



Ecologes Demonstrators in Neuperlach

Description of the design, construction, and implementation of Plant Building Blocks and Multispecies Façades.

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GLOSSARY

EC	European Commission
EU	European Union
HR	Handlungsraum der Stadtentwicklung / Urban Development Action Area
IHRK	Integriertes Handlungsraumkonzept / Integrated Urban Development Plan
ISEK	Integriertes Stadtteilentwicklungskonzept / Integrated Urban Regeneration Implementation Plan
IP	Intellectual Property
M	Project Implementation Month
NEB	New European Bauhaus
NEBourhoods	Creating NEBourhoods Together
NGO	Non-Governmental Organisation
NPL	Munich Neuperlach
OA	Open Access
T	Task
WP	Work Package
Organisation Name (Consortium)	
AGM	Architekturgalerie München e.V.
BYF	Bayerische Forschungsallianz GmbH / Bavarian Research Alliance GmbH
GC	Green City e.V.
HM	HM Hochschule München University of Applied Sciences
HM:UniverCity	HM Innovationsnetzwerk / HM Innovation Network
MGS	MGS Münchener Gesellschaft für Stadterneuerung GmbH
MS	UnternehmerTUM MakerSpace GmbH
MUC	Landeshauptstadt München / City of Munich
MUC CCI	Kompetenzteam Kultur- und Kreativwirtschaft / Team of Excellence for the Cultural and Creative Industries
MUC CULT	Kulturreferat / Department of Arts and Culture
MUC LED	Referat für Arbeit und Wirtschaft / Department of Labor and Economic Development
MUC PLAN	Referat für Stadtplanung und Bauordnung / Department of Urban Planning and Building Regulations
SCE	Strascheg Center for Entrepreneurship
STR	Str.ucture GmbH
SAAD	Studio Animal-Aided Design GmbH
SSR	Studio Stadt Region Forster Kurz Architekten und Stadtplaner Partg Mbb

TUM	Technische Universität München / Technical University of Munich
UTUM	UnternehmerTUM GmbH
Organisation Name (in Cooperation with)	
MER	Münchner Ernährungsrat e.V.
MIN	Münchner Initiative Nachhaltigkeit
OTH	Ostbayerische Technische Hochschule Regensburg
Organisation Name (Associated Partners)	
BDA	Bund Deutscher Architektinnen und Architekten e.V.
BDA-By	Bund Deutscher Architektinnen und Architekten Bayern e.V.
ByAK	Bayerische Architektenkammer, Körperschaft des öffentlichen Rechts / BAK – Federal Chamber of German Architects
BYD	Bayern Design GmbH

1 SUMMARY

This report is part of the deliverables of Creating NEBourhoods Together (2022-2025). NEBourhoods is one of the six lighthouse demonstrators of the New European Bauhaus funded by the EU to address the great challenges of climate, environment, and health. Combining co-creation and entrepreneurship while placing culture and creativity at the core of the transformation process, the project delivers accessible and empowering solutions to make the EU Green Deal beneficial for all in Munich Neuperlach and beyond.

Deliverable D4.1 documents the “Mock-up of a novel Ecolope” which aims to provide novel urban habitats for nature on the envelopes of built structures. The design of these structure uses computational workflows that e.g. combine ecological models and architectural models. In addition, this deliverable document what approvals are required in order to install such a demonstrator in public space. To this aim, two temporary demonstrators that improve local biodiversity were developed: 1) the Ecolopes Plant Building Blocks Demonstrator, and 2) in collaboration with the TUM Professorship for Digital Fabrication, the Multispecies Façades Demonstrator. In addition, We organized a workshop and exhibition to gauge the public’s perception of the demonstrators and multi-species design. We found that, generally, the public was positive about the possibilities that spaces designed for humans and other organisms could offer to biodiversity and new aesthetics in the built environment. Building owners, too, were generally positive about the potential, but more hesitant when it came to actually making alterations to existing building façades.

The Multispecies Façade demonstrator is planned to be constructed in a public space (the Feierwerk Südpolstation in Neuperlach), and the Plant Building Blocks demonstrator was placed on the private, publicly accessible roof of the PEP shopping centre. Additionally, the Plant Building Blocks were designed and constructed using traditional building methods, while the Multispecies Façade uses a novel technology – 3D printed ceramics – to produce individual elements. This led to different types and numbers of permits and approvals required, and accordingly, different amounts of time required to acquire them. Because of the extensive need for approvals, permits, and negotiations regarding liability and insurance for the construction of the demonstrator, the Plant Building Blocks have been constructed, installed, and evaluated in 2024, while the Multispecies Façade was set up in March 2025. The demonstrators will stay in place for multiple years, and there are plans for continued evaluation after the end of the NEBourhoods project.

The findings and experiences laid out in deliverable D4.1 indicate that future initiatives that aim to use novel technologies to build biodiversity-friendly constructions should consider and have an early overview of all the locally required approvals and incorporate the time required to acquire these approvals in the initial conception of the project and to have clarity on the issue of liability with potential partners early in negotiations.

2 INTRODUCTION

2.1 PROJECT OVERVIEW: CREATING NEBOURHOODS TOGETHER

“Creating NEBOurhoods Together” is one of the six lighthouse demonstrators of the New European Bauhaus funded by the EU to address the great challenges of climate, environment, and health. The aim is to collaborate on the European Green deal to create more sustainable, inclusive, and beautiful living environments across the EU. In Munich-Neuperlach (NPL), one of Europe's largest post-war urban expansion areas, NEBOurhoods is collaborating with citizens and stakeholders from culture, science, and business to implement ten actions from all fields of urban development, encompassing circular construction and redesign of residential and commercial buildings, innovative forms of mobility and energy communities, biodiversity and green space concepts and nutrition and youth culture. Encouragement of entrepreneurial thinking and action and practical implementation in co-creative processes support the formation of sustainable neighbourhoods in liveable, inclusive, and beautiful cities of the future.

