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From Ornament to Organism: Vertical Forests as a Biophilic, Climate-Responsive Typology for Sustainable Urbanism

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From Ornament to Organism:

Vertical Forests as a Biophilic, Climate-Responsive Typology for Sustainable Urbanism

THESIS

submitted in partial satisfaction of the requirements
for the degree of

MASTER OF ARTS

in Art History

by

Linda Duncan

Thesis Committee:
Associate Professor Lyle Massey, Chair
Professor Bert Winther-Tamaki
Associate Professor Roberta Wue

2025

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ABSTRACT OF THE THESIS

From Ornament to Organism:
Vertical Forests as a Biophilic, Climate-Responsive Typology for Sustainable Urbanism

by

Linda Duncan

Master of Arts in Art History

University of California, Irvine, 2025

Associate Professor Lyle Massey, Chair

As urban centers grapple with the escalating effects of climate change, pollution, and biodiversity loss, architects and urban designers are increasingly turning to innovative solutions for sustainable urbanism. One such solution is the vertical forest, a typology pioneered by Stefano Boeri that integrates dense, multi-species vegetation into high-rise buildings, creating biophilic, climate-responsive urban environments. This paper examines the ecological, social, and architectural foundations of vertical forests, such as Milan's Bosco Verticale and the Trudo Tower in the Netherlands, situating them within the broader context of sustainable architecture. While acknowledging the practical and theoretical challenges of this typology, including issues of cost, maintenance, and ecological authenticity, the paper considers how vertical forests redefine the role of vegetation in urban design and architecture, from superficial ornament to integrated ecological infrastructure, as a strategy to mitigate environmental stress and climate change. Ultimately, the paper considers the potential of vertical forests within the broader conversation on sustainable urban housing, positioning them as both a growing presence and a

catalyst toward a more biodiverse, biophilic, interdependent, and ecologically resilient urban future.

INTRODUCTION

In today's rapidly urbanizing world, cities face intensifying ecological and climate-related challenges that demand innovative responses. This is especially true for the design and architectural sectors, which must confront issues of cost, space, accessibility, and environmental responsibility. One of the most innovative emerging solutions are so-called vertical forests, pioneered by Italian architect Stefano Boeri. These are vegetated high-rise structures that integrate scaled urban forests built vertically into multifamily residential buildings. (**Fig. 1**) These dwellings represent a biophilic, climate-responsive typology that offers promising ecological and social benefits, including biodiversity, air purification, and urban cooling, yet they also face practical and theoretical challenges and limitations. This paper will analyze the foundations and efficacy of vertical forests as a response to climate change and environmental stress in urban landscapes, exploring their ecological, social, and architectural foundations, while examining their benefits, challenges, and implications for sustainable urbanism.

Urbanism and The Triple Planetary Crisis

According to recent statistics from the United Nations, cities currently cover only about three percent of the Earth's surface yet are home to over fifty percent of the global population, a figure projected to rise to seventy percent by 2050.¹ Meanwhile, based on 2020 data, just over three percent of urban land is comprised of open space, which is significantly below recommended levels.² This shortfall negatively impacts urban quality of life and underscores the

¹ United Nations Environment Programme, "Leveraging Urban Agriculture to Support Cities," *UNEP*, July 21, 2022, <https://www.unep.org/news-and-stories/video/leveraging-urban-agriculture-support-cities>.

² United Nations. "Urban Planning Must Factor in Needs of Migrants." *UN News*, July 7, 2023. <https://news.un.org/en/story/2023/07/1138682>.

need for more sustainable urban planning and land management strategies. Current environmental and social pressures on urban centers will continue to escalate. Pollution is one such pressure, which increasingly extends beyond city centers. According to the World Health Organization, 99% of the world’s urban population breathes substandard quality air³ with air pollution presently being the largest environmental cause of disease and premature death worldwide.⁴ Cities also account for approximately 75 percent of carbon emissions and up to 80 percent of energy consumption.⁵ Dense city areas also increasingly contend with rising temperatures, amplified by the urban heat island effect, which is only expected to intensify with global warming, threatening livability in dense urban centers. Suburban areas also contribute to increasing rates of pollution and carbon emissions, due to urban sprawl and greater reliance on automobiles. The methods and criteria used to design and construct buildings and infrastructure therefore have a profound effect on the environment and the quality of life of communities and are an important focal point in combating climate change. Sustainability efforts through design in the building sector offer significant potential to reduce the environmental, economic, and social impacts of construction, building operations, and management.

These three interconnected issues - climate change, loss of biodiversity, and pollution – compound and accelerate one another: climate change accelerates biodiversity loss and

³ World Health Organization, “Ambient (Outdoor) Air Pollution,” *WHO*, fact sheet, updated October 24, 2024, [https://www.who.int/news-room/fact-sheets/detail/ambient-\(outdoor\)-air-quality-and-health](https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health).

⁴ United Nations Framework Convention on Climate Change (UNFCCC), “What Is the Triple Planetary Crisis?,” *UN Climate Change News*, April 13, 2022, <https://unfccc.int/news/what-is-the-triple-planetary-crisis>.

⁵ UNEP, “Leveraging Urban Agriculture to Support Cities.”

exacerbates the impacts of pollution, while degraded ecosystems in turn reduce resilience to climate extremes.⁶ This convergence of challenges has been referred to by Under-Secretary-General of the United Nations and Executive Director of the United Nations Environment Programme (UNEP), Inger Andersen, and others currently as the “Triple Planetary Crisis.” Well before this term entered widespread use through UNEP’s messaging in 2020,⁷ a growing number of architects and urban designers working at the intersection of ecology and the built environment have increasingly endeavored to pioneer new approaches that seek to transform the built environment from a source of ecological degradation to an engine of urban sustainability. Among these innovations, the vertical forest building has emerged as a novel architectural typology that integrates dense vegetation directly into the residential high-rise form, creating a living ecosystem that filters pollutants, produces oxygen, moderates microclimates, and provides a habitat for urban wildlife.

While certainly ornamental, the dense greenery associated with vertical forests represents more than mere aesthetic embellishments; it constitutes a living, biophilic, climate-responsive ecosystem that bridges architecture, ecology, and urbanism. By incorporating vegetation directly into the building envelope, these structures effectively function not only as high-density dwellings but also as machines of ecological production - housing birds, insects, and plant life, while reducing urban sprawl, and moderating microclimates to alleviate the urban heat stress of their surrounding environs. They are, however, not without limitations, as questions regarding their cost, maintenance, and ecological authenticity continue to prompt critical examination.

