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Adaptive Ecologies: A Visionary Urban Layer for Post-Carbon Cities

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Abstract
The built environment lies at the center of two converging environmental crises: escalating carbon emissions from the construction industry and the chronic mismanagement of agricultural waste. According to the United Nations Environment Programme (2022), the building and construction sector accounts for approximately 39% of global energy-related carbon dioxide CO_2 emissions, largely due to energy use in operations and the production of high-emission materials like concrete and steel. Simultaneously, the Food and Agriculture Organization (2021) estimates that more than 4 billion tons of agricultural waste are generated annually, much of which is burned in open fields, emitting black carbon and exacerbating both global warming and public health risks.

In response to these intersecting issues, this paper proposes a visionary urban layer—a modular, adaptive, and ecologically responsive stratum that overlays the existing urban fabric. Drawing from speculative and conceptual precedents such as Constant Nieuwenhuys's New Babylon (Wigley, 1998) and Neil Spiller's *Visionary Architecture* (Spiller, 2006), this layer functions as both a spatial framework and a systemic intervention. Grounded in Donella Meadows's theory of systemic leverage (1999) and inspired by Winy Maas's *The Sponge* manifesto (2021), it incorporates mycelium-based biomaterials, closed-loop pyrolysis systems, and architectural strategies for carbon capture and waste transformation. The study contrasts a prototype of this urban layer, based on an evolved *Earthship* typology, with conventional construction methods in terms of carbon footprint, material flows, and ecological integration. It argues that visionary architecture, once dismissed as utopian, must now be engaged as a practical tool for ecological resilience and material circularity.

Keywords
carbon emissions; architectural innovation; New Babylon; mycelium; adaptive infrastructure; pyrolysis; Earthship; agricultural waste; closed-loop design

1. Introduction

As the twenty-first century advances, cities face a paradox: they are both the epicenters of environmental degradation and the laboratories for ecological transformation. Two urgent challenges define this crisis. First, the construction industry is one of the largest contributors to global climate change, responsible for approximately 39% of global energy-related CO_2 emissions, with concrete, steel, and glass among the most carbon-intensive materials in use (United Nations Environment Programme, 2022). Second, agricultural systems generate more than 4 billion tons of waste annually, a significant portion of which is either landfilled or openly burned, releasing black carbon and methane that further exacerbate the climate emergency (Food and Agriculture Organization, 2021).

These crises are not independent. They reveal a shared flaw in urban- industrial systems: a reliance on linear flows of extraction, consumption, and disposal. Traditional city-building relies on centralized production, permanent form, and resource depletion, with little capacity to recirculate materials or adapt to environmental pressures. Even contemporary “green” buildings often optimize within outdated systems, failing to address the deeper structural imbalances.

This paper responds to this condition by proposing a new model: the creation of an adaptive urban layer, a visionary yet constructible stratum that overlays existing urban fabrics with new ecological, material, and social capacities. Inspired by speculative urban proposals such as Constant Nieuwenhuys’s New Babylon, which envisioned a nomadic, elevated megastructure for post-industrial life (Wigley, 1998), and informed by Donella Meadows’s theory of leverage points for system-level change (Meadows, 1999), this layer is not merely a design gesture but a systemic intervention.

It also draws on Winy Maas’s Sponge Manifesto (2021), which calls for cities that absorb and redistribute resources like living organisms, and on Neil Spiller’s call for a visionary architecture that incorporates speculative technologies to critique and reimagine the urban future (Spiller, 2006).

Through a combination of low-carbon biomaterials such as mycelium, and closed-loop systems like pyrolysis for energy and waste-to-resource conversion, the urban layer reorients architecture from a static container of human activity to a dynamic, responsive framework for environmental repair. Rather than displacing existing buildings and infrastructures, it intervenes lightly but decisively, bridging ecological, spatial, and material gaps.

1.1. Visionary Urbanism and Systemic Intervention

At critical junctures in history, architecture has not only responded to crisis but anticipated new paradigms. Visionary design operates as a speculative tool: it imagines the city not as it is, but as it might become. In the face of environmental breakdown, this speculative

