Synthetic AIR.chitecture Lab

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The Synthetic Landscape Lab – UIBK – Innsbruck.

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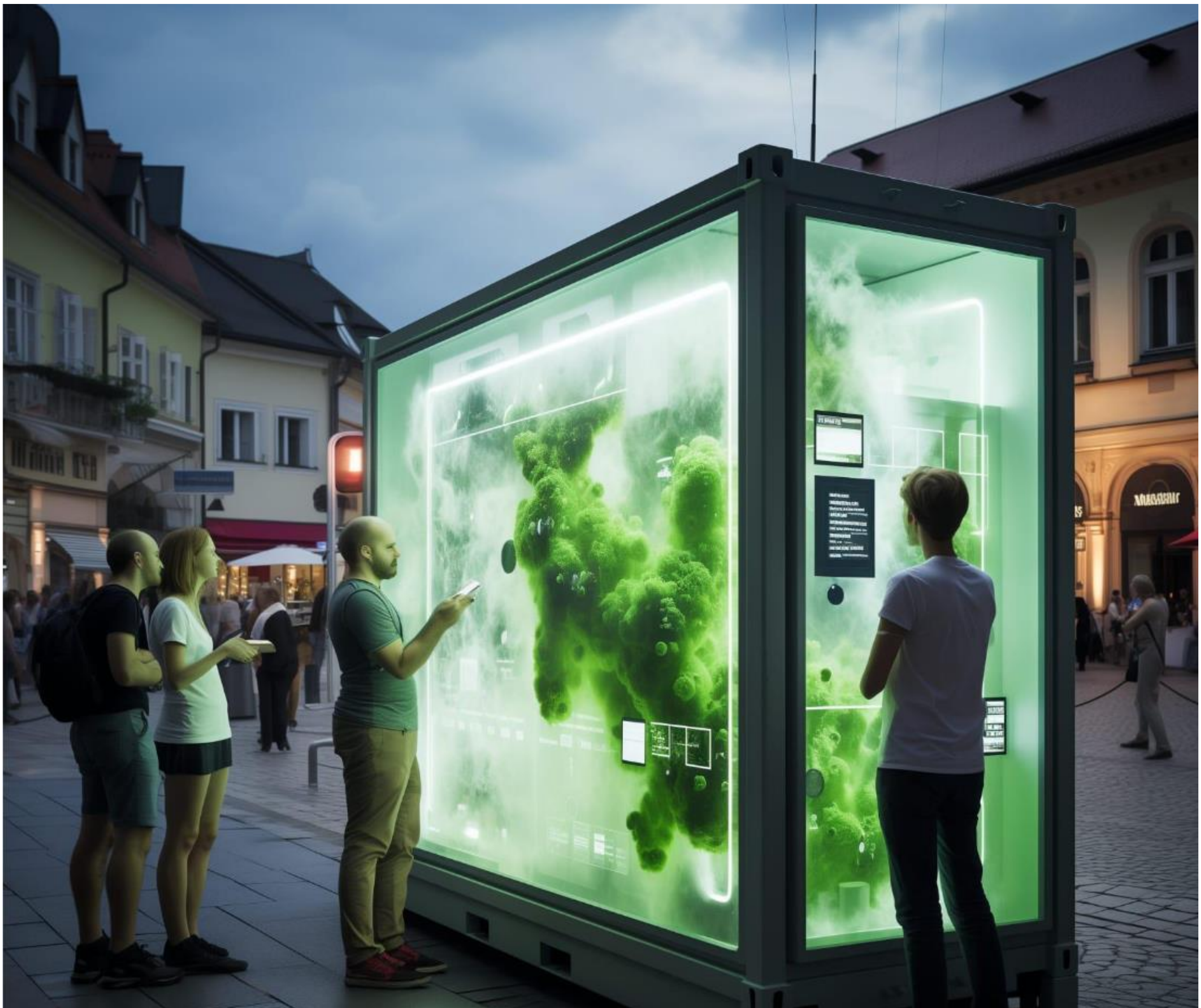

“Climate pollutants are invisible, and many of us have stopped believing in what we cannot see”.

— Naomi Klein

Air pollution is an existential threat with many pollutants pushing up global temperatures as well as posing a danger to health. World Health Organisation estimates that 98% of the global population breathe in polluted air. Research shows that air pollution harms our brain health, including our mental health, and increases our risk of dementia. Air pollution disproportionally affects the most vulnerable in society. Conversations on air pollution tend to centre on children and low-income families but there is mounting evidence that women are amongst the worst affected with air pollution ranking as the fourth leading risk factor for deaths amongst females.

When confronted with the consequences of urban air pollution, the problem can seem too large to tackle individually. In such situations, despair and fear are natural reactions. Air pollution is the invisible protagonist in our lives. Recent extreme events such as the rapid spread of COVID-19 in northern Italy in February 2020, an area known as one of the most polluted regions in Europe, studies suggest that pollution enhanced the clinical severity of COVID 19. Increasing levels of asthma and allergies in children living in densely populated cities are now widely understood to be a result of bad air quality.

The complex composition of these gaseous and particle-bound pollutants makes addressing the problem effectively very difficult. Contemporary technological tools and scientific innovations are ill-equipped to handle these complex dynamic problems, conditions with no clear boundaries or defined borders.

The Synthetic AIR.chitecture Lab offers a transformative approach where biological and medical sciences, material sciences and design come together to create a set of scalable tools, activating local action to inform policy making. This, we believe, has the potential to transform how we plan, inhabit and re-design our cities in relation to the quality of the air we breathe.

The Synthetic AIR.chitecture Lab responds to this global challenge by setting out a clear path of action; from mapping localised air quality, to enabling research into the physical and mental impacts of air quality, to creating innovative visualisation techniques to make pollution visible and creating platforms to engage the public as well as policy making public bodies.

The research project aims to create a biotechnological ‘synthetic air infrastructure’ for urban microclimatic purification, with a focus on establishing a scalable protocol using nature-based technologies, marking an innovative frontier in integrating nature into the built environment. The project will create an important platform to collect, share and analyse air quality.

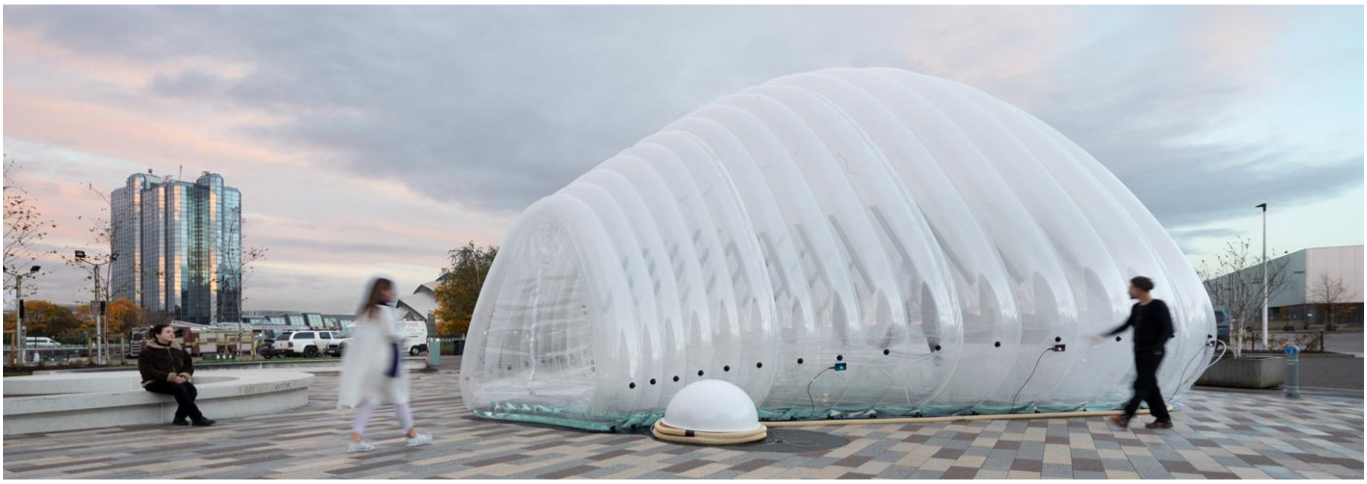

Image: AirBubble Glasgow. Courtesy: ecoLogicStudio

Objectives

The "Synthetic AIR.chitecture Lab" is dedicated to redefining urban living through a series of pilot trials for "synthetic air infrastructure", a toolkit facilitating public administrations, private stakeholders, and communities to actively monitor and improve urban air quality. Departing from the assumption that urban air quality is a nuanced issue requiring more than top-down governance and technological might, the project views it as a complex system of relationships with unique structures that requite specific contextualization. This complexity offers an opportunity for interaction and collective intervention.