⁶ UNFCCC, “What Is the Triple Planetary Crisis?”

⁷ António Guterres, “Alongside Pandemic, World Faces ‘Triple Planetary Emergency,’” press release, United Nations, November 16, 2020, <https://press.un.org/en/2020/sgsm20422.doc.htm>.

This paper seeks to position vertical forests within the longer history of architecture's greening, arguing for their significance as a transformative yet evolving typology - one that shifts the traditional architectural role of vegetation from mere superficial ornament to that of an integrated organism. As a living building form, the vertical forest building gestures toward a more innovative, biodiverse, and climate-responsive approach to ecological urban design.

The Greening of Architecture and Modern Construction

In *The Greening of Architecture*, published in 2013, authors Phillip James Tabb and A. Senem Deviren offer an overview of the history of contemporary sustainable architecture. As they indicate, there is no single or universally agreed upon definition or defined measure of sustainable design, and the use of "green" and "sustainable" have historically been used interchangeably and ambiguously. However, much of the effort within the genre has generally been focused on addressing and reversing the unsustainable past practices and missteps of the Modernist era. With the industrial revolution, and during the rise of post-World War II architectural modernism, there was an intense emphasis on technology, and with it the concomitant wasteful uses of land and resources, along with an increased dependence on fossil fuels. During this period, there was also a rapid increase in the world's population, as well as increased dependence on automobiles, leading to changes in design, construction practices, and general urban sprawl. Coupled with shifts in wealth and insatiable consumption practices, this was accompanied by little regard for resources and environmental limits.⁸

⁸ Phillip James Tabb and A. Senem Deviren, *The Greening of Architecture: A Critical History and Survey of Contemporary Sustainable Architecture and Urban Design* (Burlington: Ashgate Publishing Comoany, 2013), 11-13.

Amid a broader environmental awakening in the 1960s, green technologies began to emerge, inspired by a growing awareness of the planet's limits. These have since evolved from being focused primarily on technology, to encompassing solar and energy-efficient designs influenced in part by volatile oil availability and rising prices as well as an increased awareness of the environment, a desire for a deeper connectedness to nature, and a concern for matters of human health and wellness. During this progression, the movement naturally evolved to include the literal greening of buildings in the 1990s, with green roofs and façades as areas of focus, including green walls, green façades, greenhouses, and sky-gardens.⁹

Unfortunately, much of the history of green architecture, despite making efforts to incorporate and implement renewable technologies, continued to utilize the same conventional and ecologically damaging materials, building equipment, and systems that were commonplace during the post-World War II period they were desirous of improving upon.¹⁰ Global cement production, integral to modern construction, rapidly increased during this period, rising nearly four-fold since 1990 and more than thirty-fold since 1950, with its associated anthropogenic CO₂ emissions from production rising in tandem, underscoring the emissions growth tied to global urban expansion.¹¹

Conventional cement, and by extension concrete, with its long and ubiquitous history in modern construction, is produced and consumed at a staggering scale, making it at once the

⁹ Tabb and Deviren, *Greening of Architecture*, 111-113.

¹⁰ *Ibid.*, 11.

¹¹ Robbie M. Andrew, “Global CO₂ Emissions from Cement Production, 1928–2018”, *Earth System Science Data* 11 (2019): 1675–1710, <https://essd.copernicus.org/articles/11/1675/2019/>.

second most consumed material on Earth after water, while its conventional manufacture is also among the leading industrial sources of CO₂ emissions, significantly contributing to climate change.¹² In contrast, plants sequester and consume atmospheric CO₂ as part of their natural growth processes. They are capable of detoxifying contaminated water to use for growth, absorbing urban waste byproducts, filtering pollutants by soaking up toxic elements such as cadmium and lead,¹³ and producing clean oxygen in return. Therefore, the inclusion of plant life, with its biological utility and phytoremediation properties, in the literal greening of architecture, seems to emerge as a natural, complementary, and strategically valuable proposition.

Sky gardens are not entirely new, as evidenced by legends of the ancient Hanging Gardens of Babylon. But greening strategies re-emerged with greater traction in the 1990s, as architects and urban planners sought to integrate vegetation more intentionally into the urban built form. However, the concept of vertical forest buildings has only more recently emerged in the evolution and development of sustainable and green architecture, characterized by increasingly ambitious, large scale, and complex approaches to building-integrated forms of architectural greening.

Bosco Verticale - Prototype of the Vertical Forest Typology

One project, designed by Milanese architect Stefano Boeri, consists of two multifamily residential towers in Milan, Italy, called Bosco Verticale, which translates to Vertical Forest in English. Designed in 2009 and completed in 2014, Bosco Verticale functions as a pioneering

¹² Denise K. Deluca, “Biomimicry: Nature Inspiring Design,” in *Routledge Handbook of Sustainable Design*, Routledge Environment and Sustainability Handbooks, ed. Rachel Beth Egenhoefer (New York: Routledge, 2024), 148.

¹³ Tabb and Deviren, *Greening of Architecture*, 112.

experiment in vertically vegetated living buildings, developed as part of a larger redevelopment project in Porta Nuova, a major business district in Milan. Conceived as a prototype for a new building concept that prioritizes urban greening and biodiversity, the overall design adheres to the following principle: the building façades incorporate deep hydroponic planters, that effectively envelop the towers in greenery. The specially designed planters support over 25,000 plants in total, including 800 trees (up to 9 meters tall), and approximately 4,500 shrubs, and 20,000 plants, representing almost 100 different plant species (23 types of trees and large shrubs, and 68 varieties of smaller shrubs, including trailing and groundcover species).¹⁴ (Appendix A) There are water collection tanks, and the plants are irrigated with greywater from the buildings, along with rainfall, and groundwater, according to their needs, which are monitored by sensors. As with all plants, water vapor is then naturally released back into the atmosphere via evapotranspiration, which transports nutrients, helps to regulate plant temperature, and cools the surrounding air.