Combining co-creation and entrepreneurship while placing culture and creativity at the core of the transformation process, the project will deliver accessible and empowering solutions to make the EU Green Deal beneficial for all in NPL and beyond. The district will be carefully cultivated into a resilient urban innovation landscape. Within two years, we will create NEBOurhoods together and show how we can realise circular thinking and acting in society and the economy, activate the green transformation in building, mobility, energy, food and health and enhance public spaces.

2.2 ABOUT THE ECOLOPES FET-OPEN PROJECT

The goal of the separately funded FET-Open project ECOLOPES, *ECOlogical building enveLOPES: a game-changing design approach for regenerative urban ecosystems* (964414), is to address some of the major challenges related to urbanization – especially biodiversity loss and reduced well-being due to the lack of experience with nature – by designing building envelopes as ecolopes. An *ecolope* is defined as a multi-species living space for humans, plants, animals, and microbiota aimed to restore the human-nature relationships within cities (Weisser et al., 2023). Such an approach requires a new design paradigm for architecture as well as the development of suitable technology (Grobman et al., 2023; Weisser et al., 2023). The design of an *ecolope* requires not only the availability of biological knowledge for the



architectural design process, but also the development of a computational framework and workflow including a set of expert databases (see Weisser et al. 2023 and the project webpage www.ecolopes.eu for more information).

A key element of the ECOLOPES computational workflow is to couple an ecological model to models of architecture. The ECOLOPES ecological model simulates the development of the *ecolope* ecosystem over time. The full model will have a number of components, including soil development (that includes soil structure as a proxy for microbiota) and the dynamics of the plant and animal communities on the *ecolope*. The coupling to building design is essential, as the development of the *ecolope* ecosystem is affected by the building design (i.e., geometry), local abiotic conditions (such as radiation, precipitation, that also depend on building design), soil characteristics, human management, and by the species that either colonize the *ecolope* from the outside (i.e., native and non-native species found in the region) or are introduced by humans on the *ecolope* (e.g. ornamental plants), as well as the interactions between the components. The biotic interactions included in the model concern trophic interactions (including herbivory and predation) and competition. These interactions have the potential to weaken the abundance of some species, and can even lead to local species extinction.

Building such a model using the species as the biological unit is an extremely complex task. To facilitate the computations, the ECOLOPES ecological model uses plant (PFG) and animal (AFG) functional groups as biological units (Calbi et al., 2024). This approach allows to cluster species together that are similar in their characteristics. Conceptually, species are placed within a multidimensional niche space. Each dimension of the niche space is built using functional traits. In this approach, a functional group is a group of species that share similarities in every aspect (or every dimension) of their multidimensional niche space, and hence have a similar functional niche owing to a convergent ecological strategy and similar impacts on the ecosystem. The functional traits used to characterize the dimensions that define the niche space are chosen based on the ecological processes that we considered important for the modelling approach. The FG approach for modelling the *ecolope* ecosystem alleviates the necessity to gather knowledge about every possible plant or animal species that could enter the *ecolope*, and enables the development of a less computationally intensive model.

In addition to modelling, developing *ecolopes* will depend on innovations that find novel physical solutions to integrate the needs of other organisms such as plants, animals and microbiota into buildings. This is not part of the funded FET Open project ECOLOPES and requires a detailed knowledge of the requirements of other organisms and technical innovations that can translate this knowledge into innovative construction methods. A

promising method is the use of additive manufacturing methods that have been successfully applied at TUM to the design of façade elements that serve the dual purpose of climatic adaptation and providing nesting opportunities for birds (Larikova et al., 2022).

2.3 OBJECTIVE OF THE NEB ACTION ECOLOPES

The NEB Action Ecolopes is one of the ten NEB actions in the NEBourhoods project. In the framework of the NEB Action Ecolopes two validation approaches were conducted to test the idea of designing *ecolopes*, in particular with respect to the usefulness to plants or animals. First, the modelling approach developed in the FET Open Projekt ECOLOPES was applied to a real-world example in Neuperlach. The Plant Building Blocks were designed using the ECOLOPEs modelling approach and exposed on a building, in this case the PEP shopping centre. The second one is the design of a Multispecies Façade element using additive manufacturing (Multi-species façade demonstrator), based on the technology developed by Larikova et al. (2022). A prototype of this is exposed in Neuperlach.

2.3.1 Building blocks based on the ECOLOPES modelling approach

Validation of the modelling approach was done by computationally designing building blocks (that could be part of a future *ecolope*) and exposing them to the real world, to see if ecological community develops as anticipated. The focus was on plant development based on a plant functional group approach. Validation included installation of relatively large elements (2.4m x 2.4m x 1.6m) on the roof of the PEP shopping centre in Neuperlach and following plant development. Similar building blocks were also set up at the same time in Genoa, Italy, and Haifa, Israel, each optimized for the plant communities and climate conditions at the respective sites.

2.3.2 Multispecies Façade demonstrator

Validation of the additive manufacturing approach was done for combined climatic adaptation and nesting opportunities of birds and hedgehogs. Validation included both testing of the production pipeline, material properties and the functioning under real-world conditions. A large prototype (6m * 1.88m façade element) was developed.

2.3.3 Post-project validation

For the Plant Building Blocks based the ECOLOPES modelling approach, a final evaluation will be made in summer 2025 by the TUM Chair of Terrestrial Ecology. The Multi-species façade demonstrator is planned to stay in its place for another three years, and its success will be evaluated by teams of the TUM Professorship in Digital Fabrication and the TUM Chair for Terrestrial Ecology.