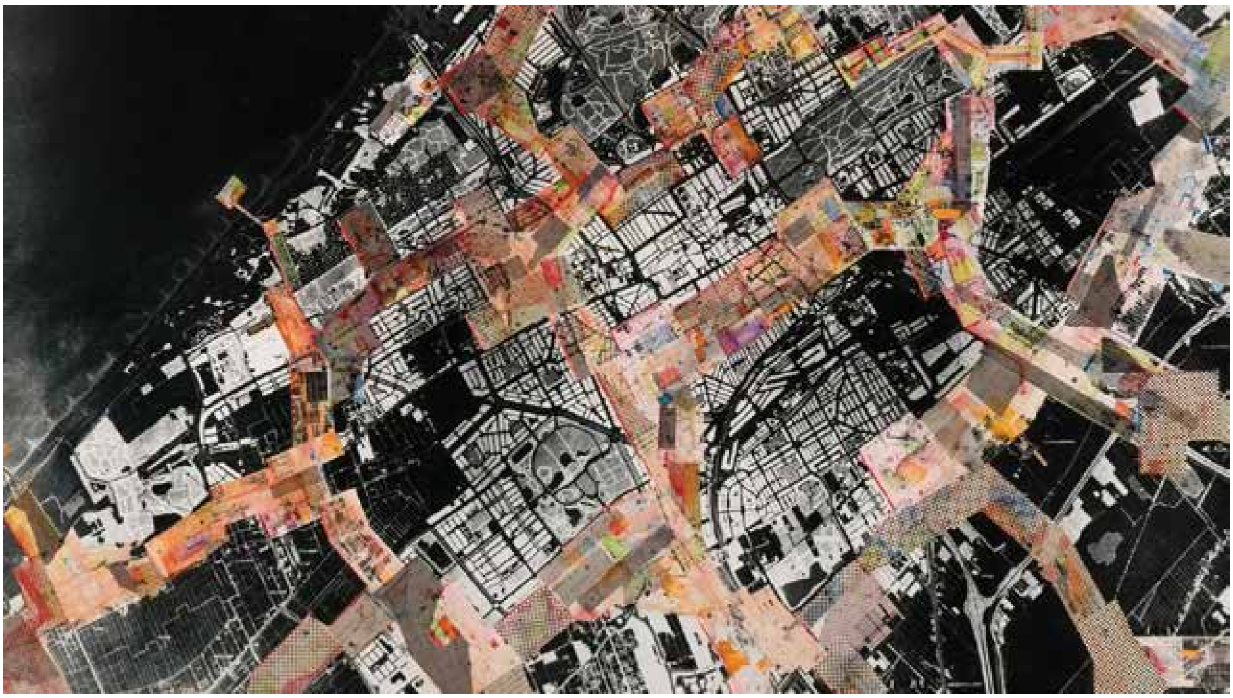

Figure 1. Imagined future utopia, *New Babylon. Fondation Constant. New York via Pictoright Amsterdam (1972)*

tradition offers more than abstraction, it enables a reframing of urban logic itself.

1.1.1. New Babylon: A scaffold for reconfiguration
Dutch artist-architect Constant Nieuwenhuys's *New Babylon* (1956–1974) imagined a global, elevated megastructure in which nomadic life, continuous transformation, and spatial freedom replaced the static logic of modernist planning. Suspended above the existing world, this utopian city allowed its inhabitants, the "Homo Ludens", to reshape their surroundings at will (Wigley, 1998).

Though largely conceptual, New Babylon serves as a spatial metaphor for non-destructive layering: it proposes an architecture that builds on top of and alongside the existing, rather than erasing it. The Visionary Urban Layer draws directly from this principle, not to create a new city, but to overlay and repair the one we already inhabit.

1.1.2. Neil Spiller and the Aesthetics of Speculation
Architect and theorist Neil Spiller (2006) defends speculative design as an essential architectural mode, one that fuses biology, computation, and narrative. In *Visionary Architecture: Blueprints of the Modern Imagination*, he argues that speculative projects are not escapes from reality, but rather critical rehearsals for future challenges.

Spiller's work champions an architecture of fluid systems, organic materials, and distributed intelligence, all of which inform this paper's approach to a layered city. By imagining mycelium as structural matter and pyrolysis as energy infrastructure, the Visionary Urban Layer converts Spiller's imaginative potential into constructible ecological systems.

1.1.3. Donella Meadows: Leverage Points in Urban Systems
While vision is essential, strategic intervention demands a systems-thinking approach. Donella Meadows's

