euPOLIS

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euPOLIS Unveiled: Pioneering Nature, Technology, and Citizen Power to Reimagine Europe's Smart Cities

AUTHOR:
Prof Čedo Maksimović, euPOLIS project technical coordinator

As the final edition of the euPOLIS project magazine ispresented, focus is shifted from the challenges of implementation future NBS-inspired urban planning paradigms, which are undoubtedly invaluable didactic (expertise building) materials to the tangible achievements realized in Gladsaxe, Łódź, Piraeus and to certain extent Belgrade,. These front runnr cities have been at the forefront of integrating nature-`based solutions (NBS) into urban environments, creating open air living laboratories where innovative approaches to concept approvals of health, well-being, and ecological resilience in open urban spaces have taken root. These concepts were further tested in four follower cities cases (Limasol, Palermo, Trebinje and Bogota) The knowledge and experience gained (form a powerful foundation to influence Europe's future planning practices policies, standardisation and legislationin developing "healthy cites for happy people.

To highlight euPOLIS's innovation achievements, a few text cases/examples from the demo sites and case studies are presented. In Gladsaxe, demonstrated are the principles of integrated sonlutions to convert a highly unattractive environment of a low quality social housing into a vibrant, aesthetically pleasing neighbourhood. It features a pioneering micro scale biofilm-based surface water treatment plant This, providing a multifunctional social space that

fosters community interaction and well-being. Complementing this, the Water Square playground integrates art, culture, and sensory gardens, creating a vibrant interface for play and mediation across all ages, embodying the euPOLIS philosophy of harmonizing built and natural environments. This case can be replicated in may other similar European and other continents' cases.

Łódź has made significant strides with the Anne R. Passage, bytransforming it from an unnoticeable "trespassing" corridor into an attractive urban space that combines innovative multifunctional space by implementing participatory planning to reconnect citizens with their environment. This project exemplifies how inclusive, culturally sensitive interventions which can regenerate urban areas, promoting accessibility and social cohesion while embedding nature-based solutions at their core amenity.

Belgrade's micro scale contribution is marked by the ALINA prototype developed by the Vertical Farm Institute (VFI), a vertical farming system that integrates sustainable food production into the urban fabric. This prototype is not only a technological innovation but also a permanent nature-based heritage of euPOLIS, symbolizing the project's commitment to resilient and self-sufficient urban ecosystems.

Piraeus, has advanced participatory methodologies that place citizens at the centre of urban regeneration planning and maintenance, ensuring that the social dimensions of health and well-being are fully addressed. Additionally, it is aimed at the growing generations, placing the green wall and the switch of the grey water usage into the Rallion Pilot School, making it the NBS-connected triangle with Microlimano and Akti Dilaveri corridors which also feature urban water recycling, surface water quality enhancement and improvement of environmental and aesthetic values of small urban public spaces (pocket parks).



Together, these interventions demonstrate that nature-based solutions are more than technical fixes; they are transformative processes that require trust, collaboration, and a shift in mindset. The euPOLIS experience calls on policymakers, urban planners, and communities to harness these insights and advocate for legislative frameworks that embed nature, technology, and citizen participation as pillars of planning Europe's future open urban spaces, which can be replicated at the level of urban districts, other cities and other countries and continents.

All stakeholders are encouraged to explore and exploit the detailed implementation processes and results available online, drawing inspiration from Gladsaxe's metabolic pond and sensory gardens, Łódź's Anne R. Passage, Belgrade's ALINA prototype, and Piraeus's community-driven innovations. The way forward for urban living is clear: it is a future where nature, technology and local communities coexist in harmony, driven by the empowered citizens and enlightened governance.

Front Runner Cities

Urban Sensor Networks: Bridging Data and Action in euPOLIS Cities

AUTHOR:
Stelios Kalogridis

euPOLIS has woven a real-time environmental monitoring tapestry across four European cities— Belgrade, Piraeus, Łódź, and Gladsaxe— thanks to the instructions, monitoring, and handled by Plegma Labs, revealing how sensor data mirrors and illuminates each city's unique ecological struggles. The findings, drawn from resilient networks, transform abstract challenges into measurable realities. Here's how these urban landscapes are confronting their environmental legacies.



Belgrade: The Air-Soil Nexus

Belgrade's industrial heritage and traffic congestion have long choked its skies, but sensors now quantify the toll: **persistent PM2.5 spikes** coincide with unstable soil moisture and tension. This dual stressor jeopardizes green infrastructure, revealing that urban greening must address both atmospheric and terrestrial instability.

On a different note, these findings hit the already vulnerable groups the hardest: the sensors show high levels of air pollution and unstable soil, especially near busy roads and factories. These areas are often home to people with fewer resources, making pollution not just an environmental problem, but a social one. Greener streets and parks in these neighborhoods could help clean the air and stabilize the soil, giving everyone a healthier place to live.

To tap into these challenges, Belgrade is now a home to the **Alina prototype,** designed by vertical farm institute as a smart, data-driven platform that integrates environmental sensor data to guide and optimize nature-based solutions. In practice, this means using real-time air and soil quality information to inform where and how to plant, irrigate, and maintain urban greenery, ensuring interventions are both effective and resilient in the face of pollution and climate variability.

Targeted planting of trees and greenery in the most affected neighborhoods can help clean the air and stabilize the soil. It's a win-win for people's health and the environment.

Piraeus: Coastal Systems Under Pressure

As a bustling port city, Piraeus battles marine degradation. Sensors detected **erratic oxygen saturation** and **resistivity swings** in coastal waters—smoking-gun evidence of pollution stress. These fluctuations threaten marine biodiversity and waterfront livability. Of course, this is not all about the fish: it's about the families who rely on the sea for work and food. Urban planning here should focus on cleaning up the water and creating green spaces along the waterfront, helping both the environment and the local economy.

The green wall at Ralleion Pilot School is a flagship nature-based solution, designed to improve air quality, regulate temperature, and enhance the learning environment. Continuous monitoring allows for the performance of the green wall to be assessed and optimized, ensuring it delivers real benefits for students and staff while serving as a model for similar interventions in other urban schools.

Urban planners can use this information to create "green buffer" zones along the waterfront—parks and wetlands that help filter pollution before it reaches the sea, protecting both nature and the local economy.





Łódź: The Heat-Energy Paradox

Łódź's dense urban fabric traps heat, yet sensors expose a hidden vulnerability: **dewpoint volatility** and **solar panel voltage** drops undermine renewable energy potential during peak demand. This paradox highlights how microclimate instability cripples sustainability efforts. In human language, challenges with humidity and energy efficiency hit especially hard in older, crowded neighborhoods. The sensors show how changing weather and moisture can affect everything from comfort in homes to how well solar panels work. Solutions like green roofs, better insulation, and more trees can make a real difference, helping people save on energy bills and live more comfortably.

The main intervention focus here is on restoring biodiversity by planting a supportive mix of grasses, shrubs, and trees—species chosen to help each other thrive even in tough urban conditions. To address water scarcity, a retention basin and a "dry river" have been introduced to collect and hold rainwater, nourishing the park and its plants. Planned shaded areas will offer relief on hot days, while a sensory playground and an accessible community garden are set to foster social integration and inclusion, especially for children and people with disabilities.

Upgrading buildings with better insulation, adding green roofs, and planting more trees can make homes more comfortable and help everyone save on energy bills.



Gladsaxe: Fractured Microclimates
Gladsaxe stands out for its commitment to green spaces. The sensors here are used to monitor temperature and humidity across parks and neighborhoods, ensuring that green areas are healthy and well-maintained. Unlike all previous cities, the main challenge isn't heat, but making sure that all parts of the city benefit equally from these green spaces.

Experts can use the data to connect parks and plant more trees where they're needed most, so that everyone—no matter where they live—can enjoy clean air and a pleasant environment.

The Modular Nature-based Reactor (MNR) is being implemented in Pileparken as an innovative, modular system for water treatment and environmental enhancement.

By leveraging real-time data on local climate and soil conditions, the MNR can be optimally managed to support healthy vegetation and improve stormwater management, directly addressing the need for sustainable, adaptive green infrastructure.

People at the Heart of the City
It's not just about the environment. As the euPOLIS project advances, the infrastructure for wearable and emotion sensors is being put in place, with the aim of eventually linking environmental data to real human experiences, like stress and well-being. While this type of monitoring is planned, and some devices are already prepared for use, the first results from cities like Belgrade are still to come. This approach will help ensure that future urban planning decisions are guided not only by air, water, and soil data, but also by how these factors impact people's everyday lives.

Front Runner Cities

Metabolic Network Reactor Technology for Healthy Urban Water Bodies

Gladsaxe - Denmark

AUTHOR:
Erzsébet Poór-Pócsi

The EU-funded EuPolis project is developing a methodology for enhancing the health and well-being of citizens by creating urban ecosystems that harmonize the urban built environment with the natural environment through integrated nature-based solutions (NBS).



Nature-based solutions in Gladsaxe offer multiple benefits to the local urban environment. By managing the natural water cycle through attractive blue-green urban solutions, they create biodiverse ecosystems, improve stormwater treatment and capture, and promote human health through interaction with nature.

" Human health and the natural water cycle are enhanced by healthy urban waters in Denmark at the Gladsaxe housing development."