2.4 OBJECTIVE OF THIS DELIVERABLE

This document is the deliverable D4.1 “Mock-up of a novel Ecolope” of the NEBourhoods project, funded under the European Union’s Horizon Europe Programme under grant agreement No. 101080052. Deliverable D4.1 falls under Task T4.2 “**Ecolopes**”, which is part of Work Package 4 “**NEB-Actions for nature- and climate-adapted Spaces and Circularity**”.

Deliverable D4.1 is a documentation of how two mock-ups (demonstrators) are designed, constructed, and exposed in Neuperlach, as well as what approvals – in the form of planning, testing, and certifications – were required to install the demonstrators at their respective locations. This serves as a replication guide so that others interested in the approach know what steps to take and where challenges lie that people should be aware of.

2.5 NEB ACTION TEAM

The project team of the NEB Action Ecolopes consisted of **Wolfgang W. Weisser and Fabio S. T. Sweet** from the Technical University Munich (TUM) **Chair for Terrestrial Ecology**. The team is supported by **Kathrin Dörfler** and **Iuliia Larikova** from TUM **Professorship of Digital Fabrication** for design and construction of the Multispecies Façades, the **NEBourhood TransitionHub** team (Munich University of Applied Sciences and City of Munich’s Team of Excellence for the Cultural and Creative Industries), by **Tina Zoch** from **MGS** (Münchner Gesellschaft für Stadterneuerung mbH) for advice on permission procedures, and replication, by **Martin Luce** from the Technical University Munich, **TUM School of Engineering and Design** for entrepreneurial advice, advice on permission procedures, and industry contacts, and the **City of Munich** (MUC) as a central stakeholder for advice and support.

3 METHODOLOGY

3.1 TYPES OF DEMONSTRATORS

3.1.1 Plant Building Blocks

1.1.1.1 Rationale

Each individual plant species has a different optimal environment in which it can thrive the best. With the Plant Building Blocks, we demonstrate how variations in microclimate on green roofs, even on a very local scale, can lead to higher plant biodiversity by providing fitting local environments for species with different needs. We use two examples: 1) a reference Building Block where the soil and sunlight conditions are identical in each individual element, 2) and an optimized Building Block with varying soil and sunlight parameters in different zones which should lead to higher biodiversity. The Plant Building Blocks will demonstrate that by just providing varying environmental conditions on a green roof more diverse plant communities can be created with minimal management, even when the initial mix of seeds is the same.

The Plant Building Blocks are designed and fabricated to focus on the non-human stakeholders, in this case plants. Similar Building Blocks were designed for buildings in Haifa and Genoa by the TECHNION team and set up in a similar way. A comparative analysis of the results will be done in the reporting of the ECOLOPES FET Open project. The results of the monitoring will allow to preliminarily validate some of the predictions made by the design simulations (e.g., solar radiation in relation to plant development).

1.1.1.2 Design

For Plant Building Block design, a design optimization framework developed by the ECOLOPES partner TECHNION was used (Selvan et al., 2023). More specifically, Building Block design is based on a simplification of geometry in relation to the initial output of the plant model. One of the main aims of the FET Open ECOLOPES project is to make biological knowledge available for the architectural design process, as well as to find architectural solutions that enable synergies and limit conflicts between the different building stakeholders: humans, plants, animals, and microbiota. This process essentially involves the development of a design approach based on a wide range of expert knowledge on architectural and

ecological principles and objectives. However, while setting architectural objectives is common in the architectural design process, e.g. enhancing thermal comfort or advancing energy efficiency, the setting of ecological objectives, alongside the architectural ones, is not a common practice, at least as far as other stakeholders such as animals are concerned. In fact, most “ecological buildings” currently do not have clear ecological objectives related to biodiversity in general, in contrast to objectives related to resource use or energy consumption. These objectives could also be named “ecological”, but do not concern other organisms directly. Table 1 shows the Key Performance Indicators (KPIs) used in the modelling approach:

Table 1. KPIs used in the optimization approach and underlying effects on human and plant objectives.

KPI	Architectural and/or ecological objectives and trade-offs
To reduce soil volume	Reduces weight (architectural objective), trade-off with plant growth (ecological objective) as more soil allows different vegetation layers to grow (herbs, shrubs, trees)
To increase shading heterogeneity	Increases the possibility for more plants to coexist with different light requirements (ecological objective).
To increase soil depth heterogeneity	Increases the occurrence of more plants being able to coexist with different soil depth requirements (ecological objective).

A simplified model architecture was developed, consisting of nine blocks with a basal area 0.8m X 0.8m (voxels) and variable height, thus resulting in a BB with the basal area (length x width) of. 2.4m x 2.4m (Fig. 1). Since the BB fabrication needed to be simplified (due to time and budget constraints), the voxels were assumed to be planter boxes, and the height depended on the soil depth in the voxel, which was determined in the optimization process (Tab. 2).

