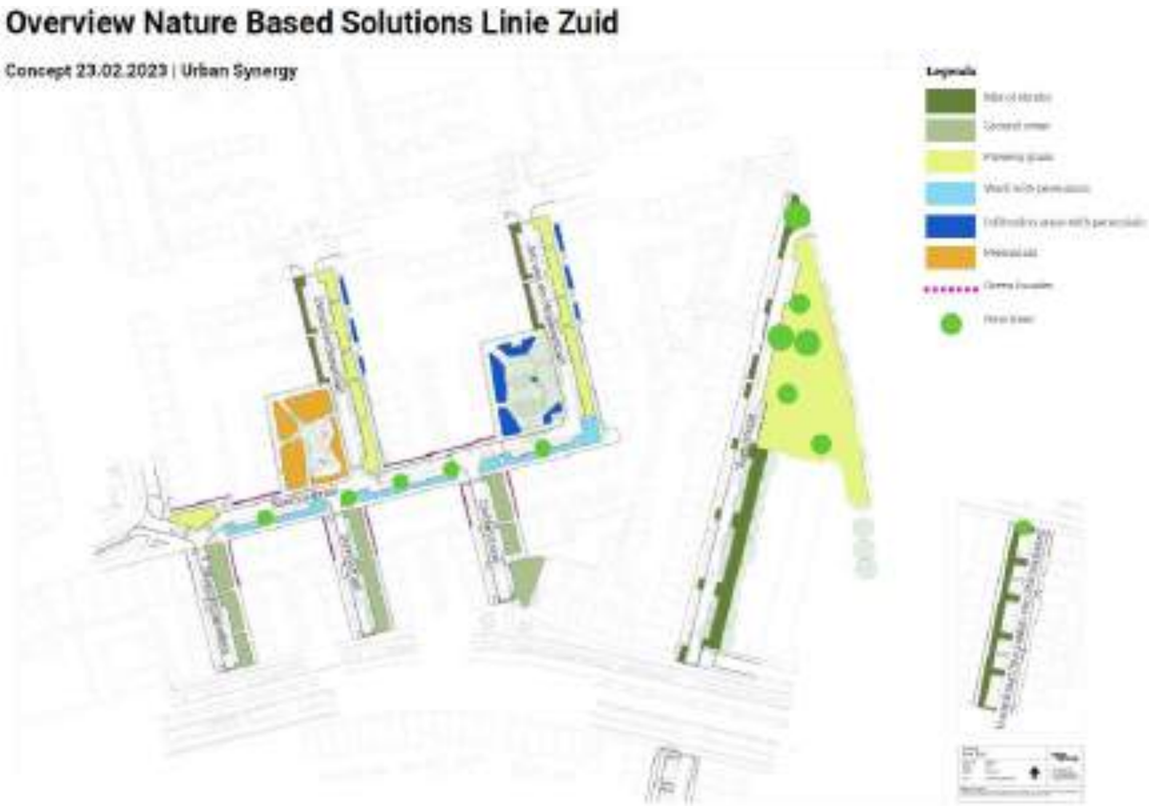

Figure 15 - Overview of NBSs in Linie Zuid

Breda has opted for a variety of NBS measures, namely: planting trees, increase greenery, vertical green facades, infiltration strips for rainwater and construction of (semi) open paving. The NBSs to be implemented are further explained in the planting plan and water management plan of Linie Zuid.

1.Varied plants areas

Grass fields and pavements will be replaced by varied plant areas. In total 1035 m^2 of shrubs, 785 m^2 of ground cover, 2668m^2 of flowery grass and 1105m^2 of various perennials will be implemented.

2.Trees

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New trees will be planted, species selected include 4x Styphnolobium japonicum, 2x Taxodium distichum, 1x Tilia flavescens 'glenleven', 5x Gleditsia triacanthos

3.Green facades

About 533m^2 vertical surface will be covered by climbing plants

4.Sunken areas

332m^2 will be modified to create area where rainwater can be temporarily stored and drained slowly.

5.Infiltration areas

260m^2 of infiltration areas will be implemented. Plants that can go deeper into the ground that the ones in the sunken area will be planted. In this zone rainwater can be temporarily stored and drained.

Planting Plan for trees

The substrate at the site is (humus-containing) sand, groundwater at -1.50 m from the ground level. Where possible, the city will widen the green sections. Green will be used at side walls and property boundaries facades realized with climbing plants. Space is reserved along the facades where residents can have a facade garden layout. The choice of planting has been taken into account with biodiversity and its plants chosen that attractive to bees and butterflies. The choice of planting has also been taken into account with the planting list with a variety of plants which have a positive impact on air quality provided from UPSURGE. Existing trees are preserved as much as possible.

Consideration for Rainwater Collection and Inflitration. Where possible, downspouts are disconnected of the sewer through which the rainwater can flow infiltrate into the adjacent green areas. Like this the sewer is relieved during peak showers and there is more rainwater retained in the area. On the squares, rainwater is collected from the adjacent roofs cushioned and slowed down discharged. Water-permeable paving is used. By optimally greening the streets and on the squares can infiltrate a lot of rainwater. Through above-ground outflow facilities rain gardens and a water square become the rainwater made visible to residents. This has an educational vision and contributes to the experience.

4.1.4 STAKEHOLDER MANAGEMENT

Stakeholder management activities for Breda are outlined in a plan (D8.1) how to manage stakeholder engagement and what steps you need to take to ensure expectations are met.

The developments within this demo site are accompanied by a participatory design process, which is organized by the municipality, the housing company *Alwel*, architects from *Urban Synergy* and environmental activist groups that provide local communities with expertise on structural, ecological and social aspects in order to develop the district into a greener area.

Stakeholder engagement and involvement actions in Breda include the following activities:

- "Door by door talks": Through initiatives by the housing company Alwel, architects from Urban Synergy and the municipality, attempts are made to obtain the opinions of residents on future activities and changes and to take these into account in the planning process. The municipality and the architects went from door to door with a little present and spoke to more than 60 tenants about the project and with their input they are adjusting the green plans.

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- Online Information and response option with PlanBreda: Besides that, residents can also give feedback and track the design process via a website called PlanBreda. https://www.planbreda.nl/default.aspx
- Pop Up exhibition: The current plans and illustrations of the plans for Doornbos-Linie as well as the results of the talks with the attendants can be seen in a pop-up exhibition in Doornbos-Line.

Figure 16 - Pop-up exhibition in Doornbos-Linie, Breda. (Source: CENTOURIS 2022)

4.2 TAILOR-MADE SENSING SYSTEM FOR BREDA

Having learnt the general sensing framework approach, the location of the NBS demonstration projects of the City of Breda for which the sensing system will be installed and adapted, this chapter introduces the planned sensing system in the city.

4.2.1 PLANNED SENSORS

4.2.1.1 AIR QUALITY

Breda will measure air concentrations of the following parameters with LCS:

- PM_{10}
- $PM_{2.5}$
- NO_2
- O_3
- CO
- CO_2

4.2.1.2 WEATHER

Breda will measure the following parameters

- Air temperature,
- Air relative humidity,
- Wind speed,
- Wind direction,
- Solar Radiation,
- Rain gauge,
- Atmospheric pressure.

4.2.1.3 OTHER ENVIRONMENTAL FACTORS

'Bee monitoring'

Novel tool for monitoring the environment is the analysis of pollen collected by bees. By means of the analysis of these natural bioindicators, qualitative and quantitative data about plant species, biodiversity, as well as certain parameters of indirect industrial and agricultural air- and soil pollution can be obtained.

Breda will have at least one hive at a pre-selected location covering 1.5 km circle around it. The samples are being collected at a regular bases from April to October. The collected samples will be grouped into 4 periods and analysed in laboratory such as DNA and chemical analyses.

The following analysis will be carried out at the UPSURGE partners within BeeOmonitoring:

- Plant diversity
- Pesticides
- Heavy metals
- Polycyclic aromatic hydrocarbon (PAH)

Breda will learn the identification, origin (such as heating, mobility, airport, recycling plant, etc.) and impact of heavy metals and pesticides. Moreover, identify the different plant diversity (quality and quantity, such as invasive species).

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The results will be made available on an online dashboard and will be published in the project reports.

Figure 17 - Location of the beehives in Breda

Breda plans to deploy the beehives at a local school falling into the pollen collection area of the bees.

Urban heat island effect

The intensity of the urban heat island effect is best measured by the difference in temperature and humidity between urban and non-urban areas, therefore no other specific element will be measured for this purpose.

Noise

Breda will monitor, analyse and record noise levels at the demonstration sites with LCS sensors.

Noise is measured in decibels (dB). Breda will have a stationary measuring system/sensor on a square ('Swammerdamstraat') at the demo site of Breda. Since this system monitors weather conditions too, it is also possible to filter out noise measurements during extreme weather conditions (for instance heavy rain, thunderstorms or maybe extreme hot days). L95-values (1h data) appear suitable as they filter out rogue events. The connecting KPI is 'influence of noise' (exposure to noise pollution).

Breda do not plan to measure any other environmental parameters.

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4.2.2 PLANNED SENSING STATIONS

Sensors are often being located in the sensing units or stations, that have limited number of slots for sensors. The adaptation of the sensing framework based on the local circumstances and the changes reflected in section resulted in the following number of sensors and sensor stations under the current conditions:

Type of sensors	Static station	Mobile station	Wearable sensors	UAV sensors	Bee monitoring
Originally planned	2	5	100	5	1
Planned in Breda	4	3	50	-	1

Table 18 - Number of sensors and sensing stations in Breda

4.2.3 LOCATION OF THE SENSORS

The sensing stations will closely follow the location of the demonstration sites, following the consideration for installing.

Figure 18 – Location of the planned sensing stations in Breda

The location of the 2 stationary sensing stations are planned to be placed most probably on a square at the end of the 'Swammerdamstraat', whereas 2 more stationary sensing station near a busy street for instance 'Vuchtstraat' at the demo site of Breda

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	PM10	PM2.5	NO2	O3	CO	CO2	Air temperature	Air relative humidity	Wind direction	Wind speed	Solar Radiation	Rain gauge	Atmospheric pressure	Noise
Swammerdamstraat #1	X	X	X	X	X	X								X
Swammerdamstraat #2	X	X	X	X	X	X	X	X	X	X	X	X	X	
Vuchtstraat #1	X	X	X	X	X	X								X
Vuchtstraat #2	X	X	X	X	X	X	X	X	X	X	X	X	X	

Table 19 – Distribution of the type of sensors at NBS locations in Breda

4.2.4 KPIs MEASURABLE BY THE SENSING SYSTEM

	No.		GROUP KPIs name	KPI/indicator	Parameters measured by sensors
Air quality	1	1.1.1	Air pollutant concentrations	Air pollutant concentrations	+ Air pollutant concentration
	2	1.2.1	Concentration levels limits	Concentration levels limits (number of days with exceedances)	+ Air pollutant concentration
	3	1.3.1	Air quality index	Air quality index	+ Air pollutant concentration
	4	1.5.1	Ambient pollen concentration	Ambient pollen concentration	+ Ambient pollen concentration
UHI Effect	10	3.1.1	Urban Heat Island (UHI) effect	Urban Heat Island (UHI) effect	+ Temperature
	11	3.3.3	Mean or peak daytime local temperatures / Air temperature - mean, peak	Mean or peak daytime local temperature	+ Temperature
	12	3.4.1	Heat waves incidences (hot days, tropical nights)	Heatwave risk (days)	+ Temperature
	13	3.4.2	Heat waves incidences (hot days, tropical nights)	Heatwave risk (tropical nights)	+ Temperature

Table 20 – Measurable KPIs in Breda

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4.2.5 INSTALLATION OF SENSORS

As described in Phase IV of the sensing system framework in D3.1, cities need to identify the place of the static sensing stations at the demonstration sites. It is recommended to install static sensors at a height of three to four meters from ground level. This could work well mounting on existing infrastructure or setting up new infrastructure element. Both may require permission and has to go through an authorization process.

4.2.5.1 STATIC SENSORS

Each demo site has to be thoroughly examined before the installation whether they are suitable for accommodating the static sensing stations. The city has to consider:

- **the ownership** of the site is clear and the owners officially let the sensors to be installed. Permissions might be need.
- if there is **sufficient space** for installing the container station
- the operation of the station, if it is easily **accessible for maintenance**
- the **orientation and placement** of the station if the location is ideal for continuous monitoring
- **connection to power and communication utilities**. Cable connection is evidently the easiest, but solar power supply with battery or wireless communication is a viable option too.
- if the installed station **fits into the environment**. Some city regulation might require a permission if the static station is in line with the cityscape or not.
- the **security** of the device, if it is protected against vandalism or cannot be easily stolen.
- capturing additional information during the installation and continuously about the surroundings or device itself. It is highly recommended to **document auxiliary information** in a log the maintenance, calibration process, as well as the temporary activities in the area, that might impact the results of the monitoring such as car-free day, construction activities etc.

Consideration	Swammerdamstraat	Vuchtstraat
Ownership	X	X
Sufficient space	X	X
Accessibility	X	X
Orientation	X	X
Power utility connection (cable)	X	X
Communication utility connection (cable)		
Fitting into the environment	X	X
Security	X	X
Auxiliary documentation	X	X

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101003818.

Table 21 - Installation aspects for the demonstration sites in Breda

4.2.5.2 Mobile sensors

The installation of mobile sensors is considered easier than in the case of static sensors. These sensors stations will be mounted in an undisturbed position on non-combustion-engine run vehicles, such as electric car, bus or bicycle. They need permission from the owner of the vehicle, proper attachment to install securely the sensor case not to fall off during operation or not to be easily stolen. The mobile sensors have off-grid power supply and wireless communication connection and shall operate soundly following a calibration step.

4.2.5.3 Wearable sensors

Wearable sensors belong to a specific category of mobile sensors, that can be mounted on humans, on clothes or accessories. These light, hardly noticeable sensor devices shall be installed, turned on easily (plug-and-play for laymen users) following the first calibration and utilized regularly mapping the air-quality related few parameters (due to limited size and weight of the device) in which the users were exposed to. The challenge in installing and using wearable sensors lays in the consent of the users to register their location as geolocation of the air-quality mapping is necessary. All demonstration cities, including Breda shall make sure that the users are aware of what information will be collected and how, and they are fully aware of the GDPR declaration details for which they have to give their consent before start using the wearable sensors. Data collected from wearable sensors will be recorded and stored as anonymous devices with no link with registered user.