By delivering a toolkit, the project enables communities to promptly engage in designing and transforming the air they breathe, both in public spaces and private homes. The ultimate goal is to make the invisible aspects of urban air quality visible, providing individuals with a tangible understanding of its intricate nature. This understanding empowers people to take immediate action, altering their exposure to harmful pollutants in the urban atmosphere, thereby fostering a more active and informed engagement with urban health and wellbeing.

The "Synthetic AIR.chitecture Lab" project pioneers ground-breaking innovations beyond the current state of art. It introduces a novel form of urban planning centred on the ubiquitous distribution of pollutants in the urban air as the main driver for redesigning cities and their processes. We may call this a "white plan", shifting away from traditional urban massing and zoning concepts. The focus is on creating a shared atmosphere that unites stakeholders toward designing a healthy space for collective life and a new sustainable civilisation. This civilisation arises from the definition of new urban practices of "cyber-gardening", embodying a novel interaction of digital and biotechnologies, representing a departure from the limitations of the machine age that shaped contemporary cities during the industrial revolution till modernity.

The project's overarching goal is not merely problem-solving, such as in the objective of eliminating air pollution, but represents a paradigm shift in urban planning, emphasising a holistic approach to air quality and its role in shaping urban environments, fostering a collaborative effort among diverse stakeholders for a healthier, more sustainable future.

List of Objectives

1. Measure and map air quality:
Apply bio-digital sensing and mapping technologies to decode air pollutant components and distribution.
Measurability: High (can be quantified through data collection)
Verifiability: High (data can be compared with established standards).
Feasibility: Feasible with available sensor technology

2.Research the health and psychological impacts of air quality:
Study the effects of air quality on human health and psychology.
Measurability: Moderate (health metrics can be measured).
Verifiability: High (research findings can be reviewed).
Feasibility: Feasible with research expertise.

3.Improve localized air quality:
Implement nature-based air purification and microalgae bio-digital processing to reduce localized pollution.
Measurability: High (pollution reduction can be measured).
Verifiability: High (data can confirm effectiveness).
Feasibility: Feasible based on existing biotechnology.

4.Create innovative visualization techniques:
Develop immersive and interactive visualizations to make the invisible air pollution and air mining visible.
Measurability: High (user engagement metrics can assess impact).
Verifiability: High (perception change can be evaluated).
Feasibility: Feasible with visualization tech.

5.Establish the AIR.chitecture Tool-KIT as an information platform:
Build a platform to collect, share, and analyse air quality data.
Measurability: High (data collection and usage can be tracked).
Verifiability: High (platform utilization can be assessed).
Feasibility: Feasible with mobile application and website

6.Enhance public awareness of air pollution and promote engagement:
Increase public understanding and involvement in addressing air pollution.
Measurability: High (awareness surveys and report data can gauge impact).
Verifiability: Moderate (engagement can be observed).
Feasibility: Feasible with awareness campaigns and workshop

7.Revitalize cultural heritage and landscapes:
Contribute to the preservation and revitalization of cultural assets.
Measurability: High (visitors of cultural heritage can be measured).
Verifiability: High (activities in cultural heritage can be verified).
Feasibility: Feasible with cultural initiatives.

8.Activate the creative industries:
Collaborate with and inspire the local cultural and creative sectors through installations and exhibitions.
Measurability: High (partnerships and projects can be tracked).
Verifiability: Moderate (innovations and collaborations can be confirmed).
Feasibility: Feasible with industry support.

9. Enhance the well-being of urban residents:
Improve overall quality of life by improving air pollution, activating the CCIs, and redesigning the environment.
Measurability: Moderate (well-being survey can be measured).
Verifiability: Moderate (improved well-being can be assessed).
Feasibility: Feasible with urban planning and community engagement.

Methodology

Concept

The central concept of Synthetic AIR.chitecture Lab posits that spaces conventionally deemed voids in our cities are, in reality, dynamic fields. These spaces host a blend of chemicals—biological and artificial in origin—that pervades ubiquitously and is shared among all urban life participants. Within our contemporary cities, we assert that the design and master planning of future urban landscapes should not commence with traditional considerations of massing, zones, and boundaries typical of modern planning. Instead, the starting point should be the omnipresent medium of air that we all breathe daily.

The core assumption of the project is grounded in the idea that air pollution is not solely a problem requiring resolution but presents an opportunity to reconceptualise our engagement in urban realms and reshape the way we inhabit our cities. Given the trajectory of urbanization in our society, it serves as an opportunity to re-evaluate our social interactions within urban areas and redefine the production and consumption processes integral to our existence as an urban civilization.

The fundamental premise of the Synthetic AIR.chitecture Lab asserts that by transforming, re-metabolizing, and purifying the atmosphere we breath, we will foster a healthier and more sustainable urban civilization and at the same time instigate novel circular processes of production in the urban realm. This transformative approach is poised to generate innovative systems of interaction among citizens and other living organisms in the urban realm, introducing a new paradigm that goes beyond our current understanding of green cities or of urban re-greening as it extents its formulation to the urban microbiome. It envisions a living AIR.chitecture, which permeates all spaces we inhabit, and affects our individual physical and psychic equilibrium, as well as the harmony within urban communities.

Bio-digital Design Approach

Through bio-digital design, the project endeavours to seamlessly integrate biophilic design considerations with replicable and scalable fabrication technologies, creating a comprehensive framework for designing, manufacturing, building, and testing sustainable pilot projects.

Biophilic design strategies involves the integration of living microalgae, serving dual roles as biosensors and remediation agents. Acting as biosensors, these microalgae can detect chemicals in the atmosphere, while also functioning as remediation agents capable of absorbing pollutants and transforming them into valuable biomass. This harvested biomass holds versatile applications as biomaterial for new products, superfoods, and a sustainable source of bioenergy.

The project's core initiative revolves around testing a circular metabolic process, which will be implemented in pilot schemes across five diverse European locations. This approach harmonizes the principles of the Atelier's spatial design approach with the scientific lab's methodology. Traditionally, the Atelier design approach focuses on spatial, cultural and material practices, often operating in the public eye, while the Lab approach, intertwined with innovation, science, technology, and industry, often functions behind closed doors.

The ultimate aim of the project is to create unique pilot initiatives by synergizing these two sensibilities—spatial design and scientific innovation. This collaboration seeks to develop a pioneering bio-digital design approach that leverages the strengths of both disciplines. In doing so, the project aspires to contribute ground-breaking solutions to the multifaceted challenges posed by urban air quality, positioning bio-digital design as a transformative force in shaping the future of urban environments.

Trans-disciplinarity: the Atelier and the Lab Models

The project relies on a unique collaboration across multiple disciplines, making it inherently interdisciplinary. Design, digital technologies, digital cultures, medical science, social sciences, biology, and atmospheric sciences converge to create a distinctive toolkit aimed at addressing urban air pollution as a socio-cultural opportunity as well as an environmental design challenge. This interdisciplinary approach is crucial as it overcomes methodological challenges, particularly in establishing direct interactions between scientific innovation and urban design approaches.