Water in the Urban Environment

Water serves two primary functions within urban blue/green ecosystems. First, through the natural water cycle, it supports ecosystems and biodiversity by providing habitat for diverse plant and animal species and by supporting vegetation growth. The second is where water bodies help to regulate and mitigate impacts of excessive stormwater runoff and periods of drought and water scarcity by reducing the impacts of flooding, enhancing hydrologic infiltration leading to natural groundwater recharge, and also by acting as a natural buffer or retention pond for water storage.



The Need for Healthy Surface Waters

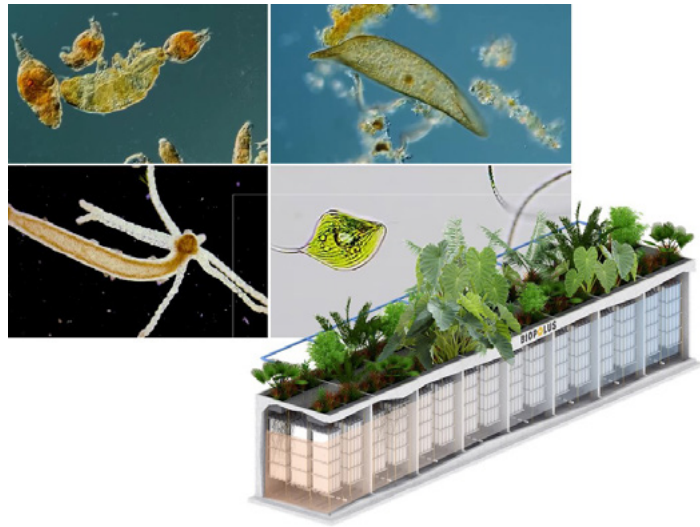
Urban surface waters are more susceptible to diffused source pollution since they are located in urban environments. Good water quality must be maintained to prevent algal blooms, to maintain a healthy aquatic habitat, and to ensure that the stored water will be safe and healthy when cycled back into the natural water cycle or when used later for activities such as irrigation.



Bioengineering the Natural Environment

Biopolus Metabolic Network Reactor technology (MNR) utilizes a specially engineered ecosystem consisting of 2,000 to 3,000 species, including plants, microbes, and other higher-level organisms for high-level nature-based water treatment. The MNR system can be used to treat various water types, including wastewater and urban surface waters to a desired level of water quality.

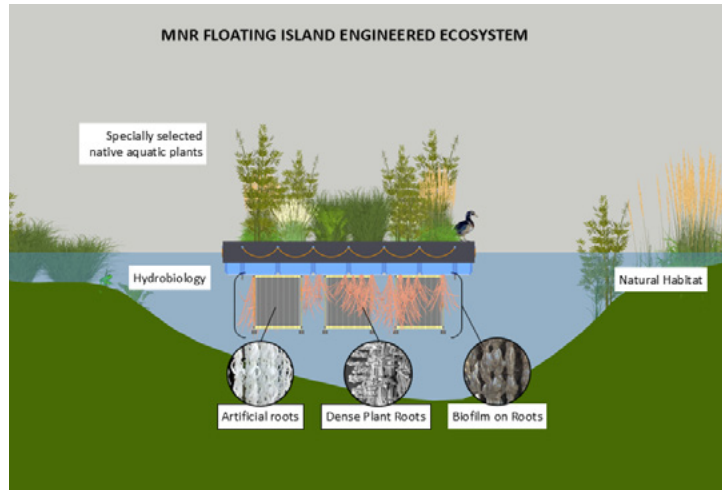
The MNR system works by using natural and synthetic plant roots to provide optimal surface area for attached biofilm microbial growth, which, along with an aeration system, creates an engineered ecosystem with a healthy and diverse microbial community that can break down contaminants in water.



" For wastewater treatment, the process takes place in a series of MNR reactors. As the water flows from one reactor to the next, it is continuously cleaned, as the various species in each tank break down the different contaminants. "

An Attractive Solution for Surface Water Treatment

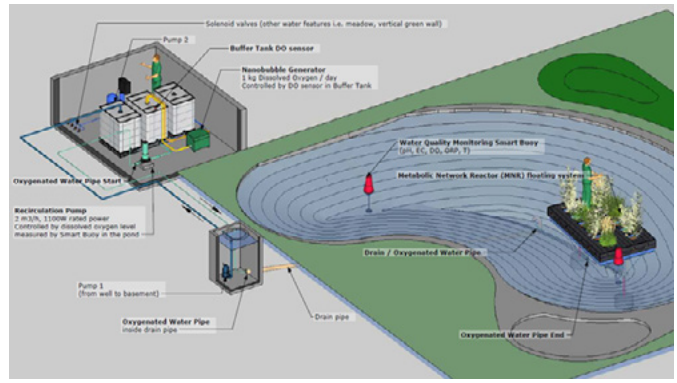
The MNR floating island at Gladsaxe and the pond itself creates a complex nature-based ecologically engineering environment. The MNR island works by creating a habitat for beneficial organisms on natural and artificial root surfaces (with a thriving biofilm microbial community), to treat and inoculate the pond water, maintaining good water quality and healthy ecology.



" For surface water treatment, the MNR technology has been adapted to swim above the waterbody. A man-made floating island contains plant racks that house specially selected native aquatic plants whose roots are submerged into the water. Below the plant racks are MNR artificial carriers that act as artificial root surfaces, which along with the plant roots create a habitat that is ideal for beneficial organisms. The MNR floating island is supplemented with an aeration/ circulation system, which helps maintain oxygen rich water in the waterbody. "

MNR Floating Island

The following illustration shows how the natural environment is enhanced through engineered ecosystem design, whereby mechanisms are installed for automated pond water aeration, using a micro-nano bubble generator, and water circulation via a system of pumps and a programed monitoring and control system.



The following rendering illustrates the attractive nature of the MNR floating island solution when it is used to treat and maintain the water in a small catch basin pond of an apartment complex.



Testing and Installation

The MNR floating island system will be installed at the Gladsaxe site during the first week of April 2025. Installation work will include the installation of the MNR floating island, the installation of the pond circulation and aeration equipment, planting and landscaping in and around the pond, and the integration of the monitoring equipment and the control logic with other onsite systems.

The MNR floating island was tested in Hungary, with preliminary plants, in a small lake in the town of Baja for approximately 6 months. The following image is the MNR floating island taken in the fall of 2024 on Lake Baja.



Global Roll Out

The Gladsaxe complex stormwater management solution, which includes the MNR floating island, the evaporation system by BySpectrum, and the Biowater climapond by Amphi, provides an excellent nature-based solution for surface water management. The integrated system provides solutions for stormwater infiltration, stormwater retention and treatment, flood prevention, climate change adaptation, ecosystem restoration, increased biodiversity, and human health benefits through leisure areas and interaction with nature. The partners working on the Gladsaxe solutions are committed to the project and will continue to monitor and analyze the solutions after the completion of EuPolis. The ultimate goal is to exploit the results and to introduce the solution throughout Europe and the world, promoting local and sustainable decentralized circular urban water management.

Revamping Urban Spaces: euPOLIS in Łódź

Łódź - Poland

AUTHOR:
Aleksandra Trzcińska



As European cities grapple with the whirlwind of urbanization, social upheaval, economic shifts, and climate crises, one thing is clear: the future of our cities depends on more than just economic calculations. In Łódź, Poland, the euPOLIS project is pioneering a new era of urban planning, one that puts the needs and voices of local communities at its core. By harnessing the power of nature-based solutions and community engagement, euPOLIS is transforming urban landscapes and forging a new bond of trust between residents and local authorities.

Eager to deliver a people-friendly change, the euPOLIS project is developing a spatial planning methodology using nature-based solutions (NBS). It assumes the synergy of a people/health-focused approach with the significant environmental and economic benefits of ecological blue-green solutions.



Harnessing Nature-Based Solutions for Sustainable Cities

The euPOLIS project aims to replace or combine traditional, costly engineering systems designed to protect the environment with natural systems to create resilient urban ecosystems while improving the quality of life for residents. The project responds to critical challenges such as poor environmental quality and low biodiversity in public spaces and water resources, high air pollution in the urbanized center, water shortage, soil degradation, heat waves, and the occurrence of the heat island effect, which a growing number of cities are facing, especially those with high housing density and lack of access to green spaces in city centers.

The basis for deciding on specific nature-based solutions (NBS), for us, was primarily the conditions of the demonstration site, the analysis of the initial state with the expected end state, as well as the opinions of the residents of our city, who were actually invited to get involved in the project from the very beginning.

The main focus was on restoring biodiversity to the demo site, so as to be able to achieve the effect of mutual 'support' between the different species of grasses, shrubs, and trees, knowing that a small linear park in the city center 'squeezed' between dense buildings would not have favorable conditions for survival. Another important aspect is the question of being able to collect and retain rainwater that will feed the demonstration area, hence the appearance of a retention basin and a so-called 'dry river'. We will also be creating shaded areas to provide respite for residents on hot days. A planned sensory children's playground and a community vegetable and fruit garden (both adapted for people with disabilities) are expected to contribute to greater integration of the local community.



Tackling Environmental and Social Issues with NBS

Here we come to the key challenge that has been present throughout the project, that is, the hard-to-achieve public participation in the project sections, even those specifically dedicated to it. Over the five years of the project, and with the organization of two online surveys and five different on-site workshops (including two informational and educational and one planning workshop on co-design), a total of only 169 people (!) took part, despite the fact that before each event there was a promotional campaign in the field (posters, flyers), in the municipal newspaper (promotional articles) and on social media run directly by the municipality.