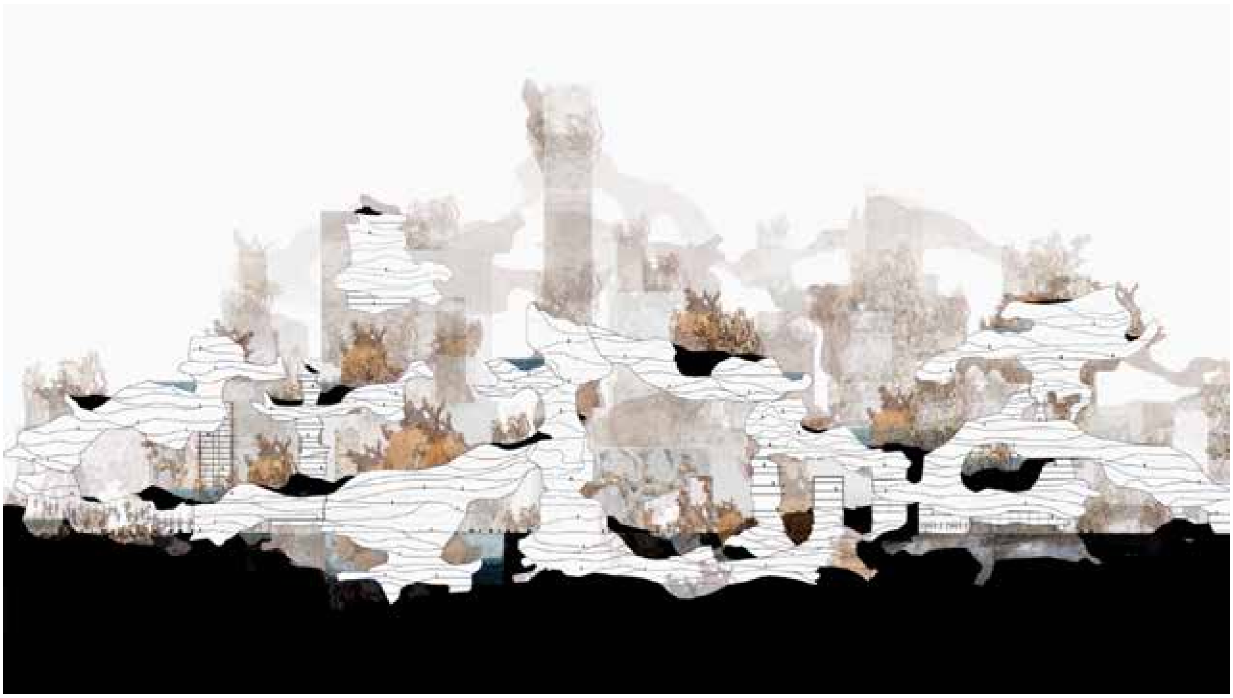

Figure 2. "What if we create a new layer on the Earth that incorporates growing human habitation and consumption?". Winy Mass. Dezeen (2021)

seminal essay *Leverage Points: Places to Intervene in a System* (1999) outlines a framework for systemic change. High- impact leverage occurs not by adjusting surface-level variables, but by modifying the structure of feedback, the flow of information, and even the goals of the system.

The adaptive urban layer targets several such points: it introduces new material flows (from waste to value), distributed feedback mechanisms (like energy and water loops), and redefines the purpose of architecture from static shelter to regenerative infrastructure. This positions the layer as a tool not only for mitigation but for reprogramming urban metabolism through material and systemic recoding.

1.1.4. Winy Maas and The Sponge: A New Ground Plane
In his manifesto *The Sponge*, architect Winy Maas (2021) proposes a city designed to absorb, store, and redistribute flows of energy, water, and information, just as a natural sponge does. For Maas, the future city is no longer defined by formal typologies but by its capacity to respond to environmental and social input.

The Visionary Urban Layer echoes this absorptive principle. It is porous, retrofittable, and multifunctional. It transforms rooftops, voids, and infrastructural edges into spatial and energetic reservoirs, capable of filtering water, capturing carbon, and connecting fragmented systems. As in *The Sponge*, architecture becomes a medium of reparation and redistribution, rather than consumption.

2. An Adaptive Urban Layer For A Post-Carbon City

This paper proposes a transformative intervention: a *Visionary Urban Layer* that overlays, integrates, and reactivates the existing urban fabric. It is not a new masterplan or isolated mega-project, but a modular, distributed, and regenerative system. It responds to two urgent global challenges, carbon emissions and agricultural waste, by rethinking the material, energetic, and ecological operations of the city itself.

Rather than demolishing or rebuilding, this layer grows atop and between existing structures, stitching together voids, rooftops, and neglected urban edges into a cohesive ecological framework. It is inspired by the non-destructive superimposition of Constant Nieuwenhuys's New Babylon (Wigley, 1998), the biotechnological imagination of Neil Spiller (2006), and the adaptive sponge-like logic proposed by Winy Maas (2021).

2.1. Material System: Mycelium-Based Construction
At its structural core, the layer relies on mycelium composites, biomaterials grown from agricultural waste (e.g., straw, husks, sawdust) and colonized by fungal networks. These materials are lightweight, biodegradable, fire-resistant, and can be shaped into bricks, panels, or insulation (Ecovative Design, 2023). Critically, mycelium composites are carbon-negative: they sequester CO_2 during growth, unlike cement or plastic-based insulation which emit large quantities of greenhouse gases during production (MycoHAB, 2024). This not only solves a waste management issue, repurposing agricultural byproducts, but also creates building systems that store rather than emit carbon, aligning material cycles with climate goals (FAO, 2021; UNEP, 2022).