The research project focuses on four main urban air quality modules: mapping, sensing, processing and visualizing, each representing methodological steps toward creating a complete Synthetic AIR.chitecture Unit, a tool kit for the comprehensive design and engineering of the urban atmosphere we breathe every day. In the mapping module, the collaboration between technological sciences and urban design is crucial for engaging citizens in citizen science projects. This involves creating tools enabling citizens to become scientists, scanning the city for pollutant concentrations and reporting sources, resulting in high resolution urban air quality maps. These maps will be visualized through digital design technologies to raise awareness of both opportunities and challenges, to enable a more granular mapping and visualization of the urban atmosphere.

In the sensing module, the medical sciences, biotechnology and digital design innovation converge differently. Investigation into human response to breathing polluted air encompasses impacts on lungs, respiratory systems, cognitive abilities, and stress levels. The exploration extends to defining emotional granularity in response to urban atmosphere challenges. Simultaneously, scientific approaches measure responses through galvanic skin response (GSR) measurements and interactions with living microalgae, creating a symbiosis between humans and the city's microbiome.

The processing module applies systems integrating microalgae cultivation into urban spaces and architectural structures. The innovative design of a new photobioreactor will allow algae to thrive in areas where traditional gardening methods are impractical due to limited space and challenging microclimates. Simply put, we intend to establish air-purifying units through urban biotechnology, collectively engaging in transforming and gardening the urban atmosphere.

Lastly, the visualization module will merge visual art and big data analysis to present all the measurements and data collected through the analytical modules in a visually immersive format. This initiative aims to allow urban stakeholders to appreciate the unique and complex phenomenon of urban air quality, fostering a deeper understanding of its intricacies. In essence, the project seeks to blend the methodologies of the urban Atelier with the protocols of the Lab. This approach harnesses the potential of collective design methodologies informed by the bio-digital augmentation of scientific innovation. The goal is not only to measure the extent of the urban air pollution problem but also to leverage the capabilities of microorganisms and digital technologies in synthesizing a healthy urban microclimate for the cities we inhabit.

Open science: Cyber Gardening the city

The project introduces an innovative approach to open science, coined as "cyber-gardening the city." Essentially, each pilot scheme implemented in the five Europeans partner cities becomes an open-air laboratory.

On one side, these pilots are strategically located in the public realm, ensuring accessibility to citizens at different times and seasons. Once accessed, each pilot project goes beyond communicating project findings; it actively involves citizens in the experimentation process. This involvement takes shape through citizen science approaches, such as the proposed distributed mapping project in the Macedonian capital of Skopje, and direct experimentation in cities like Bratislava and Lviv. Here, the sensing and re-metabolization of air pollutants integrates direct engagement through workshops and studios.

Citizens not only acquire new practical skills in cyber-gardening, respiration, cultivation, monitoring, and biomaterial production but also are given the opportunity to engage repeatedly with these practices on daily basis. In Bratislava, this engagement will manifest in the central public market alongside other urban agricultural activities, while in Lviv, it will be directly experienced in an immersive sculptural sensing pavilion located in the city center.

Additionally, in Amsterdam the project will inhabit the unique Microbe Museum, the only one of its kind in the world, to expand on the impactful possibilities of the visualization process, making the urban microbiome visible and accessible to citizens of all ages. This approach transforms the visualization of the urban atmosphere into a playful educational activity. We have termed it "Cyber-Gardening the City," a notion that extends beyond literal urban cultivation, such as tending to an urban allotment, to a methodological perspective that redefines urban planning.

In this approach, stakeholders at all levels are not involved in traditional top-down decision-making but rather participate in an interactive “cultivation”, intended here as an act of culturalisation, of the urban realm, through the medium of its atmosphere. This process entails translating insights gained through direct observation, scientific measurement, and interaction into actionable practices for nurturing and caring for the urban realm. The outcome is a transformative improvement of the urban atmosphere, influencing our perception, feelings, and understanding of the public space. Similar to tending a garden, the beautification of the urban realm arises from direct interactions with the living systems that shape its structure.

In essence, the model we wish to develop for urban air quality design becomes the medium for envisioning and defining a sustainable and vibrant city of the future. This approach emphasizes a holistic and interactive approach to urban development, incorporating living systems and fostering a deeper connection between citizens and their surrounding natural environment.

Inter-scalarity: **Inter dependence of scales**

This project proposal is inherently multidisciplinary, or transdisciplinary, or perhaps better described as interdisciplinary. It is engaging with multiple scales, ranging from the microscopic scales of algal cells, lung structures, and air pollutant particles, up to the bodily scale, the lungs, and organs, and further to the scales of architecture, the spaces we inhabit, and extending to the scale of infrastructure—the city, the territory, and the overall atmosphere or microclimate of our cities.

This journey across scales allows a deeper comprehension of how these are interconnected and interdependent. For instance, a measurement taken at the microscopic scale of PM10 particles will directly reflect in terms of urban infrastructure and the sources generating these emissions. Conversely, the bubble of clean air created through the filtration process facilitated by living single cell microalgae colonies is inhabited by our bodies, and we can feel the effects directly on ourselves, measurable through Galvanic Skin Response (GSR) sensors.

This interdependence of scales will enable us to traverse up and down across them, appreciating the underpinning correlations. Practical and immediately actionable solutions to the urban air quality problem will become apparent as a series of actions and practices involving every stakeholder in the city, transforming everyone from a passive breather to an active "designer" of the air we all share.

Mapping

The mapping module plays a crucial role in collecting and analyzing data related to urban atmospheres. Through various sensing technologies, it measures unique characteristics such as air composition and identifies territorial-scale pollutant sources. The information extracted serves as valuable input for other modules.

Technology

Local partner: city of Skopje air pollutant sensors and tracking software.
More than 200 sensors have already been installed on the territory of the City of Skopje. The pointed number is continuously growing, and additional new ones are being installed. Currently, installed sensors register two parameters of the ambient air, namely PM2 particles and PM10 particles. The sensing data could be accessed on the mobile phone app Air Quality & Pollen - AirCare. Besides, the City of Skopje has been engaged with the research of air pollution management and reporting for several years.

Scientific expert: measurement and footprint of urban carbon and air pollution.
The Department of Atmospheric and Cryospheric Sciences (ACINN), University of Innsbruck.
The mapping module employs mobile observations of ultrafine particles (UFPs) and Lung Deposition Surface Area (LDSA) as proxies for urban air pollutants, enhancing our understanding of their sources. It utilizes advanced technology to construct a two-dimensional footprint of urban carbon and air pollution in near real-time. Real-time UFP measurements visualize and quantify urban air pollution, shedding light on its distribution. These measurements, combined with continuous observations at the Innsbruck Atmospheric Observatory (IAO) and merged with urban activity and energy consumption data, form an information system that advises the public and decision-makers on health risks related to air pollutants and carbon emissions.

This holistic approach increases awareness and understanding of pollutant sources and their dynamics, aligning with the Synthetic AIR.chitecture Lab's goals. Simultaneously, addressing the challenge of demanding computational resources for real-time visualization, the module adopts a parametric approach inspired by Kljun et al (2015). While this approach has limitations in urban areas due to specific surface assumptions, the mapping module aims to adapt and further develop it for urban surfaces within the Synthetic AIR.chitecture Lab, enhancing our ability to visualize and understand urban carbon and air pollution sources and dynamics.

Design Integration

The Skopje Super.Cloud. AirMeasuring and AirReporting citizens science trial run in Skopje.
The Skopje Super.Cloud pilot project is an hyper-body of data, molecules and algorithms defined by a custom designed collection of mapping protocols (con-putation as collective thinking) spanning 16 orders of magnitude and involving the direct participation of the citizens of the city of Skopye.

Scale 2.5 x 10^{-9} meters - Nano scale
Bacteria and Viruses inhabit some of the larger PM10 particles thus establishing a ecosystems unique to the Super.Cloud. The finest PM2.5 provide a range of minerals and metallic molecules. They can infiltrate any environment in Skopje and the respiratory system of its citizens.