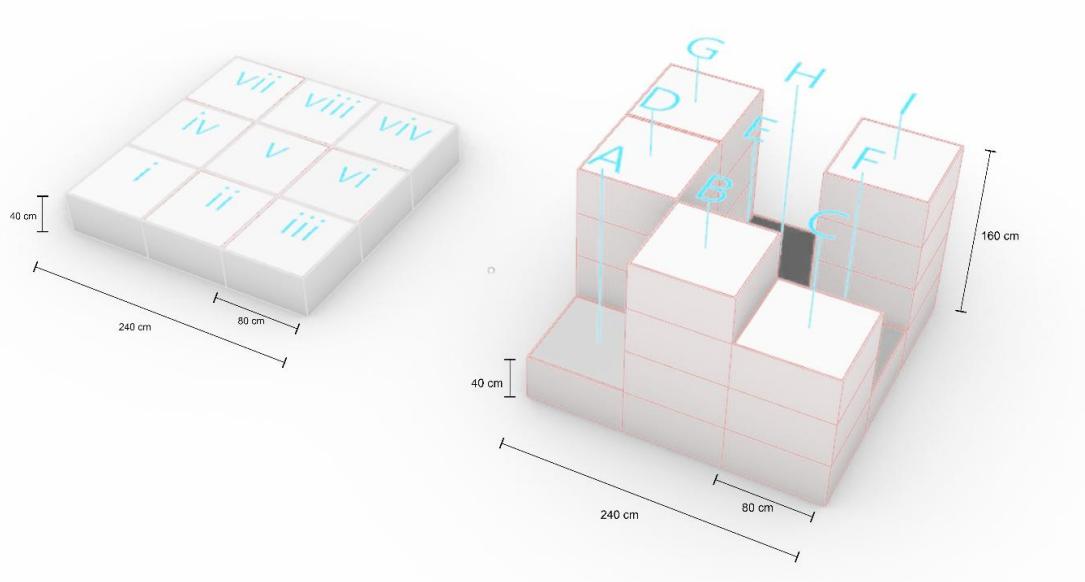


Figure 1. Reference (left) and optimized Plant Building Block (right) in Munich. Dimensions of the Building Blocks are indicated in centimetres. Image by Surayyn Uthaya Selvan, TECHNION-Israel institute of Technology.

Trade-offs are important for the optimization. First, different soil depths allow different vegetation layers to grow (e.g., herbs, and shrubs - fundamental ecological niche). Based on the analysis of the requirement of different plant species, three soil depth levels were used between 0 to 1 m. On the other hand, soil depth also affects the shading of the building with different consequences at the different test sites (Haifa, Munich, and Genoa), considering that different light conditions occur at the different locations considered. Using the Multi-Attribute Decision-Making (MADM) procedure, the top-performing solution per site was selected to be constructed in a 1:1 prototype. For comparison, a separate structure of 3 x 3 voxels with uniform height (soil depth) was also constructed (Fig. 1).

The same plant species and the same number of seeds per element were seeded in the Building Blocks in all these countries; the plant species were taken out of plant functional groups that are present in all three of these regions. The plant species that were chosen were *Achillea millfolium*, *Bromus erectus*, *Daucus carota*, *Erodium Cicutarium*, *Hypericum perforatum*, *Medicago lupulina*, *Ononis spinosa*, *Plantago lanceolata*, *Prunus spinosa*, *Sambucus nigra*, *Sanguisorba minor spp. minor*, *Solidago virgaurea*, *Spergula arvensis s. str.*, and *Sonchus asper*.

Table 2. Optimisation results of the Optimised Plant Building Block and the Reference Plant Building Block, based on their location in Munich.

Optimisation Results												
no	desc	unit	value									
1	Best Performing Alternative	x	{40;19}									
2	TOPSIS Score	x	0.754379									
genomes												
3	Random Height Seed Value	x	35020									
4	Random Soil Depth Value	x	57514									
fitness objectives												
5	Total Installation Weight	kg	1560.0661									
6	Soil Depth Standard Deviation	m	27.394258									
7	Shading Percentage Standard Deviation	%	0.11024									
Optimized Planter Box ID	unit	A	B	C	D	E	F	G	H	I		
8	Total Height	m	0.4	1.6	1.2	1.6	0.4	0.4	1.6	0.4	1.6	
9	Soil Depths	m	0.1	0.35	0.1	0.1	0.1	0.1	0.1	0.1	0.35	
10	TOTAL SOIL VOLUME	m3	0.05929	0.207515	0.05929	0.05929	0.05929	0.05929	0.05929	0.05929	0.207515	0.83006
11	Direct Sun Hours	hrs	2944	4158	4158	4158	1284	2246	4158	1129	4158	
12	Shading Percentage	%	37.955743	12.370917	12.370917	12.370917	73.003161	52.665964	12.370917	76.206533	12.370917	
13	TOTAL NUMBER OF OPTIMIZED MODULES	u	1	4	3	4	1	1	4	1	4	23
Reference Planter Box ID	unit	i	ii	iii	iv	v	vi	vii	viii	viv		
14	Total Height	m	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	
15	Soil Depths	m	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	
16	Total Soil Volume	m3	0.207515	0.207515	0.207515	0.207515	0.207515	0.207515	0.207515	0.207515	0.207515	1.867635
17	Direct Sun Hours	hrs	4072	4042	3956	4030	3973	3856	4070	4022	3916	
18	Shading Percentage	%	14.183351	14.815595	16.62803	15.068493	16.269758	18.735511	14.225501	15.237092	17.471022	
19	TOTAL NUMBER OF REFERENCE MODULES	u	1	1	1	1	1	1	1	1	1	9
20	FINAL NUMBER OF MODULES	u										32
21	FINAL AMOUNT OF SOIL VOLUME	m3										2.697695

1.1.1.3 Construction

The basic structure of a Plant Building Block element is as follows:

- Box-like structures of 80cm*80cm*X cm (X, in the case of the Munich Plant Building Block, was 40cm) were assembled to function as the element's outer casing. These are stacked and attached to each other to reach the desired height of the element (Fig 2).
- A platformed lightweight inside structure with a height of $[Element\ height] - [Soil\ depth] - [Lightweight\ drainage\ material\ depth]$ is then fixed to the inside of the element to allow for each element to have the desired amount of *soil depth* (normally less than the *element height*) while still having the required *element height* to fulfil its shading role (Fig. 3).
- On top of the platformed inside structure, a water-permeable fabric layer, which also covers the insides of the element, is placed to allow for water drainage without letting through the lightweight drainage material and the soil.
- On top of the fabric layer comes a lightweight drainage layer (in our case, cm of clay granules).
- On top of the lightweight drainage layer comes soil, in which plants are seeded.