During the workshops, each time, in addition to the topic of designing a demo site and selecting NBSs, we had to deal at the outset with the resentment of residents and the complaints they made about 'the city' in general. It didn't matter who was running the meeting and for what purpose, what was important was that they could express their dissatisfaction with various aspects of the municipality directly. In the end, we were always able to move on from these criticisms to the actual substance of the workshop and achieve the intended goals and results.

Another challenge proved to be the administrative procedures related mainly to tenders and public procurement law, as well as the appearance of a new unexpected 'player'. One of the city plots, which is directly adjacent to the demo site, was sold during the project to a private developer who, for his own purposes – the construction of a new apartment building and the supply of a heating and hot water source to it – made a connection for a new heat pipeline, the route of which was entirely laid through our demo site. Arrangements with the heat supplier and discussions with the developer took almost nine months, which was not without its negative impact on the project schedule.

However, in spite of the obstacles and difficulties,



most of which were unforeseeable at the planning stage of the project, we have overcome them and are finally reaching the stage of realization and implementation of the NBS on the demo site. On the one hand, this is the most anticipated phase of the project, and on the other hand, it is the most demanding phase, because the schedule of activities is already as tight as the bowstring just before the arrow is released.

Admittedly, it is too early to draw final conclusions and summaries of how we have dealt with the huge and exciting challenge that is certainly the euPOLIS project, but we have certainly learned two things: patience and flexibility.

Patience with each of the parties we have had to work with during the project – the residents; the staff of other units in the municipality (on whom we have depended to varying degrees and at different stages, even if they did not share our enthusiasm and did not feel the time pressure that was and is still weighing on us); and the external parties with whom we have had to conduct not infrequently difficult discussions and negotiations.
Flexibility in our approach to our own work, to the project's set timetable and budget, to the sometimes misconceptions about how things are done and for how long...

But, given all this, was it worth embarking on this journey? Yes, it definitely was. And we would venture out on it again, especially as we now have a backpack full of new experiences and skills.

Front Runner Cities

ALINA
The Living Vertical Farm Sculpture

AUTHOR:
Daniel Podmirseg



Developed by the vertical farm institute (vfi) as part of the Horizon 2020 project euPOLIS, ALINA is a living object — a sculpture that seamlessly merges art and design, technology, and digital innovation. This installation functions not only as a research unit, but also as an educational and sensory experience designed to raise awareness of the past, present, and future of urban food production.

At its core, ALINA makes the fundamental principles of plant growth — light, water, nutrients, substrates, and photosynthesis — visible in a compact, dynamic form. Visitors can observe the growth cycles of various edible plants first-hand, transforming an abstract biological process into an accessible, tangible learning experience. Transparency in design, material and communication is key. Beyond its technical framework, ALINA serves as a catalyst for dialogue on sustainability, urban resilience, and the role of agriculture in the city of tomorrow.

Educational Sculpture

More than a food-producing system, ALINA is a dissemination sculpture that encourages open dialogue on how we have grown, currently grow, and will grow food. Its design highlights the



reliance of plants on finely balanced inputs, with LED lighting tuned to red and blue spectra to optimise photosynthesis.

Resilience and Innovation
As a design object, ALINA encourages reflection on the future of urban food production. It aims to inspire and provoke alternative design strategies. It does not present itself as the solution to food security, but rather as a symbolic expression — a visual riddle — representing the activation of urban voids for productive use.

Dynamic Visitor Experience
Constantly evolving, the sculpture offers new perspectives with each visit as plants progress through different growth stages, fostering continuous engagement and discovery.

ALINA's Journey and Urban Integration
ALINA is the redesign of the research-object at the vfi developed within euPOLIS project and was first presented at the Mikser Festival in Belgrade, where it captured public attention and ignited discussion on urban agriculture and resiliency. Following this, it was installed permanently at the Faculty of Civil Engineering, University of Belgrade, making it accessible to researchers, students and the wider public. This placement reinforces its role as a teaching tool while embedding vertical farming into the academic and civic fabric of the city.

ALINA's Role in euPOLIS and Beyond
Research and Monitoring
As a modular research platform, ALINA enables the collection of data on lighting, nutrients, water quality and plant yields. These parameters are monitored and analysed to support AI-based optimisation processes that improve efficiency and scalability in vertical farming systems.

Public Engagement
Through exhibitions like FoodPrint and additional outreach activities, ALINA contributes to broader awareness of sustainable food systems. Interactive formats such as the "tasteLAB" offer workshops and tastings that complement the installation and deepen public understanding of nutrition and sustainability.

Developed by the vertical farm institute (vfi) as part of the Horizon 2020 project euPOLIS, ALINA is a living object — a sculpture that seamlessly merges art and design, technology, and digital innovation. This installation functions not only as a research unit, but also as an educational and sensory experience designed to raise awareness of the past, present, and future of urban food production.



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Front Runner Cities

Cultivating Green Futures: Schoolyard Greening and Vertical Gardens in Piraeus

Piraeus - Greece

AUTHORS:
Efthymios Hardavellas, Panagiota Kaloumenou

" As part of the euPOLIS project, the Municipality of Piraeus has played an important role in supporting nature-based solutions within the Ralleion Model Experimental Primary School (RMEPS), aiming to enhance the school environment for students and staff alike. "



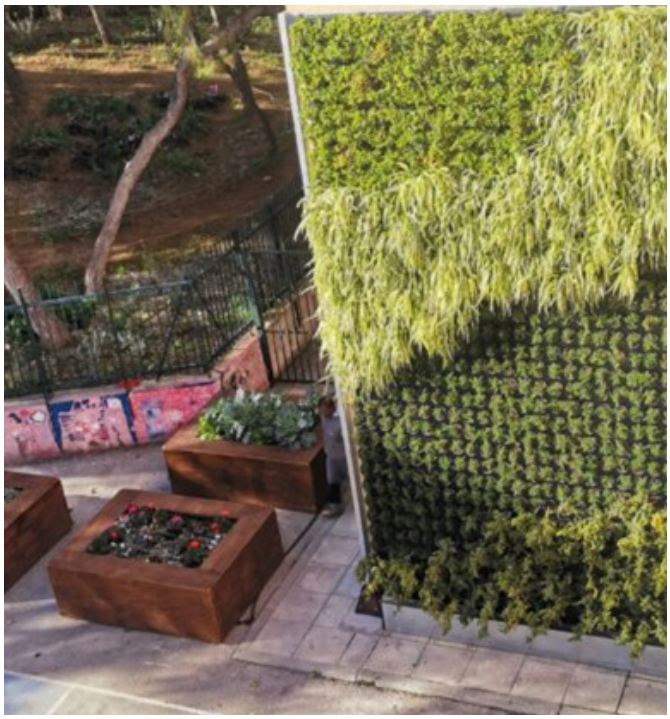
Grove Clean-Up and Replanting

Within the school grounds lies a grove that originally consisted only of pine trees. Through euPOLIS, the Municipality facilitated essential pruning of these trees and improved the soil quality by plowing and adding fertilizer to the infertile ground. To encourage interaction and learning, a pathway was carefully outlined with rope to define planting areas, creating a welcoming route for students and teachers to explore the new greenery.

In a hands-on workshop, students from the Environmental Class actively participated in planting over 500 small bushes and geophytic plants in the designated areas of the grove. This collaborative effort not only enriched the school's biodiversity but also fostered environmental awareness among the young participants.

Additionally, three large, insulated plant pots were installed, each dedicated to different types of plants. Students planted aromatic herbs such as





spearmint, mint, and basil; vegetables including lettuce, cauliflower, and broccoli; and flowering plants like cyclamens. These installations provided an ongoing educational resource and a living connection to nature right on school grounds.

Vertical Garden Installation

Another notable intervention is the creation of a vertical garden on an otherwise blank wall within the school premises. This green wall system is composed of modular units that hold plants in perforated pots, allowing roots to receive air and moisture from all directions. Each pot includes a small water reservoir to keep the plants consistently hydrated, while excess water is collected in a 600-liter steel tank at the base and recirculated via a pump, making the system more sustainable and resilient.

The vertical garden hosts over 960 individual plants, transforming the wall into a vibrant, living ecosystem that improves air quality and adds a refreshing natural element to the school environment.

Cognitive development & emotional well-being

Beyond enhancing the physical environment, these nature-based interventions offer a valuable, hands-on learning opportunity for students. Engaging directly with plants, soil, and green infrastructure fosters a deeper connection to nature, helping children become more environmentally conscious, attentive, and resilient in the face of future challenges. Research shows that outdoor learning and interaction with natural environments not only improve cognitive development and emotional well-being but also cultivate a stronger sense of stewardship for the planet (Louv, 2008; Wells & Evans, 2003). By integrating these green spaces into everyday school life, euPOLIS is helping raise generations who are better equipped—both intellectually and emotionally—to understand and address environmental issues.

The Municipality of Piraeus: A Supportive Partner

Throughout these interventions, the Municipality of Piraeus has been a key partner, providing logistical support, facilitating workshops, and ensuring the integration of these nature-based solutions within the school's educational framework. This collaboration reflects the city's broader commitment to enhancing urban green spaces, promoting sustainability, and engaging local communities in environmental stewardship.