Ecological Performance and Biodiversity

Unlike mineral façades made of glass, steel, or stone, these vegetative shields do not reflect or amplify the sun's rays, but rather filter and diffuse sunlight, providing shading and thereby creating a welcoming and comfortable internal microclimate, that results in reduced energy demands and mitigates urban heat island effects. Together with this, the green curtain façade is said to produce oxygen and absorb CO₂, microparticles, and dust, while simultaneously attenuating noise pollution. Vertical forests offer a multifaceted model of urban sustainability -

¹⁴ Enrico Pinto, "A House for Trees, Animals, and (also) Humans," in *Bosco Verticale: Morphology of a Vertical Forest*, edited by Stefano Boeri Architetti, trans. Sylvia Adrian Notini (New York: Rizzoli, 2025), 10.

one where form and flora coalesce to produce both ecological and social value that extends well beyond aesthetic enhancement. These buildings function as living systems that actively contribute to the health of the urban environment and its inhabitants.

Vertical forests function as living systems that contribute significantly to improving air quality. The extensive vegetation planted on the balconies and façades of the Bosco Verticale in Milan captures approximately 30 tons of carbon dioxide annually, along with various other pollutants and particulate matter, while producing approximately 19 tons of oxygen.¹⁵ These buildings effectively function as urban lungs and livers, breathing in pollution, filtering toxins, and exhaling oxygen back into the cityscape, to mitigate the adverse effects of urban pollution. This contributes to improved air quality and has the potential to enhance respiratory conditions and benefits for residents.

The vertical forest building typology mitigates the Urban Heat Island effect (UHI) both by providing natural shading and through the process of evapotranspiration. The dense vegetal canopies help cool both the building surfaces and the surrounding air, thereby reducing dependence on energy-intensive cooling systems. Deciduous trees provide shade in summer and in shedding their leaves in autumn, permit sunlight to pass through in winter, contributing to seasonal thermal efficiency. (**Figs. 2 & 3**) These localized microclimate benefits are particularly valuable in the context of global warming, as the intensification of urban heat exacerbates health risks and increases energy demand and consumption.

¹⁵ Stefano Boeri, “Bosco Verticale,” in *Bosco Verticale: Morphology of a Vertical Forest*, ed. Stefano Boeri Architetti, trans. Sylvia Adrian Notini (New York: Rizzoli, 2025), 89.

Satellite imaging conducted by the European Space Agency in 2022 further reinforces these findings, as the ESA's thermal mapping identified Bosco Verticale, mapped collectively with the adjacent Biblioteca degli Alberi (BAM) park, as markedly cooler zones within the Milanese urban fabric, emphasizing the typology's broader impact on neighborhood-scale UHI mitigation.¹⁶ (**Fig. 4**) Empirical data from Milan's Bosco Verticale supports these environmental benefits. According to the Porta Nuova Impact Report, developed by Tiresia, Politecnico di Milano, and the European House – Ambrosetti, average surface temperatures in the surrounding area decreased by nearly 8 °C (14.4 °F) between 2011 and 2021, following the expansion of vegetated zones associated with the project.¹⁷ In addition, summer heating of the building façade was measurably reduced.¹⁸ Furthermore, Bosco Verticale's internal building temperatures

¹⁶ Boeri, "Bosco Verticale," 87.

¹⁷ Kelly Russell Catella, "A Complex Ecosystem," in *Bosco Verticale: Morphology of a Vertical Forest*, ed. Stefano Boeri Architetti, trans. Sylvia Adrian Notini (New York: Rizzoli, 2025), 131.

¹⁸ Boeri notes a reduction of up to 30 ° - a seemingly high reported figure. It is important to emphasize that Boeri refers specifically to reduction of the summer temperature of the façade, not ambient air temperature. It is reasonable to assume he is referencing particular sun-exposed mineral surfaces which, in the absence of vegetative cover, would experience significant solar gain. Given Boeri's broader critique of mineral urban materials, which reflect and amplify heat, this reported reduction is noteworthy and merits consideration. See his language specific to summer façade in: Stefano Boeri, *Un Bosco Verticale: Libretto di Istruzioni per il Prototipo di Una Città Foresta / A Vertical Forest: Instructions Booklet for the Prototype of a Forest City* (Montova: Corraini Edizioni, 2015), 122; and more broadly in: Stefano Boeri, "Bosco Verticale," in *Bosco Verticale: Morphology of a Vertical Forest*, trans. Sylvia Adrian Notini (New York: Rizzoli, 2025), 89.

likewise demonstrated a reduction of 2–3 °C (3.6–5.4 °F), contributing to lower associated energy needs,¹⁹ with a 30-40% reduction in energy consumption reported in summer months.²⁰

Moreover, the vertical forest design addresses the challenge of urban sprawl by not only responding to the growing need for vertical housing, but simultaneously enabling the densification of vertical green space, through its unique form of vertical reforestation. The buildings (Confalonieri tower is 18 floors/ 76m and De Castilia tower is 26 floors/ 110m), comprised of 131 apartment units, support vegetation equivalent to 30,000 square meters of forest and undergrowth, all situated on just 3,000 square meters of urban land.²¹ Together, these ecological and urban benefits position vertical forests as a promising architectural typology that integrates environmental functionality into the fabric of urban living, aligning architecture with principles of sustainability as well as regenerative design.

The philosophy underlying the vertical forest typology isn't just a matter of greening, it extends beyond aesthetics and environmental gestures to address a broader and increasingly important component of sustainability that has been gaining in relevance, recognition, and importance as a vital component of the modern understanding of sustainability: the need to integrate and promote biodiversity. This modern and expanded understanding of biodiversity as essential to sustainability reflects a new form of ethical urbanism, one that embraces a non-anthropocentric perspective, requiring a broader and more inclusive planetary view. It

¹⁹ Boeri, "Bosco Verticale," 89.

²⁰ Stefano Boeri, "Italian Architect Stefano Boeri on Sustainable Design and His 'Vertical Forests'", (Worldview) WBEZ Chicago, October 6, 2016, <https://www.wbez.org/worldview/2016/10/06/italian-architect-stefano-boeri-on-sustainable-design-and-his-vertical-forests>.