Scale 1.7 meter - Human scale
Particulate matter, a fraction of the size of human hairs penetrates deep into the lungs of the inhabitants of Skopje reaching their blood vessels and causing DNA transcription errors. Thus, Super.Cloud simultaneously inhabits the past, present and future of Skopje. As this future becomes more apparent, Skopje's inhabitants are now mobilizing. Armed with pollution sensors they feed Super.Cloud's expanding data stack.

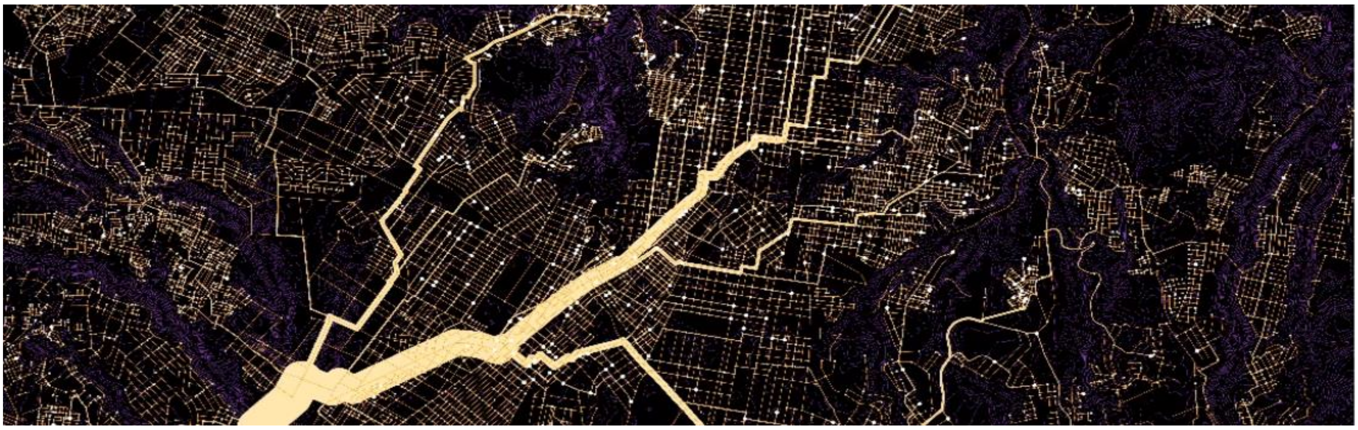

Image: DeepGreeen, Guatemala City. Courtesy: ecoLogicStudio and UNDP.

Scale 1 x 10^2 meters - architectural scale
A variety of monitored as well as illegal emission sources from private homes, factories and vehicles provide constant feeding of organic and inorganic particles, renewing Super.Cloud's morphing body. At this scale, reporting it is a form of activism, which carries unique social and health risks. These risks are mitigated with appropriate mapping technology, in turn boosting reporting’s efficacy.

Scale 3 x 10^4 meters - urban scale
Super.Cloud adapts to Skopje's urban morphology, sensing its granularity, density and volumetric heterogeneity. As the prevailing winds blow through the urban massing, Super.Cloud is seen retreating from areas of acceleration and turbulence temporarily finding refuge in sheltered zones. The growing amount of data in Super.Cloud's digital stack begins to form images of simulated urban scenarios, in turn feeding the citizens' collective imagination, collective agency and their active participation in Super.Cloud's future evolution.

Scale 1 x 10^5 meters - territorial scale
From the top of the surrounding hills Super.Cloud appears as if gently resting within the topographic basin of Skopje. From here it can be admired and photographed in all its glorious and apparently innocuous beauty.
The main outcome of the Super.Cloud pilot will be incorporated in the final tool-KIT as a **new typology of collective air pollution mapping and reporting application** to the adopted by cities, combining citizens science with remote sensing and digital design technologies.

Social Integration

Air Reporting in the city of Skopje. The introduction of a citizen reporting app within the mapping module promotes social integration by enabling individuals to record and report instances of air pollution. This active engagement fosters a more inclusive and informed community, as citizens become key stakeholders in urban air quality management. By empowering individuals to participate in monitoring and reporting, the initiative increases awareness of air quality issues and promotes collective responsibility. Additionally, it enhances policy transparency by providing real-time, location-specific data to policymakers and urban planners, enabling evidence-based decision-making and policy adjustments in response to citizen feedback.

Sensing

Sensing explores the sensitivity of living systems, emphasizing human responses to urban air, encompassing physical impacts, respiratory reactions, and mental stress. This module also considers biosensing, studying the visible and biochemical responses of organisms like microalgae to the urban atmosphere's chemical composition. It increases the ability of citizens and other urban stakeholders to perceive the composition of air locally and extract information that feeds into the other modules.

Technology

Micro algae as biosensors. Department of Botany, University of Innsbruck.
The sensing module employs cutting-edge technology to monitor and interpret algae's responses to environmental conditions, particularly air pollution. It utilizes a Pulse-Amplitude-Modulation (PAM) chlorophyll fluorimeter with a fibre-optic probe to measure the quantum yield of photosystem II in real-time. This allows for rapid and repeatable assessment of algae's physiological status and health, providing early indicators of stress. The module employs Algae Online Monitoring systems to continuously monitor the algal culture. These systems differentiate between light-induced chlorophyll fluorescence quenching and stress-related signals, enhancing our understanding of the culture's health.
The module also explores an alternative sensing method based on natural colour changes in algae due to carotenoid production. Specific carotenoids respond to stress by inducing distinct colours, and pigment bleaching can occur under severe stress conditions. The module utilizes advanced analytical techniques like high-performance liquid chromatography (HPLC) and mass spectrometry coupled with liquid chromatography (LC-MS/MS) to quantify pigment compositions and identify carotenoid breakdown products. Moreover, the module investigates stress-related transcriptional responses through mRNA sequencing (RNA Seq.) of model green algae and cyanobacteria. This multi-faceted approach enhances our understanding of how algae can serve as environmental sensors, particularly in urban settings with air pollution.

Psychological and Physical Impact on Human. Danylo halytsky lviv national medical university.
The study, titled "Analysis of the state of health within the Air Studio Art Pavilion" aims to assess health impacts over one year with more than 1000 participants. Selection criteria include adults aged 18-65 who consent to participate, with flexibility for withdrawal. It categorizes patients by sex, duration in the Pavilion, season, and time of day. It includes interviews on the day after exposure. Statistical methods encompass descriptive statistics, t-tests, and ANOVA for quantitative data collected via Galvanic Skin Response sensors and Pearson's chi-square for categorical, adjusted for multiple comparisons. The study protocol includes pre- and post-exposure assessments, plus an additional follow-up, using core health metrics, quality of life, and mental health screenings, ensuring comprehensive health evaluation.

Design Integration

AIR.chitecture Sensing Module: the Air Studio Art Pavilion in Lviv
Upon entering the Air Studio Art Pavilion, visitors will experience the sensation of floating within a bubble of clean air. A delicate TPU membrane, filled with a mix of 90% air, 9% water, and photosynthetic bio-sensitive microalgae organisms, will wrap this bubble. The immediate and positive effects of this purified air bubble will become apparent to all sensitive visitors while less perceptive ones will have the opportunity to explore their reaction in more depth. All visitors will engage in collaborative sessions within small groups, focusing on conscious breathing within this purified air bubble. Visitors with a more deep interest will be connected to GSR sensors that measure real-time physical and emotional reactions to this unique environment and will participate in the study conducted by a local team of experts from the Medical University in Lviv.

Image :

Artist’s impression of the Air Studio Art Pavillon in Lviv.