Follower Cities

Palermo Recognized for Sustainable Urban Planning: A Step Towards a Greener Italy

Palermo - Italy

AUTHOR:
Elenia Drago



In 2024, the Municipality of Palermo received the Certificate of Good Territorial Practice for a More Sustainable Italy from the Italian Alliance for Sustainable Development (ASviS). This recognition highlights Palermo's Integrated Urban Planning Methodology that leverages Nature-Based Solutions (NBS), developed within the wider context of innovative European urban sustainability initiatives, including the euPOLIS project. The award signifies a meaningful contribution to Italy's evolving sustainable development efforts at a local scale.

Linking Local Action with Broader Urban Sustainability Goals

The Certificate of Good Territorial Practice, awarded by ASviS, spotlights initiatives that embody practical, replicable models advancing the Sustainable Development Goals (SDGs). Palermo's approach reflects a methodology increasingly embraced across Europe — one that harnesses natural systems and community participation to foster urban resilience, improve public health, and enhance well-being.



The Integrated Urban Planning Methodology that Palermo has implemented resonates closely with a growing paradigm exemplified by projects like euPOLIS. This European research and innovation project promotes nature-based urban transformations that integrate ecological functions with social, cultural, and economic dimensions, enhancing city livability while addressing challenges such as biodiversity loss, water scarcity, and fragmented urban spaces.

Nature-Based Solutions and Participatory Urban Renewal

At the heart of Palermo's initiative is the deployment of Nature-Based Solutions that restore and leverage natural assets in urban environments. This strategy aligns with the core euPOLIS objectives: creating more resilient, inclusive, and accessible urban spaces by systematically integrating blue-green infrastructure and promoting active community involvement.

The broader euPOLIS framework aims to implement planning methodologies that support public health and well-being through the inclusion of natural elements in the urban fabric. It encourages participatory governance models that engage diverse citizen groups, ensuring interventions are tailored to local needs and embody sustainability principles over the long term.

Towards Sustainable Urban Ecosystems in Italy and Beyond

Palermo's certification by ASviS is a tangible example of how localized, nature-based urban planning efforts contribute to wider European efforts in regenerating cities sustainably. Such recognition underscores the importance of collaborative, knowledge-driven advances that not only protect the environment but also enrich social cohesion and economic vitality.

As urban challenges become increasingly complex, the evolution of planning approaches—like those promoted by euPOLIS and exemplified in Palermo—point toward a future where cities are healthier, more resilient, and connected more deeply with nature and their communities.

Empowering Urban Transformation: The euPOLIS Community Guide for Replication of Social-Cultural Urban Hubs

AUTHOR:
Maja Lalić

Cities worldwide are searching for ways to foster vibrant, inclusive, and resilient communities. At the heart of this movement is the euPOLIS Community Guide for Replication of Social-Cultural Urban Hubs (SCUH), a comprehensive, field-tested resource designed to help cities and organizations create and sustain community-driven cultural spaces that drive urban regeneration, citizen engagement, and public health.

What is the euPOLIS Community Guide?
The euPOLIS Community Guide is a strategic, step-by-step manual developed through a unique synthesis of hands-on experience, co-creation, and international knowledge exchange. Its central aim is to help cities and stakeholders replicate the success of social-cultural urban hubs: dynamic, hybrid spaces that serve as platforms for civic participation, creativity, and sustainable development.

Drawing from the acclaimed Mikser House model and the collaborative frameworks of the euPOLIS project, the guide offers a practical roadmap for transforming underused urban spaces into thriving community centers. These hubs act as "third places"—welcoming environments beyond home and work that nurture artistic production, participatory planning, and social entrepreneurship, while advancing sustainability and social cohesion.



Key Components and Methodology
The guide's methodology is built on three pillars:

Real-World Experience:
Lessons from the Mikser Association's successful hubs in Belgrade and Sarajevo—including Mikser House and Refugee Aid Miksalište—demonstrate how adaptive reuse, cultural innovation, and grassroots engagement can revitalize neighborhoods and empower citizens.

Collaborative Co-Creation:
The guide integrates insights from diverse cities through teamwork tools, workshops, and mentoring sessions. Local authorities, citizens, and experts contributed to shaping strategies for engagement, inclusivity, and sustainable development, ensuring the guide's relevance across varied urban contexts.

Global Knowledge Exchange:
International events like the Urban Lab at the Mikser Festival brought together over 70 experts, city representatives, and activists to share best practices, challenges, and recommendations for future improvements in participatory urban planning.



The Replication Toolbox:
Seven Phases to Success

The guide provides a step-by-step toolbox for replicating SCUH, structured into seven development phases:

1. Initial Funding and Feasibility

Develop a business plan, conduct feasibility studies, and secure seed funding through grants, sponsorships, and crowdfunding.

2. Planning and Assessment

Identify underused spaces, engage stakeholders through surveys and workshops, and build partnerships with local businesses and institutions.

3. Designing Inclusive and Sustainable Spaces

Apply the "sustainability star" framework, incorporate nature-based solutions, ensure accessibility, and design programs that blend culture with sustainability education.

4. Implementation and Activation

Renovate spaces using eco-friendly materials, launch digital platforms for engagement, and organize opening events to attract community interest.

5. Community Engagement Strategies

Utilize both online and offline tools, partner with organizations representing sensitive groups, and empower trusted community members as mediators.

6. Securing Operational Funding and Sustainability

Diversify revenue streams, maintain ongoing fundraising, and build partnerships with universities, local governments, and NGOs.

7. Monitoring, Evaluation, and Adaptation

Use ICT solutions for real-time feedback, measure health and well-being impacts, and adapt programs based on user input to maintain inclusivity and relevance.



Why Social-Cultural Urban Hubs Matter

Social-cultural urban hubs are more than just community centers—they are catalysts for urban transformation. By bridging institutional gaps and empowering grassroots actors, these hubs enable participatory urban planning, foster innovation, and support nature-based solutions and circular economy practices. They transform symbolic engagement into real decision-making power, helping cities become more resilient, inclusive, and sustainable.

Real-World Impact: The Mikser House Model

A highlight of the guide is the Mikser House case study, which illustrates how abandoned industrial spaces in Belgrade and Sarajevo were transformed into multifunctional creative hubs. These centers have become models of how culture and cross-sector collaboration can address urban challenges, support refugee communities, and drive long-term neighborhood revitalization.

Applicability and Scalability

The guide is designed for broad applicability—not only within the original euPOLIS demonstration cities but also in diverse urban environments globally. Its scalable, adaptable framework makes it a valuable resource for city planners, cultural organizations, NGOs, and community leaders seeking to foster sustainable, citizen-led change.

Integration with Other euPOLIS Tools

The Community Guide is intended to work in synergy with other euPOLIS tools, such as visualization platforms and planning matrices, enabling a holistic approach to urban regeneration. This integrated strategy ensures that interventions are both socially acceptable and environmentally effective, maximizing their positive impact on cities and communities.

The euPOLIS Community Guide for Replication of Social-Cultural Urban Hubs stands as a pioneering resource for anyone committed to building healthier, more inclusive, and creative cities. By translating proven methodologies and collaborative insights into actionable steps, it empowers communities everywhere to shape their urban future.

In order to download the euPOLIS Community Guide please scan the QR Code

Revolutionizing Urban Well-Being: Inside the EuPOLIS Visualisation Tool

AUTHOR:
Eirini Marinou



Urban planners, public health experts, and city stakeholders face a common challenge: how to measure and maximize the positive impact of nature-based solutions (NBS) in our cities. The EuPOLIS Visualisation Tool emerges as a cutting-edge solution, offering a comprehensive, interactive platform to track, visualize, and interpret the tangible and intangible benefits of urban interventions for public health, well-being, economic development, social cohesion, and cultural vitality.

What Is the EuPOLIS Visualisation Tool?

At its core, the EuPOLIS Visualisation Tool is an integrated data visualization and analytics platform. Rather than building a new system from scratch, the tool leverages an existing robust platform, aggregating datasets from across the EuPOLIS project. This integration ensures that users—from policymakers to researchers and local stakeholders—have direct access to a unified interface for exploring the impacts of NBS deployments in demonstration cities such as Belgrade, Lodz, Piraeus, and Gladsaxe.



Key Features and Capabilities

Interactive Data Exploration

Users can access the Visualisation tool via a dedicated button on the EuPOLIS website. The interface is designed for intuitive navigation, allowing users to dynamically filter, select, and compare key indicators across sites and time periods. This empowers stakeholders to track trends, benchmark progress, and make evidence-based decisions1.

Customizable Visualization

The platform offers a range of visualization options, including graphs, tables, and immersive 3D map environments. Users can tailor the display to focus on specific parameters—such as public health trends, economic impacts, social engagement, or cultural benefits—enabling both high-level overviews and granular analysis.

Seamless Data Integration

The tool aggregates diverse datasets, including pre- and post-intervention data, sensor feeds, and community feedback. This holistic approach ensures robust comparisons and insights, supporting both immediate Visualisation and long-term impact assessment1.

Advanced 3D Mapping

Recent upgrades include the integration of 3D models directly onto interactive maps (powered by Mapbox), providing a visually rich context for interpreting data in relation to the urban environment. This feature enhances spatial understanding for both technical experts and the general public.