2.2. Energy System: Pyrolysis and Waste-to-Heat Integration
A second key component of the layer is decentralized pyrolysis, the thermal decomposition of organic matter in low-oxygen conditions to produce biochar and syngas. Integrated into residential or community-scale modules, small pyrolysis units convert household or neighborhood organic waste into usable thermal energy for heating, cooking, and even steam generation. The byproduct, biochar, is a stable form of carbon that can enrich soil, filter water, or be stored as a carbon sink (United States Biochar Initiative, 2020).

Unlike conventional incineration, pyrolysis retains the carbon in solid form while capturing the energy from waste, turning the city's biomass flows into closed-loop energy systems. Studies show that biochar production can sequester 50–70% of biomass carbon and provide high-grade heat for small- scale applications (Lehmann & Joseph, 2015).

2.3. Water System: Myco-filtration and Greywater Cycling

The urban layer also manages water flow through fungal ecologies. Before being discharged or reused, greywater passes through myco-filtration beds, substrates like wood chips inoculated with fungi such as *Pleurotus ostreatus*, which break down pathogens, pharmaceuticals, and hydrocarbons (Stamets, 2005; Mnkandla & Otomo, 2021). This method is energy-efficient and low- cost, offering a biological solution to water purification at the building or block scale.

Combined with indoor planters or hydroponic corridors, the system reuses water multiple times, circulating it between washing, irrigation, and even cooling, drastically reducing potable water demand and nutrient runoff.

2.4. Spatial Strategy: Infill, Overlay, and Adaptation

The Visionary Urban Layer is deployed not in empty land but across the underused spaces of existing cities: rooftops, highway medians, alleyways, blind facades. It provides new circulation paths, energy and food nodes, water infrastructure, and communal platforms. These interventions are non-invasive, favoring lightweight components, modular deployment, and reversible assemblies. The layer is porous, absorptive, and regenerative. It becomes a new urban interface, one that connects broken ecologies, closes loops of energy and matter, and creates opportunities for collective care.

3. Case Study: Earthship reimagined, a closed-Loop urban node

To ground the vision of an adaptive urban layer in tangible strategies, this section presents a reimagined Earthship, not as an isolated off-grid home in the desert, but as a modular urban node embedded within the proposed architectural layer. Originally designed by Michael Reynolds in the 1970s, Earthships were conceived as self-sufficient buildings using recycled materials, passive solar design, greywater recycling, and indoor food systems (Binder & Reynolds, 2024).

This reinterpretation retains the Earthship's closed-loop ethos, but integrates it with contemporary biomaterials, waste-to-energy systems, and ecological design logics that align with urban challenges.

3.1. Structure and Material Logic: From Tires to Mycelium

Traditional Earthships were constructed using earth-packed tires, an effective but labor-intensive method. In the urban variant, walls and partitions are made

Figure 3. Carbon sequestering structure (mycelium), designed for human and more-than-human species.
Sebastián Domínguez, Esteban Martínez (2025)