4.2.5.4 Bee monitoring

The sensors of the bee monitoring are the bees. They are based in their home, their hives where from they cover an area of about 1,5 km^2 with sampling. The location of the hives in urban environment requires careful planning. Breda made contact with the association of bee keepers and a local school, and they determined the exact location of the hive to be deployed at the school.

4.2.5.5 UAV sensors

The UPSURGE partnership made decision to exclude the use of UAV-mounted data collection.

4.2.6 Co-location and calibration

In the process of calibration to the local circumstances is essential that sensors show reliable values. Breda plans to seasonally recalibrate the low-cost sensor monitoring stations, preferably remotely, following the initial recalibration and co-location as described in the recommendations of D3.1 that is mix of on-site and virtual activities.

This calibration will be carried out by using the closest, relevant EAI station in the city and satellite models. Depending on the distance of the EAI station, sensor could be put on the EAI station for few weeks before installation and periodically for calibration. However, LCS monitoring stations have to be periodically recalibrated, preferably remotely. In particular to provide fast and cost-effective periodical calibration, the project will use the Copernicus virtual reference station network (10x10km grid) already tested in other projects (such as UIA

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Prato Urban Jungle), running seasonal calibration of the whole network deployed in each demonstration city.

The closest and relevant EAI reference station in Breda are the followings:

	EAI reference station #1	EAI reference station #2
Station name	Breda-Bastenakenstraat	Breda-Tilburgseweg
Link to location	https://maps.app.goo.gl/d3hVJ9VLPYTBrPqXA	https://maps.app.goo.gl/fENQm5tQKLTE69yR7
Link to data	-	-
Sampling point	SPO-NL00241_00008_100	SPO-NL00240_00008_100
Type	Suburban - Background	Suburban - Traffic

Table 22 - EAI reference stations in Breda

This way, calibrations shall be part of the public procurement process in which cities do not only buy the products, but service for the maintenance of the monitoring stations.

After each deployment and calibration, the contractor shall make available a report with the results of the initial calibration checks of the sensor systems deployed at the air quality monitoring station.

4.2.7 BUDGET/COST ESTIMATION

Based on the information coming from market research, the estimated total budget for the purchase is expected to be in the range of €43-48.000 (net).

CONFIGURATION	Sensor	Costs		
	Type	Estimated Cost / item in EUR	Number of items	Total estimated cost
REFERENCE STATION	FIX STATION	€ 45,000	0	€ -
STANDARD - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2	FIX STATION	€ 4,500	0	€ -
MOBILE - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2	MOBILE STATION	€ 4,500	3	€ 13,500
WEATHER - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, Wind direction, Wind speed, Solar radiation, barometric pressure, rain gauge	FIX STATION	€ 5,500	2	€ 11,000
SOIL + HIDROS21 - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, n°1 soil sensor Hidros21 soil water depth, soil temperature, soil conductivity, rain gauge	FIX STATION	€ 6,000	0	€ -
SOIL - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, n°2 soil water content, n° 2 soil temperature, rain gauge	FIX STATION	€ 5,500	0	€ -
AIR - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, SO2, NOISE	FIX STATION	€ 5,500	2	€ 11,000
AIR BLACK CARBON - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, SO2, NOISE, Black carbon sensor AETS AE51 with system integration	FIX STATION	€ 6,000	0	€ -
WEARABLE	WEARABLE	€ 200	50	€ 10,000
Other additional costs (VAT, technical fees, city costs for installation, etc.)				€ 20,500
			SUM	€ 66,000
			Available budget	€ 66,000

Table 23 – Budget/cost estimation

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4.2.8 PROCUREMENT PROCESS AND CHALLENGES

The sensors will be purchased prior to the construction of the NBS, as part of public procurement in accordance with Dutch law. Breda will to install sensors during construction works at the locations of NBS points.

According to the procurement policy of Breda we can purchase the sensors based on a single private procurement.

- The preparation entails the entire process entails the use of the framework's (D3.1) Phase I – III. Defining the objectives of the sensing system, mapping and assessing the background conditions, identifying needs and selecting the sensors with the sensing expert and the UPSURGE partners. This step finishes with the formulation call for the procurement including the technical specifications for the sensing system. This step takes about 6 months. The contract with the supplier includes installation, calibration and maintenance of the sensors.
- The estimation of the procurement process will take about 2 months.

Figure 19 - Planned timeline in Breda

4.2.9 PROJECT AFTER-LIFE

Following the UPSURGE project, the installed sensing system at the NBS locations will be operated further to monitor the impact of the NBS at least 5 years after project finish. Following 5 years, Breda will reconsider the location of the fix monitoring stations if they can be relocated to other areas. The mobile sensors will be used primarily on routes touching the NBS sites. however, they will measure other areas of the city too. Following the project, the routes while using the mobile sensors may not touch the NBS sites.

In the longer term, it is hoped that, Breda will adopt a responsibility for the equipment, although, this will rely on the ability of the project to secure future funding.

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5 PLANNED SENSING SYSTEM FOR THE CITY OF BUDAPEST 18

5.1 INTRODUCING THE CASE IN BUDAPEST 18

5.1.1 ABOUT BUDAPEST 18

Budapest, the capital city of Hungary, consists of 23 districts. Budapest's 18th District is the fourth largest district in Budapest. Bp18 or Pestszentlőrinc – Pestszentimre is located on the outskirts of Budapest, in the south-east of the city centre. The district is mainly a green suburban residential peripheral district, with mostly low-rise, loosely built-up single-family houses, smaller apartment buildings and to a smaller extent some socialist type of 10-storey blocks of flats. The BP18 is relatively homogeneous, and overall garden-like, with a mosaic and scattered network of institutions. This is because individual neighbourhoods have built up gradually since the end of the 19th century having individual characters with their own church, school, and kindergarten. Thus, the institutional centre of the BP18 has gradually emerged as a single district that is still evolving.

Today, nearly 100,000 people live in the district, in 23 self-described residential neighbourhoods. Urban density is 25.9 citizens per hectare, which is less than Budapest's average of 32.5. The breakdown of the population by age shows that the majority of the district's permanent population is made up of working-age people, 18-59-year-olds, followed by over 65s and then 0-14-year-olds. In terms of the gender composition of the population, the proportion of women exceeds that of men, similar to the national ratio. It can also be noted that in the 18-59 age group, there is an excess of women, whereas the proportion of men is higher for the age group younger than 18.

The BP18 has a mainly residential, garden suburban character, with some housing estates. Of the 1800 hectares (ha) of green spaces, 23.84 ha are public, and 1,776 ha are private. The public areas are used as recreation areas with benches, fireplaces and playgrounds, several sports fields, and spaces for public events. Some of the public areas are small parks and forests. There are also 11,510 m^2 of water surface.

BP18 is considered a commuter town as there are limited employment opportunities, and more people work outside the district than within it. The employment rate in the district is 47.28%. Some institutions of national importance operate within the district, including the Marczell György Main Observatory of the Hungarian Meteorological Service and the country´s largest international airport, which is named after Ferenc Liszt.

The area is characterized by dry continental climate, that is reflected in the 400-600mm of total annual precipitation. The annual mean temperature is between 11 – 12 °C. In contrast to the north-west wind direction that prevails in the country, the microclimate of the district is characterized by the more and more frequent east-southeast wind direction due to the changing climate. Urban heat island effect is not typical for the area having a suburban characteristic This way, District 18 experiences a mean temperature 3-6 °C lower than in the downtown of Budapest throughout the year. However, the urban heat island effect may be perceivable at airport and at larger industrial sites in their microclimate.

5.1.2 CHALLENGES

However, even if it is characterized by relatively many green spaces, significant air pollution can be detected along the three main roads linking the district with other parts of the city,

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due to increased traffic load coming from the commuting residents and the transit traffic from Liszt Ferenc International Airport.

BP18 has territorial connection with Liszt Ferenc International Airport (BUD Airport), which is situated at the outskirts of the city. The majority of the areas of BUD Airport is found in the District 18 and the entrances on the landside are located there too. Significant air pollution (typically PM10 and PM2.5) can be detected along the 3 main roads linking the district with other parts of the city due to increased traffic load coming from the commuting residents and the transit traffic. The situation is worse in the wintertime, when in part of the family houses solid fuels are used for heating, as gas prices are rising. Electric heating is not yet common, due to high investment costs.

Besides, urban flash floods stemming from sealed soil surface and climate change are more and more affecting the areas such as it has been facing severe submergence cases in recent years. The drainage system in many parts of the district and the soil structure of the area is incapable of absorbing or leading off run-off water properly, no “easy” or one-off solution can be applied effectively. The BP18 aims to apply NBS for absorbing and retaining excess rainwater and encourages citizens to do so as well. Therefore, within UPSURGE, rain gardens are being implemented on public and private land to absorb and retain excess rainwater.

Regarding soil: the main characteristic is river sediment - sand and gravel with high permeability. However, on some parts there are thick clay layers, in various depth, with high water sealing potential. Where the clay layer is close to the surface, the infiltration capacity is low. The situation is worsened by high ratio of paved areas, even around family houses, for car parking and driveways. With climate change, BP18 has to face more frequent extreme and intense precipitation events: longer drought periods and more frequent torrential rains. These heavy downpours do not infiltrate evenly into the soil, but run off quickly. Adapting to the changing conditions, complex management of rainwater has become necessary, during which the goal is to manage (retain and utilize) the rainwater locally.

The Climate Strategy identified flash floods as key climate issue in BP18 with high exposure, high sensitivity and high vulnerability. According to the climate models, the number of sudden heavy rainfalls will increase – rainfall events of more than 30 mm could double in the period 2021-2050 –, while annual precipitation will decrease. The Climate Strategy includes adaptive measures, including the increase of green and blue infrastructure.

Figure 20 - Runoff caused problems in BP18 (Source: BP18)

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5.1.3 Demonstration sites

BP18 plans to implement various NBS across the district on public and on private land.

Figure 21 - Location of Budapest District 18 demonstration sites (Source: BP18, IETU)

5.1.3.1 Raingarden and parking lot with biodiverse lawn

Raingarden and parking lot with biodiverse lawn will be implemented at Tomory Lajos Museum, which is a local, cultural institution. The task of the museum is to make its visitors aware of the historical, cultural, community and the environmental values of District XVIII, Pestszentlőrinc–Pestszentimre. It aims to be considered a museum representing the past and identity of the local community. As an important element of the cultural heritage, it educates visitors and school kids to think in a frugal, environmentally protective way. The institution is engaged in the production of permanent and temporary exhibitions, traditional and digital publications, research services and research work. Museum pedagogy, local knowledge, local history and scientific education for all ages are of importance for the museum.

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The neighbouring parks', Bókay-garden's excess stormwater flows into the garden of Tomory Lajos Museum, that is being problematic due to badly filtering soil and two long ditches of raingarden are being planned for protecting the museum and the rest of the areas from being overflown. The same soil structure cause problem in the street in front of the museum, where stormwater ditches and car parking places compete in function with each other. The soil structure under the car park is being converted into such one, that is permeable and be able to comfort biodiverse grass improving microclimate and biodiversity.

5.1.3.2 Green walls

Green walls will be made at the Zsebők Zoltán Clinic. The specialized public clinic is important for the outpatient specialist care in the district. In order to meet the needs of the district population, the district municipality opened a 1,200 sqm, 3-storey specialist clinic in July 2009. The Zsebők Zoltán Clinic experiences a deep refurbishment in which green wall building plays a vital role. Few green walls are being set up as integral part of the building with multiple function for the health care facility.

5.1.3.3 Tree trenches

Tree trenches will be built on both side of Szálfa street, that is a local deep point in the area, with a steep slope towards the southern end of the street. A 900m long section of the Szálfa street's water ditches are being converted into tree trenches. About 820 m^2 of tree trenches being 2-3m wide are able to infiltrate the large amount of rainwater coming from higher parts of the neighbourhood and to provide multiple layers plants with trees to evapotranspirate the excess water that is not able to filtrate into the groundwater.

5.1.3.4 Raingardens

25 small raingardens will be established in public spaces, all over the district. Some of them will be built between sidewalk and road, others next to a kindergarten or playground. The objective is to reduce the amount of rainwater on the sealed surface in case of torrential rains, and purify air besides roads. The locations were suggested by residents in an open call, and was examined by experts.

25 small raingardens will be created in privately owned gardens and kindergartens. The objective is education, to raise awareness towards the importance of water retention and air purifying effect of the plants at the same time. The locations will be selected in frame of a tender, possibly with request for own contribution.

5.1.4 Stakeholder management

The project intends to involve local citizens and stakeholders. In January 2022 a public consultation was conducted to find the most affected, and thus the most suitable places.

A co-design workshop was organized in February 2023 before finalizing design plans. The aim of the workshop was two-fold: on one hand to explore highest priorities in the locations, design and aspects of raingardens, on the other hand to further raise awareness of the role of NBS solutions for air quality, runoff management, retained water evaporative benefits to vegetation and health, heatwave moderation.

Establishment of NBS demos on public locations will be organized as public events (Spring-Autumn/ 2023). Local people will be able to gain knowledge about the essential elements that would be needed for an effective NBS and ask questions from experts. For each

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location, an interpretative information board will be installed (picture, short text and QR code for further information)

The establishment of raingardens on non-public space will start with several educational institutions. Kindergartens and schools will be invited to apply for raingardens. The design, planning and realization will be made as a collaborative project, involving teachers/educators, children and parents to raise awareness, to engage in the future maintenance activities.

The establishment of raingardens on private properties will be announced in a public call for application. The private raingardens will be realized Spring-Autumn of 2024.

While establishing the raingardens, Local Competency Groups and Place Labs will be formed from local citizens, NGOs and stakeholders. After the project duration, these engaged persons will help the Asset Management Company of BP18 to maintain raingardens, follow and communicate results and benefits, and educate citizens.

Figure 22 - Beginning of the co-design event at Tomory Lajos Museum in BP18, 14th February, 2023

Figure 23 - Working in groups to design the public raingardens, 14th February, 2023

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101003818.

Figure 24 – Site and plant selection cards, 14th February, 2023

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5.2 Tailor-made sensing system for the Budapest 18

Having learnt the general sensing framework approach, the location of the NBS demonstration projects of the BP18 for which the sensing system will be installed and adapted, this chapter introduces the planned sensing system in the city.