²¹ Boeri, "Bosco Verticale," 87.

acknowledges that it is no longer acceptable to simply prioritize our human interests exclusively, without regard for, or to the detriment of other species. This non-anthropocentric, ethical, and expanded worldview remains deeply concerned with the fate and wellbeing of humans, but repositions it within a new kind of discourse, in which humanity is no longer alone on life's pedestal.²²

Boeri consistently refers to the Bosco Verticale as a home for trees that also houses humans and birds. This is not just a catchy phrase – in fact, Boeri explains that the plants are integral in driving the building design, and he considers them the buildings' first and foremost residents.²³ The plants must be carefully studied and selected by a team that includes experts in botany, agronomy, and ethology, and are specific to the building location and local environs, as they take into consideration each side of the building and its associated sun exposure, as well as the different elevations, in laying out the plant locations, unique to each proposed site. The building is then designed around the layout of the plants and their requisite planter locations, which direct the ultimate design and make the planting scheme the primary driver of the architectural form.

Boeri suggests that the vertical forest speaks an elementary “mute” architectural language, where grand or “shouted” architecture is tamed, taking second place to the greenery on

²² Stefano Boeri, Down from the Stand: Arguments in Favor of a Non-Anthropised Urban Ethics,” *Volume (Amsterdam, Netherlands)*, no. 18 (2008): 56.

²³ Sam Lubell, “How Milan’s Bosco Verticale Has Changed the Way Designers Think About Sustainable Design,” *Architectural Digest*, November 3, 2020, <https://www.architecturaldigest.com/story/how-milans-bosco-verticale-has-changed-the-way-designers-think-about-sustainable-design>.

the pedestal.²⁴ Therefore, though the typology is infinitely replicable, each iteration is inherently unique and responds directly to its selected vegetation.

The design seeks to not only address the need for vertical housing to mitigate urban sprawl but also foregrounds the relationship between humans and other living species within designed urban environments. Boeri's long-standing fascination with trees, since his childhood, has inspired this vision. In many ways, there is a poetic confluence between the notions of home and hospitality: as this home for trees also serves as host and habitat for wildlife. Approximately thirty bird species have nested there, alongside bats, butterflies, ladybugs, honeybees, spiders, and other insects, forming a biodiverse interspecies ecosystem and complex cohabitation that also includes a hamster, rabbit, cats, and dogs, along with humans, among its many inhabitants.²⁵ (Appendix A) Sustainable designs such as Bosco Verticale in Milan foster ecological resilience and can serve as critical habitats for urban biodiversity - a role of particular importance as wildlife increasingly struggles to survive and has, in many ways, often been intentionally excluded from dense metropolitan areas through a kind of forced expropriation.

Boeri repeatedly refers to the project as a building prototype for a new form of biodiversity architecture, one which places not only humans but the relationship between humans and other living species at its center. He has expressed his hope that others would adopt and improve on the concept – and for that reason intentionally did not attempt to trademark the design. In fact, several other architects have since designed vertical forests, as the typology has proliferated internationally – Boeri refers to the buildings collectively as a family. These forward

²⁴ Boeri, Musante, and Muzzonigro, *A Vertical Forest*, 87.

²⁵ Pinto, “A House for Trees, Animals, and (also) Humans,” 10.

design elements of vertical forests, such as habitat protection, coupled with heat island reduction, water management, and biophilic elements are reflected in several of the world's green-building rating systems, including those in the US Green Building Council, according to World Green Building Council director, Victoria Kate Burrows.²⁶ While not the first building project to incorporate green infrastructure, the Bosco Verticale towers in Milan have been instrumental in raising awareness of the broader green building movement and have become a global poster child and symbol for this evolving architectural form.²⁷

It's interesting that the Bosco Verticale would come to be regarded as a 'global poster child' for sustainable architecture, as Boeri envisioned the buildings functioning as billboards for the emerging design concept during their development and promotion phase. Art has long served as a tool to help us to visualize concepts that are difficult to grasp, while also serving as a mirror, prompting deep reflection and aiding to illuminate broader societal concerns. Green projects such as this remind us that architecture can be a catalyst - not only for shelter, but for ecological imagination, and have the enduring capacity to spark interest, dialogue, and action.

²⁶ Lubell, "How Milan's Bosco Verticale Has Changed the Way Designers Think."

²⁷ Ibid.

Challenges and Critiques

Actor Networks and the Prototype

According to Bruno Latour’s Actor Network Theory, networks spread influence through people as well as through objects.²⁸ In fact, Boeri, a university professor,²⁹ Milanese politician, and former editor of architectural magazines *Domus* and *Abitare*, had to lean into networks to bring this project to fruition. At one point, he even enlisted a journalist friend to run promotional images of the proposed towers covered in trees in an Italian newspaper, with the compelling headline: “A Milano nascerà la prima torre biologica e sostenibile,” which roughly translates in English as “Milan will be the birthplace of the first biological and sustainable tower,” to help generate public interest and influence the approval of the developers. The associated article stated that, “in addition to carbon dioxide, the leaves of the trees would also absorb the pollutant micro-particles created as a result of urban traffic and would therefore help to clean the air in Milan, as well as producing oxygen in turn.”^{30 31} The concept faced skepticism from every angle, during design, construction, and even after completion, until the project could prove itself

²⁸ Bart Lootsma, “Desde arriba, el tumulto; bajo los adoquines, la playa / From above, the tumult – under the paving stones, the beach,” in *2G: Revista Internacional de Arquitectura / International Architecture Magazine*, no. 62, Stefano Boeri (Barcelona: Editorial Gustavo Gili, 2012), 19.

²⁹ Professor of Urban Planning at the Politecnico di Milano, and has also served as a visiting professor at several prestigious institutions, including Harvard University’s Graduate School of Design (GSD), the Strelka Institute in Moscow, the Berlage Institute in Rotterdam, and the École Polytechnique Fédérale de Lausanne (EPFL), per his biography: Stefano Boeri Architeti, “Stefano Boeri,” Stefano Boeri Architeti, accessed March 4, 2025, <https://www.stefano-boeri-architetti.net/en/stefano-boeri-biography/>.

³⁰ Boeri, Musante, and Muzzonigro, *A Vertical Forest*, 6–8.

³¹ Boeri, “Italian Architect Stefano Boeri, WBEZ.”

successful – building the prototype was a tremendous hurdle, but one that has resulted in a physical model now able to be experienced, studied, and used to spur future iterations and improved systems.

In fact, Boeri’s Studio rents a unit in one of the towers, so that they can continue to monitor this experiment, and study its ongoing evolution.³² Only two to three trees reportedly experienced difficulties over the eight years (as of 2022).³³ Although not the first buildings to successfully incorporate greenery, they have brought tremendous exposure and attention to the green building movement and to sustainability overall.