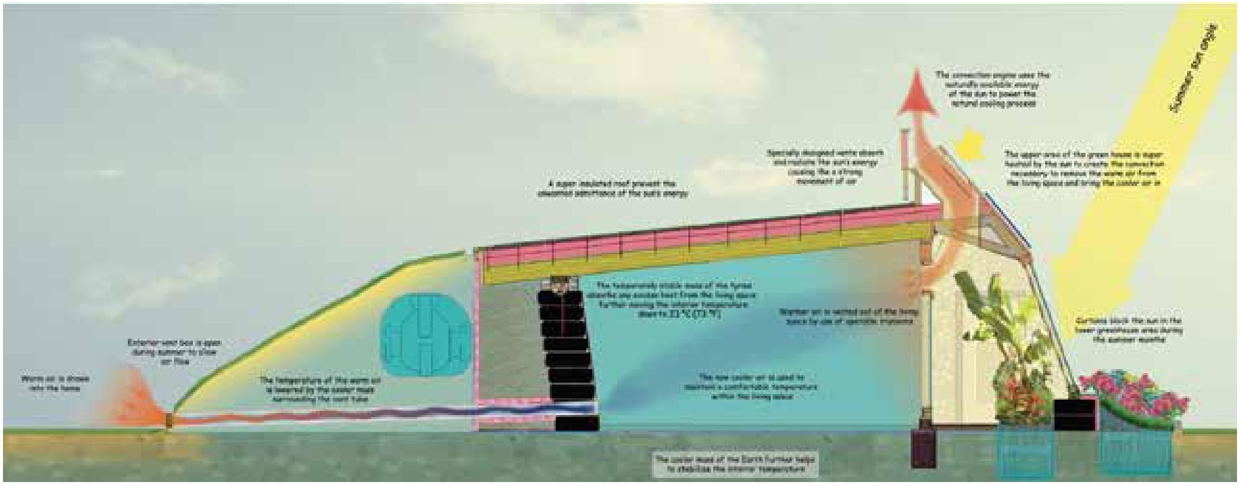

Figure 4. Natural convection cooling an Earthship. *Amaze Smith (2011)*

from mycelium-based composites grown from local agricultural waste such as straw and corn husks. These materials provide structural lightness, thermal insulation, fire resistance, and biodegradability (Ecovative Design, 2023).

According to the MycoHAB project in Namibia, mycelium bricks store up to 0.8 kg of CO_2 per kilogram of material, offering a carbon-negative alternative to concrete (The Guardian, 2024). This substitution transforms the Earthship from a recycler of industrial waste to a generator of biological infrastructure.

3.2. Bio-Energy from Waste: Pyrolysis in Action

Instead of relying on photovoltaics alone, the urban Earthship incorporates a compact pyrolysis system that processes household organic waste into biochar and thermal energy. The thermal output is used for space heating, water heating, and small-scale mechanical systems (e.g., pumps or fans), and the resulting biochar enriches the soil in the building's integrated greenhouse (United States Biochar Initiative, 2020).

This creates a feedback loop: waste becomes heat, and heat powers systems while producing a byproduct (biochar) that enhances food-growing systems. The process also prevents methane emissions that would result from organic waste decomposition in landfills (Lehmann & Joseph, 2015).

3.3 Water and Food: Myco-filtration and Micro-Agriculture

Greywater produced in the home, kitchen, shower, and laundry, passes through a fungus-based myco-filter, in which mycelial networks break down pathogens and contaminants. Research shows that fungi such as *Stropharia rugosoannulata* can remove up to 99% of E. coli from greywater (Mnkandla & Otomo, 2021).

Filtered water irrigates interior hydroponic beds where leafy greens, herbs, and fungi are cultivated year-round. This reuses water multiple times before discharge, integrating food production and filtration into one living system (Stamets, 2005).

water → fungus → food → waste → energy → heat → water.