These elements are connected to each other for structural integrity.

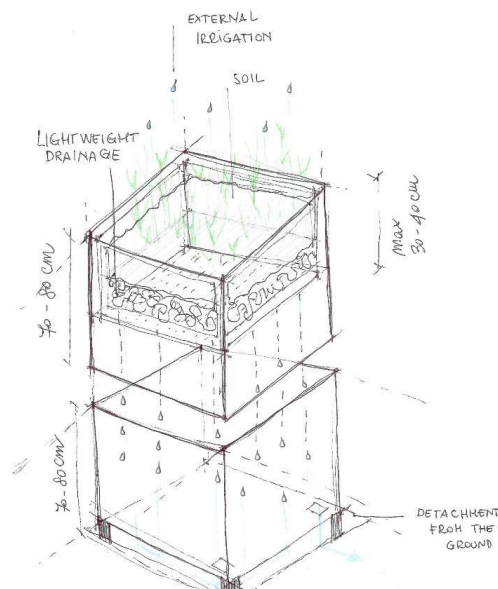


Figure 2. General design of the Plant Building Blocks. Image by Maria Canepa, University of Genoa.



Figure 3. The Optimized Plant Building Block under construction, showing the platforms on top of which the platform, drainage layer, and soil are later placed.

1.1.1.4 Maintainance

The Plant Building Blocks are watered three times per week until the plants have grown enough to sustain themselves independently, to avoid the saplings from dying from drought stress. Irrigation can be done manually or with an automated irrigation system. Due to proximity to an urban beekeeper's hive on the same roof in Neuperlach, plants will provide nutrients for honeybees while being pollinated by them.



*Figure 4. Early growth stages of the optimized Plant Building Block mock-up on the roof of the PEP shopping centre.
Image source: Fabio Sweet, TUM Chair of Terrestrial Ecology.*

3.1.2 Additively Manufactured Multispecies Façades – Collaboration with TUM

Professorship of Digital Fabrication

1.1.1.5 Rationale

Many birds nest in cavities of buildings in cities. In many modern buildings, however, these cavities are often closed off or completely absent in their design for better building insulation, leading to a loss of bird habitat. However, insulation of buildings and building-cavity breeding birds do not need to be mutually exclusive. Using additive manufacturing, we can design locally customised and integrative facades that address multiple objectives and functions. These

facades not only enhance aesthetic appeal but also support biodiversity and contribute to improving indoor and outdoor climate conditions (Larikova et al., 2022). In our partnership with the **TUM Professorship of Digital Fabrication**, we demonstrate how improved building insulation and biodiversity enhancement can be seamlessly combined, and how a wide variety of cavity-integrative structures can be used as part of an Ecolope. The Multispecies Façade was placed at the Feierwerk Südpolstation, a youth centre in Neuperlach, continuing their efforts to bring concepts of sustainability and multispecies design to the local youth.

1.1.1.6 Design

The Multispecies Façade is made of additively manufactured ceramic tiles and was designed based on updated principles laid out in Larikova et al. (2022). Because of building restrictions at the Feierwerk Südpolstation indicated by the designers Architekten Kunze Seeholzer, namely a Wärmedämmverbundsystem (exterior insulation finishing system) with mineral fibre plates that cannot absorb additional pressure, we opted for a free-standing installation installed close to - but not in - the building façade, to demonstrate the Multispecies Façade elements without altering the building itself (Fig. 5). The façade elements were designed with human and animal needs in mind. The façade elements for this demonstrator considered two bird species, the *house sparrow* and the *black redstart*, and one mammal, the *hedgehog*. These three species have different needs, and the most important criteria for these species were based on research done in the field of ecology and direct consultations with specialists and industry professionals (Larikova et al., 2022). To demonstrate geometric differentiability, two main environmental parameters were used for design optimisation: The reduction of solar radiation on the building facade, to improve the microclimate for both birds and humans and the reduction of wind façade pressure, which influences parameters such as façade weathering and suitability for birds. Therefore, the frontal surfaces of the elements contain vertical folds to effectively reduce façade wind pressure and solar radiation. Further, the façade elements are designed to fit into the standard ventilated façade system, which allows for the integration of biodiversity-enhancing elements without compromising necessary functions of the building envelope such as insulation (Fig. 6). Integration into standard mounting systems for standard ceramic tiles enables easier planning and reduces costs by avoiding the need for customised substructure components. Additionally, the design allows for the elements to be easily dismantled for regular nest cleaning. The material used for the production is mineral-based: clay, sourced locally in the western part of Germany. Furthermore, the material mixture includes 40% recycled content, which increases the sustainability and durability of the elements.



Figure 5. Concept image of what the Multispecies Façade structure should look like at the Südpolstation in Munich-Neuperlach. Image source: Iuliia Larikova, TUM Professorship of Digital Fabrication.