Live Sensing and Real-Time Updates

The “Live Sense” option allows users to access real-time environmental and health metrics, making the platform not only a retrospective analysis tool but also a live dashboard for ongoing interventions.

Scalability and Future-Proofing

The tool is designed with flexibility in mind, supporting the addition of new indicators, metrics, and data sources as project needs evolve. This ensures its relevance for future urban development initiatives and replication in other cities.



Who Benefits from the Tool?

City Planners and Decision-Makers

Gain actionable insights for sustainable urban development, resource allocation, and policy formulation.

Researchers and Analysts

Access a rich, structured dataset for evaluating the effectiveness of NBS and understanding complex urban dynamics.

Community Stakeholders

Engage with transparent, accessible information about how interventions are improving well-being, social cohesion, and local environments.

Real-World Applications

Tracking Public Health and Well-Being

Monitor metrics such as air quality, emotional well-being, and physical health outcomes before and after NBS implementation.

Evaluating Economic and Social Impact

Assess changes in local economic activity, social engagement, and cultural participation linked to urban interventions.

Biodiversity and Environmental Visualisation

Visualize improvements in biodiversity, green space quality, and ecosystem services at demonstration sites.

User Experience

The EuPOLIS Visualisation Tool is engineered for both expert users and the general public. Its dashboard translates complex datasets into clear, actionable visuals, making sophisticated analytics accessible without sacrificing depth or rigor. Whether you are a municipal engineer, a public health official, or a concerned citizen, the platform offers a tailored entry point to explore how nature-based solutions are reshaping urban life.

Conclusion

The EuPOLIS Visualisation Tool stands at the forefront of urban innovation, bridging the gap between technical complexity and public engagement. By providing a transparent, interactive, and continuously evolving platform, it equips cities to not only measure the success of nature-based interventions but also to foster healthier, more resilient, and inclusive urban communities.

Integrated NBS-Based Urban Planning Methodology for Enhancing Health and Well-Being of Citizens

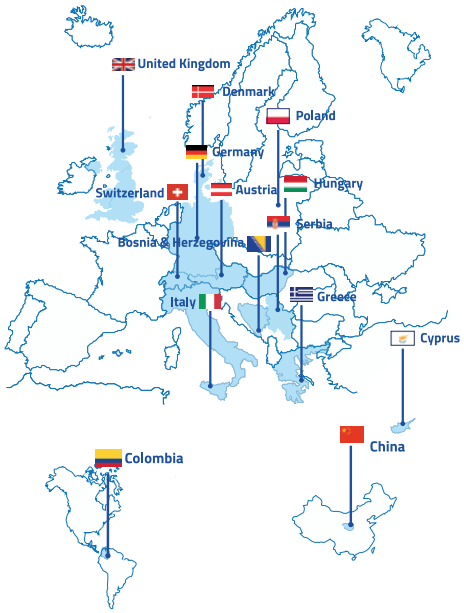


Nature and Citizens Hand in Hand

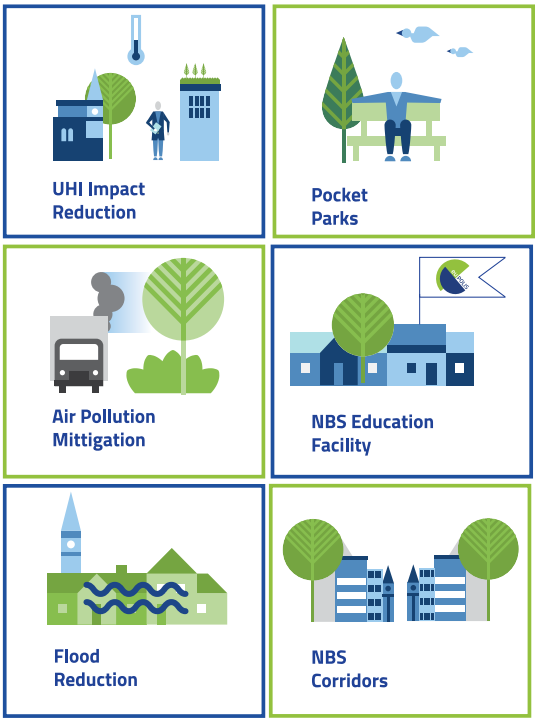
Urban planners and engineers are integrating nature-based solutions (NBS) to address contemporary environmental, social and economic challenges. The EU-funded euPOLIS project deploys natural systems to enhance public health and well-being and create resilient urban ecosystems. The project aims to regenerate and rehabilitate urban ecosystems to create inclusive and accessible urban spaces. The project's solutions are being tested in four cities: Gladsaxe, Lodz, Belgrade, and Piraeus.

28 Partners

13 Countries



Nature-Based Solutions to be implemented



4 Front-Runner Cities to pilot the euPOLIS approach: Gladsaxe, Lodz, Belgrade and Piraeus

5 Follower Cities to implement the replicate and demonstrate corresponding advantages of the euPOLIS innovations: Bogota, Trebinje, Limassol, Palermo and Fengxi New City



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eupolis-project.eu | facebook.com/eupolis2020 | twitter.com/eu_polis | linkedin.com/company/eupolis/

Goal Driven Planning Matrix: A Smart, Inclusive Tool for Healthier, Greener Cities

AUTHOR:
Ranko Božović

The Goal Driven Planning Matrix (GDPM) is a central, innovative tool developed within the EU-funded euPOLIS project, by group of Consortia partners, under the leadership of Ranko Božović. The tool aims to enhance public health and well-being through nature-based solutions in urban environments.

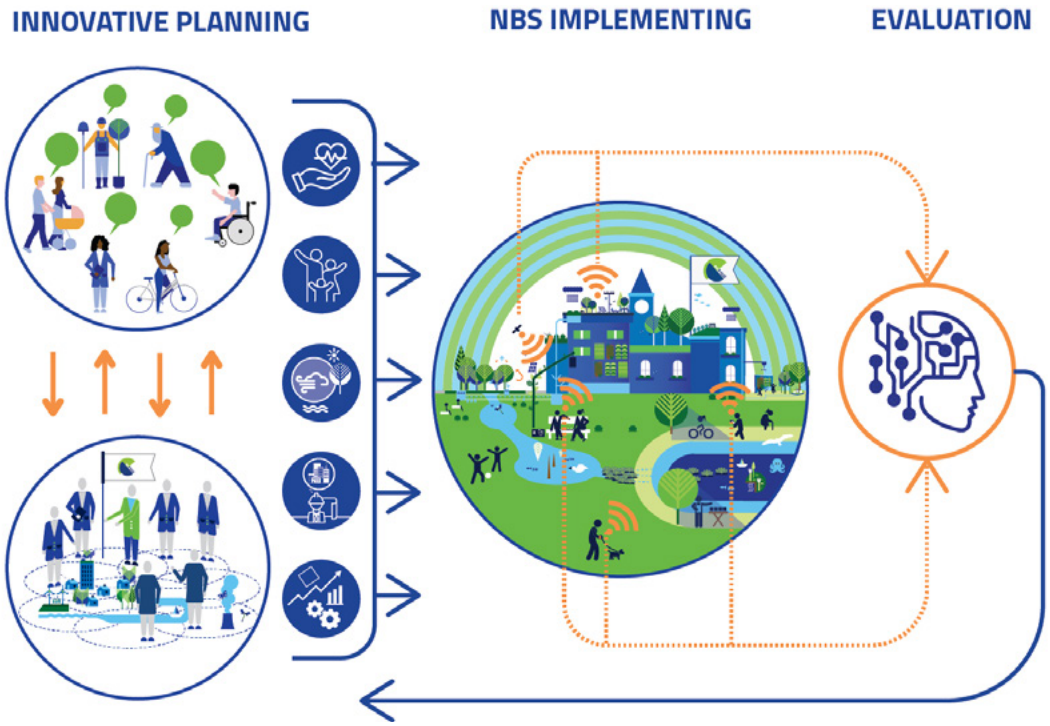
What is the Goal Driven Planning Matrix?
The GDPM is a complex, multilayered strategic planning tool designed to support urban planners, stakeholders, and communities in the detailed design and implementation of interventions that improve health and well-being in cities, but also addresses social cohesion, economy and resilience. It integrates diverse data and perspectives to guide decision-making in a structured, transparent way, ensuring that urban planning is both effective and socially inclusive.

Core Features and Structure

- **Multilayer Approach:**

The GDPM operates on multiple layers, reflecting the complexity of urban environments and the diverse factors influencing health and well-being.

- **The first layer** focuses on a comprehensive set of evaluation indicators covering the full spectrum of public health and well-being.
- **The second layer** integrates these indicators into a livability model aligned with the New European Bauhaus priorities, encompassing seven key factors.
- **The third layer** incorporates social sustainability and economic viability through a Business Activation Matrix, emphasizing long-term sustainability of nature-based interventions.



Integration of Stakeholder Input:
A key strength of the GDPM is its ability to systematically collect and analyze opinions from various stakeholders, including citizens, experts, and authorities. System than activates available interactions to create tangible and non-tangible synergies. This ensures that all voices are considered in the planning process, fostering participatory urban design.

Clear Distinction Between Goals and Means:
The matrix distinctly separates "what should be done" (the goals) from "how it can be done" (the methods, solutions and resources). This clarity aids planners in aligning objectives with feasible actions and available resources.