One certified air quality reference station is located in BP18, at Gilice tér, therefore considering the conditions, available budget and multiple locations, BP18 decided to establish low-cost sensors. While these will not provide official data, they will be selected to respect minimal quality standards in order to provide robust tools for investigating air quality dynamics at a higher spatial and time-scales, providing further information compared to those provided by the sole reference station. The sensors also will be able to show the effect of NBS on its immediate surrounding area.

The sensors are chosen a homogenous way, to have the opportunity to easily compare data from UPSURGE cities, with an additional aspect the sensors should be easy to install and maintain. Data transmission requirements were identified: every sensor should transmit data to Upsurge platform respecting the fixed dataset.

The project includes different types of sensors: fixed, mobile, wearable, as described in following chapter.

5.2.1 Planned sensors

The most complex and type of sensors will be installed by BP18 measuring environmental parameters of air, soil and water.

5.2.1.1 Air quality

BP18 will measure air concentrations of the following parameters with LCS:

- PM_{10}
- $PM_{2.5}$
- NO_2
- O_3
- CO
- CO_2

5.2.1.2 Weather

BP18 will measure air concentrations of the following parameters

- Air temperature,
- Air relative humidity,
- Wind speed,
- Wind direction,
- Solar Radiation,
- Precipitation,
- Atmospheric pressure.

5.2.1.3 Other environmental factors

'Bee monitoring'

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101003818.

Novel tool for monitoring the environment is the analysis of pollen collected by bees. By means of the analysis of these natural bioindicators, qualitative and quantitative data about plant species, biodiversity, as well as certain parameters of indirect industrial and agricultural air- and soil pollution can be obtained.

BP18 will have at least one hive at a pre-selected location covering 1.5 km circle around it. The samples are being collected at a regular bases from April to October. The collected samples will be grouped into 4 periods and analysed in laboratory such as DNA and chemical analyses.

The following analysis will be carried out at the UPSURGE partners within BeeOmonitoring:

- Plant diversity
- Pesticides
- Heavy metals
- Polycyclic aromatic hydrocarbon (PAH)

BP18 will learn the identification, origin (such as heating, mobility, airport, recycling plant, etc.) and impact of heavy metals and pesticides. Moreover, identify the different plant diversity (quality and quantity, such as invasive species).

The results will be made available on an online dashboard and will be published in the project reports.

Figure 25 - Planned location of the beehives in BP18

BP18 plans one location for the "beemonitoring" task at Gilice tér with two hives, that is located between two demonstration sites, Tomory Lajos Museum and Szálfa Street in the area of the City Management Company.

Urban heat island effect

The intensity of the urban heat island effect is best measured by the difference in temperature and humidity between urban and non-urban areas, therefore no other specific element will be measured for this purpose.

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Noise

BP18 will monitor, analyze and record noise levels at the demonstration sites with LCS sensors at two locations.

Soil

- Soil water content
- Soil temperature
- Infiltration capacity,
- Soil conductivity
- Soil water content

Water

- Surface water level
- Groundwater level

5.2.2 PLANNED SENSING STATIONS

Sensors are often being located in the sensing units or stations, that have limited number of slots for sensors. The adaptation of the sensing framework based on the local circumstances and the changes reflected in section resulted in the following number of sensors and sensor stations under the current conditions:

Type of sensors	Static station	Mobile station	Wearable sensors	UAV sensors	Bee monitoring
Originally planned	2	5	100	5	1
Planned in BP18	5	3	50	-	1

Table 24 - Number of sensors and sensing stations in BP18

5.2.3 LOCATION OF THE SENSORS

The sensing stations will closely follow the location of the demonstration sites,

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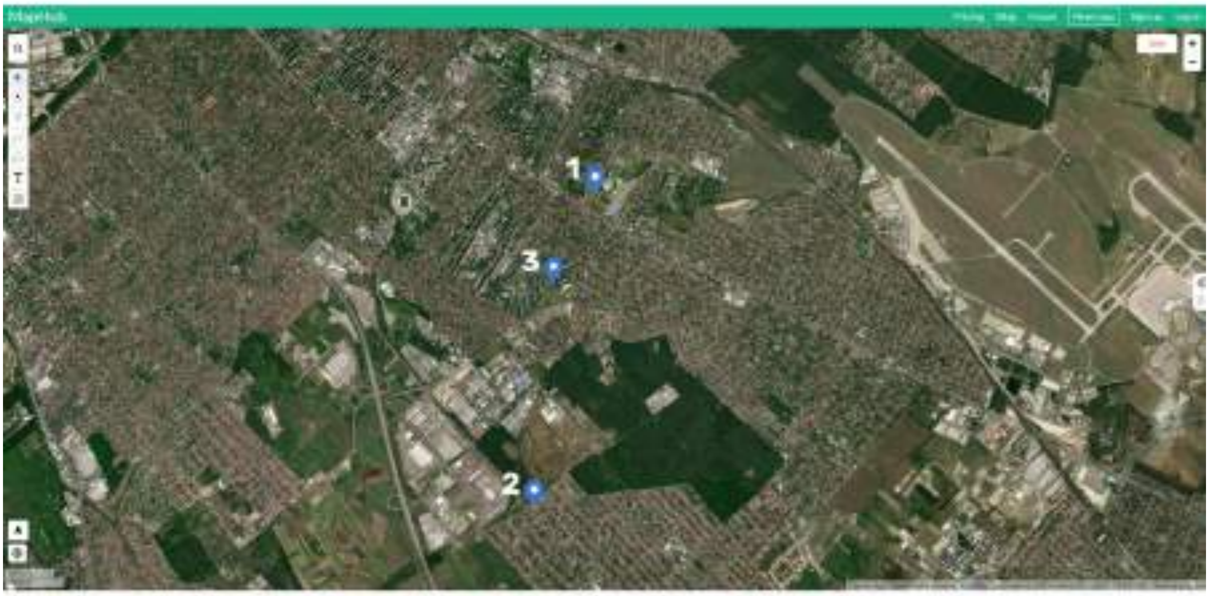

Figure 26 – Map of the location of the sensing stations in BP18

BP18 plans three fix stations and a garden to place the bee hives.

1) Zsebők Health Center
2) Szálfa-Street – Vasút Street
3) Tomory Lajos Museum

	PM10	PM2.5	NO2	O3	CO	CO2	Air temperature	Air relative humidity	Wind direction	Wind speed	Solar Radiation	Rain gauge	Atmospheric pressure	Infiltration capacity, soil conductivity	Soil water content	Barometric pressure soil temperature	surface water level	Groundwater level	Noise
Zsebők Health Center	X	X	X	X	X	X	X	X	X	X	X	X	X						X
Szálfa Street - Vasút Street	X	X	X	X	X	X	X	X	X	X	X	X	X						X
Tomory Lajos Museum														X	X	X	X	X	

Table 25 - Distribution of the type of sensors at NBS locations in BP18

5.2.4 KPIs MEASURABLE BY THE SENSING SYSTEM

Having the most diverse set of sensors, the connected KPIs measurable by the sensing system outnumber the measurable KPIs than at other cities. BP18 is able to measure the following KPIs.

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	No.		GROUP KPIs name	KPI/indicator	Parameters measured by sensors
Air quality	1	1.1.1	Air pollutant concentrations	Air pollutant concentrations	+ Air pollutant concentration
	2	1.2.1	Concentration levels limits	Concentration levels limits (number of days with exceedances)	+ Air pollutant concentration
	3	1.3.1	Air quality index	Air quality index	+ Air pollutant concentration
	4	1.5.1	Ambient pollen concentration	Ambient pollen concentration	+ Ambient pollen concentration
Soil	6	2.7.1	Soil	Soil temperature	+ Temperature
Water	20	6.1.1	Water balance	Infiltration capacity	+ Water level; Volume of water; Substrate capacity
UHI Effect	10	3.1.1	Urban Heat Island (UHI) effect	Urban Heat Island (UHI) effect	+ Temperature
	11	3.3.3	Mean or peak daytime local temperatures / Air temperature - mean, peak	Mean or peak daytime local temperature	+ Temperature
	12	3.4.1	Heat waves incidences (hot days, tropical nights)	Heatwave risk (days)	+ Temperature
	13	3.4.2	Heat waves incidences (hot days, tropical nights)	Heatwave risk (tropical nights)	+ Temperature
Health	41	13.3.2	Influence of air quality	Proportion of population exposed to ambient air pollution	+ Air pollutant concentration

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	42	13.4.1	Influence of noise	Noise	+ Sound level

Table 26 - Measurable KPIs in BP18

5.2.5 Installation of sensors

As described in Phase IV of the sensing system framework, cities need to identify the place of the static sensing stations at the demonstration sites. It is recommended to install static sensors at a height of three to four meters from ground level. This could work well mounting on existing infrastructure or setting up new infrastructure element. Both may require permission and has to go through an authorization process.

The case of the BP18 is more complicated having several demonstration sites.

5.2.5.1 Static sensors

Each demo site has to be thoroughly examined before the installation whether they are suitable for accommodating the static sensing stations. The city has to consider:

- **the ownership** of the site is clear and the owners officially let the sensors to be installed. Permissions might be need.
- if there is **sufficient space** for installing the container station
- the operation of the station, if it is easily **accessible for maintenance**
- the **orientation and placement** of the station if the location is ideal for continuous monitoring
- **connection to power and communication utilities**. Cable connection is evidently the easiest, but solar power supply with battery or wireless communication is a viable option too.
- if the installed station **fits into the environment**. Some city regulation might require a permission if the static station is in line with the cityscape or not.
- the **security** of the device, if it is protected against vandalism or cannot be easily stolen.
- capturing additional information during the installation and continuously about the surroundings or device itself. It is highly recommended to **document auxiliary information** in a log the maintenance, calibration process, as well as the temporary activities in the area, that might impact the results of the monitoring such as car-free day, construction activities etc.

Consideration	Zsebők Health Center	Szálfa street	Tomory Lajos Museum
Ownership	Y	Y	Y
Sufficient space	Y	Y	Y
Accessibility	Y	Y	Y
Orientation	Y	Y	Y
Power utility connection (cable)	Y	Y	Y

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Communication utility connection (cable)	N	N	N
Fitting into the environment	Y	Y	Y
Security	Y	Y	Y
Auxiliary documentation	Y	Y	Y

Table 27 - Installation aspects for the demonstration sites in BP18

5.2.5.2 MOBILE SENSORS

The installation of mobile sensors is considered easier than in the case of static sensors. These sensors stations will be mounted in an undisturbed position on non-combustions engine run vehicles, such as electric cargobikes used for green surface management or the electric vans used for watering public space by the City Management Company, or the electric shared cars used by the municipality workers. The mobile sensors have off-grid power supply and wireless communication connection and shall operate soundly following a calibration step.

5.2.5.3 WEARABLE SENSORS

Wearable sensors belong to a specific category of mobile sensors, that can be mounted on humans, on clothes or accessories. These light, hardly noticeable sensor devices shall be installed, turned on easily (plug-and-play for laymen users) following the first calibration and utilized regularly mapping the air-quality related few parameters (due to limited size and weight of the device) in which the users were exposed to. The challenge in installing and using wearable sensors lays in the consent of the users to register their location as geolocation of the air-quality mapping is necessary. BP18 plans to collect information near educational institutions with the help of parents, pupils and engaged local citizens.

BP18 will make sure that the users are aware of what information will be collected and how, and they are fully aware of the GDPR declaration details for which they have to give their consent before start using the wearable sensors. Data collected from wearable sensors will be recorded and stored as anonymous devices with no link with registered user.

5.2.5.4 BEE MONITORING

The sensors of the bee monitoring are the bees. They are based in their home, their hives where from they cover an area of about 1,5km^2 with sampling. The location of the hives in urban environment requires careful planning. BP18 agrees on a location with local bee-keepers based on the localization conditions to deploy a hive.

5.2.5.5 UAV SENSORS

The UPSURGE partnership made decision to exclude the use of UAV-mounted data collection.

5.2.6 CO-LOCATION AND CALIBRATION

In the process of calibration to the local circumstances is essential that sensors show reliable values. BP18 plans to seasonally recalibrate the low-cost sensor monitoring stations, preferably remotely, following the initial recalibration and co-location as described in the recommendations of D3.1 that is mix of on-site and virtual activities.

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This calibration will be carried out by using the closest, relevant EAI station in the city and satellite models. Depending on the distance of the EAI station, sensor could be put on the EAI station for few weeks before installation and periodically for calibration. However, LCS monitoring stations have to be periodically recalibrated, preferably remotely. In particular to provide fast and cost-effective periodical calibration, the project will use the Copernicus virtual reference station network (10x10km grid) already tested in other projects (such as UIA Prato Urban Jungle), running seasonal calibration of the whole network deployed in each demonstration city.

The closest and relevant EAI reference station in Budapest are the followings:

	EAI reference station #1	EAI reference station #2
Station name	Budapest Teleki	Budapest Gilice
Link to location	https://maps.app.goo.gl/JgBHTcB2g35KHLUd7	https://maps.app.goo.gl/LmCAJivNYQFicdz16
Sampling point	SPO-HU0045A_00005_100	SPO-HU0022A_00005_100
Type	Urban - Traffic	Suburban - Background

Table 28 – EAI reference stations in BP18

This way, calibrations shall be part of the public procurement process in which cities do not only buy the products, but service for the maintenance of the monitoring stations.

After each deployment and calibration, the contractor shall make available a report with the results of the initial calibration checks of the sensor systems deployed at the air quality monitoring station.

5.2.7 BUDGET/COST ESTIMATION

Based on the information coming from market research, the estimated total budget for the purchase is expected to be in the range of €48-53.000 (net). This exceeds the limit of EUR 34,000 for public procurement procedure; therefore an open tender would be introduced.

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CONFIGURATION	Sensor	Costs		
	Type	Estimated Cost / item in EUR	Number of items	Total estimated cost
REFERENCE STATION	FIX STATION	€ 45,000	0	€ -
STANDARD - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2	FIX STATION	€ 4,500	0	€ -
MOBILE - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2	MOBILE STATION	€ 4,500	3	€ 13,500
WEATHER - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, Wind direction, Wind speed, Solar radiation, barometric pressure, rain gauge	FIX STATION	€ 5,500	2	€ 11,000
SOIL + HIDROS21 - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, n°1 soil sensor Hidros21 soil water depth, soil temperature, soil conductivity, rain gauge	FIX STATION	€ 6,000	1	€ 6,000
SOIL - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, n°2 soil water content, n° 2 soil temperature, rain gauge	FIX STATION	€ 5,500	0	€ -
AIR - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, SO2, NOISE	FIX STATION	€ 5,500	2	€ 11,000
AIR BLACK CARBON - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, SO2, NOISE, Black carbon sensor AETS AE51 with system integration	FIX STATION	€ 6,000	0	€ -
WEARABLE	WEARABLE	€ 200	50	€ 10,000
Other additional costs (VAT, technical fees, city costs for installation, etc.)				€ 14,500
			SUM	€ 66,000
			Available budget	€ 66,000

Table 29 – Budget/cost estimation

5.2.8 Procurement process and challenges

The national thresholds for public tender procedures, regarding supply contracts is net 15,000,000 HUF (~37,500 EUR).