The Air Studio Art Pavilion aims to create an "emotional granularity map" by collecting data on visitors' reactions and feelings to the urban atmosphere. This map, generated from feedback provided by visitors over time, offers insight into the physical and emotional impact of transitioning from polluted to purified air. By exploring emotions, the pavilion enhances understanding of therapeutic practices for coping with city pollution and stress. It fosters collective awareness and offers a new typology of urban restorative spaces. This new typology frames architecture as an "extended cognitive system" through which individuals learn, upgrade, and redesign their inner circuitry, manifesting in actions and relationships with the surrounding environment.

Visitors will engage with biometric sensors, particularly Galvanic Skin Response (GSR) sensors, to monitor interactions and emotional responses to photosynthetic algal bio-sensors. Through breathing techniques and meditation, visitors connect with their inner space, gaining insights into perception and cognitive abilities. Sensing technologies will thus support human advancement toward emotional intelligence. By recognizing the variability of emotional responses and utilizing language as a tool to articulate these differences, visitors cultivate a deeper understanding of emotions. Despite the absence of consistent, specific fingerprints of emotions, the exploration of emotional granularity proposed here allows for a richer vocabulary to express feelings, ultimately fostering a more profound connection with urban environments and human experiences.

Social Integration

The SENSING module's unique focus on studying human responses to urban air quality and bio-sensing, particularly the visible and biochemical reactions of organisms like microalgae to the environment's chemical composition, finds relevance in the context of the Lviv current revitalization project. By engaging with Lviv’s historical center, a bustling urban destination hosting diverse activities and events, the Air Studio Art Pavilion in Lviv pilot project actively engages citizens and visitors, providing a new platform for them to experience and interact with the urban environment. This aligns with the SENSING module's aim of increasing the ability of urban stakeholders to perceive and understand local air composition. As the city center of partner city Lviv hosts numerous events, including markets, festivals, and concerts, the Air Studio Art Pavillon becomes a space where a new program and related urban practice can take place, where people can physically sense the urban atmosphere, potentially influencing their respiratory reactions and overall well-being. This aligns with the module's objectives of studying and enhancing urban environments.

Besides, examining how improved air quality impacts social cohesion and individual well-being within communities by assessing health outcomes in a controlled environment, the study might contribute to a broader understanding of how environmental factors influence social interactions, participation in community life, and overall quality of life.

Processing

This module processes the urban atmosphere in terms of its bio-chemical composition resulting in air purification and the conversion of pollutants into valuable biomass. This module delves into remediating the urban atmosphere through designed interactions between atmospheric particles and living organisms. It highlights the socially significant role of photosynthetic processes and the advanced integration of biotechnology in urban agricultural practices.

Technology

Screening and Culture of Micro algae: Department of Botany, University of Innsbruck**.**
It is well known that city trees help cleanse the air by directly removing pollutants. Lesser appreciated is the potential for algae to fulfil similar functions within the urban landscape. In this part, stress tolerance of multiple photosynthetic microorganisms will be investigated to help select those that could be most efficient at decontaminating polluted air. Species will include those we currently have successful experience within urban bioreactor installations (e.g. cyanobacteria such as Spirulina, the green alga Chlorella and Chlamydomonas, and the red alga Porphyridium), but also model halophytes, such as Nannochloropsis and Dunaliella with recognized stress tolerance. Strains will be sourced from our own algae collection (ASIB), University of Innsbruck, and the Culture Collection of Algae (SAG), University of Göttingen, and screened for their tolerance to hazardous air pollutants found in urban environments, including ozone, volatile organic compounds and smoke. In summary, our results will help determine which photosynthetic microorganisms are most suitable for urban environments of contrasting pollution.

Microalgae powered bio-polymerization for the compostable 3D printing materials. PANARA
During the air purification process, algae powder will be created as a by-product. This powder is not waste but can be used as a component in polymer blends to create bioplastics with unique properties. The know-how and IP (Panara is the owner of patent and patent licence for bioplastic blends) of the Panara company will contribute to the creation of bioplastic containing the algae powder. This bioplastic will contain polymers only from renewable sources, will be biodegradable and suitable for 3D printing. Algae powder can affect the colour of bioplastic, mechanical, physical and rheological properties. It can also contribute to lowering the price and improving competitiveness. Panara has sufficient technical and personnel capacities to ensure preparation, processing and testing algae contained bioplastic. The following facilities and instrumentation will be used:

- Preparation of suitable polymer blends - laboratory scale - co-rotating laboratory twin-screw extruder Lab Tech 16-40 LTE 16-40 (screws diameter 16 mm, L:D 40);
- Preparation of suitable polymer blends - pilot scale - co-rotating twin-screw extruder LabTech LTE 26-40 (screws diameter 26 mm, L:D 40) situated in the CEPOMA centre in Nitra;
- Evaluation of rheological properties of mixed polymeric materials and virgin polymers - Polymer processing analyser RPA 2000, high-pressure two-chambered capillary rheometer Göttfert RG 20; high-pressure three-chamber capillary rheometer Göttfert RG 75 for measurement and evaluation of all rheological characteristics (pVT diagrams, all types of corrections, measurement of melt ductility, die swelling, thermal conductivity and melt density of polymers and their temperature dependencies)
- Preparation of monofilaments - laboratory scale - single-screw extruder Brabender with screw diameter 19mm and L:D 25
- Preparation of monofilaments - pilot scale - single-screw extruder Labtech LE 25-30 with calibration, screw diameter 25 mm and L:D 30
- Evaluation of physical-mechanical and dynamic-mechanical properties - universal testing device Zwick / Roell Z 2.5; dynamic-thermal analysis (DMTA) DMA1 analyser from Mettler Toledo usable for measuring mechanical and viscoelastic properties of polymers depending on temperature, time and frequency. The measurement uses cyclic stress of polymers, which allows to evaluate the elastic and loss modulus.

Design Integration

Air.chitecture Processing Module: the Bio.design Atelier in Bratislava Old Market.

Upon entering the market hall visitors will encounter vertical planting systems and bioreactors housing algae cultivation. The glass tubes within these reactors contain living cultures of photosynthetic microalgae. These microalgae play a crucial role in absorbing carbon dioxide and pollutants from the air, converting them into biomass. The entire process is powered by solar energy, creating a connection between the Biosphere, which contains nutrients, and the Urbansphere, where carbon dioxide and air pollutants from cities are present.

The Atelier will employ various species of microalgae for bio-digital design, including Cyanidium, Spirulina, Chlorella, and Porphyridium. The biomass harvesting process results in algae powder, a by-product extracted through a station with flasks and filtering surfaces. Living cells, only visible through a microscope, will continue to grow inside glass reactors, fuelled by the photosynthetic process. Algae cells consume pollutants as nutrients, allowing them to reproduce and multiply until harvested.

The harvested biomass serves as a foundation for creating biodegradable alternatives to plastics, known as biopolymers. A dedicated area in the Atelier will engage visitors in the synthesis of these biopolymers and their transformation into 3D-printable pellets. The 3D printing process, highlighted in an adjacent exhibition area, emphasizes the efficient use of biodegradable materials, resulting in products with significant mechanical resistance and minimal waste. The atelier will feature the production of small prototypes such as biodegradable stools, created using 3D printing machines with varying concentrations of algae biomass, showcasing different mechanical and aesthetic properties.

In conclusion, the pilot project will bring to the centre of Bratislava a new typology that expands the opportunity a market place can offer in generating new circular economies of air-purification, cultivation, digital craftsmanship and and biomaterial production. Visiting the Bio.design Atelier will unveil a new emerging space where taking care of our health will coincide with taking care of the biosphere we are part of. The main outcome will be incorporated in the tool-KIT as a new typology of urban productive spaces to the build in the public realm of all cities, combining bio and digital technologies into new form of advanced urban agriculture and biophilic design.

Social Integration

Combining the Bio.design Atelier and the Old Market Hall of Bratislava offers an exciting opportunity for enhanced social interaction and urban revitalization. The processing module's immersive and hands-on approach, which addresses air pollution and environmental awareness through advanced urban agriculture and integration of biotechnology in the urban ream, can serve as a catalyst for community engagement within the Old Market Hall and the development of novel circular production processes and related practices.