Gender Related Planning Criteria (GRPC):
The GDPM incorporates specific criteria to address the needs and interests of different population groups, ensuring that urban solutions are equitable and sensitive to gender and social diversity.

How Does GDPM Work in Practice?
- The matrix begins with an analysis of urban synergies at demonstration sites, identifying challenges and potential within the euPOLIS five thematic categories related to health, urban metabolism, social cohesion, and climate resilience.
- It then converts these insights into tailored intervention recommendations, supported by data from other euPOLIS work packages, including monitoring and assessment tools.
- The GDPM supports customized spatial solutions for each case study city, ensuring context-specific and community-rooted planning.

The Role of Technology and Data
- The GDPM leverages open-source, upgradeable data gathering tools, including low-cost gateways and wearable technologies, to collect real-time data on environmental and social parameters.
- Platforms adapted to the euPOLIS scenarios support data-driven decision-making and community engagement.

Why is GDPM Important?
Traditional urban planning often lacks a systemic, integrated approach that balances technical, social, and environmental dimensions. The GDPM fills this gap by providing a optimized design brief for projects through holistic, participatory, and evidence-based framework that enhances urban livability while addressing climate resilience and social inclusion. It is designed to be replicable and adaptable to different urban contexts across Europe and beyond.

Networking Solutions for the Evaluation of Nature- Based Interventions in Cities

AUTHORS:
Anastasios Doulamis, Eftychios Protopapadakis, Emmanuel Sardis, Ioannis Kavouras, Nikolaos Ipiotis, Stelios Kalogridis

In this paper we describe the adopted framework for data collection from multiple sensors, distributed among different cities in EU. Adopted approaches can be used as a basepoint for the creation of IoT networks, scalable and capable of supporting multiple communication protocols. The research focuses on open source, low-budget solutions. Selections were made considering multiple trade-offs in terms of scalability, costs, range, extensibility, and security. The delivered systems have been deployed for evaluating the impact of nature-based solutions, in 4 European cities.

Keywords—
IoT, sensors, urban planning, health-monitoring

I. INTRODUCTION

The regeneration and rehabilitation of urban ecosystems, through nature-based solutions, can be beneficial by improving the physical health and wellbeing of the citizens. Yet, the validation and demonstration of any impact requires the collection of appropriate data. Such a monitoring process implies the utilization of multiple sensors and the deployment of appropriate infrastructure to support the data flows.

This article focuses on the several cellular, wireless and wireline interfaces, to address the requirements in euPOLIS project, covering the networking of the various sensors. Figure1 demonstrates the data flows in the project and the communication between multiple sensor types and the euPOLIS gateway.

Project's needs dictated for a customized gateway solution to communicate through various wireless and wired protocols, with in-situ sensors to perform data collection, pre-processing, compression and transfer of the processed data to

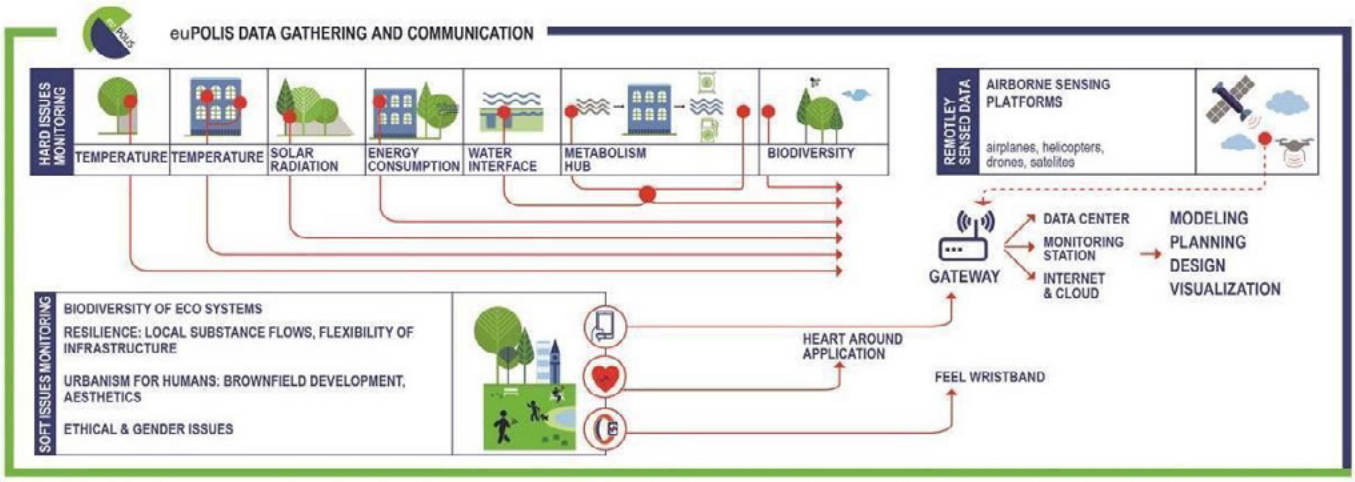


Fig. 1. euPOLIS data gathering, communication and implementations.

the project's Data Management System, in order to reduce network cost, and enhance real-time observations, while being scalable and robust.

The measured parameters were related to water, air and soil quality, and meteorological conditions. The selection for appropriate sensors was limited, at first, by specific factors as the ability to operate through build in batteries, transmission frequency adjustment, ease of installation and maintenance, IP ratings, and utilization of open protocols for data transfer.

The proposed network infrastructure takes into account the need for additional sensors and features that may arise. Also, the new devices and sensors need to be managed securely and the network infrastructure and the gateway will offer expansive capabilities and additional flexibility to accommodate multiple wireless and wired protocols. The developed solution will be able to manage and monitor the health of the sensors and their data loggers, to ensure the data and sensor availability.

The remaining of the paper is structured as follows:
Section 2 provides some indicative work on monitoring scenarios.
Section 3 focuses on the tradeoffs between the various communication technologies. Analytical details are provided in terms of scalability, costs, range, extensibility, and security, among others and provide key insights.
Section 4 concludes this work.

II. RELATED WORK

The progress in digital technologies, such as cloud computing, high-performance and optimized computing systems, along with tailored sensor manufacturing, has enhanced the ability of agencies to gather, store, and analyze data in very high resolution on an unprecedented scale. [1].

In [2] a smart solution for cultural heritage is presented, which involves the use of a distributed smart IoT sensor network to capture environmental data near monuments, complemented by a visualization platform, focusing on discussing

IoT connectivity and power efficiency aspects. The proposed solution was implemented and evaluated at four cultural heritage locations: Rhodes in Greece, Venice in Italy, Granada in Spain, and Tonsberg in Norway.

In [3], an evaluation and review of IoT platforms is conducted using several criteria: communication protocols, data visualization, data processing, external service integration, security, installation procedures, and documentation. More than 30 platforms were assessed, with the FIWARE platform showing the best overall performance across all the specified criteria.

Smart cities offer a compelling vision of the future, where IoT technologies form the foundation for a network of interconnected devices, sensors, and systems. These collect extensive real-time data, enabling well-informed decisions that advantage both the city and its inhabitants [4].

III. COMMUNICATION TECHNOLOGIES

We provide here an analysis of the tradeoffs between the various communication technologies to identify the most appropriate toolsfor the euPOLIS project. The key concept is the establishment of robust communication between the gateways and the installed sensor systems.
The considered technologies take into account several factors such as performance, reliability, usability, robustness, redundancy, cost, latency and reaction time, power efficiency and general efficiency in smart-city environment applications.
The gateway development focused on supporting multiple protocols, such as Modbus and LoRaWAN, and communication technologies such as Rest API and MQTT; which are technologies that are widely used in smart cities and smart parks use cases.
The LoRaWAN protocol has been chosen as the most appropriate wireless communication technology for sensor networks deployed within a smart city concept. The Modbus protocol has been chosen as the most appropriate wired communication technology for wired sensor networks, and a hybrid one that combines Modbus and LoRaWAN protocols.
The proposed gateway can support and integrate additional protocols if needed. The euPOLIS gateway as currently developed, mainly supports the protocols described above to avoid additional costs that may arise and reduces the possible failure points, obtaining expandability, scalability and interoperability.

A. Wired

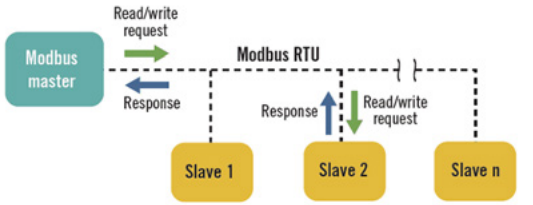
Modbus has become a standard communications protocol in industry and is currently the most commonly available means of connecting industrial electronic devices (interfaces: Serial and Ethernet protocols (ASCII, RTU, TCP/IP) which

are simpler protocols). It is a one-way protocol because the majority of the sensors support Modbus RTU or TCP.