Embodied Carbon and Materials

Despite their innovative contributions to ecology, biodiversity, and sustainable urbanism, vertical forests have faced several significant challenges and criticisms, particularly concerning their perceived embodied environmental costs. Sustainability awards have historically been awarded for matters relating in large part to energy efficiency, ongoing carbon capture, and the efficiency of the completed building project. A critical blind spot in these considerations has been the subject of embodied carbon - the upfront emissions required to build each structure - which has been estimated to be nearly half of the CO₂ emissions – while some scholars argue it being closer to 80% when accounting for the entire value chain more rigorously.³⁴ Even LEED, one of the most aggressive green building certifications, primarily evaluates operational

³² Boeri, “Italian Architect Stefano Boeri, WBEZ.”

³³ BVB Landscaping, “Trudo Tower: The First Vertical Forest in Northern Europe,” webinar, YouTube video, March 2, 2022, <https://www.youtube.com/watch?v=qyjqAnpwwhM>.

³⁴ Matthew King, “Wisconsin’s Wooden Skyscrapers,” *Belt Magazine*, September 26, 2024, <https://beltmag.com/wisconsins-wooden-skyscrapers/>.

performance and ongoing carbon efficiency. Therefore, many critics take issue with sustainability awards and ratings that do not adequately account for embodied carbon and matters of circular economies. As a result, many critics challenge sustainability labels that overlook these upstream impacts. Common building materials such as concrete and steel are typically known for their high carbon footprints due to the energy-intensive nature of their production, transport, and installation. While products such as mass timber are currently receiving significant attention as a novel, alleged climate solution, due to its inherent carbon sequestration, cleaner and faster construction process, reduced weight, and ease of transport, this material was only recently approved in the United States for its fire resistance and use in buildings up to 18 stories, marking a substantial increase from its previous six-story limit.³⁵ Approval and adoption vary significantly worldwide, with many countries in the Global North gradually permitting taller mass timber structures, although fire safety codes and height regulations remain inconsistent. While it is quickly being adopted en masse presently by a growing list of leading multinational corporations³⁶ opting for the material to advance their sustainability goals, it is not currently approved for skyscrapers. It is important to also note that there are still many unknowns, with concerns regarding moisture, mold, lifespan, and emissions from cultivation and extraction. In addition, the material may potentially be imported from long distances, reducing its sustainability to window dressing, particularly when concrete and steel

³⁵ WoodWorks, “Tall Mass Timber Trends and Exposed Timber Allowances,” *Wood Products Council*, accessed August 12, 2025, <https://www.woodworks.org/resources/tall-mass-timber-trends-and-exposed-timber-allowances/>.

³⁶ Headquarters and campus developments for: Amazon, Microsoft, Adidas, Walmart, Google, and Under Armour.

may also potentially still be used for foundation, core, stairs, elevators, and other elements.³⁷

While its carbon-sequestering characteristics are promising, there are also questions concerning the use of plasticizers and resins as adhesives and laminators, which may raise alternative environmental issues. It is quite possible that much like the use of cement, this material may eventually similarly demonstrate that one problem was caused by solving another.

In the case of Bosco Verticale, some critics have questioned the perceived extra embodied carbon required for the numerous planters, suggesting that solar would have been preferred to vegetation. The towers are LEED Gold certified, and incorporate the requisite solar for building systems, but while Boeri is not a critic of solar, he repeatedly insists that incorporation of biodiversity should be prioritized. In any event, during the design of Bosco Verticale, discussions of embodied carbon were not yet a mainstream concern, and while Boeri is a sustainability advocate, he openly prioritizes biodiversity in his design.³⁸ He has, however, reported having also begun to design with mass timber in mind.³⁹

While building low to mid-rise buildings in wood had been an option, Boeri regarded the high-rise as an “anti-sprawl device” arguing that comparable biodiversity conditions could only be found in a suburban locale, which he contended consumes a larger area of soil and potentially degrades the proximity of communal services,⁴⁰ which might also potentially lead to more roads and further travel distance. **(Fig. 5)** In this sense, Bosco Verticale may be interpreted as the

³⁷ King, “Wisconsin’s Wooden Skyscrapers.”

³⁸ Boeri, “Italian Architect Stefano Boeri, WBEZ.”

³⁹ Lubell, “How Milan’s Bosco Verticale Has Changed the Way Designers Think.”

⁴⁰ Boeri, Musante, and Muzzonigro, *A Vertical Forest*, 52.

vertical stacking of sizeable single-family homes that otherwise would have covered an exponentially larger area.

Regarding the design, it is noteworthy that although Boeri positions the vertical forest as a departure from the mineral façades of modernist and contemporary architecture, Bosco Verticale nonetheless incorporates substantial expanses of glass at the bases, aligning with the aesthetics of the surrounding Porta Nuova redevelopment. This mineral grounding is not merely stylistic but also functional, insulating the vegetation from public access and potential pests. As agronomist Laura Gatti observes in *Morphology of a Vertical Forest*, “being raised from the ground protects from many other problems, like Japanese beetles, that once devastated nearby parks.”⁴¹ Gatti further notes that the towers are unsuited to mosquitoes, which cannot survive at higher altitudes. Tenant restrictions reinforce this controlled ecology, prohibiting residents from introducing additional plants into the carefully curated system.

These measures reveal a small paradox within the vertical forest: conceived in opposition to mineral surfaces, yet still somewhat reliant on them for ecological management and urban integration, albeit to a limited extent relative to the overall building. At the same time, this paradox highlights a broader, general tension across the construction industry between ecological aspirations and the material realities of modern high-rise development, as the sector continues to explore new materials and sustainable approaches. While Bosco Verticale gestures toward sustainability, the towers remain materially intensive and resource-heavy, raising systemic questions about embodied carbon and sustainability – an issue confronted by the building sector as a whole, and not unique to vertical forest construction.

⁴¹ Boeri, “Bosco Verticale,” 10.