Above the threshold, the municipality shall follow the public procurement process that is legally prescribed. They have to use the Electronic System of Public Procurements (in Hungarian Elektronikus Közbeszerzési Rendszer, in short EKR), and that is a forum of the calls, registration and bidding. It is open to all EU based companies.

It is important to note, that Municipalities in Hungary are not allowed to claim back VAT. So always have to be calculated with gross amount.

The preparation process started with the identification of the climate change related and air quality problems of the cities. In BP18 air quality data are available from the national observation station at Gilice square. During matchmaking matrix process we identified pollutants with limit value exceedances or close to this limit. For identifying the local climate change events, we checked the complaints of the citizens, arriving on our customer service office and in social media. IETU prepared the dedicated KPI list for UPSURGE, BP18 chose – based on the above written aspects – the following ones: Air Quality, Heat Island Effect, Water scarcity and water retention potential, and the socio-economic indicator is Health and wellbeing.

After several consultation and market research with municipality expert on sensing system, OPERATE and the consortium early 2023, we decided to prefer LCS, with acceptable level of

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data accuracy. We also started to collect the needs regarding output in data visualization. Based on this, POR created the sensing system framework, and OPERATE also the technical specification for Air Quality, Weather and Soil humidity sensors.

Public Procurement: BP18 estimated cost of the sensors required the public procurement process and converted the information from the preparation process, specified some points for legal language to be able to make a public call for sensing system (stationary and mobile sensors) within the Electronic System of Public Procurements. The call was announced at the end of Summer.

Installation: 2 of the selected locations are Municipally owned sites: Zsebők Zoltán Clinic and Tomory Lajos Museum, so installation can be done with owner consent. The electricity supply and anchorage of the sensors can be done by VG18. At Szálfa street the sensors can be fixed on the electric poles. There is a requirement to get consent from electricity supplier, and contract on regular lump sum, based on the power need of the sensor. Utility agreement is also required, by all of the existing companies. A technical drawing should be prepared, to present the fixing method of the device. There are contractors, that can complete the described process, including fixing.

Figure 27 – Planned timeline for BP18

5.2.9 Project after-life

The equipment purchased, used and maintained throughout the project will be owned and managed after the project by the City Management Company of the BP18 and used for following-up the conditions and for awareness raising activities within the district in the topic of air-quality, water retention and urban climate.

The stationary sensors will be utilized beyond the project lifetime at the NBS locations in order to measure the impact of the vegetation for a longer time period. Following that, the BP18 will analyze and reconsider, if the stations shall stay for longer measurements or be relocated to measure elsewhere within the BP18 impact of NBS.

The mobile sensors being bound to non-combustion engine run or human-run vehicles cover larger areas even if they are connected to the neighbourhoods in which the NBS investments are located. Following the project, they may continue to operate within the area of the municipality but not that much bound to the NBS locations.

Wearable sensors will be utilized by citizens in communities near the location of the NBS investments. BP18 plans to continue this approach, but they may extend them to other areas of the district as the sensor wearing citizens may cover large areas within the district.

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6 PLANNED SENSING SYSTEM FOR THE CITY OF KATOWICE

6.1 INTRODUCING THE CASE IN THE CITY OF KATOWICE

6.1.1 ABOUT KATOWICE

Katowice is a city in southern Poland with approximately 300,000 inhabitants living within 164 km^2. It is the capital of the Silesian Voivodeship and the largest city of the Górnośląsko-Zagłębiowskiej Metropolii integrating 41 cities and communes, inhabited by over 2 million people. For most of its existence, there were mines and heavy industry plants in the city. After 1989, transformation processes in the city led to a radical change in the structure of the industry. Traditional industry has been largely replaced by high-tech companies and centres of creative industries, based on modern technologies and innovative sectors.

The city is located in southern Poland, about 50km North of the Silesian Beskids in the Silesian Highlands. The relief makes the area peculiar, as it has two rivers Klodnica and Rawa belonging to two different watersheds (Oder and Vistula respectively) dividing the city into different parts. The median elevation of the city is 266 meters above sea level, but the minimum elevation is at 245 m above sea level.

The climate of Katowice is described as moderately continental with cold winters and warm summers. The average annual temperature in Katowice is 8.6 °C, and the lowest average temperature in January is -3.6 °C. The winter is cold and gray, snowfalls are frequent but generally not abundant. Sometimes, cold waves from Siberia can occur, and the temperatures can drop to -20 °C (-4 °F) or below. In summer, the temperatures are pleasant and suitable for outdoor activities, although sometimes there can be rain and thunderstorms. Every now and then (and more often in recent years due to global warming), there can be short heat waves, with maximum temperatures exceeding 30 °C (86 °F). The highest record is 37.2 °C (99 °F) which was set in August 2013. The characteristic weak winds blow from the southwest, through the Moravian Gate.

6.1.2 CHALLENGES

The main challenges for the city of Katowice include: reducing heat islands, reducing particulated matter levels, improving low retention, and improving the living comfort of the city's inhabitants. Katowice is a city with extensive experience in mitigating the effects of many years of environmental degradation.

Urban heat island effect is increasing with the changing climate in the City of Katowice. The city aims at adapting to the changing circumstances and mitigating the impact. The adaptation plan of the city identified and analysed the needs for adaptation within the areas impacting vulnerable population and critical infrastructure such as public transport. The city follows the concept of unsealing the ground as much as possible, planting shrubs, perhaps planting a tree. The overriding goal is to develop an innovative approach to improving air quality in highly urbanized areas, replacing the bus shelters with a longer and wider structure with a green roof. In the heavily urbanized space, there is a space for passengers with a bus shelter, however they lack the green infrastructure and natural elements, discouraging people to use them. The goal for Katowice by introducing nature-based solutions (NBS) to reduce the heat island, improve retention and make these places healthier, more human-friendly.

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The selected demonstration sites (bus stop and urbanized areas) are characterized by a large extension of heavily urbanized areas sealed by asphalt, concrete or cobble-stones, lack of shade, green areas. Moreover, the lack of water retention, proximity to the road means high concentration of air pollution and noise and drier urban microclimate.

Taking into account vulnerable social groups (e.g., the elderly, sick people, etc.), the increased temperature in the urban climate esp. at heat waves negatively affects their health (fainting, dehydration of the body).

The tangible heat island effect of sealed surfaces is proved by thermal images taken by special thermal camera confirming the perceived problem of urban climate in the area of the concerned public transport stops supporting the arguments, why they are not found attractive by the citizens, public transport users.

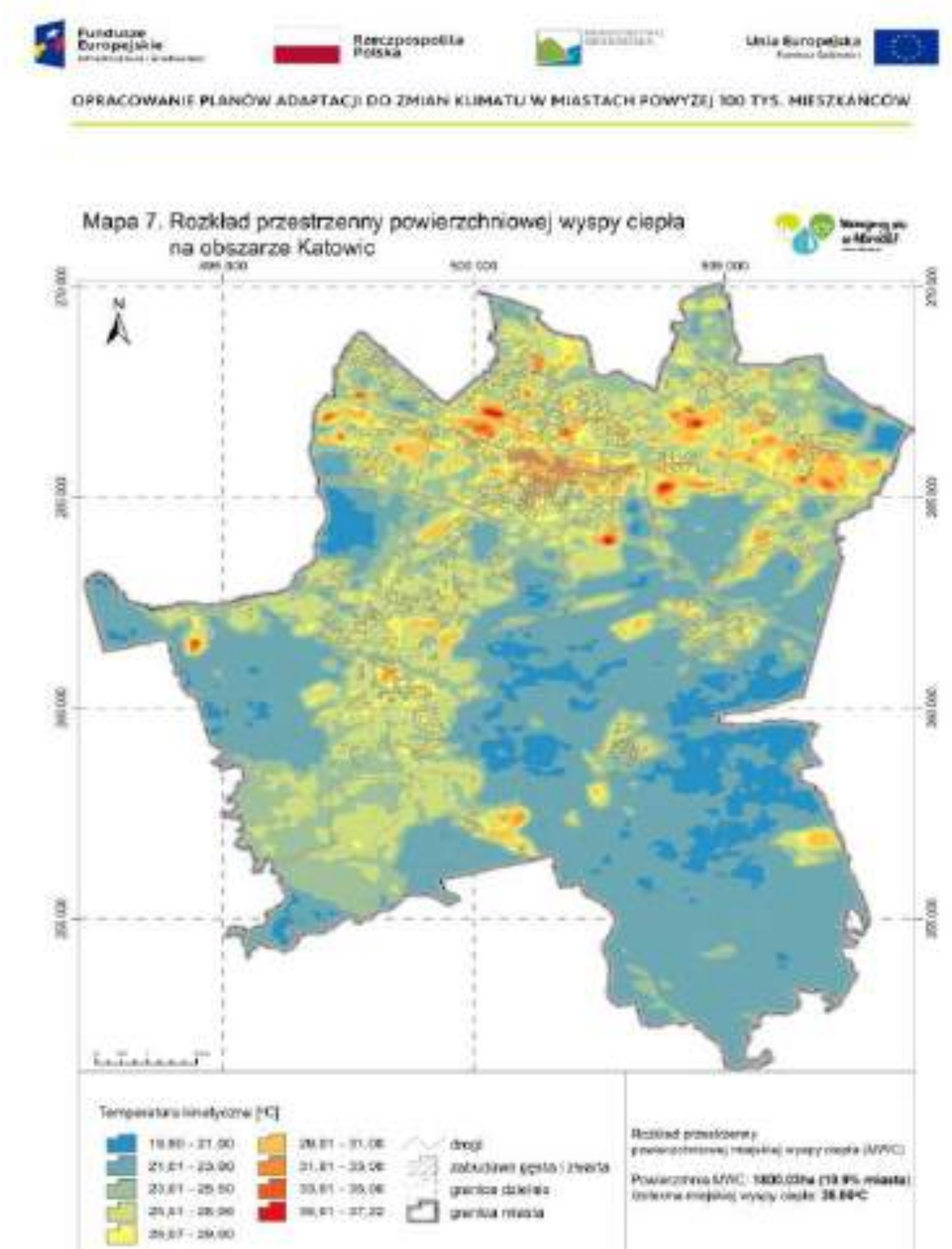

Figure 28 - Spatial distribution of the surface heat island in the area of Katowice. Map with data taken from the attachment to the resolution nr XII/268/19 Katowice City Council of 26 September

2019 on the adoption of "Plan for the adaptation of the City of Katowice to climate change until 2030". p. 180

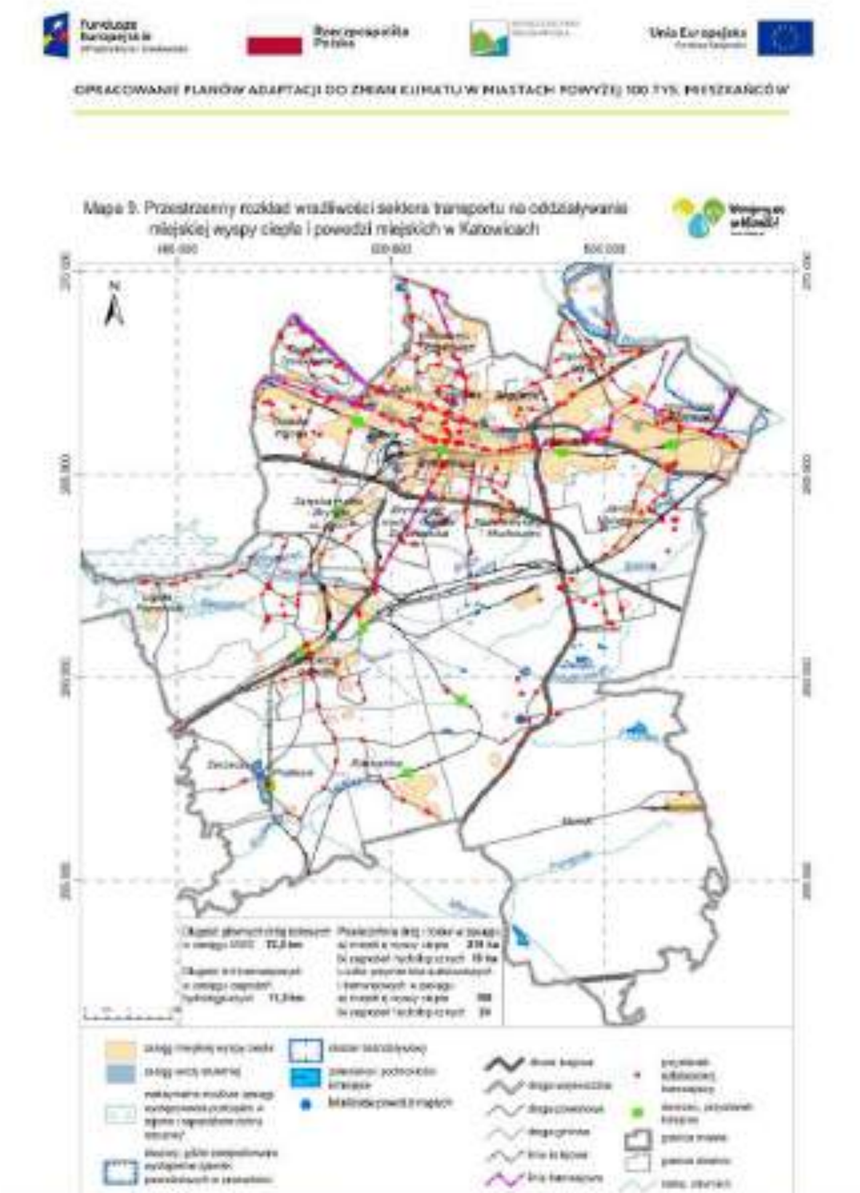

Figure 29 - Spatial distribution of sensitivity of the transport sector to the impact of urban heat island and urban floods in Katowice. Map with data taken from the attachment to the resolution nr XII/268/19 Katowice City Council of 26 September 2019 on the adoption of "Plan for the adaptation of the City of Katowice to climate change until 2030" p. 182