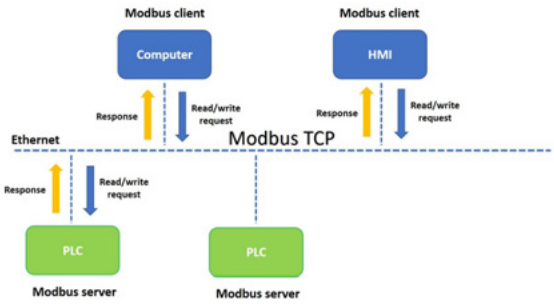
BACnet (interfaces: Ethernet, IP, MS/TP, Zigbee) can be supported by the euPOLIS gateway because the gateway can communicate to the BACnet sensors via local Ethernet network. It is not a primary technology for wired communication because BACnet is used mainly in smart building applications and indoor sensors. The majority of industrial sensors support Modbus protocol. This is the reason why the more reasonable choice is to use a protocol that is easier to find in different sensors. If the city already has or needs to install a BACnet sensor, then euPOLIS gateway can support it via the DataBroker module if it is in the same local network.

The euPOLIS gateway also supports a hybrid solution. It uses a Modbus-to-LoRaWAN module to support sensors that only accept Modbus protocols, e.g. a specialized water quality sensor for measuring pH of water. In such a case, the Modbus- to-LoRaWAN module enables the communication between these sensors to the gateway.

Modbus has many similarities with Bacnet [8,9], but was preferred due to its wider use in existing infrastructures that might need to be integrated during the project implementation. It is suitable for small/medium volume of data (≤ 255 bytes), openly published and royalty-free, easy to deploy and maintain, and it moves raw bits or words without placing restrictions or vendors BACnet offers scalability between cost, performance, and system size. It is adopted by major vendors in North America and other countries. It provides robust inter networking including multiple LAN types, and un-restricted growth and the ability to add new features at anytime



https://community.home-assistant.io/t/multiple-modbus-slaves-identical-sensors-request/491589



https://plcynergy.com/modbus-tcp-protocol/

B. Wireless

Short-range wireless communication protocols such as ZigBee, z-wave, and Wi-Fi, were not chosen; they are designed, mainly, for smart home applications, not for enterprise or smart city applications. The signal strength decay is significant in longer distances, while in terms of scalability the capabilities are lower than those of NB-IoT, SigFox and LoRaWAN.

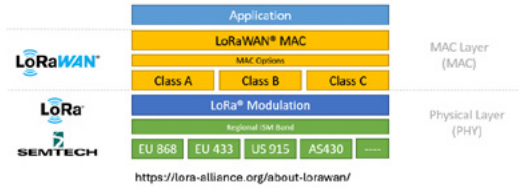
At first, Wi-Fi is a short-range wireless protocol that is difficult to implement, expensive, and unreliable to operate in the euPOLIS case. It would be costly, because many WiFi access points would be required throughout the city. It would be difficult to implement because multiple buildings with Internet access and electrical power would be required to install the access points. Due to network noise from other Wi- Fi and short-range signals, the solution may be unreliable. These wireless networks are primarily used in smart homes or smart offices where the space and environment do not change frequently.

Secondly, both ZigBee and Z-Wave are short-range wireless protocols (<100 meters) and they are classified as mesh networks. In a mesh network, the signal starts from the central hub, similar to a star network. However, devices do not need to communicate directly with the central gateway.

In a mesh network, each device functions as a repeater, relaying the signal to another device. This configuration allows mesh networks to be more flexible, but in case one or more nodes fail, it may affect the whole network and the

signals may be lost, as it is quite difficult to design a network with increased redundancy.
The specific case study involves handling information from sensors located in specific places. As such no mobility sampling schemes [22] were considered.

ZigBee and Z-Wave are primarily used in smart homes or smart buildings use cases. It is very difficult to use them in a smart city environment, due to the mesh technology, as mentioned above. implementing them is more expensive compared to other network topologies, which can make them a less appealing choice. Constructing and managing their topology is challenging and labor-intensive. There is also a high likelihood of redundant connections, contributing to increased costs and the possibility of decreased efficiency [10,11].



https://lora-alliance.org/about-lorawan/



https://qubino.com/z-wave-9-features-that-make-it-awesome/



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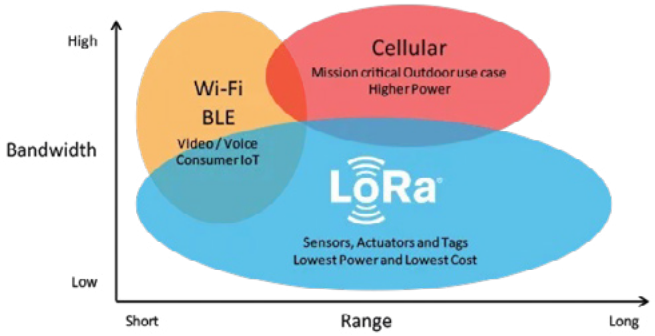


1) The range criterium

Concerning smart city and smart park use cases, the most commonly used solutions are solutions using wireless long- range protocols like Sigfox, NB-IOT-LTE, or LoRaWAN [12,13].

LoRaWAN and Sigfox have similar principles offering low signal strength decay with very low power consumption and very high scalability, but Sigfox is a closed network protocol, meaning that the users have to pay monthly subscriptions / licensing for each sensor, whereas LoRaWAN is an open network protocol, which means that the users may host their own LoRaWAN network free-of-charge.

Furthermore, sensors that use the LoRaWAN communication protocol are more widely available on the market compared to Sigfox, which is very important for the cities that need to implement such solutions, as they have many available options to choose from. Finally, the data exchange rates in LoRaWAN are higher compared to SigFox, and the initial deployment cost of LoRaWAN is lower compared to SigFOX.



2) Subscription costs

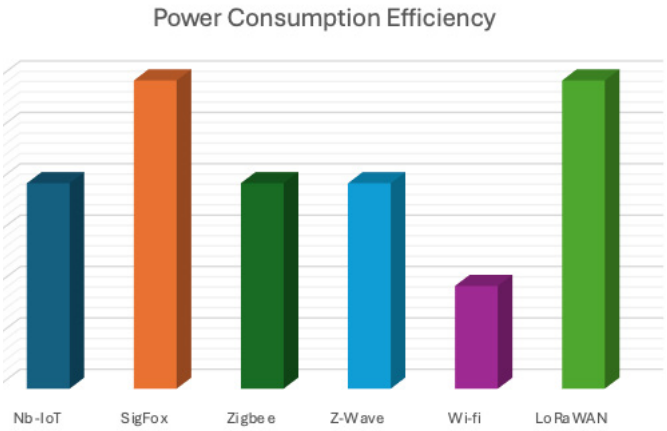
Regarding the comparison between LoRaWAN and NB- IoT-LTE, LoRaWAN is preferred because it is free to use, while NB-IoT-LTE needs licensing/ subscription. When a LoRaWAN network is deployed, a gateway is needed to collect the data from the sensors.

In the euPOLIS case, the gateway has all the necessary components regarding the LoRaWAN protocol. In case there is a need for additional sensors' deployment, these sensors can be easily added to the existing network and collect their measurements without any additional costs.

In NB-IOT-LTE, each sensor requires a monthly cost of around a few euros, which is determined by the provider. LoRaWAN is designed to provide long-range communication between widely ranging sensors and an IoT gateway that may be deployed up to 15-20 km away, using bandwidth ranging from 0.3KBps to 50Kbps, depending on environmental conditions. Moreover, LoRaWAN offers lower signal strength decay compared to NB-IoT-LTE, while it also offers private network support.

NB-IoT or Narrowband IoT, alternatively, is a licensed IoT protocol from the 3GPP standard organization. It operates on a licensed Radio Frequency (RF) spectrum, making it accessible exclusively through a mobile operator's network. The primary objective of the NB-IoT standard is to enhance indoor coverage and accommodate a vast number of low- throughput devices. As a

result, NB-IoT and its network architecture are more effectively optimized for applications like wearables and smart buildings.



3) Consumption and efficiency

Both LoRaWAN and NB-IoT end devices are designed to consume low power, achieved by transitioning end devices to sleep mode when inactive. However, LoRaWAN uses less power than NB-IoT, making it a more practical option for applications requiring minimal maintenance of the end device. Furthermore, LoRaWAN's lower power consumption also renders it a more cost-effective choice compared to NB-IoT. Further details about peak energy consumption and short idle times can be found in [24].

The LoRaWAN protocol offers increased general efficiency because LoRaWAN sensors can send measurements for 10 or even more years without any battery replacement or any other maintenance in case data- transmission frequency is set to 20 minutes intervals. LoRaWAN is a primary choice for companies providing Energy Harvesting powered IoT solutions, which is one of the main reasons why LoRaWAN can be a better fit for Industrial IoT (IIoT) applications. Finally, a LoRaWAN gateway has low power consumption with a maximum of 15 Watts.