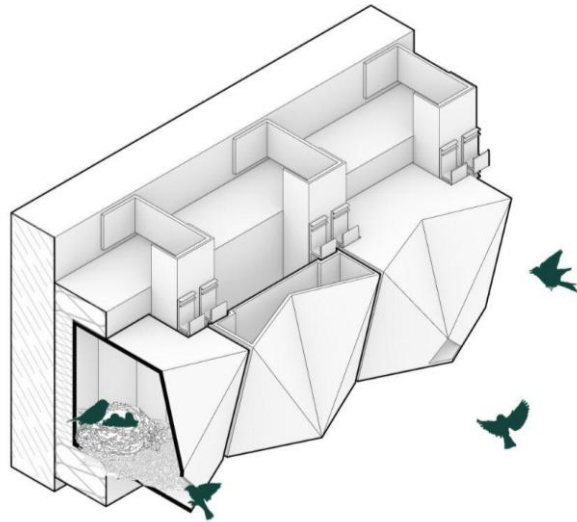


Figure 6. Axonometric image of the biodiversity-enabling façade element integrated into the ventilated façade system. Image source: Iuliia Larikova, TUM Professorship of Digital Fabrication.

The size of the prototype is 1.8 m x 6.5 m (width x height). It consists of 85 additively manufactured ceramic tiles that are fixed on a freestanding substructure with underground fundament, imitating the ventilated facade system. Nineteen tiles are biodiversity-enabling, while the rest are self-shading. The biodiversity-enabling tiles are distributed on the prototype according to the needs of the chosen species. The lower row consists of five tiles with shelters for *hedgehogs*. Five elements in the middle part of the prototype with larger openings are planned to host *black redstarts*. The upper part is dedicated to *house sparrows*; as they prefer to live in colonies, nine elements with smaller openings are positioned close to each other.

1.1.1.7 Construction

The Multispecies façade was installed in March 2025, and the plan for construction was as follows:

- The ceramic façade elements are additively manufactured at the Professorship of Digital Fabrication at the Technical University of Munich, where they dry in a controlled environment and biscuit fired after the drying process.
- The biscuit-fired elements sent to **TONALITY GmbH**, the industry partner of the Professorship of Digital Fabrication, to conduct the glazing with a certified façade glaze and second firing of the elements.

- The independently free-standing steel sub-construction was placed close to the façade of the Feierwerk Südpolstation, a children's and youth leisure centre, to hold the façade elements. This sub-construction is standing on a submerged foundation, affixed with large steel bolts and blocked with heavy concrete blocks. This and the next construction steps were conducted by the construction company Stahlbau März.
- Structures that the ceramic façade elements can slide into are attached to the sub-structure.
- Façade elements were fixed into the Multispecies Façade (See Fig. 7).
- A fence with a space of 10cm under it to allow hedgehogs to pass was placed around the Multispecies Façade to protect it and its inhabitants from disturbance, and signage was placed explaining what the Multispecies Façade is.
- Bird-friendly plants are placed around the fence.

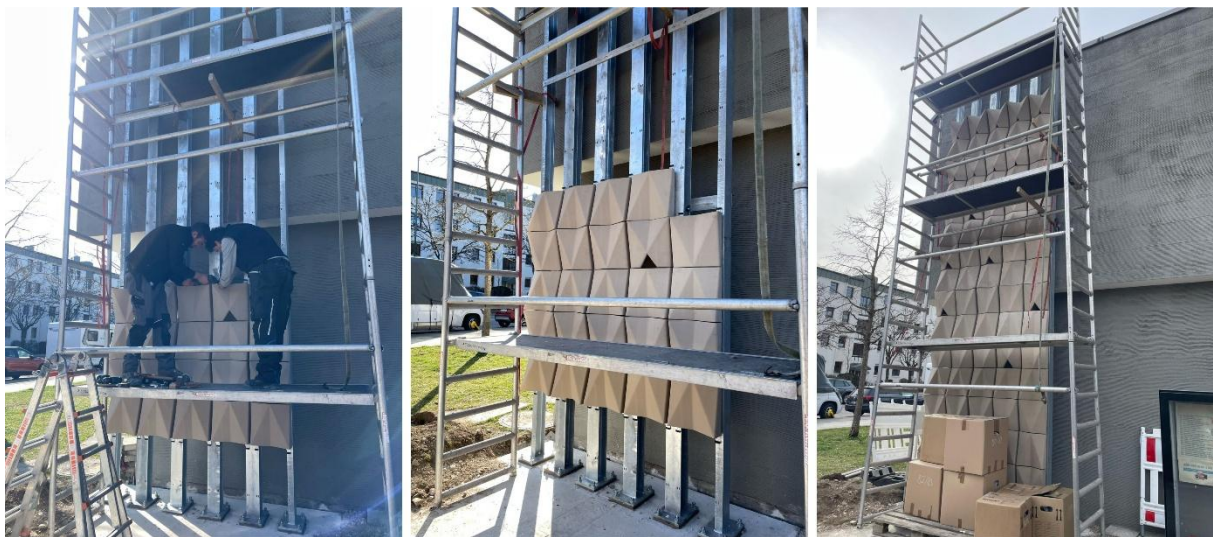


Figure 7. Under construction images of the Multispecies Façades. Image source: Iuliia Larikova, TUM Professorship of Digital Fabrication.

4 ANALYSIS OF CURRENT SITUATION, RISKS, AND POTENTIAL

4.1 CURRENT SITUATION

The Plant Building Blocks have been constructed at the PEP shopping centre, and the Multispecies Façade will have been installed at the Feierwerk Südpolstation by the end of March 2025.