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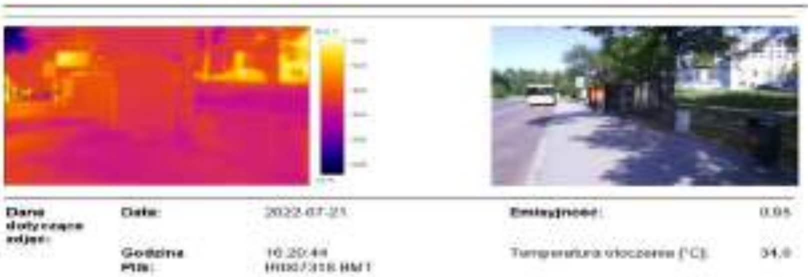

Figure 30 – Daylight picture and thermal picture of the bus stop "Ochojec-Hospital" at Ziołowa street in Katowice

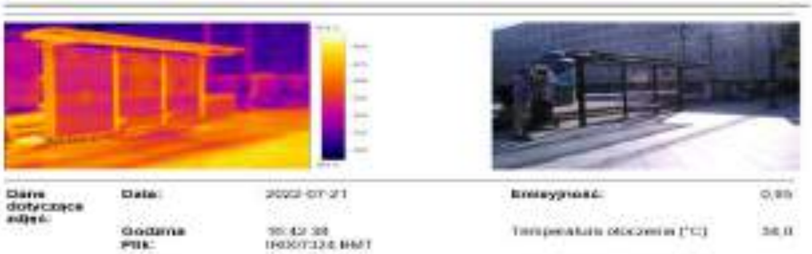

Figure 31 – Daylight picture and thermal picture of the bus stop at Jagiellońska street in Katowice

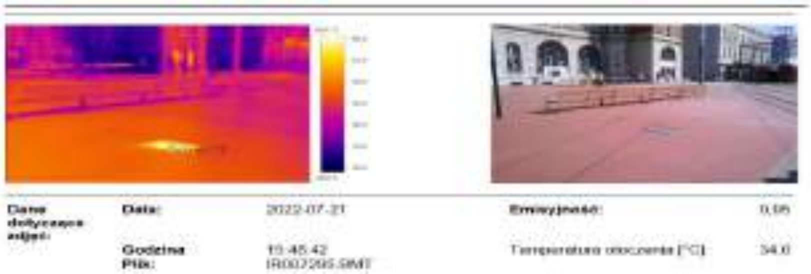

Figure 32 – Daylight picture and thermal picture of the urban area between Korfanty str. and the Market Square in Katowice

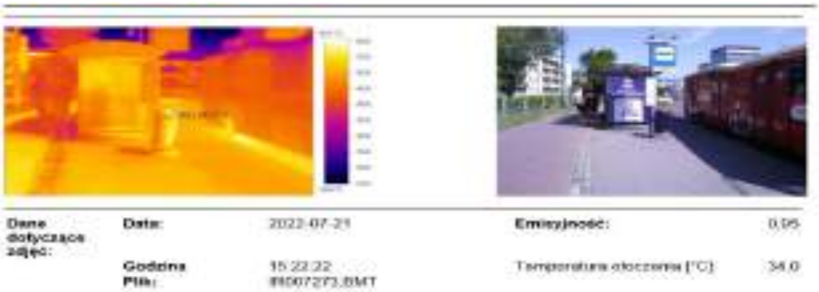

Figure 33 – Daylight picture and thermal picture of the bus stop "Oak Church" at Chorzowska street in Katowice

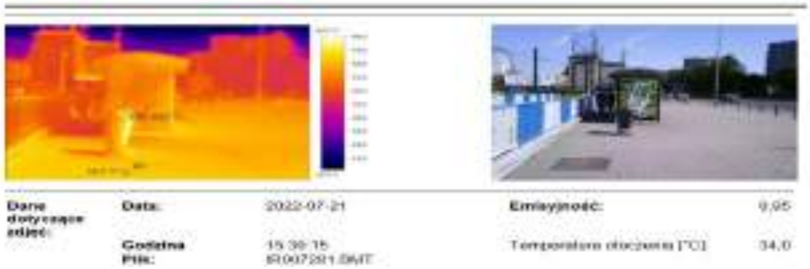

Figure 34 – Daylight picture and thermal picture of the bus stop "Park Śląski Zoological Garden" at Chorzowska street in Katowice

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6.1.3 Demonstration sites

The City of Katowice plans to implement five green roof bus-stops at various areas of the city. The following sections describe below the location and the plans connected to the 5 sites.

Figure 35 – Overview map of the areas of intervention in Katowice

6.1.3.1 Bus stop #1 - Ochojec-Hospital

The point is located next to a large parking lot, the level of air pollution is high, a large amount of concreted surface. Underground infrastructure in the form of a power grid and rainwater drainage system, however, it is possible to plant columnar or smaller trees on the slope and next to the stop. The place can be developed with low green infrastructure in the form of ornamental shrubs and perennials and ornamental grasses; however, the selection of species must be thought out and the selected species must be resistant to air pollution and periodic droughts. New plantings should be easy to care for and do not require regular irrigation and fertilization. In this location, the greening of the roof of the bus shelter should be taken into account, it can be in the form of a sedum mat

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Figure 36 - GoogleMaps satellite view of [Ziołowa 45/47,40-635 Katowice]

6.1.3.2 Bus stop #2 - Jagielońska

The point is located among strict buildings, the surface is made of cubes. The zone is characterized by a lack of shade, "urban heat island phenomenon", high air pollution and lack of water retention. Underground infrastructure is concentrated in the area of the stop, no possibility to plant trees. The area requires unsealing, i.e. the removal of part of the hardened areas in order to increase the natural retention of the area, also by introducing green area in the form of low shrubs, perennials, grasses, vines, resistant to periodic droughts, winter road salting and air pollution. New plantings should be easy to care for and do not require regular irrigation and fertilization.

Figure 37 - GoogleMaps satellite view of [Katowice Jagiellońska,40-035 Katowice]

6.1.3.3 Urban area between Korfanty str. and the Market Square

The point is located in the middle of the downtown of the city, surrounded by buildings, pavement made of cubes.

The phenomenon of the urban heat island is observed here, lack of shade, dry. A problematic place in terms of planting trees, no possibility of introducing intensive green infrastructure.

The underground infrastructure is quite closely arranged in this location. Possible introduction of green plants in pots, climbers on trellis-type structures. In the case of consent to unpave, it seems reasonable to introduce ornamental shrubs as well as perennials and perennial grasses referring in composition to the vegetation in the strips on the other

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side of the square. New plantings should be easy to care for and do not require regular irrigation and fertilization.

Figure 38 - GoogleMaps satellite view of Katowice Main Square

6.1.3.4 Bus stop #3 - The "Oak Church" bus stop at Chorzowska street

The point is located on a very busy cobble-stoned street, the place is characterized by high noise levels, dry and polluted air. There is hardly any shade and the area exposed to intense gusts of wind.

The underground network of technical infrastructure in the form of a power line and combined and rainwater drainage systems are quite densely located, and any works should take into account the tram traction located there, as well as land ownership issues. The place is best suited to introduce low intensity green surface in the form of ornamental shrubs, perennials, grasses as well as vines, as in the previous points, selection of species dedicated to difficult urban conditions, i.e. selected plant species cannot be demanding, resistant to temporary droughts, salinity. New plantings should be easy to care for and do not require regular irrigation and fertilization.

In this location, the greening of the roof of the bus shelter should be taken into account, it can be in the form of a sedum mat.

Figure 39 - GoogleMaps satellite view of Dąb Kościół,40-121 Katowice

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6.1.3.5 Bus stop #4 - The "Park Śląski Zoological Garden" bus stop at Chorzowska street

This area is a problematic place, the occurrence of the urban heat island phenomenon, noise, lack of shade, unfriendly terrain. The nearest neighbourhood of the discussed point is a very busy street. Therefore, air pollution is high in this neighbourhood.

Underground infrastructure power and telecommunication networks cross the area. Their location makes it possible to plant trees, here also columnar or ultimately lower trees are required, at the time of planting with a crown starting at a minimum height of 220 cm. However, the fact that there is a bridge infrastructure under the point, the presence of which may be a collision for planting trees, may be problematic. However, it is required to introduce a large amount of accompanying green plants as ornamental shrubs, perennials, grasses, it is preferable to use vines on supports in this location. New plantings should be easy to care for and do not require regular irrigation and fertilization.

In this location, the greening of the roof of the bus shelter should be taken into account, it can be in the form of a sedum mat.

Figure 40 - GoogleMaps satellite view of [Park Śl Ogród Zoologiczny,40-870 Katowice]

6.1.4 Stakeholder management

Stakeholder management activities for Katowice are outlined in details in the plan (D8.1) how to manage stakeholder engagement and what steps you need to take to ensure expectations are met.

Stakeholders involved in the UPSURGE project have already participated in meetings regarding future NBS points in September 2022. During the meetings, the assumptions of the UPSURGE project were presented, the principles of creating NBS were discussed and the focus was on creating guidelines for the concept based on the knowledge base held by the local community. During each workshop, at least two proposals for the development of the discussed areas were obtained, with an indication of how we should adapt the space for people using it.

After taking into account the ideas and comments of stakeholders in the second round of meetings in 2023 (currently in progress), the designer presents a concept created together with stakeholders. In 2023, three consultations with stakeholders have already taken place. On March 1, 2023, a meeting was held on the topic of the green bus stop Park Śląski at Chorzowska Street in Katowice, on March 2, 2023, a meeting was held on the topic of the green bus stop Ochojec-Hospital at Ziołowa Street in Katowice and on March 10, 2023, the topic of the meeting was the bus stop "Oak Church" at Chorzowska Street in Katowice. The meetings were held in the buildings of local institutions, in the vicinity of the discussed NBS

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points. Meeting about the urban area between Korfanty street and the Market Square in Katowice will take place on March 22, 2023 where the city plan to discuss the progress of this NBS point, present the concept based on previous arrangements with stakeholders and conduct talks with them. Furthermore, a meeting regarding the bus stop at Jagiellonska Street in Katowice was planned for April. Stakeholders were informed about the meetings via a post on Facebook, by e-mail and by phone.

Stakeholders actively participate in the meetings. On the basis of the collected data (among others, attached in point 2.4), the City of Katowice developed with stakeholders a concept for the adaptation of the bus stop space. During those meetings, in cooperation with the social side, the following concept was created:

Figure 41 - Materials from the workshop with stakeholders, about the green bus stop "Ochojec-Hospital" at Ziołowa street in Katowice.

Figure 42 - Concept of a green stop "Ochojec-Hospital" at Ziołowa street in Katowice

Figure 43 - Materials from the workshop with stakeholders, about the green bus stop "Oak Church" at Chorzowska street in Katowice

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Figure 44 - Concept of a green stop "Oak Church" at Chorzowska street in Katowice

Figure 45 - Materials from workshop with stakeholders, about the green bus stop "Park Śląski Zoological Garden" at Chorzowska street in Katowice.

Figure 46 - Concept of a green stop "Park Śląski Zoological Garden" at Chorzowska street in Katowice

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6.2 TAILOR-MADE SENSING SYSTEM FOR THE CITY OF KATOWICE

Having learnt the general sensing framework approach, the location of the NBS demonstration projects of the City of Katowice for which the sensing system will be installed and adapted, this chapter introduces the planned sensing system in the city.

6.2.1 PLANNED SENSORS

6.2.1.1 AIR QUALITY

The City of Katowice will measure air concentrations of the following parameters with LCS:

- PM_{10}
- $PM_{2.5}$
- NO_2
- O_3
- CO
- CO_2

Poland's air quality index is calculated on the basis of 1-hour results from measurements of air concentrations of nitrogen dioxide (NO2), PM10 dust, PM2.5 dust, and ozone (O3). Air quality indices for individual pollutants are calculated based on the 1-hour values of concentrations of these pollutants, assigned to the appropriate category from the table of ranges for the indices of individual pollutants. (https://powietrze.gios.gov.pl/pjp/content/health_informations)

6.2.1.2 WEATHER

The City of Katowice will measure the following weather parameters

- Air temperature,
- Air relative humidity,
- Wind speed,
- Wind direction,
- Solar Radiation,
- Rain gauge,
- Atmospheric pressure.

6.2.1.3 OTHER ENVIRONMENTAL FACTORS

'Bee monitoring'

Novel tool for monitoring the environment is the analysis of pollen collected by bees. By means of the analysis of these natural bioindicators, qualitative and quantitative data about plant species, biodiversity, as well as certain parameters of indirect industrial and agricultural air- and soil pollution can be obtained.

The City of Katowice will have at least one hive at a pre-selected location covering 1.5 km circle around it. The samples are being collected at a regular bases from April to October. The collected samples will be grouped into 4 periods and analysed in laboratory such as DNA and chemical analyses.

The following analysis will be carried out at the UPSURGE partners within BeeOmonitoring:

- Plant diversity

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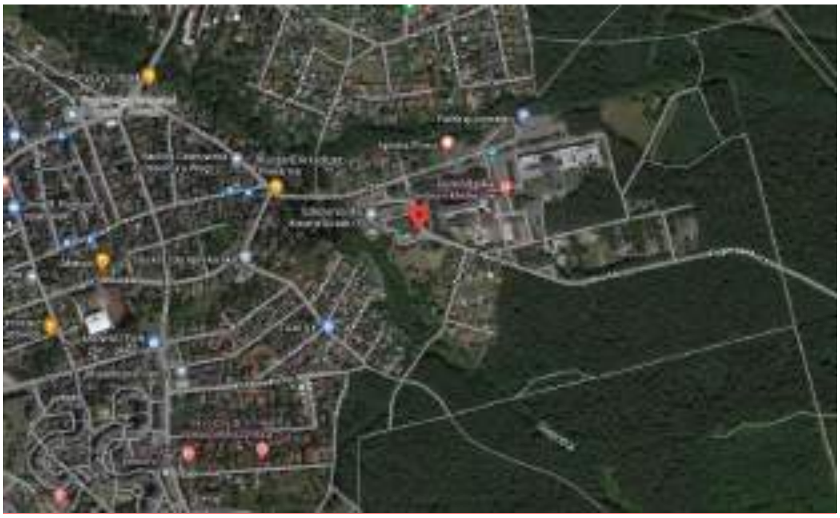
- Pesticides
- Heavy metals
- Polycyclic aromatic hydrocarbon (PAH)

The City of Katowice will learn the identification, origin (such as heating, mobility, airport, recycling plant, etc.) and impact of heavy metals and pesticides. Moreover, identify the different plant diversity (quality and quantity, such as invasive species).