Social Justice and Environmental Inequalities

Another area of criticism has been issues of social justice, where green urbanism can produce inequities in access to real or perceived environmental goods.⁴² Normative assumptions of greening automatically being seen as something “good” need to be addressed more critically.⁴³ In the green space paradox, green initiatives often create an immediate added value, but that value is not universally enjoyed by all urban inhabitants.⁴⁴ In a duality of circumstance and contradiction, as areas are greened, often even just symbolically, inequitable disparities become more pronounced, as gentrification can be almost immediate, sometimes creating instant wealth through economic value for landowners, while access and affordability for socially vulnerable groups become unattainable, resulting in “sustainability-led evictions” and displacement.⁴⁵ Environmental privilege is often also experienced, as some groups are enabled almost exclusive access to coveted amenities, such as coastal areas, open land, forests, and parks, through subtle exclusionary dynamics and racialized landscapes, even in well-intentioned projects.⁴⁶ Such inequities also emerge in Bosco Verticale, which is an expensive and desirable project attracting high income clients. **(Fig. 6)** These issues raise the question of whether a greening project can truly be considered sustainable while leaving the socially and economically vulnerable

⁴² Hillary Angelo, “Added Value? Denaturalizing the ‘Good’ of Urban Greening,” *Geography Compass* 13, no. 8 (2019): 1, <https://doi.org/10.1111/gec3.12459>.

⁴³ *Ibid.*, 2.

⁴⁴ *Ibid.*, 8.

⁴⁵ *Ibid.*, 4.

⁴⁶ *Ibid.*

unattended.⁴⁷ The United Nations' Sustainable Development Goal #11 calls for sustainable urban developments to create “inclusive, safe, and resilient cities.”⁴⁸

Costs, Value, and Maintenance

Cost concerns and the complexity of maintenance are also frequently cited, even amongst other green initiatives, attracting labels of “eco-elitism.” The project totaled just a 5% increase in costs for the vertical forest component,⁴⁹ but in the past 10 years the property value has doubled showing that the cost/value ratio favors the inhabitants who were early adopters. Additional non-monetary value has also been created, as the buildings have become iconic not just in Milan, but also in Italy, appearing in guidebooks and spurring tourism in the area (walking tours of the area are offered regularly), as well as being featured in art, cartoons, and other pop-culture outlets.⁵⁰ Bosco Verticale is also rated among the top Instagrammable buildings. As for complexity of maintenance, the greenery is maintained 100% by property management,⁵¹ from the balconies (reached from inside the units and scheduled via a resident app) and by sky

⁴⁷ Lucia Di Paola, “Milan’s Private Vertical Forests vs. Horizontal Urban Greening,” in *The Green City and Social Injustice: 21 Tales from North America and Europe*, ed. Isabelle Anguelovski and James J. T. Connolly (New York: Routledge, 2022), 30.

⁴⁸ United Nations Department of Economic and Social Affairs, Statistical Division, “Sustainable Development Goals Report 2025: Goal 11 – Sustainable Cities and Communities” (2025), <https://unstats.un.org/sdgs/report/2025/goal-11/>.

⁴⁹ Deutsche Welle, “Bosco Verticale – The Living Building,” *DW News*, video, 5:29, October 21, 2013, <https://www.dw.com/en/bosco-verticale-the-living-building/video-17169348>.

⁵⁰ Stefano Boeri, “Bosco Verticale in Pop Culture,” in *Bosco Verticale: Morphology of a Vertical Forest*, ed. Stefano Boeri Architetti, trans. Sylvia Adrian Notini (New York: Rizzoli, 2025), 231–237.

⁵¹ The maintenance is typically reported as performed twice annually from the balconies and twice annually by sky gardeners, but these figures sometimes vary across the literature over the years, as it seems likely that growth and maintenance needs may fluctuate slightly.

gardeners, who rappel from the roof, an activity that has also sparked public interest.⁵² (Fig. 7)

Despite the hands-off nature of the vegetation, residents remain actively engaged and invested, as they report taking gardening classes, and routinely monitor the wildlife, submitting images of nests, migrating birds, and plants conditions.⁵³

Trudo Tower and Inclusive Green Urbanism

Boeri has had the chance to rethink his concept in response to criticisms and address the design's possible relationship to social equity. The regeneration and greening of former industrial areas has become a defining feature of urban transformation across cities in the Global North.⁵⁴ In 2006, the Eindhoven-based housing corporation Trudo, known for prioritizing social needs in its development portfolio, initiated a major redevelopment master plan for the historically significant Strijp-S District.⁵⁵ Located in the heart of Eindhoven, Strijp-S had served throughout much of the twentieth century as a restricted industrial complex, housing production

⁵² The short film *The Flying Gardeners* (2018), produced by The Blink Fish in collaboration with Stefano Boeri Architetti, documents the arborists rappelling from the roof of Bosco Verticale to perform plant maintenance. The Blink Fish, *THE FLYING GARDENERS*, YouTube video, 9:02, March 14, 2018, <https://www.youtube.com/watch?v=kPVIKV9Nh2A>.

⁵³ Laura Gatti, "Why We All Should Be Gardeners in the Eco-Cities of the Future," TEDxMünster, YouTube video, 14:25, posted October 2019, Münster, Germany, <https://www.youtube.com/watch?v=0J64B37FAqw>.

⁵⁴ Several notable examples include: One Central Park, a mixed-use urban development on a former inner-city industrial site in Sydney, Australia, featuring two vertical garden towers designed by Jean Nouvel and Patrick Blanc; The High Line, an approximately 1.5 mile long public park built on a disused elevated freight rail line on Manhattan's West Side in New York City; and Promenade Plantée (also known as Coulée Verte René-Dumont) a nearly 3 mile elevated park in Paris, constructed atop a former railway viaduct, connecting various green spaces, and designed by Jacques Vergely and Philippe Mathieux, which served as a key inspiration for the High Line.

⁵⁵ Trudo, *Supporting People Stories: Trudo Vertical Forest* (Eindhoven: Trudo, n.d.), https://www.trudo.nl/files/shares/trudo/SP_Stories_Trudo_Toren_EN.pdf.

facilities, research laboratories, and administrative offices for the Lighting Division of Philips. Due to its restricted access, the area came to be known as the “Forbidden City.”