This integration not only improves air quality but also provides a platform for educational programs, workshops, and public discussions on environmental issues. Collaborating with the Old Market Hall, with its diverse cultural events and local food markets, turns the pilot projects into a community hub, fostering a sense of environmental responsibility and collective action. Together, these initiatives encourage social interaction, empower citizens to take an active role in environmental stewardship, and contribute to the creation of new practices, skills and ultimately business opportunities towards a vibrant, sustainable local business ecosystem.

Visualising

The Visualising module showcases digital and material applications to present results from remediation, sensing, and mapping processes, aiming to provide stakeholders with a profound understanding of the urban atmosphere's complex nature. This module makes the invisible visible, engaging both civic administrators and urban dwellers in designing a healthy urban atmosphere.

Technology

Micro algae pigment for visualising: Department of Botany, University of Innsbruck.
Micro algae were the first pioneers to conquer land and changed our planet substantially. Living on land required new mechanisms to tolerate various stresses such as high irradiation and desiccation. Today, urban environments bring more atmospheric stresses in the form of air pollution that we all have to face. Here, we bring into focus the beautiful life forms of algae used within the pilot projects. Plexiglas light-microscopy images of the algae will be displayed to highlight the fascinating macromolecular strategies that algae use to tolerate stress.

We will also take advantage of the desiccation tolerance of various algal species to portray, in-vivo, how stress impacts pigment compositions in the dry state. Algae will be transferred onto cellulose-acetate filters for drying, and exposed to the natural atmospheric condition at the installation to enable the public to see how their environment is effecting changes in pigment compositions. The local environment will be monitored in terms of light intensity, relative humidity and temperature.

Computational modelling and VFX animation techniques: Synthetic Landscape Lab, University of Innsbruck
The Visualisation module employs cutting-edge computational modelling and VFX animation techniques to interpret complex datasets into immersive, intuitive experiences. Within this pilot, researchers will work with the datasets available within the collections and archives of ARTIS-Micropia, as well as a network of distributed sensors in the Botanical Park of Amsterdam (sensing and bio-sensing), to feedback into the visualisation apparatus that is installed inside the Museum.

The collected information will be interpreted through computational and generative modelling, rendering, animation and video-editing techniques, as well as the production of physical mock-ups with projection mapping techniques, attempting to construct dynamic visual narratives aimed at providing intuitive insights into the Microsphere, focusing specifically on organic architectures that deal with air and its processing by biological organisms. The scientific description of the datasets will be coupled with visual languages aimed at delivering intuitive, pre-logical forms of communication that are able to engage a general audience.

Design Integration

AIR.chitecture Visualizing Module: the Air Control Room at ARTIS-Micropia museum, Amsterdam.
The Visualisation module will be designed by taking into consideration the features of both the interior space of ARTIS-Micropia, and the outdoor landscape of the Botanical Park of Amsterdam. The indoor installation will be structured around a spatial design, of which it can be seen as an augmentation, by combining the design of the physical space and props with multi-screen and projection mapping technology.

The distribution of the biosensors in the Botanical Park will be designed as a light infrastructure, that is integrated in the existing landscape. The shape and visual appearance of the sensors will be designed to merge into the natural surroundings, while catching the attention and curiosity of the visitors, allowing them to better understand the indoor installation and the physical substrate that is supporting it.

Image:

Artist's impression of the Air Control Room at ARTIS-Micropia museum, Amsterdam.

Upon entering the Air Control Room at ARTIS-Micropia Museum, the visitors will be surrounded by large scale projections, as well as an exhibition display that includes materials from the Museum collection and a few large-scale 3d printed models. Some of the projections will show dynamic visualizations of atmospheric data collected in the Botanical Park of Amsterdam, aimed at describing features of the air as it changes over time, while others will describe the microscopic organic architectures that deal with air and its processing by biological organisms, relying on scientific datasets as those in the collection of the Museum.

The experience continues outdoor in the Botanical Park, where a network of biosensors is distributed over its landscape. The visitors are able to explore their design, and understand the integration of natural and technological, physical and digital elements that is characteristic of the Visualization module.

Social Integration

ARTIS-Micropia, the world's only microbial museum, provides a unique setting to the Visualising pilot project enhancing public engagement and understanding of the urban atmosphere's complex nature, particularly regarding microorganisms. Micropia's expertise in showcasing the invisible world of microbes aligns well with the Visualising module's goal of making the invisible visible in the context of urban air purification.

ARTIS-Micropia contributes its knowledge and resources to Visualising to create compelling digital and material presentations that focus on the role of microorganisms in urban air quality and their impact on human's respiratory system and immune system. This is of particular value especially in the post pandemic age when real impact is often confused by misinformation and paranoia. Recent research showed that specifically particulate matter and Cd showed the most adverse effect on COVID-19 prevalence, while particulate matter and as showed the largest dangerous impact on excess mortality rate. This module contributes to educating the public and stakeholders about the challenges and opportunities to be found in the relationship of microbes with air quality and highlights their significance in addressing environmental challenges.

Through interactive exhibits, visualizations, and educational programs, this partnership can bridge the gap between open lab science and dissemination. It can engage civic administrators, urban dwellers, students, and policymakers in the process of understanding and appreciating the vital role microorganisms play in improving air quality.

SynthAir ToolKIT

The complete SynthAir Unit integrates the 4 modules, mapping, sensing, processing and visualizing into a single coherent ToolKIT. This will be deployed for the first time in Innsbruck, the final pilot of this project, and will be embodied into two scalable components, the AIR.chitecture Tool-KIT website and the Urban Air Station prototype, enabling comprehensive urban air quality planning.

The SynthAir Toolkit operates through a network of four interconnected modules: mapping, sensing, processing, and visualizing. This cybernetic model allows each module to receive information from the others and provide feedback data, creating a synergistic and evolving system. The overarching goal is to make the invisible aspects of urban air quality visible, providing individuals and communities with a tangible understanding of its intricate nature.

The mapping module within the SynthAir Toolkit plays a pivotal role by engaging citizens in collecting urban air quality data and fostering community involvement. It combines technological sciences with urban design to empower citizens as active participants in **scanning and reporting pollutant concentrations**. The resulting high-resolution air quality maps, visualized through digital design, raise awareness and support localized decision-making, contributing to the toolkit's goal of healthier and more sustainable cities. This collaborative approach informs policymakers and enhances the toolkit's adaptability to diverse urban contexts.

The sensing module provides a comprehensive understanding of human responses to urban air quality for the SynthAir Toolkit. By measuring not only traditional health impacts but also cognitive abilities, stress levels, and emotional granularity, it offers a holistic perspective on the challenges posed by the urban atmosphere. This module employs scientific approaches and innovative interactions with microalgae, creating a symbiotic relationship between humans and the city's microbiome. It enriches the toolkit with valuable data that informs urban planning and promotes healthier and more informed communities and the design of **restorative spaces** in cities.

The processing module lays the biotechnology foundation for SynthAir Toolkit. By integrating microalgae cultivation into urban spaces and architectural structures using innovative photobioreactors, it enables the creation of air-purifying units across the urban landscape. This transformative approach reshapes our interaction with the urban atmosphere, fostering the development of nature-based technologies. The module enhances the toolkit's capabilities by offering solution to urban air purification, demonstrating the potential for biotechnological integration in the built environment, and promoting **advanced urban agricultural practices and business ecosystems**.

The visualization module combines visual art and big data analysis to present all the measurements and data collected through the analytical tasks of the other modules. This initiative aims to allow urban stakeholders to appreciate the unique and complex phenomenon of urban air quality, fostering a deeper understanding of its intricacies. It provides a **visual narrative** that enhances public awareness and informs decision-makers.

The SynthAir Toolkit proposes a paradigm shift in urban planning. We call it **"White planning"**, that is the design and planning of the urban air quality. The consortium feels this will provide a necessary and timely integration to the accepted practice of the "blue-green" planning of the water and land infrastructures.