The results will be made available on an online dashboard and will be published in the project reports.

Katowice plans one location for the "beemonitoring". The original suggestion was to place the hives near a NBS site, opposite the "Jagiellońska / Plac Sejmu" bus stop. However, the Silesian Beekeepers Association in Katowice (Śląski Związek Pszczelarzy w Katowicach) was consulted in this issue. For safety reasons, a high hedge would have to be placed in the proposed location. Given the circumstances, at a meeting with external experts, the Lavender Garden in Katowice on Ziołowa Street was selected as the new location for the hives.

Figure 47 - Location for bee monitoring in Katowice



Urban heat island effect

The intensity of the urban heat island effect is best measured by the difference in temperature and humidity between urban and non-urban areas, therefore no other specific element will be measured for this purpose.

Noise

The City of Katowice will monitor, analyze and record noise levels at the demonstration sites with LCS sensors.

Following consultations with a sensing expert, the City of Katowice does not plan any further sensors for monitoring soil or water parameters.

6.2.2 Planned sensing station

Sensors are often being located in the sensing units or stations, that have limited number of slots for sensors. The adaptation of the sensing framework based on the local circumstances and the changes reflected in section resulted in the following number of sensors and sensor stations under the current conditions:

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Type of sensors	Static station	Mobile station	Wearable sensors	UAV sensors	Bee monitoring
Originally planned	2	5	100	5	1
Planned in Katowice	5	4	50	-	1

Table 30 - Number of sensors and sensing stations in Katowice

6.2.3 LOCATION OF THE SENSORS

Station locations and design of the monitoring network was defined to guarantee air quality monitoring in all five experimental sites, 2 of those are also equipped with additional noise sensor (Bus stop 1 and Bus stop 2, to monitor effect of bus disturbance) and three sites are equipped with additional meteorological sensors. In particular the site where bees are monitored, Zoological Garden and Market square. The monitoring network, composed of 5 fixed stations and 4 mobiles ensure an accurate monitoring grid in the experimental sites and in the rest of urban area.

	PM10	PM2.5	NO2	O3	CO	CO2	Air temperature	Air relative humidity	Wind direction	Wind speed	Solar Radiation	Rain gauge	Atmospheric pressure	Noise
Bus stop #1 - Ochojec-Hospital	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bus stop #2 - Jagielońska	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Korfanty str. and the Market Square	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bus stop #3 - "Oak Church"	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bus stop #4 - The "Park Śląski Zoological Garden"	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 31 - Distribution of the type of sensors at NBS locations

6.2.4 KPIS MEASURABLE BY THE SENSING SYSTEM

	No.		GROUP KPIs name	KPI/indicator	Parameters measured by sensors
Air qualit	1	1.1.1	Air pollutant concentrations	Air pollutant concentrations	+ Air pollutant concentration

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	2	1.2.1	Concentration levels limits	Concentration levels limits (number of days with exceedances)	+ Air pollutant concentration
	3	1.3.1	Air quality index	Air quality index	+ Air pollutant concentration
	4	1.5.1	Ambient pollen concentration	Ambient pollen concentration	+ Ambient pollen concentration
UHI Effect	10	3.1.1	Urban Heat Island (UHI) effect	Urban Heat Island (UHI) effect	+ Temperature
	11	3.3.3	Mean or peak daytime local temperatures / Air temperature - mean, peak	Mean or peak daytime local temperature	+ Temperature
	12	3.4.1	Heat waves incidences (hot days, tropical nights)	Heatwave risk (days)	+ Temperature
	13	3.4.2	Heat waves incidences (hot days, tropical nights)	Heatwave risk (tropical nights)	+ Temperature
Health	41	13.3.2	Influence of air quality	Proportion of population exposed to ambient air pollution	+ Air pollutant concentration
	42	13.4.1	Influence of noise	Noise	+ Sound level

Table 32 - Measurable KPIs in the City of Katowice

6.2.5 Installation of sensors

As described in Phase IV of the sensing system framework in D3.1, cities need to identify the place of the static sensing stations at the demonstration sites. It is recommended to install static sensors at a height of three to four meters from ground level. This could work well mounting on existing infrastructure or setting up new infrastructure element. Both may require permission and has to go through an authorization process.

The case of the City of Katowice is more complicated having several demonstration sites.

6.2.5.1 Static sensors

Each demo site has to be thoroughly examined before the installation whether they are suitable for accommodating the static sensing stations. The city has to consider:

- the ownership of the site is clear and the owners officially let the sensors to be installed. Permissions might be need.

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- if there is **sufficient space** for installing the container station
- the operation of the station, if it is easily **accessible for maintenance**
- the **orientation and placement** of the station if the location is ideal for continuous monitoring
- **connection to power and communication utilities**. Cable connection is evidently the easiest, but solar power supply with battery or wireless communication is a viable option too.
- if the installed station **fits into the environment**. Some city regulation might require a permission if the static station is in line with the cityscape or not.
- the **security** of the device, if it is protected against vandalism or cannot be easily stolen.
- capturing additional information during the installation and continuously about the surroundings or device itself. It is highly recommended to **document auxiliary information** in a log the maintenance, calibration process, as well as the temporary activities in the area, that might impact the results of the monitoring such as car-free day, construction activities etc.

Consideration	Bus stop 1	Bus stop 2	Urban site	Bus stop 3	Bus stop 4
Ownership	X	X	X	X	X
Sufficient space	X	X	X	X	X
Accessibility	X	X	X	X	X
Orientation	X	X	X	X	X
Power utility connection (cable)	X	X	X	X	X
Communication utility connection (cable)	X	X	X	X	X
Fitting into the environment	X	X	X	X	X
Security	X	X	X	X	X
Auxiliary documentation	X	X	X	X	X

Table 33 - Installation aspects for the demonstration sites in Katowice

6.2.5.2 MOBILE SENSORS

The installation of mobile sensors is considered easier than in the case of static sensors. These sensors stations will be mounted in an undisturbed position on non-combustion-engine run vehicles, such as electric car, bus or bicycle. They need permission from the owner of the vehicle, proper attachment to install securely the sensor case not to fall off during operation or not to be easily stolen. The mobile sensors have off-grid power supply and wireless communication connection and shall operate soundly following a calibration step.

6.2.5.3 WEARABLE SENSORS

Wearable sensors belong to a specific category of mobile sensors, that can be mounted on humans, on clothes or accessories. These light, hardly noticeable sensor devices shall be installed, turned on easily (plug-and-play for laymen users) following the first calibration and

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utilized regularly mapping the air-quality related few parameters (due to limited size and weight of the device) in which the users were exposed to. The challenge in installing and using wearable sensors lays in the consent of the users to register their location as geolocation of the air-quality mapping is necessary. All demonstration cities, including the City of Katowice shall make sure that the users are aware of what information will be collected and how, and they are fully aware of the GDPR declaration details for which they have to give their consent before start using the wearable sensors. Data collected from wearable sensors will be recorded and stored as anonymous devices with no link with registered user.

6.2.5.4 Bee monitoring

The sensors of the bee monitoring are the bees. They are based in their home, their hives where from they cover an area of about 1,5 km^2 with sampling. The location of the hives in urban environment requires careful planning. The City of Katowice agrees on a location with local bee-keepers based on the localization conditions to deploy a hive.

6.2.5.5 UAV sensors

The UPSURGE partnership made decision to exclude the use of UAV-mounted data collection.

6.2.6 Co-location and calibration

In the process of calibration to the local circumstances is essential that sensors show reliable values. The City of Katowice plans to seasonally recalibrate the low-cost sensor monitoring stations, preferably remotely, following the initial recalibration and co-location as described in the recommendations of D3.1 that is mix of on-site and virtual activities.

This calibration will be carried out by using the closest, relevant EAI station in the city and satellite models. Depending on the distance of the EAI station, sensor could be put on the EAI station for few weeks before installation and periodically for calibration. However, LCS monitoring stations have to be periodically recalibrated, preferably remotely. In particular to provide fast and cost-effective periodical calibration, the project will use the Copernicus virtual reference station network (10x10km grid) already tested in other projects (such as UIA Prato Urban Jungle), running seasonal calibration of the whole network deployed in each demonstration city.

The closest and relevant EAI reference station in Katowice are the followings:

	EAI reference station #1	EAI reference station #2
Station name	ul. Plebiscytowa/A4	ul. Kossutha 6
Link to location	https://maps.app.goo.gl/uwFYkM29PxjtkQDo8	https://maps.app.goo.gl/hucPG7Ybos9PZwaK6
Link to data	https://powietrze.gios.gov.pl/pjp/current/station_details/table/813/30/14?theme=contrast	https://powietrze.gios.gov.pl/pjp/current/station_details/table/814/3/1
Sampling point	SPO_PL0567A_8_001	SPO_PL0008A_8_001
Type	Urban - Traffic	Urban - Background

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Table 34 - EAI reference stations in Katowice

This way, calibrations shall be part of the public procurement process in which cities do not only buy the products, but service for the maintenance of the monitoring stations.

After each deployment and calibration, the contractor shall make available a report with the results of the initial calibration checks of the sensor systems deployed at the air quality monitoring station.

6.2.7 BUDGET/COST ESTIMATION

Based on the information coming from market research, the estimated total budget for the purchase is expected to be in the range of €49-54.000 (net). This exceeds the limit of EUR 34,000 for public procurement procedure; therefore a tender would be introduced.

CONFIGURATION	Sensor	Costs		
	Type	Estimated Cost / item in EUR	Number of items	Total estimated cost
REFERENCE STATION	FIX STATION	€ 45,000	0	€ -
STANDARD – Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2	FIX STATION	€ 4,500	0	€ -
MOBILE - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2	MOBILE STATION	€ 4,500	4	€ 18,000
WEATHER - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, Wind direction, Wind speed, Solar radiation, barometric pressure, rain gauge	FIX STATION	€ 5,500	3	€ 16,500
SOIL + HIDROS21 - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, n°1 soil sensor Hidros21 soil water depth, soil temperature, soil conductivity, rain gauge	FIX STATION	€ 6,000	0	€ -
SOIL - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, n°2 soil water content, n° 2 soil temperature, rain gauge	FIX STATION	€ 5,500	0	€ -
AIR - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, SO2, NOISE	FIX STATION	€ 5,500	2	€ 11,000
AIR BLACK CARBON - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, SO2, NOISE, Black carbon sensor AETS AE51 with system integration	FIX STATION	€ 6,000	0	€ -
WEARABLE	WEARABLE	€ 200	50	€ 10,000
Other additional costs (VAT, technical fees, city costs for installation, etc.)				€ 10,500
			SUM	€ 66,000
			Available budget	€ 66,000

Table 35 – Budget/cost estimation

6.2.8 PROCUREMENT PROCESS AND CHALLENGES

The sensors will be purchased prior to the construction of the NBS, as part of public procurement in accordance with Polish law. The City of Katowice will to install sensors during construction works at the locations of NBS points. Before purchasing sensors, it is planned to measure the temperature of selected locations.

The city considers the possibility to include the specification of sensing system into the tender procedure for the construction of NBS points, this way the company winning the NBS competition shall performing the installation of the systems. However, to this point it has not been decided, technically separate or joint procurement could be better in the Polish system

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of public procurements taking into account the market availability of static, mobile and wearable LCS to be used at the demonstration sites, on vector vehicles or by citizens.

The City of Katowice estimates the installation of the sensing system only after the finishing of design phase of the NBS demonstration projects, that is projected to be finished by the of 2023, when the public procurement could start then the installation of the sensor system can take place.

The sensing system at the City of Katowice will be purchased through a public procurement procedure, that is in line with the Polish and European standards. This process entails the following steps with estimated time duration.

- The preparation entails the entire process entails the use of the framework's (D3.1) Phase I – III. Defining the objectives of the sensing system, mapping and assessing the background conditions, identifying needs and selecting the sensors with the sensing expert and the UPSURGE partners. This step finishes with the formulation call for public procurement including the technical specifications for the sensing system.
  This step takes about 9 months including 4 months for the tender specification elaboration.
- The estimation of the public procurement process may differ from the reality, as there are many legal and technical aspects that may prolong the process. However, a successful tender process may take about 2-3 months in the best case.

2) The installation of sensors is possible only after selecting the contractor and signing the contract with them. The modification of the condition on the demonstration site, installation with calibration may take 4-6 months.

Figure 48 – Planned timeline in Katowice

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6.2.9 Project after-life

Following the UPSURGE project, the installed sensing system at the NBS locations will be operated further at least 5 years after project finish. Being owner of the static, mobile and wearable sensors, the City of Katowice takes over the responsibility for operation and maintenance following the warranty period.

Drawing the conclusions from the lessons learnt, looking at the citizens feedback, the City of Katowice may experiment with the UPSURGE sensing system, extend and develop it further.

Having analysed the data and lessons learnt from the stationary stations of monitoring network, the City of Katowice may relocate the devices in the project afterlife to monitor other NBSs in the city for other relevant locations of the same kind upon need.

The mobile sensors, that are mounted on vectors such as non-combustion engine run vehicle such as electric buses or bicycles will be able to operate along other tracks all around the city, but their operation route may be change or be extended to reach out to other relevant locations in Katowice.

The wearable sensors will be distributed to and used citizens periodically. Wearable sensors are able to monitor whole travel journeys, and they flexible enough to re-located them within a city and measure other places for different purposes beyond the project lifetime.

The bee monitoring activities, devices and know-how belongs to the BeeODiversity, that conducts the bee monitoring during the project with the help of the City and local bee keepers. These activities may continue following the end of the project depending on the analysis and results of the UPSURGE measurements.