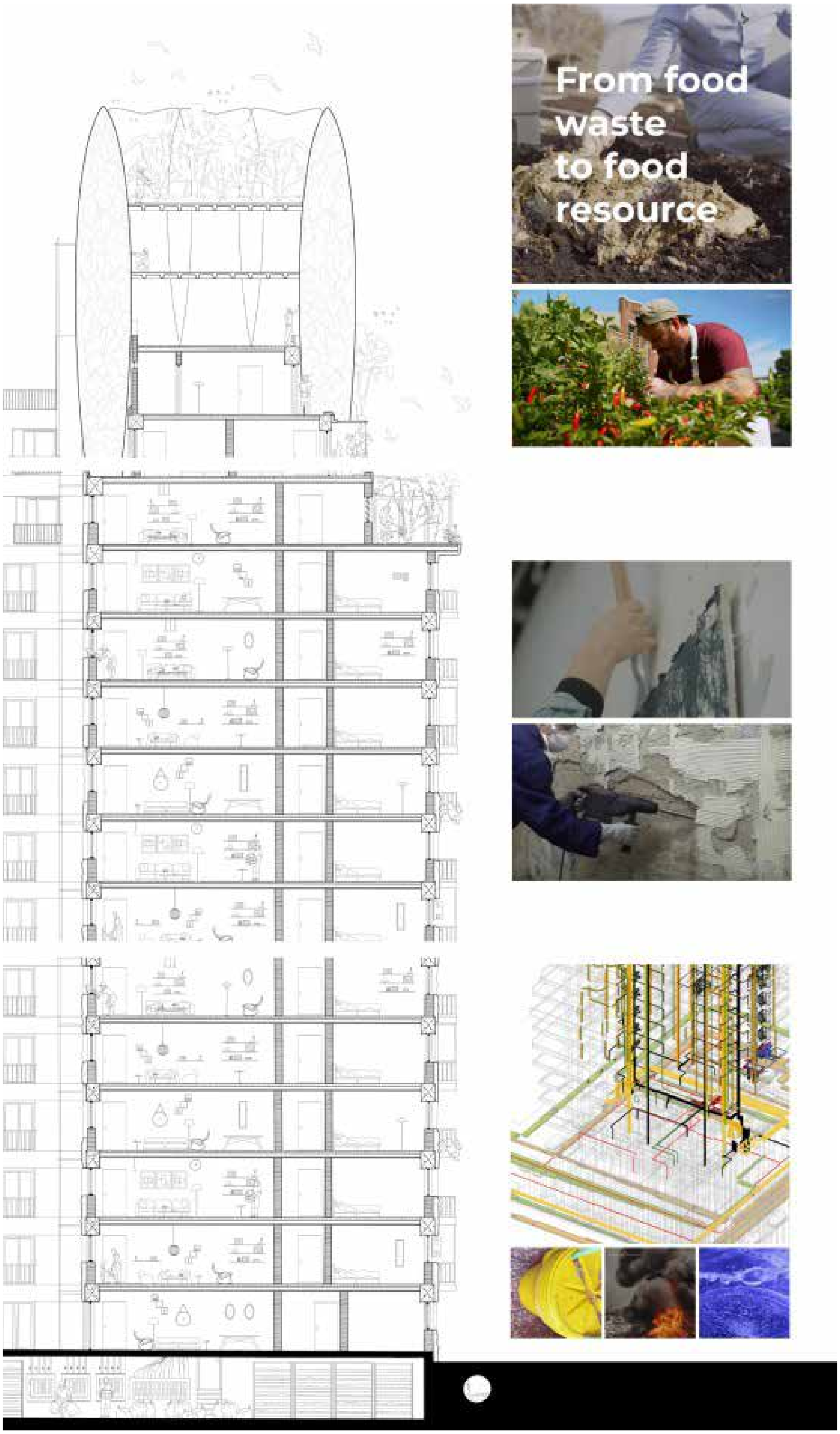

Figure 5. Metabolic system proposed within a tenement typology in New York. *Sebastián Domínguez*

3.4. Integration with the Urban Layer

Unlike rural Earthships, this unit is conceived as part of a collective infrastructure. Installed on rooftops or over highway voids, each module connects to others through resource-sharing networks: excess heat, water, or even mushrooms can be exchanged between nodes. Collectively, they form a patchwork of resilience embedded into the city's physical and ecological systems.

This case study demonstrates how a speculative, visionary architectural approach can be translated into deployable, low-tech urban tools. It also affirms that the solution to carbon-intensive construction lies not in high-tech towers, but in biological systems, waste re-valorization, and infrastructural empathy.

4. Conventional Architecture Vs. Closed-Loop Urban Systems

To assess the effectiveness of the proposed urban layer and the reimagined Earthship node, this section compares them with conventional building systems across four key dimensions: carbon emissions, material cycles, energy generation, and waste management.

4.1. Carbon Emissions and Embodied Energy

Conventional architecture relies heavily on carbon-intensive materials such as concrete, steel, and glass. The production of cement alone contributes approximately 8% of global CO_2 emissions (Lehne & Preston, 2018). These materials also require high energy input during transport and assembly, often leading to long-term environmental costs over the building's life cycle.

In contrast, the Earthship prototype uses mycelium bricks and panels, which are biologically grown from local agricultural waste, and require minimal processing energy. MycoHAB estimates that their material stores up to 0.8 kg of CO_2 per kilogram produced, making it not just low-carbon but carbon- negative (The Guardian, 2024). Furthermore, these materials are biodegradable or compostable, allowing full reintegration into the environment at end-of-life.

Indicator	Conventional Architecture	Earthship + Urban Layer
Embodied Carbon (kg CO_2/m^2)	500–800 kg	<150kg or lower (est.)
End-of-Life Path	Landfill or demolition	Compostable/ reusable
Material Source	High (industrial)	Low (biological growth)

4.2. Energy Systems and Operational Emissions

Most urban buildings are grid-dependent and draw power from fossil-fuel- based energy mixes. Operational emissions, from heating, cooling, lighting, and appliances, contribute substantially to a building's lifetime environmental impact (United Nations Environment Programme, 2022).

The Earthship node's waste-to-energy system uses pyrolysis to produce clean heat and biochar from organic waste. This can supplement or replace traditional heating and generate net-positive thermal energy for water boiling or mechanical systems (United States Biochar Initiative, 2020). Because the energy source is locally sourced biomass, the system drastically reduces reliance on external grids and minimizes scope 1 and scope 2 emissions.