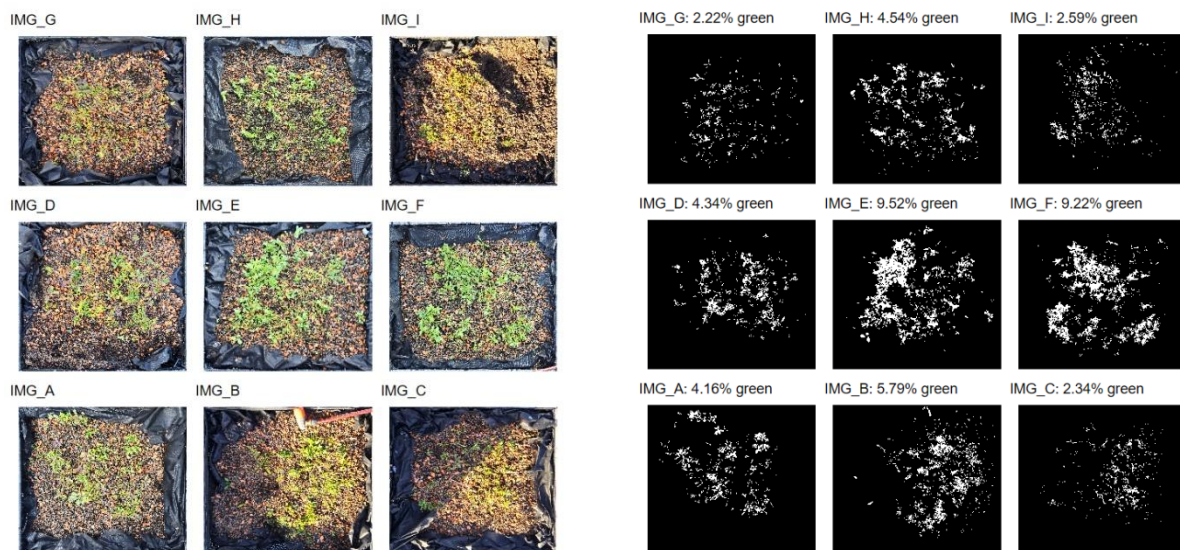


Figure 8. Optimized Plant Building Block on 09.10.2024, a few weeks after the sowing of the seeds. Despite the late sowing season, the effects of shading on the building blocks are apparent in the early coverage, which is higher in the shaded planters (E, F, and H). Left: Birds eye view Plant Building Block photos. Right: Green extracted from the photos. Image source: Fabio Sweet, TUM Chair of Terrestrial Ecology.

4.2 POTENTIAL

The Plant Building Blocks can stay at their location for the foreseeable future and provide insights into how plant biodiversity on roofs can be enhanced using various levels of shading and soil depth, creating a variety of local microclimates. Using this, the Ecological model can be further evaluated. In addition, the Plant Building Block will provide nutrients to the honeybee hive that is present on the same roof.

Once constructed, the Multispecies Façade will provide habitat for house sparrows, black redstarts, and hedgehogs, while also providing an aesthetically pleasing installation to the Südpolstation. It also provides the opportunity for the users of the Feierwerk Südpolstation to discover and experience behaviours of the structure-nesting animals. As its construction was planned for early spring and can stay in place for several years, colonization by the envisioned species and perceptions of the users of the building can be monitored and evaluated.

5 IMPLEMENTATION AND EVALUATION

5.1 APPROVALS REQUIRED TO INSTALL THE ECOLOPES

To allow for the construction of the demonstrators, various permits, material tests and insurances to allow for these permits were required. The permits and allowances required differed per partner - bringing to light the difference between gaining permission to place an installation on public and private property.

5.1.1 Plant Building Blocks - private property

5.1.1.1 Material Testing

Not required, built with common materials.

5.1.1.2 Structural engineering tests (Statik)

In order to safely place the Plant Building Blocks on top of the roof of the PEP, we were required to have a structural engineer determine whether the location could safely hold the weight of the Building Block and whether the Building Block design itself was wind-safe. Once that was determined, construction could start.

5.1.1.3 Permits and insurances

No specific permits and insurance were needed because of the private nature of the PEP shopping centre. The complete Einkaufszentrum and all the built elements in and around it are covered by the building's insurance.

5.1.2 Multispecies additively manufactured façade elements - public space

5.1.2.1 Material Testing

To ensure the safety of the produced façade elements, bending strength and breaking load limit tests were conducted. These tests ensure that the façade elements can withstand wind loads and can therefore be safely placed on the façade. The framework for the bending tests

of the additively manufactured elements was developed by the Professorship of Digital Fabrication in collaboration with the Laboratory of Building Structures at the Technical University of Munich. The framework was based on the process described in the German regulatory document DIN EN ISO 10545-4 and adjusted for additively manufactured façades.

The first tests were conducted on 16 test pieces with four different configurations. They yielded an average result of 7.8 N/mm², exceeding the DIN requirement of 6 N/mm². A second batch of tests, using an improved material mixture with a reduced water percentage, is scheduled for December 2024. Higher values are anticipated. The tests were performed on simplified printed geometries, and the necessary finite element method (FEM) simulations were carried out to estimate the distribution of these values for the complex geometry of the façade elements.

5.1.2.2 Structural engineering testing of the substructure (Statik)

Before agreement could be reached on placing the Multispecies façade at the Südpolstation, we were required to have a Certified Structural Engineer assess various structural and safety aspects of the prototype's substructure.

The Structural Engineer focused on three main aspects:

1. the stability and strength of the construction, ensuring it can bear the load of the additively manufactured elements and withstand wind loads,
2. whether it could be placed at the intended location, considering the underground infrastructure, and
3. safety for pedestrians and passers-by.

The calculations prepared by the Structural Engineer ensure the appropriate selection of profiles for the substructure system and were provided to the subcontractor for its execution.