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7 PLANNED SENSING SYSTEM FOR THE CITY OF MARIBOR

7.1 INTRODUCING THE CASE IN THE CITY OF MARIBOR

7.1.1 ABOUT MARIBOR

Maribor (Marburg) has a total population of 112,838 and is the second largest city in Slovenia, and is located in the north-east of the country, east of the Alps, at an altitude of 270 meters (900 feet). The city is surrounded by wine hills and Pohorje mountain. Located at the Drava River, near the Austria border and 127 km from Ljubljana, Maribor is the capital of Štajerska, Slovenian Styria. The city has a good geographical position, which makes it an important junction, linking Northern and Southern as well as Eastern and Western Europe. Historically, Maribor was an important transit, cultural and industrial city in socialist Yugoslavia. Since this time, Maribor has been affected by severe structural political, economic and demographic changes. Today these influences are still visible in the city, but Maribor is on its way to becoming a trans-regional financial, educational, trade and cultural centre. In 1975, the University of Maribor was founded, and this has helped the city to become a more popular, vibrant, and modern city.

To further improve the living conditions in the city, Maribor's UPSURGE demonstration site will establish a biophilic-designed network of nature-based spaces throughout the waterway of Pekrski Potok, creating a seemingly free-flowing continuity of natural environments leading to a climate-resilient neighbourhood. To implement this approach, the city of Maribor will redesign its spatial planning approach while implementing biophilic-oriented solutions. Actions include, for example, greening the riparian and surrounding surfaces to combat air pollution, alleviate heat island effects, effects of flash floods and soil sealing, and provide spaces for citizens' well-being. In addition, Maribor will assess the impact of biophilic solutions on behaviour change (especially mobility), the elderly population as well as possible changes in moral/ethical values focused on sustainability.

The climate of Maribor is moderately continental, with cold winters and quite warm summers. In winter, precipitation is quite frequent, and often occurs in the form of snow, although it is generally not abundant because winter is the driest season. During the most intense cold spells, the temperature can drop to -20 °C (-4 °F) or even below. The cold record is -25.8 °C (-14.4 °F), set in January 1985. Summer is quite warm, with nights usually cool. The sun shines quite often, although thunderstorms can break out, even of strong intensity. Sometimes there can be very hot periods, during which the temperature can reach or exceed 35 °C (95 °F). The heat record is 40.6 °C (105.1 °F), set in August 2013. The predominant average hourly wind direction in Maribor varies throughout the year.

7.1.2 CHALLENGES

The city of Maribor faces major challenges of air pollution and elevated heat in the area. The study illustrates the potential difference in UHI (Urban Heat Island) intensity concerning global emission scenarios. The four-time periods under consideration indicate a gradual increase in UHI intensity. The higher PM10 and PM2.5 concentrations in colder months, which was the result of more frequent use of heating systems and also a consequence of temperature inversions (Ivanovski et al., 2021).

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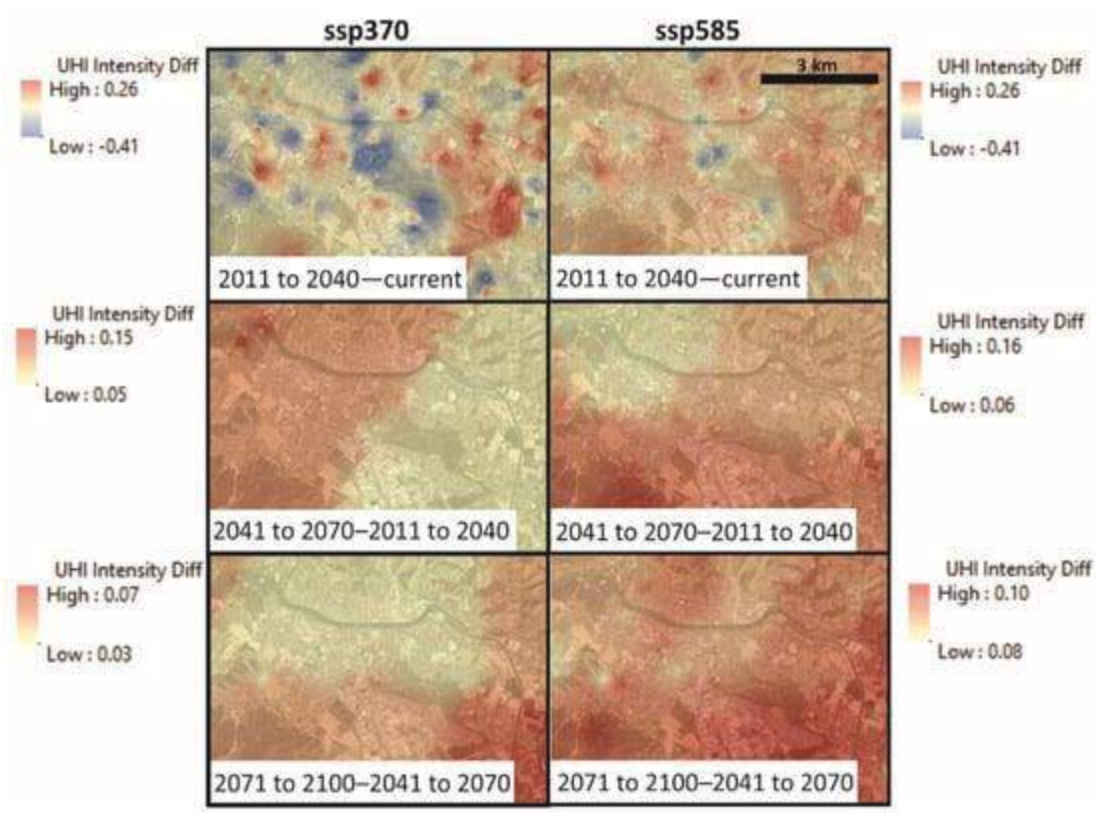

Figure 49 - Key City Challenges of Maribor and the UHI scenarios (Source: Ziberna et al., 2021)

In this part of Maribor, where the demonstration project is foreseen, there is no air-quality measuring station showing the exact air-quality of the area. The nearest one is almost 3km airline away. The area has mixed type of housing with mixed type of heating systems, as well as traffic on both sides of demonstration site. These impacts need to be learn first by measurements in order to be able to influence effectively with the help of nature-based solution in the second part of the project.

Based on measurements in other parts of Maribor biggest challenge are all kinds of PM particles what will also be our focus.

7.1.3 Demonstration site

With implementation of NBS, Maribor will create different type of area with more trees and providing shade in summer month, and sharing the function of each bank of the creek among pedestrians and cyclist to make the area attractive for inhabitants to spend their leisure time. With larger number of plants, trees on the site, the local air-quality will be improved and the standard of living, quality of life in neighbourhood raised.

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The NBS in Maribor will be implemented in Pekre creek park, which is a part of city that is mainly built for permanent residents. The site is connected on both sides with streets and runs between apartments and private houses. There is a pedestrian walkway through the site which is also used by cyclists.

Figure 50 - Location of Maribor demonstration site within the city

Figure 51 - Maribor demonstration site

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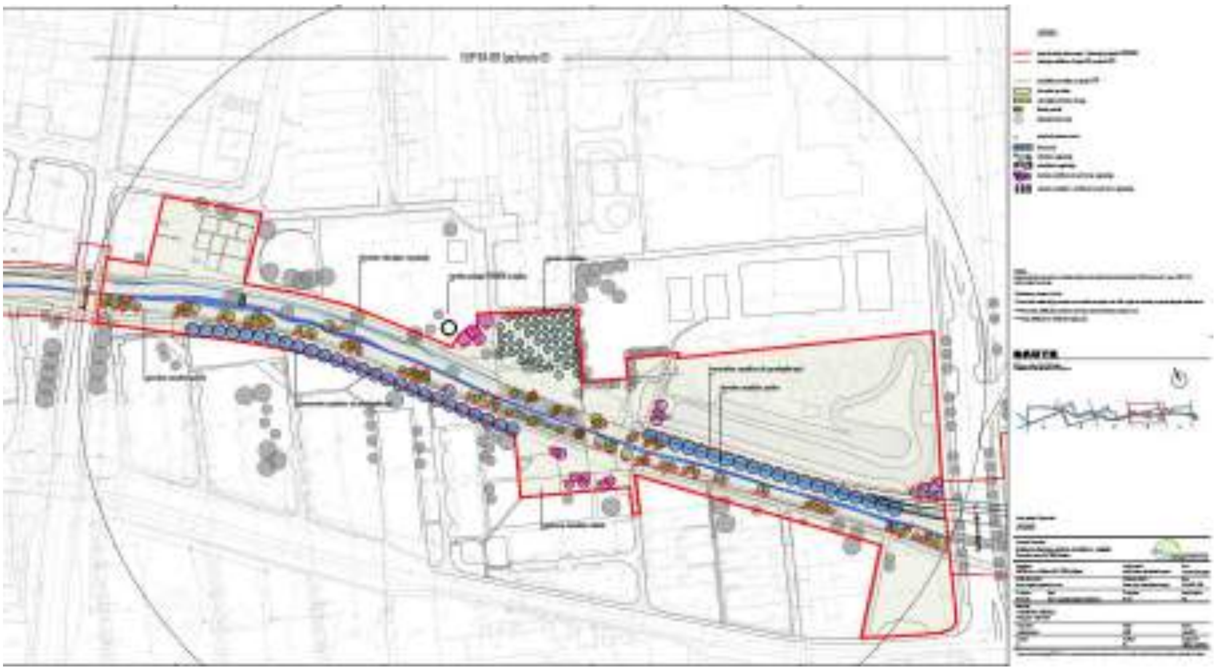

Figure 52 - planned intervention area and the planting plan

This part of Maribor city was developed in the 70's and 80's. Pekre creek park should have been arranged in the 80s, but the project did not succeed and since then area was more or less as it is now. However, the linear park was one of the parts of the city that was not developed at that time, therefore, the UPSURGE demonstration site has remained unchanged. The demonstration site will be done in 1/5 of whole park area on length of 850m where a new green corridor will be created and will be constituted mainly of trees.

The site is currently used by inhabitants for leisure activities. The site is mainly grassed with few trees and a creek flowing through the whole site. Since there is no public lightning, the site is underused at nighttime.

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Figure 53 - Current images about the site in Maribor: a) Day b) Night and c) Seasonal

The site was selected for 3 main reasons :

- This site is part of the bigger project 'Linear park Pekrski potok' that will be implemented by the Municipality
- There are currently no measuring stations for weather and air quality in this part of the city
- Plots that will be used in the demo site are owned by the municipality

The demonstration site in Maribor will establish 500m of a new green corridor demarcating the existing waterway and grey infrastructure. It will be equipped with tree species selected to target particular air pollutants prevalent in this area. As part of the biophilic design approach developed and implemented in Breda, the Maribor demonstration site will also establish three pocket parks, one of which will be equipped as a meditation garden to rest and improve the well-being of citizens. The second will be equipped with an urban mobile forest with a dog park and the third will be a tree nursery where pollutant-targeted trees will be grown to transplant around the city to combat air pollution. Maribor aims also to implement a blue-green NBS using willow twigs (willow spilling) to regulate and create retention capacity for 100m of stream banks for cases of flash flooding.

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7.1.4 STAKEHOLDER MANAGEMENT

The Municipality of Maribor had the intention of arranging green areas along the Pekrski Creek well before the official start of the Upsurge project, in response to calls from the local community. The architectural design of the entire area along the creek was initially developed taking into account the opinions of the local residents. They primarily represented their interests through the representatives of the local community and a civil initiative, both of which became the most important stakeholders alongside the municipality in our activities. As a result, we participated in joint meetings and workshops organized in collaboration with the municipality, where we presented our part in the landscaping, planting, and the establishment of measurement stations. We also explained the significance of the demonstration to the local educational institutions, with whom we plan to collaborate more intensively after the installation of the measurement stations for educational activities, especially for the younger generation.

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7.2 TAILOR-MADE SENSING SYSTEM FOR MARIBOR

Having learnt the general sensing framework approach, the location of the NBS demonstration projects of Maribor for which the sensing system will be installed and adapted, this chapter introduces the planned sensing system in the city.

7.2.1 PLANNED SENSORS FOR MARIBOR

7.2.1.1 AIR QUALITY

Maribor will measure air concentrations of the following parameters with LCS:

- PM_{10}
- $PM_{2.5}$
- NO_2
- O_3
- CO
- CO_2

7.2.1.2 WEATHER

Maribor will measure air concentrations of the following parameters

- Air temperature,
- Air relative humidity,
- Wind speed,
- Wind direction,
- Solar Radiation,
- Rain gauge,
- Atmospheric pressure.

7.2.1.3 OTHER ENVIRONMENTAL FACTORS

'Bee monitoring'

Novel tool for monitoring the environment is the analysis of pollen collected by bees. By means of the analysis of these natural bioindicators, qualitative and quantitative data about plant species, biodiversity, as well as certain parameters of indirect industrial and agricultural air- and soil pollution can be obtained.

Maribor will have at least one hive at a pre-selected location covering 1.5 km circle around it. The samples are being collected at a regular bases from April to October. The collected samples will be grouped into 4 periods and analysed in laboratory such as DNA and chemical analyses.

The following analysis will be carried out at the UPSURGE partners within BeeOmonitoring:

- Plant diversity
- Pesticides
- Heavy metals
- Polycyclic aromatic hydrocarbon (PAH)

Maribor will learn the identification, origin (such as heating, mobility, airport, recycling plant, etc.) and impact of heavy metals and pesticides. Moreover, identify the different plant diversity (quality and quantity, such as invasive species).

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The results will be made available on an online dashboard and will be published in the project reports.

RRA-PODRAVJE is in touch with local beekeeping organisation to use one of their hives that is close to demo site for this activity.

Figure 54 - Planned location of beehive in Maribor

Urban heat island effect

The intensity of the urban heat island effect is best measured by the difference in temperature and humidity between urban and non-urban areas, therefore no other specific element will be measured for this purpose.

Noise

In Maribor, noise levels will monitored, analysed and recorded near the demonstration site with LCS sensors.

7.2.2 Planned sensing station in Maribor

Sensors are often being located in the sensing units or stations, that have limited number of slots for sensors. The adaptation of the sensing framework based on the local circumstances and the changes reflected in section resulted in the following number of sensors and sensor stations under the current conditions:

Type of sensors	Static station	Mobile station	Wearable sensors	UAV sensors	Bee monitoring

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Originally planned	2	5	100	5	1
Planned in Maribor	4	3	50	-	1

Table 36 - Number of sensors and sensing stations in Maribor

7.2.3 LOCATION OF THE SENSORS

The exact placement of the static sensors depends on finalization of the plans, when all technical requirements for installation and operation are elaborated in details. However, the location for the stationary sensing stations are planned along the Western and Eastern road bordering the demonstration site (marked with red), and in the vicinity of the kindergarten being located in the centre of the site (marked with yellow) as depicted in the planting plan below. This way, we have a good capture of traffic related background and a calmer environment in the middle of the site.