Following the decline of Philips’ manufacturing in Eindhoven, the Strijp-S site was reimagined as a model of contemporary urban renewal. Trudo formulated a redevelopment master plan with a clear vision to preserve the district’s iconic industrial legacy, while transforming this once-enclosed industrial zone into a vibrant, mixed-use site environment anchored in sustainability and culture. **(Fig. 8)** The master plan balanced heritage preservation and new construction, with a commitment to emphasize urban greening and environmental resilience by densifying the development, while remaining mindful of air quality and climate concerns. The biodiversity and healthy living advantages embedded in Boeri’s vertical forest concept held appeal, but in alignment with their social mission, Trudo was committed to exploring its application within the concept of affordable housing – simultaneously tackling both climate and an affordable housing crisis.⁵⁶

Trudo Tower as Vertical Forest for Social Housing

Completed in 2021, Trudo Tower, also designed by Boeri, is the first vertical forest building in Europe constructed specifically for social housing, and embodies a convergence of ecological architecture, social equity, and biodiverse urban design. **(Fig. 9)** Applying the vertical forest typology to serve a broader demographic challenges conventional notions of green architecture, which has historically catered to high-end development, with limited accessibility. In a rather poetic fashion, this physically and symbolically, once-forbidden area is now transformed into a truly equitable place, open to all. As ethical planetary biodiversity underpins

⁵⁶ Trudo, *SP Stories*.

the ethos of the vertical forest design, centered on the notion of co-existence across species, it would seem that the election of this design form for social housing signals a more expansive understanding of sustainability: one that transcends a mere application of aesthetic greenery, and invites a more sincere ecological integration into everyday living. As developers have historically sought to competitively outdo one another, including in competing to “out-green” each other, it is hopeful to imagine that this typology, along with alternate green innovations, would be multiplied within the realm of social housing models globally.

Design Features and Ecological Performance

Trudo Tower contains 125 rent-controlled apartments across nineteen stories; thirty units were reserved for residents with urgent housing needs (including immigrants and individuals with disabilities), eighty units were allocated on the basis of financial need, and the remaining fifteen units were awarded by lottery. Each was initially rented for approximately 633 euro per month, providing high-quality living at low cost.⁵⁷ While conceptually following the formal design of the Bosco Verticale, the Trudo apartments are much smaller, at approximately 50 m² (540 sf), but each includes at least one balcony of at least 4 m² (43 sf), and vegetation-filled planters, enabling micro-habitats on all four sides of the building.⁵⁸ (**Fig. 10**)

The design choices were strategically cost optimized: using prefabricated concrete, and standardized apartment configurations, saving time and expense by streamlining construction. Physical staggering of balconies on the façades allows for variety in exterior visual design and accommodates vegetation at different heights. In each of the vertical forest buildings, vegetation

⁵⁷ Trudo, *SP Stories*.

⁵⁸ *Ibid.*

is meticulously selected according to the local environment, with a mixture of native and non-native plant species, prioritizing heartiness, particularly for wind and climatic resilience, as well as size, growth patterns and maintenance feasibility, as well as for their ornamental value, seasonal diversity, and ecological function. The building includes four subterranean 20,000-liter rainwater receptacles, and planters designed with moisture sensors, which monitor and regulate irrigation. According to the senior gardener for the project, Martin Verberne, tenants agree not to add or remove any plants, and maintenance is strictly performed by professional gardeners.⁵⁹ In a radio interview, Boeri further stated that some maintenance is carried out by drones, which also reduces costs.⁶⁰ During Storm Eunice in February 2022, winds up to approximately 125 km/h battered the region, yet the trees held fast. Wind speeds are compounded at higher elevations, making wind a primary safety concern for vertical forest buildings.⁶¹ An elaborate system anchors the trees with belts and cables within the planters, which prevents the base of the trees from being uprooted.⁶²

In total, 135 trees (projected to grow up to 9 meters tall), together with the shrubs and ground cover, amount to approximately 10,000 plants, from at least 70 different species, spanning approximately 820 m² of planters that ornament the building façades.^{63 64} This lush

⁵⁹ BVB Landscaping, “Trudo Tower.”

⁶⁰ Boeri, “Italian Architect Stefano Boeri, WBEZ.”

⁶¹ For a short video that discusses wind and how the trees are anchored at the Bosco Verticale, see: News video – not opposed to solar, but need more, 5%, and wind challenges. Deutsche Welle, *Bosco Verticale – The Living Building*, DW News, video, 5:29, October 21, 2013, <https://www.dw.com/en/bosco-verticale-the-living-building/video-17169348>.

⁶² BVB Landscaping, “Trudo Tower.”

⁶³ Ibid.

vertical ecosystem absorbs approximately 50,000 kg of CO₂ and produces roughly 13,750 kg of oxygen annually⁶⁵ – creating a new paradigm in which vegetation and living nature serve as integral components of the architectural design, rather than merely ornamental. The first bird’s nest was observed in June 2021, shortly after planting was complete (but before full building completion), making it the first recorded avian resident(s) of the tower and signaling an immediate ecological impact.⁶⁶ The vertical planting palette was carefully curated to provide multisensory and seasonal variation, alternating in their growth and flowering phases, with bursts of red and grey foliage among the greenery. In addition to being ensconced in a living, biodiverse façade, residents also enjoy access to a 350 m² communal garden on the ground level.

Not unlike the Bosco Verticale, critics have raised concerns about the use of concrete and have also questioned whether additional building units should have been prioritized over greenery. However, the development team maintains that the cost premium of the vertical forest element (estimated at 5%)⁶⁷ was justified in alignment with Trudo’s mission to extend the vertical forest experience to the affordable housing market.⁶⁸ As Boeri has noted: the Trudo project successfully demonstrates that it is not an exclusive prerogative of the wealthy, and that

⁶⁴ Trudo, *SP Stories*.

⁶⁵ Ibid.

⁶⁶ BrightVibes, New Dutch Vertical Forest Is Literally the Greenest Social Housing Project Around, *BrightVibes*, accessed July 4, 2025, <https://www.brightvibes.com/new-dutch-vertical-forest-is-literally-the-greenest-social-housing-project-around/>.

⁶⁷ BVB Landscaping, “Trudo Tower.”

⁶⁸ Trudo, “Trudo Toren,” *Trudo*, accessed July 4, 2025, <https://www.trudo.nl/trudo-toren>.

living in contact with trees and greenery can be made accessible across all income levels.⁶⁹ The Trudo project thus importantly marks a critical shift in the sustainable housing discourse: one moving away from exclusivity toward inclusivity, without sacrificing architectural aspiration or ethical ecological commitment.

Biophilia and Urban Wellbeing

According to Eindhoven-based interior designer and founder of the Biophilia Design Academy, Lianne Bongers, the city of Eindhoven has long been working toward restoring connections between its residents and nature. This ongoing effort is evidenced by a series of green pilot projects, building refurbishments, and nature-integrated new construction developments across the city.⁷⁰ Notably, projects such as the BioArt Village and BioArt Laboratories, located in a forested area adjacent to Strijp-S and housed in a repurposed World War II German military bunker complex serve as an experimental cross-disciplinary hub, where art, science, and ecological thinking converge.