Metric	Conventional Systems	Earthship Prototype
Primary Energy Source	Fossil grid mix	Pyrolysis + solar
Energy from Waste	No	Yes
Operational Carbon Emissions	High	Low/Negative

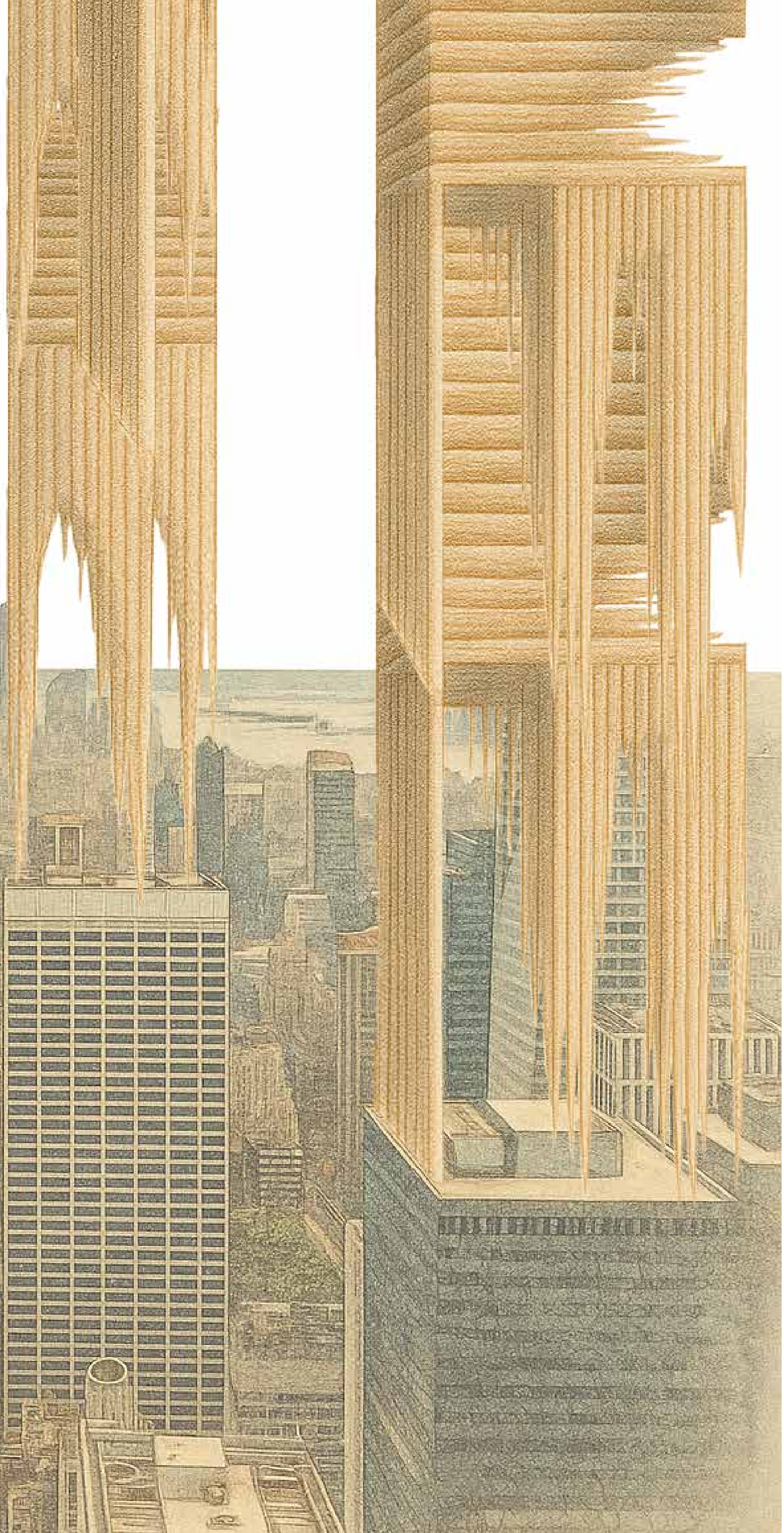

Figure 6. Speculative image of the Adaptive Urban Layer. *Sebastián Domínguez, Esteban Martínez (2025)*

4.2. Waste Management and Water Use

In typical buildings, greywater and blackwater are directed into centralized sewer systems, requiring vast amounts of energy and chemicals for treatment. At the same time, rainwater is often wasted, and food waste is sent to landfills where it decomposes anaerobically, producing methane.

By contrast, the urban Earthship incorporates on-site myco-filtration, allowing greywater to be safely reused in hydroponic agriculture and non-potable systems (Stamets, 2005). Paired with rainwater harvesting, the system dramatically reduces potable water demand and urban runoff.