5.1.2.3 Permits and agreements required

- Statement of agreement (Einverständniserklärung) from the architects of the Feierwerk Südpolstation (Kunze-Seeholzer) because of the right of architects to reflect on changes made to their built designs (Urheberrecht), and discuss the placement and size of the Multispecies Façades with them. *Achieved.*

- Proof of structural engineering tests having been done, to be tested by the Municipality. *Achieved.*
- If the elements could not be set up independently and interventions in the existing building were necessary, this must be agreed with the architects Kunze-Seeholzer and the head of the municipal construction department. *Achieved.*
- Proof that traffic safety is guaranteed. *Achieved with structural tests.*
- An agreement that safety - also for pedestrians - must be ensured and that once per year a status report on that must be produced.
- An agreement that when it is time to disassemble the structure, the municipality will not be responsible for the costs. *Money is set aside for this purpose at the TUM School of Engineering and Design.*

5.1.2.4 Insurances

Because of the novel nature of the Multispecies Façade, an added requirement for its construction was the acquisition of a corporate insurance policy. Since the Technical University Munich, as a public organization within the Bavarian state, does not usually take on insurance policies, special permission was requested from and granted by the Bavarian state to take on such a policy for the Multispecies Façade.

5.2 NEBOURHOODS KPI'S ACHIEVED TO DATE

NEB Action Ecolopes (NEBourhoods Task 4.2) has contributed to the progress of the following project KPI's:

- KPI 1.1: A co-creation workshop has been held.
- KPI 2.1: Iuliia Larikova's team, which is working on bringing the Multispecies façades to the market, is core to the Multispecies Façade demonstrator.
- KPI 3.1: Ecolopes Plant Building Block constructed on PEP roof. Evaluation in progress. Multispecies Façades constructed at the Feierwerk Südpolstation.
- KPI 4.1: Participation in NEB Festival 2024 in Brussels.

5.3 PARTICIPATIVE PROCESSES AND OUTREACH

5.3.1 Finding a location for the demonstrators in Neuperlach - Connecting with local stakeholders

With the help of **Jana Köstler** from the **NEBourhoods Transition Hub**, the **Südpolstation** children's and youth centre was found as a suitable location for the **Multispecies façade**; nesting space for building-breeding birds and hedgehogs would be created, and the youth of the Südpolstation would gain more direct experiences with them.

A suitable location for the **Plant Building Block** was found after a tip from **Christine Jakoby of Studio Animal-Aided-Design** that **PEP**, the large shopping mall in Neuperlach, would be interested in collaborating on the project. The Plant Building Block was placed on the roof next to Parkdeck D of the PEP shopping centre after talks about a suitable location with the PEP's technical manager, Martin Schwartz. Although there were initial plans on close co-creation with the people responsible for the Südpolstation, this finally did not materialise because of the limited timeframe, technological limitations, and communication difficulties because of unaligned expectations.

5.3.2 Workshops and exhibitions

As part of outreach initiatives of the NEBourhoods project, we organized a co-creative workshop and an exhibition to familiarize the public with Ecolopes and to gather their views on it.

The "Lego"-Workshop "Eco-lopes" - where participants could use Lego to collaboratively design an *ecolope* at the Munich Creative Business Week (MCBW)(Fig. 9). In the workshop, participants were given the roles of different stakeholders, each with different priorities, and collaboratively designed building envelopes that were beneficial to human and non-human stakeholders. During the design process, factors like legal building requirements (firefighters' access routes) and potential synergies and conflicts between stakeholders were discussed.



Figure 9. Example of one of the designs that formed out of the MCBW workshop. Image source: Fabio Sweet, TUM Chair of Terrestrial Ecology.

The workshop was part of an open workshop series organized together with Studio Animal-Aided Design (SAAD) and GreenCity Munich e.V. on 16 May 2024, in which co-creation with and for nature was a central theme (Fig. 10). The findings stemming from the workshop series were evaluated at the end of the workshop series.



Figure 10. NEBourhoods' Actions workshop poster for "How to co-create; let's do it, Nature!" during the MCBW, designed by Christine Jakoby of SAAD.

The Genoa team of the FET Open project ECOLOPES organized an exhibition about what an 'ecolope' could look like on the buildings in Neuperlach at the NEBourhoods Boulevard, an infotainment event for residents of Neuperlach, on 19 October 2024. Here, **Francesca Mosca** (UniGe) and **Sissy Chen** (TUM) exhibited designs originating from a studio with architecture students from the Technical University Munich, wherein the students envisioned what Ecolopes interventions would look like on archetypical buildings of Neuperlach – and with which they could show visitors what Ecolopes would mean for them (Fig. 11). Generally, visitors had positive views of the proposed designs.



Figure 11. Designs of TUM Architecture students with potential ECOLOPES futures for Neuperlach buildings that were exhibited at the NEBourhood Boulevard. Image source: Francesca Mosca, Architecture and Design Department, University of Genoa.

6 CONCLUSION AND FUTURE OUTLOOK

The NEB action Ecolopes as well as the NEB action Animal-Aided Design showed that city dwellers accept the idea of a Multispecies design and are willing to take part in a creative process. The demonstrators were welcomed, even though the implementation run against a number of practical hurdles.

Validation of the predictions of the Ecolopes Plant Ecological Model will provide evidence that the model can be used to make predictions about plant development under real-world conditions, in the interaction between building design and planting. Such predictive models are needed to be able to include ecological aspects into computer-aided design.

The demonstrator combining climate adaptation to a building with providing living space for other organisms, in particular animals, realizes a core idea of ECOLOPES. Once its functioning has been proven, with respect to the material properties, the predicted effects of climate regulation, and the ecological role, solutions such as the one demonstrated here can play a major role in the New European Bauhaus. It is planned that IP connected to both the design and production of these multispecies blocks will be protected and exploited, potentially by a start-up company. With computational fabrication of facades becoming more and more common, there are ample opportunities for implementing such solutions in different types of buildings, including factories and office buildings.

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