In conclusion, serving as the end product of the Synthetic AIR.chitecture Lab, the SynthAir Toolkit tests scalable technologies for the White planning of the urban environment. The AIR.chitecture Tool-KIT website and the Urban Air Station prototype provide urban stakeholders with scientifically sound and architecturally/socially integrated tools to re-design and purify the urban atmosphere. It empowers communities and individuals to take immediate action and actively participate in creating healthier urban environments. This toolKIT represents a paradigm shift in urban planning, emphasizing the critical role of air quality in shaping our cities and fostering a more sustainable civilization.

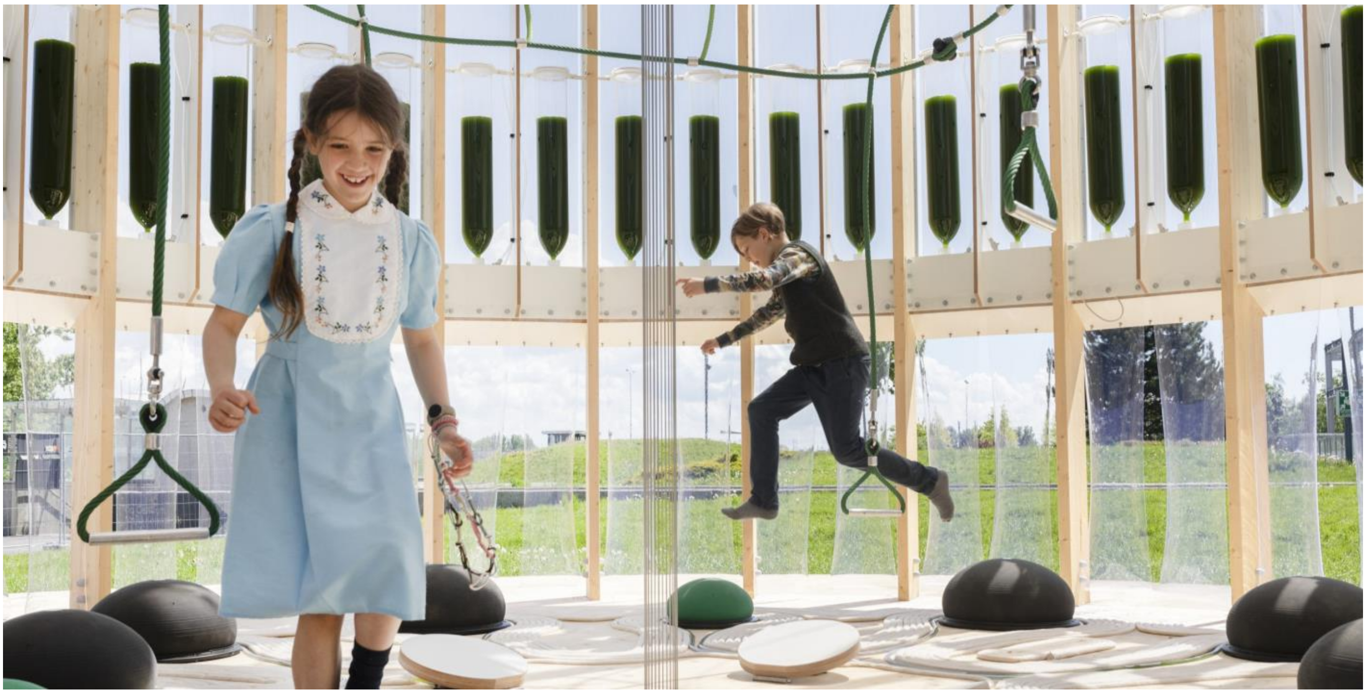

Image: AirBubble, air-puryfing biotechnological playground, Warsaw. Courtesy: ecoLogicStudio

Impact

A global challenge lies in developing effective policies to reduce air pollution in cities in the immediate. The Synthetic AIR.chitecture Lab responds to this challenge by engaging with citizens, communities and local governments to design and implement pockets of immediate improvement in air quality through a unique combination of science and design innovation.

The Synthetic AIR.chitecture Lab introduces a transformative approach where biological and medical sciences, material sciences and design come together to create a set of scalable tools that offer new possibilities in activating bottom-up action together with top-down policy making. This we believe, has the potential to transform how we plan, inhabit and re-design our cities in the future; beginning with the fundamental element that keeps us alive and healthy: the quality of the air we breathe. Both the individual pilot projects and the overall Toolkit developed by The Synthetic AIR.chitecture Lab seek to transform the current sense of desperation into empowerment towards urban air quality regeneration. The project's goal is to map and visualise air quality and pollution at high resolution, with enough granularity to enable localised responses to emerge. The project will employ nature-based biotechnology to enable the actualisation of nature-based purification systems capable of re-metabolising pollutants into living biomass.

Digital monitoring and pollution simulation systems will aid the development of the project's strategy with precision. The technologies will allow a more precise quantification of the benefits and potentials of pollutants re-metabolisation, or air pollution mining. As a space for public activities, buildings and landscape serve as an excellent medium for bringing technology-focused lab research into public view through the practice of design and aesthetics.

The pilot initiatives will act as testing modules to form a scalable toolkit that will capture the project's overall output. This includes the AIR.chitecture Tool-kit website and the Urban Air Station. This will be an innovative urban air quality monitoring station with bio-purification capabilities. Its modular design and scalable approach will form one of the core research outputs of the project.

The toolkit will facilitate local action and allow for these local initiatives to contribute to new emerging infrastructures and policies. These infrastructures can effectively bring about changes at various scales, from the microscopic and local architectural scale to the urban and infrastructural scale. This approach not only exerts pressure for change on governmental institutions but also offers new knowledge, ensuring ongoing engagement and creating an important legacy for the project.

Wider impacts

Wider Scientific Effects:

1. **Advancements in Biotechnology:** Synthetic AIR.chitecture Lab pioneers the integration of living organisms, particularly microalgae, in addressing environmental challenges. This approach advances the field of biotechnology by demonstrating how biological systems can be harnessed for practical solutions such as air purification and carbon capture.

2. **Bio-Digital Integration:** The project showcases a harmonious integration of biological and digital technologies. This interdisciplinary approach contributes to the emerging field of bio-digital integration, where living organisms and digital systems work synergistically to achieve sustainable and innovative outcomes.

3. **Carbon Capture and Utilization (CCU) Research:** By using microalgae to capture and convert pollutants and carbon dioxide into valuable products, Synthetic AIR.chitecture Lab contributes to research in CCU. This research is crucial in exploring sustainable alternatives for managing carbon emissions and finding innovative ways to utilize captured carbon.

4. **Materials Science:** The project explores the use of bioplastic polymers derived from living organisms. This has implications for materials science, providing insights into the development of sustainable materials that can be used in various applications, from biodegradable products to 3D printing.

5. **Urban Ecology and Architecture:** Synthetic AIR.chitecture Lab 's application in urban environments and architecture fosters research in urban ecology. It encourages the exploration of how biological systems can be integrated into the built environment to create more sustainable and environmentally friendly spaces.

6. **Public Health and Environmental Impact Studies:** The project's focus on air purification directly relates to public health and environmental impact studies on both physical and mental health. Research stemming from the project can contribute to a better understanding of how improving air quality can positively impact human's quality of life and their symbiosis with the surrounding urban ecosystem.

Wider Social-Economic Effects:

1. **Improved Public Health:** By purifying urban air and reducing pollutants, the project directly contributes to improved public health. Better air quality can lead to a reduction in respiratory issues and other health problems associated with poor air conditions.

2. **Inclusive and Interactive Spaces:** The design of Synthetic AIR.chitecture Lab pilots creates inclusive and interactive spaces. By allowing direct interaction with the air-purifying technologies, the project encourages people of all ages and genders to engage with environmental concepts, making sustainability accessible to a broad audience.