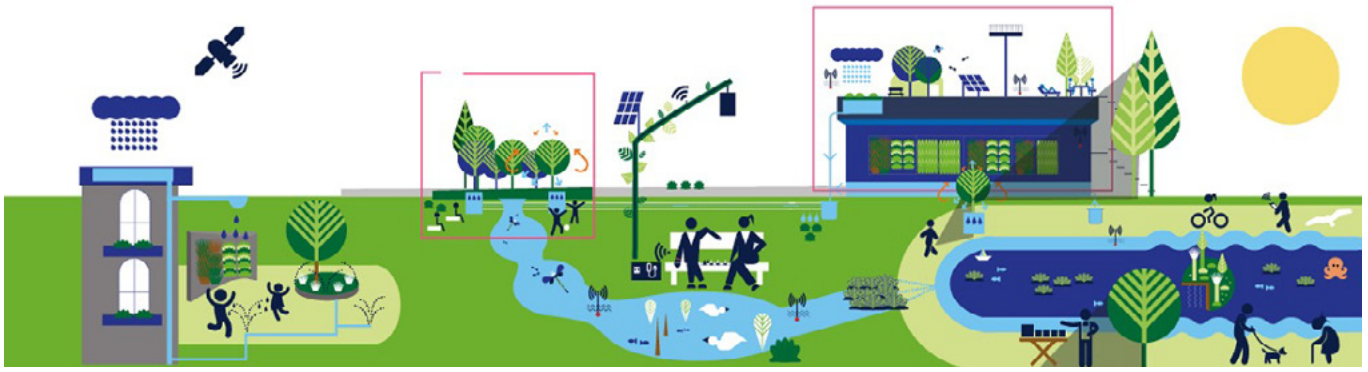
In terms of usability, the sensor size does not depend on the communication protocols they offer, but lower energy consumption significantly increases a LoRaWAN network's usability. Moreover, many industrial deployments are located in remote, hard-to-reach areas. For such companies, it would be ideal if the maintenance of IoT end-devices, such as sensors, could be minimized or eliminated, and this is the reason LoRaWAN is a great fit for smart city use cases.
A solution based on a LoRaWAN network is cheaper in the long term; additional sensors can be added if required, without any additional costs. At this point, planning for a more energy-aware approach, battery-less LoRaWAN communications [21], could become a viable alternative in the near future.

4) Scalability and extensibility

In terms of scalability and extensibility, LoRaWAN is preferred because a LoRaWAN network can integrate a large number of sensors. If a 10-byte payload is utilized, up to approximately 1,500 sensors can be incorporated into a LoRaWAN architecture. Considering that a gateway module has the capacity to simultaneously communicate with and monitor 8 channels, the number of sensors able to communicate on a single channel can increase further.

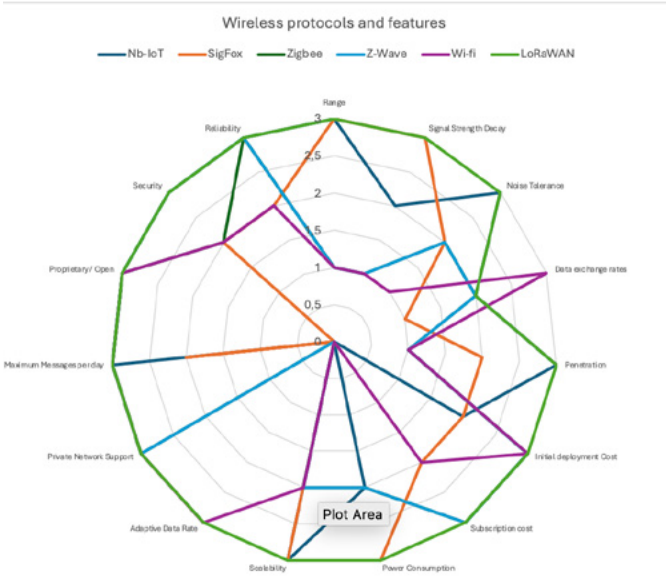
In a real-life scenario, one gateway with 8-channel support can accept at least 120 sensors, also depending on the installation topology and the interference of the area. This number can be even higher in case additional gateways are installed in the area of interest. The performance of the LoRaWAN communication protocol depends on how many channels the gateway supports.

If it supports one channel, the gateway can receive data from one sensor at the same time. If it supports more than one channel, for example, eight channels, the gateway can receive eight sensors at the same time. The channel is the frequency spectrum, for example: 868.1, 868.3, 868.5, 868.7, etc.



If multiple gateways with overlapping coverage are installed in an area of interest, then the network redundancy is increased. In case of a gateway failure, the sensor measurements can be collected from the other gateways with a simple configuration change. Moreover, in case a sensor fails, since this is not a mesh network, it does not affect the rest of the network, increasing the network performance and robustness.

Another advantage of LoRaWAN is security; LoRaWAN has an end-to-end (sensor to application server) security, using AES-128 encryption. Finally, ABI Research estimates that, by 2026, LoRa will be the leading non-cellular LPWA network technology and will account for more than half of all non- cellular LPWA connections. LoRaWAN is very robust against channel interference, while it is hard to detect and intercept. That is another reason why LoRaWAN provides robustness and offers a future-proof solution.



LoRaWAN reliability depends on the number of sensors that are located in the area of interest and is in most cases, very reliable. The reliability of the LoRaWAN protocol depends on the antenna coverage and the sensor's positioning. If a smart city deployment includes multiple LoRaWAN antennas, then the LoRaWAN network becomes even more reliable.

In order to keep the gateway availability as high as possible and increase the network's reliability, certain steps should be taken, e.g. (i) data rate should be, just as with uplink, as efficient as possible. The downlink data rate is based on the uplink data rate, so if efficient uplinks are sent, the network will respond with efficient downlinks. (ii) Downlink messages should be avoided if possible, and in case downlinks are sent, the payload must be kept small. (iii) The confirmation of uplink is often not necessary, so should be avoided [15]. The performance of the LoRaWAN is optimized for use cases dealing with sensor measurements with reduced needs in terms of data sizes, as LoRaWAN offers low-bandwidth.

LoRaWAN has an increased range and coverage compared to solutions using zigbee or a cellular network, making it ideal for smart cities and smart parks use cases, also thanks to its lower power consumption [16,17]. The latency of the LoRaWAN is aligned with the euPOLIS use case requirements, as it focuses mostly on environmental monitoring. Other approaches supporting ultra-low latency and low energy design [23] could be considered if there was more strict requirements on the obtained data time intervals.

The latency depends on the distance between the sensor and the nearest gateway. LoRaWAN is suitable for specific Industrial IoT applications where lower Spreading Factors (SF) are sufficient, achieving an end-to-end delay of less than 400 milliseconds. However, for long-distance transmissions of up to 15 kilometers that necessitate a higher SF, the end-to- end latency could exceed one second but this is still acceptable because the sensors transmit on average every 10 to 20 minutes, meaning that actual real-time transmission is not needed [18].

Response time (or reaction time) is, in general, the time required for a system to react to an external modification, i.e., the time to reach a certain level of such modification. Considering a temperature data logger, the response time of the temperature sensor is the time taken to warn about a temperature change above a given threshold.

The process of heat exchange between the sensor and the measured object takes time to complete, which is why there is always a delay, varying in significance, in detecting the actual temperature compared to what the sensor displays. A response time is necessary for the sensor (considering a temperature sensor, for example) following a thermal "jump" to detect a portion of it. This portion is typically expressed as 90% of the jump, hence it is referred to as T90.

Occasionally, other percentages like 50% are also considered, which is then called T50. Ideally, if a temperature sensor starts at 0°C and is suddenly placed in an environment of 100°C, T90 refers to the duration it takes for the sensor to register 90°C, or 90% of the temperature difference from 0°C to 100°C. The response time (or reaction time) of a sensor is not affected by the adopted communication technology or communication protocol [19].

Summarizing, as analysed in [20], for applications where the critical aspects are the long-range communication, low- power consumption and low-cost, which is the case in euPOLIS that focuses on environmental monitoring without a high-data rate need, LoRaWAN appears to be the best option among these protocols, especially when considering its excellent penetration capabilities through obstacles, the zero long-term costs, and its noice tolerance, beneficial in urban settings where interference is common.

Moreover, Adaptive Data Rate (ADR) is a crucial feature for optimizing communication efficiency and network capacity, particularly in variable environments, making LoRaWAN and Wi-Fi stand out. The ability to establish private networks is significant for security and control, which all protocols except Sigfox offer. For smart city implementations where scalability is key, NB-IoT, SigFox, and LoRaWAN stand out due to their ability to support a large number of devices per cell or gateway.

On the other hand, Wi-Fi, while commonly used, might face scalability issues in dense urban environments, while Zigbee and Z-Wave are more suited for smaller networks due to their lower scalability thresholds. Table I presents the evaluation of protocols. A green colour indicates high performance, blue and red correspond to medium and low, respectively

IV. CONCLUSIONS

This manuscript outlines the work performed under the euPOLIS project, related to networking solutions for the evaluation of nature-based interventions. Following an analysis of various existing communication technologies, both wireless and wired, LoRaWAN and Modbus were selected to be implemented at a first stage to support and collect data from the sensory networks installations in four cities: Belgrade (Serbia), Piraeus (Greece), Gladsaxe (Denmark), Lodz (Poland). The selection criteria took into account available technologies and project's requirements. The market research was performed focusing on low-maintenance and battery- based permanent sensors, to maximize their usability. The main goal was the production of a compact and extensible IoT network of low-cost sensors that can support extensive monitoring environmental parameters in urban areas.

TABLE I. COMPARISON OF WIRELESS PROTOCOLS

Features \ Protocol	NB-IoT	SigFox	Zigbee	Z-Wave	Wi-fi	LoRaWAN
Range						
Signal Strength Decay						
Noise Tolerance						
Data exchange rates						
Penetration						
Initial deployment Cost						
Subscription cost						
Power Consumption						
Scalability						
Adaptive Data Rate						
Private Network Support						
Maximum Messages per day						
Proprietary / Open						
Security						
Reliability						

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