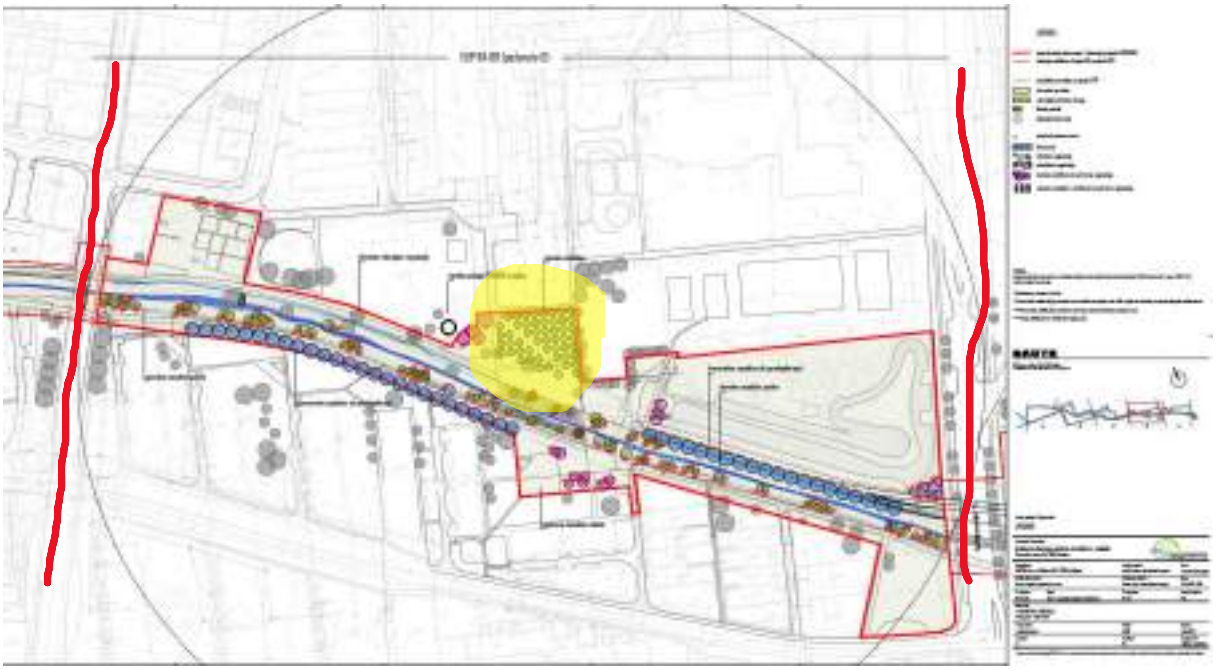

Figure 55 - Location of the sensor stations

	PM10	PM2.5	NO2	O3	CO	CO2	Air temperature	Air relative humidity	Wind direction	Wind speed	Solar Radiation	Rain gauge	Atmospheric pressure	Noise
Radvanjska Cesta	X	X	X	X	X	X								X
Kindergarden #1	X	X	X	X	X	X	X	X	X	X	X	X	X	
Kindergarden #2	X	X	X	X	X	X	X	X	X	X	X	X	X	

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Kardeljeva cesta	X	X	X	X	X	X								X

Table 37 - Distribution of the type of sensors at NBS locations in Maribor

7.2.4 KPI'S MEASURABLE BY THE SENSING SYSTEM

	No.		GROUP KPIs name	KPI/indicator	Parameters measured by sensors
Air quality	1	1.1.1	Air pollutant concentrations	Air pollutant concentrations	+ Air pollutant concentration
	2	1.2.1	Concentration levels limits	Concentration levels limits (number of days with exceedances)	+ Air pollutant concentration
	3	1.3.1	Air quality index	Air quality index	+ Air pollutant concentration
	4	1.5.1	Ambient pollen concentration	Ambient pollen concentration	+ Ambient pollen concentration
UHI Effect	10	3.1.1	Urban Heat Island (UHI) effect	Urban Heat Island (UHI) effect	+ Temperature
	11	3.3.3	Mean or peak daytime local temperatures / Air temperature - mean, peak	Mean or peak daytime local temperature	+ Temperature
	12	3.4.1	Heat waves incidences (hot days, tropical nights)	Heatwave risk (days)	+ Temperature
	13	3.4.2	Heat waves incidences (hot days, tropical nights)	Heatwave risk (tropical nights)	+ Temperature
Health	41	13.3.2	Influence of air quality	Proportion of population exposed to ambient air pollution	+ Air pollutant concentration
	42	13.4.1	Influence of noise	Noise	+ Sound level

Table 38 – Measurable KPIs in Maribor

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7.2.5 Installation of sensors

As described in Phase IV of the sensing system framework, cities need to identify the place of the static sensing stations at the demonstration sites. It is recommended to install static sensors at a height of three to four meters from ground level. This could work well mounting on existing infrastructure or setting up new infrastructure element. Both may require permission and has to go through an authorization process.

7.2.5.1 Static sensors

Each demo site has to be thoroughly examined before the installation whether they are suitable for accommodating the static sensing stations. The city has to consider:

- the ownership of the site is clear and the owners officially let the sensors to be installed. Permissions might be need.
- if there is sufficient space for installing the container station
- the operation of the station, if it is easily accessible for maintenance
- the orientation and placement of the station if the location is ideal for continuous monitoring
- connection to power and communication utilities. Cable connection is evidently the easiest, but solar power supply with battery or wireless communication is a viable option too.
- if the installed station fits into the environment. Some city regulation might require a permission if the static station is in line with the cityscape or not.
- the security of the device, if it is protected against vandalism or cannot be easily stolen.
- capturing additional information during the installation and continuously about the surroundings or device itself. It is highly recommended to document auxiliary information in a log the maintenance, calibration process, as well as the temporary activities in the area, that might impact the results of the monitoring such as car-free day, construction activities etc.

The static sensor stations in Maribor will be located on the land owned by the Municipality of Maribor. The municipality has already granted general permission for the use of its land for demonstration purposes. If the sensors are to be mounted on, for example, public lighting poles, it will also be necessary to obtain permission from the public utility company, which should not pose a significant obstacle.

Consideration	RC	KG#1	KG#2	KC
Ownership	X	X	X	X
Sufficient space	X	X	X	X
Accessibility	X	X	X	X
Orientation	X	X	X	X
Power utility connection (cable)		X	X	
Communication utility connection (cable)				
Fitting into the environment	X	X	X	X

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Security	X	X	X	X
Auxiliary documentation	X	X	X	X

Table 39 - Installation aspects for the demonstration sites in Maribor

7.2.5.2 MOBILE SENSORS

The installation of mobile sensors is considered easier than in the case of static sensors. These sensors stations will be mounted in an undisturbed position on non-combustions engine run vehicles, such as electric car, bus or bicycle. They need permission from the owner of the vehicle, proper attachment to install securely the sensor case not to fall off during operation or not to be easily stolen. The mobile sensors have off-grid power supply and wireless communication connection and shall operate soundly following a calibration step.

The exact location, route of the mobile sensors within the demonstration area in Maribor will be determined based on the assessment and availability of existing city management, public transport non-fossile fuel run vehicles such as e-vans, e-bikes or e-buses. However, the option to involve the kindergarten and parents are being examined, this way such routes will be mapped, that definitely run across the demonstration site and they monitoring data will record data mostly from the neighbourhood.

7.2.5.3 WEARABLE SENSORS

Wearable sensors belong to a specific category of mobile sensors, that can be mounted on humans, on clothes or accessories. These light, hardly noticeable sensor devices shall be installed, turned on easily (plug-and-play for laymen users) following the first calibration and utilized regularly mapping the air-quality related few parameters (due to limited size and weight of the device) in which the users were exposed to. The challenge in installing and using wearable sensors lays in the consent of the users to register their location as geolocation of the air-quality mapping is necessary. All demonstration partners will make sure that the users are aware of what information will be collected and how, and they are fully aware of the GDPR declaration details for which they have to give their consent before start using the wearable sensors. Data collected from wearable sensors will be recorded and stored as anonymous devices with no link with registered user.

7.2.5.4 BEE MONITORING

The sensors of the bee monitoring are the bees. They are based in their home, their hives where from they cover an area of about 1,5km^2 with sampling. The location of the hives in urban environment requires careful planning. The City of Maribor agrees on a location with local bee-keepers based on the localization conditions to deploy a hive.

7.2.5.5 UAV SENSORS

The UPSURGE partnership made decision to exclude the use of UAV-mounted data collection.

7.2.6 CO-LOCATION AND CALIBRATION

In the process of calibration to the local circumstances is essential that sensors show reliable values. Maribor plans to seasonally recalibrate the low-cost sensor monitoring stations, preferably remotely, following the initial recalibration and co-location as described in the recommendations of D3.1 that is mix of on-site and virtual activities.

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This calibration will be carried out by using the closest, relevant EAI station in the city and satellite models. Depending on the distance of the EAI station, sensor could be put on the EAI station for few weeks before installation and periodically for calibration. However, LCS monitoring stations have to be periodically recalibrated, preferably remotely. In particular to provide fast and cost-effective periodical calibration, the project will use the Copernicus virtual reference station network (10x10km grid) already tested in other projects (such as UIA Prato Urban Jungle), running seasonal calibration of the whole network deployed in each demonstration city.

The closest and relevant EAI reference station in Maribor are the followings:

	EAI reference station #1	EAI reference station #2
Station name	Maribor Vrbanski plato	Maribor
Link to location	https://maps.app.goo.gl/uUzHEn6T1cAGFZWa6	https://maps.app.goo.gl/NJLU2Bqe7g9m3SCA7
Link to data	https://okolje.maribor.si/okolje/	https://okolje.maribor.si/okolje/
Sampling point	SPO-SI0059A_00008_100	SPO-SI0002A_00008_100
Type	Urban - Traffic	Urban - Background

Table 40 – EAI reference stations in Maribor

This way, calibrations shall be part of the public procurement process in which cities do not only buy the products, but service for the maintenance of the monitoring stations.

After each deployment and calibration, the contractor shall make available a report with the results of the initial calibration checks of the sensor systems deployed at the air quality monitoring station.

7.2.7 BUDGET/COST ESTIMATION

Based on the information coming from market research, the estimated total budget for the purchase is expected to be in the range of €40-45.000 (net). This exceeds the limit of EUR 34,000 for public procurement procedure, therefore a tender would be introduced.

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CONFIGURATION	Sensor	Costs		
	Type	Estimated Cost / item in EUR	Number of items	Total estimated cost
REFERENCE STATION	FIX STATION	€ 45,000	0	€ -
STANDARD - Air temperatura, air humidity, PM10, PM2.5, NO2, O3, CO, CO2	FIX STATION	€ 4,500	0	€ -
MOBILE - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2	MOBILE STATION	€ 4,500	3	€ 13,500
WEATHER - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, Wind direction, Wind speed, Solar radiation, barometric pressure, rain gauge	FIX STATION	€ 5,500	2	€ 11,000
SOIL + HIDROS21 - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, n°1 soil sensor Hidros21 soil water depth, soil temperature, soil conductivity, rain gauge	FIX STATION	€ 6,000	0	€ -
SOIL - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, n°2 soil water content, n° 2 soil temperature, rain gauge	FIX STATION	€ 5,500	0	€ -
AIR - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, SO2, NOISE	FIX STATION	€ 5,500	2	€ 11,000
AIR BLACK CARBON - Air temperature, air humidity, PM10, PM2.5, NO2, O3, CO, CO2, SO2, NOISE, Black carbon sensor AETS AE51 with system integration	FIX STATION	€ 6,000	0	€ -
WEARABLE	WEARABLE	€ 200	50	€ 10,000
Other additional costs (VAT, technical fees, city costs for installation, etc.)				€ 20,500
			SUM	€ 66,000
			Available budget	€ 66,000

Table 41 – Budget/cost estimation

7.2.8 PROCUREMENT PROCESS AND CHALLENGES

The sensors will be purchased prior to the construction of the NBS, as part of public procurement in accordance with Slovenian law. Initially, in Maribor, it was planned to integrate static sensors into the existing municipal measurement network, which would have required the sensors to be technically advanced and consequently more expensive. In 2023, two public procurement procedures were carried out in Maribor, but they were unsuccessful for administrative and technical reasons. Therefore, in Maribor, we will also procure sensors that will be comparable to sensors in other demonstration cities and are more cost-effective. This will make the ongoing public procurement process significantly easier.

- The preparation entails the entire process entails the use of the framework's (D3.1) Phase I – III. Defining the objectives of the sensing system, mapping and assessing the background conditions, identifying needs and selecting the sensors with the sensing expert and the UPSURGE partners. This step finishes with the formulation call for public procurement including the technical specifications for the sensing system.
  This step takes about 9 months including 4 months for the tender specification elaboration. RRA-PODRAVJE conducts market research with both domestic and foreign suppliers, and the final decision will be made based on the inputs from the project partner responsible for the sensors

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- The estimation of the public procurement process may differ from the reality, as there are many legal and technical aspects that may prolong the process. However, a successful tender process may take about 2-3 months in the best case. RRA-PODRAVJE plans to purchase the sensors directly from the selected most cost-effective supplier, who will provide the most comprehensive service possible.
- The installation of sensors is possible only after selecting the contractor and signing the contract with them. The modification of the condition on the demonstration site, installation with calibration may take 4-6 months.

Figure 56 – Planned timeline for Maribor

7.2.9 PROJECT AFTER-LIFE

Following the UPSURGE project, the installed sensing system at the NBS locations will be operated further at least 5 years after project finish. The ownership and maintenance of the sensors is likely to be transferred to a public utility company or the Municipality of Maribor at the end of the project, depending on the preferences and needs of these stakeholders.

Having analyzed the data and lessons learnt from the static stations of monitoring network, Maribor may relocate the devices in the project afterlife to monitor other NBSs in the city. The mobile sensors, that are mounted on vectors such as non-combustion engine run vehicle such as electric buses or bicycles.

The bee monitoring activities, devices and know-how belongs to the BeeOdiversity, that conducts the bee monitoring during the project with the help of the City and local bee keepers. These activities may continue following the end of the project depending on the analysis and results of the UPSURGE measurements.

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