3. **Innovation in Design and Architecture:** Synthetic AIR.chitecture Lab represents an innovative approach to design and architecture, showcasing how nature-inspired solutions can be integrated into urban spaces. This can influence future architectural practices, promoting environmentally conscious design and supporting a new sensibility in the emerging field of Biophilic design.

4. **Inspiration for Sustainable Practices:** The project serves as an inspirational example of how sustainable practices, such as nature-based technologies and circular economies, can be implemented. It may inspire individuals, businesses, and cities to adopt similar strategies in their practices.

5. **Contributions to Circular Economies:** By converting pollutants into raw materials for new products, Synthetic AIR.chitecture Lab contributes to the development of circular economies. This approach encourages a shift from linear consumption patterns to more sustainable practices, promoting resource efficiency and waste reduction.

6. **Green-economy:** The project's focus on sustainable materials and technologies will create economic opportunities in industries related to bioplastics, bio-design, and sustainable urban planning, contributing to green economies.

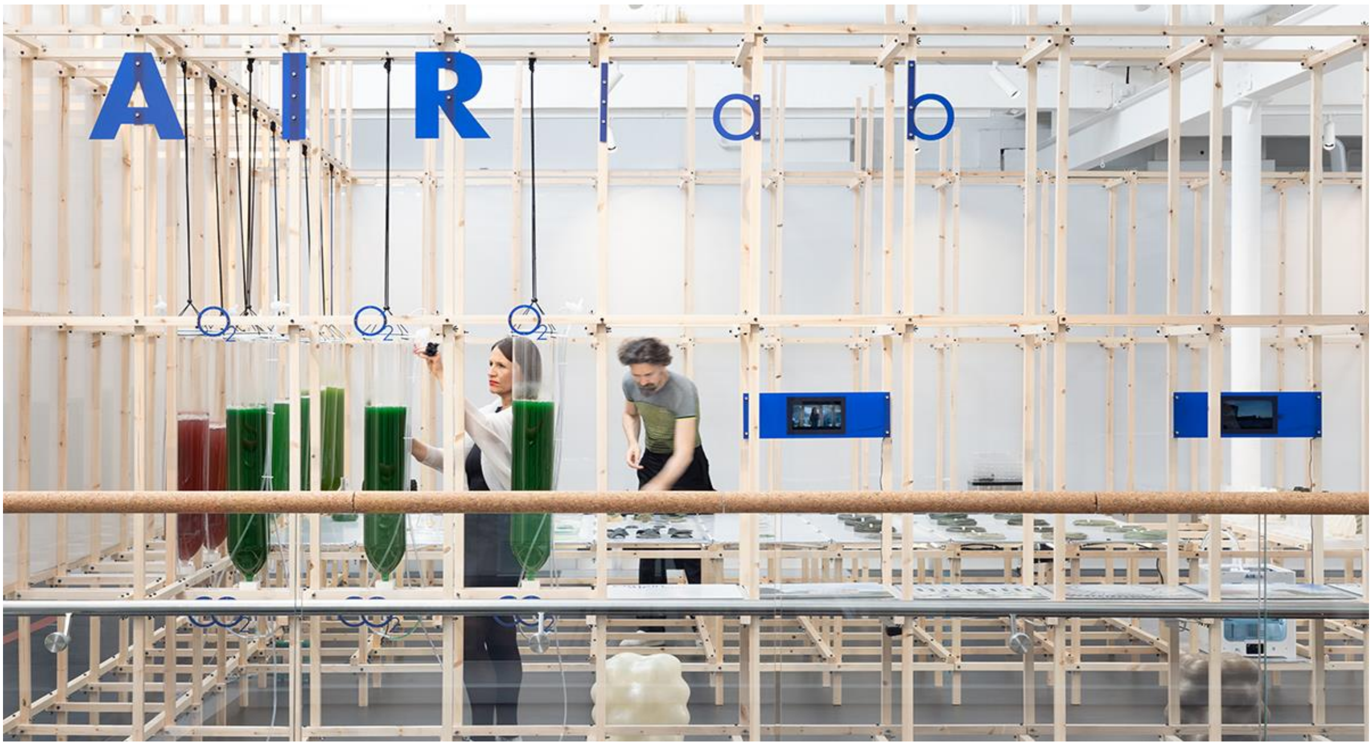

Image: Otrivin AIRlab, London. Courtesy: ecoLogicStudio

Scales

Target groups that will benefit from this project are varied in kind and scale. Here is a summary of the most significant ones.

1. Urban Communities:
Size: Depending on the size of the urban area, this group could range from thousands to millions of residents.
Benefits: Improved air quality directly impacts the health and well-being of urban residents, reducing respiratory issues and enhancing overall quality of life. The project offers tools to take immediate action and achieve immediate relief.

2. Municipalities and Local Governments:
Size: The size of municipalities varies. Our five pilot studies range from heritage towns to capital cities.
Benefits: Increased know-how on air quality; more granular monitoring, higher community engagement in finding effective solutions, implementing nature-based technologies, healthier communities with lover healthcare costs and positions municipalities as leaders in environmental innovation.

3. Educational Institutions:
Size: Schools, colleges, and universities with potentially large student populations.
Benefits: Educational institutions benefit from the project as an educational tool, fostering environmental awareness and providing students with hands-on experience in sustainable technologies leading to new kind of expertise and inter-disciplinary curricula.

4. Public Spaces and Tourist Attractions:
Size: Museums and science centres and tourist destinations.
Benefits: Implementing clean air policies and nature-based technologies in parks, squares, heritage sites and museum attractions enhances the overall experience for visitors, promoting sustainable practices and eco-tourism.

5. Research and Innovation Institutions:
Size: Research institutions and innovation hubs involved in environmental and biotechnological research.

Pilot Projects

The five pilot projects are the core deliverables of this research. They test the development of new architectural and urban typologies in the public realm focussed on the immediate and significant improvement of urban air quality. They embody a new point of connection between science, art, and architecture in the future planning of healthy and liveable cities, serving as the testing ground for the final deliverables of this project.

They are all designed and built following the approach of zero waste and full construction reversibility.

The first pilot project, the Mapping Module, set in the Macedonian city of Scopje, will be titled "Super.Cloud. Air Measuring and Air Reporting Citizen Science Trial run in Skopje." It will propose the development of an Urban Air plan or "white plan" for the city. Regular events will be held with the city council to test run this innovative Air Planning application of collective air pollution mapping and reporting.

The second pilot project, located in the Ukrainian city of Lviv, will be called the "Air Studio Art Pavilion." It aims to create an immersive space in a specially designed pneumatic pavilion to test a new typology of urban restorative space in a central urban piazza. Citizens will experience the effects of breathing in a clean or purified bubble while learning to monitor their physical and mental responses. A collaboration with the medical department from Lviv University will measure physical and psychological effects of local air quality on a selected pool of urban dwellers.

The third pilot, titled "The Bio-design Atelier," will take place in the unique Old Market Hall in Bratislava. It will test a new type of urban productive space built in a busy public market. It will involve the public in new practices of advanced gardening, transforming and repurposing pollutants into biopolymers for sustainable design products.

The fourth pilot on visualizing, titled "The Air Control Room," will be located at the ARTIS-Micropia museum, Amsterdam. The only microbial museum globally, it will allow visitors to engage with the possibility of making the invisible aspects of air quality into beautifully captivating visible representations. From the bio-sensing capabilities of microorganisms, to the intricacies of the human breathing apparatus and the possibilities generative AI in bio-art and design this module will give Air.chiecture tool-KIT a powerful visual interface.

Finally, the fifth pilot project, taking place in Innsbruck, Austria, will embody the overall project's final deliverables. It includes the AIR.chitecture Tool-KIT website and the Urban Air Station. This will be a new kind of urban air quality monitoring station with bio-purification capabilities. Its modular design and scalable approach will form one of the core disseminating and exploitation assets of the project.