Metric	Conventional Building	Adaptive Urban Layer
Organic Waste Integration	None	Pyrolysis + mycelium
Greywater Treatment	Centralized/ discarded	On-site reuse
Agricultural Waste Application	No	Yes (material + energy)

4.3. Spatial and Social Function

Conventional buildings tend to prioritize single-use programming and are largely inert in terms of resource flows. Surfaces like roofs, walls, and alleys are underutilized and often contribute to urban heat islands and stormwater overloads.

The Visionary Urban Layer activates these surfaces through modular, ecological infrastructure: growing food, capturing carbon, producing energy, and supporting biodiversity. It reconnects spatial voids and provides civic value, serving as infrastructure for equity, not just efficiency.

Attribute	Conventional Design	Adaptive Urban Layer
Surfaces as Infrastructure	No	Yes (productive / regenerative)
Civic Engagement Potential	Low	High (community nodes)
Spatial Flexibility	Limited	High (modular / plug-in)

5. Visionary Architecture As A Tool For Systemic Change

The urgency of the climate crisis and the rising material pressures of urbanization demand a reorientation of architectural thinking, from optimization within outdated systems to strategic interventions that reshape those systems entirely. This layer is not simply an aesthetic or technological proposal, but a systemic reframing of what architecture and urban infrastructure can be.

Historically, visionary architecture has often been dismissed as utopian or impractical. Yet as Constant Nieuwenhuys, Archigram, and Superstudio demonstrated, visionary design offers a critical lens: it reveals the inadequacies of current paradigms and imagines alternatives that reconfigure our relationships to space, material, and time. In the Anthropocene, these alternatives must become more than images, they must become strategies. Similarly, Neil Spiller insists that speculative architecture has the power to “chart what might be, not just what is,” thereby expanding the boundaries of what architecture can address (Spiller, 2006, p. 10).

What distinguishes the adaptive urban layer is its ability to operate at multiple scales of impact, echoing Donella Meadows’ insight into leverage points. It does not merely optimize the performance of individual buildings (a low- leverage action), but intervenes at higher levels: shifting material flows, embedding regenerative energy systems, and challenging the purpose of architecture itself. By functioning as both infrastructure and ecology, it changes the goals and feedback loops of the urban system, aligning built form with circular, restorative principles.

Moreover, its foundation in real-world technologies, mycelium composites, biochar systems, pyrolysis, and myco-filtration, ensures that it can move from theory to application. These components are not speculative fantasies; they are being tested and deployed today. Yet the challenge lies in synthesizing them into coherent spatial frameworks, supported by governance models and policy shifts that recognize adaptive, regenerative architecture not as luxury, but necessity.
This synthesis requires a new kind of architectural practice, one that blurs disciplinary boundaries and engages with biology, engineering, policy, and social justice.

The Adaptive Urban Layer, like New Babylon or The Sponge, is not just a thing to be built, it is a method of thinking, designing, and intervening. It demands participatory design, radical material experimentation, and a willingness to act at both infrastructural and poetic scales. It enacts this concept by turning neglected spaces, rooftops, overpasses, blind facades, into productive, connective tissue. Its ecological logic is not decorative but performative: it grows from waste, powers itself, filters its own water, and supports micro-agriculture.

Furthermore, it reframes architectural authorship. While conventional design assumes a top-down process of spatial control, this layer is modular, iterative, and participatory. It invites inhabitants to become co-managers of energy, water, and food, participants in an ecosystem, not just users of a space.

In a world where cities are responsible for the majority of carbon emissions, the most radical move may be not to build more, but to overlay wisely: to layer healing mechanisms atop the systems we already have.

6. Conclusion

The intersection of carbon emissions, agricultural waste, and urban fragmentation demands a reframing of architecture's purpose in the 21st century. The Visionary Urban Layer proposed here is not a replacement for the city but an ecological scaffold—one that overlays, connects, and heals existing urban systems through lightweight, modular, and regenerative interventions.

Rooted in the visionary tradition, and grounded in the systemic thinking of Donella Meadows, this layer offers more than form: it presents a functional material infrastructure capable of absorbing waste, generating energy, purifying water, and closing feedback loops. Through mycelium-based materials, biochar-producing pyrolysis, and myco-filtration, architecture is repositioned as a dynamic interface between humans and ecosystems.

The reimagined Earthship prototype demonstrates how such systems can be applied at micro-urban scales, becoming nodes of resilience, autonomy, and resource intelligence. Compared to conventional building methods, these systems drastically reduce carbon output, re-valorize waste, and foster local adaptability.
In a time of accelerating ecological collapse, architecture must intervene at higher leverage points—not only improving performance but changing the goals of the system itself. The Visionary Urban Layer is one such intervention: speculative in origin, practical in deployment, and essential for an urban future defined not by extraction, but by ecological integration, circularity, and collective care.

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