Biophilic design, as Bongers and scholars emphasize, is not merely a decorative style or aesthetic – it’s a design philosophy grounded in science and evidence-based environmental psychology, seeking to create environments that enhance human well-being through intentional relationships with nature and natural elements. As our cities and populations continue to rise, so too must our ambitions, not only in height but in ethos. Once a radical prototype, the vertical

⁶⁹ Stefano Boeri Architetti, “Trudo Vertical Forest Eindhoven,” *Stefano Boeri Architetti*, 2017–2021, accessed July 4, 2025, <https://www.stefanoerichitetti.net/en/project/trudo-vertical-forest/>.

⁷⁰ “El diseño biofílico a la conquista de Eindhoven.” *Diario Más Noticias*, March 5, 2025. <https://diariomasnoticias.com/el-diseno-biofilico-a-la-conquista-de-eindhoven/>.

forest building now stands as an evolving typology and a living emblem of architecture's potential to coexist with nature rather than dominate it. From Milan to Eindhoven and beyond, these vegetal towers gesture toward a future in which urban greening embraces biodiversity, biophilic design, and social equity in equal measure.

CONCLUSION

If modernism once stripped architecture of ornament, the vertical forest seeks to replace that absence, not with mere decoration, but with a new paradigm – one in which buildings host living, breathing ecosystems. This shift in the paradigm, from the role of vegetation as mere ornament to an integrated organism, redefines how we imagine the city itself - as a biodiverse, interdependent system. Though vertical forests may not present a perfect or universal solution, their evolution from elite prototypes to inclusive social housing, their growing global proliferation, and their biophilic ethos, along with their continued push toward adaptive sustainability, represent more than symbolic greening; they mark a critical transition in how we design, build, and dwell - not apart from nature, but within it.

FIGURES



Figure 1. Bosco Verticale towers in Milan, illustrating vertically integrated urban forestry within residential high-rises. Photo by Stefano Boeri Architetti. Accessed April 1, 2025. <https://www.stefanoboeriarchitetti.net/en/project/vertical-forest/>.



Figure 2. Bosco Verticale in summer, featuring lush, full canopies. Featured in Tom Ravenscroft, “Bosco Verticale,” *Dezeen*, January 20, 2025. https://static.dezeen.com/uploads/2025/01/bosco-verticale-stefano-boeri-21st-century-architecture_dezeen_2364_col_3-1704x959.jpg



Figure 3. Bosco Verticale in autumn, showing trees with thinning foliage. Photo courtesy of New Mags. Accessed August 14, 2025.

https://new-mags.com/cdn/shop/files/RI1565_5.jpg?v=1751927432&width=1361



Figure 4. The Bosco Verticale towers with the adjacent Biblioteca degli Alberi Milano park. The image illustrates the lush greenery enveloping the towers and the integration of the adjacent public green open space in the Porta Nuova district of Milan. Photo by Iwan Baan. Featured in Tom Ravenscroft, “Bosco Verticale,” Dezeen, January 20, 2025, <https://www.dezeen.com/2025/01/20/bosco-verticale-stefano-boeri-21st-century-architecture/>.



Figure 5. Terrace of Bosco Verticale in Milan, showing a suburban feel. Photo courtesy of COIMA. From Forbes, October 29, 2020. <https://imageio.forbes.com/specials-images/imageserve/5f9aa8561b1c437e103c483b/One-of-the-6-terraces/960x0.jpg>.



Figure 6. Penthouse flat with glass walls opening onto plant-filled terraces at Bosco Verticale, Milan. Photo courtesy of COIMA. From Forbes, October 29, 2020. <https://specials-images.forbesimg.com/imageserve/5f9aa7fe7ef5840c50bba2fb/The-penthouse-flat-has-glass-walls-on-all-sides-that-open-onto-plant-filled-terraces/960x0.png?fit=scale>.



Figure 7. Sky gardener performing routine maintenance on the vertical garden system at Bosco Verticale, Milan. Photograph by Laura Cionci, published October 9, 2015, Milan. From Domus, https://www.domusweb.it/en/video/2015/10/09/the_flying_gardeners.html.



Figure 8. Eindhoven mixed-use space with an industrial legacy. Photograph by Giovanni Nardi. From Stefano Boeri Architetti, *Trudo Vertical Forest*, accessed July 2025. https://www.stefano boeri architetti.net/wp-content/uploads/2021/09/Trudo-Vertical-Forest_SBA_Giovanni-Nardi-Photography_5Y6A1829-300x170.jpg.



Figure 9. Trudo Tower, first vertical forest in Europe for social housing, promoting sustainability and equity. Photograph by Giovanni Nardi. From Stefano Boeri Architetti, *Trudo Vertical Forest*, accessed July 2025. https://www.stefano boeri architetti.net/wp-content/uploads/2021/09/Trudo-Vertical-Forest_SBA_Giovanni-Nardi-Photography_5Y6A1861-300x170.jpg.



Figure 10. Each small apartment in the Trudo Tower includes a balcony outfitted with adjacent vegetation, integrating natural elements into every dwelling. Photography by Norbet van Onna. From James Parkes, “Stefano Boeri Covers Social Housing Tower with 10,000 Plants,” *Dezeen*, October 14, 2021. https://static.dezeen.com/uploads/2021/10/trudo-vertical-forest-social-housing-stefano-boeri-eindhoven-architecture-norbert-van-onna_dezeen_2364_col_2-1704x1136.jpg.

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APPENDIX A: Bosco Verticale List of Plants and Wildlife⁷¹

VEGETATION

Large trees:

1. *Quercus ilex*
2. *Fagus sylvatica*
3. *Corylus colurna*
4. *Gleditsia triacanthos* ‘Sunburst’

Medium trees:

5. *Acer campestre*
6. *Amelanchier arborea* ‘Robin Hill’
7. *Cladrastis lutea*
8. *Fraxinus ornus* ‘Obelisk’
9. *Laburnum alpinum*
10. *Malus* ‘Golden Hornet’
11. *Malus* ‘Red Jewel’
12. *Olea europaea sylvestris*
13. *Parrotia persica*
14. *Prunus subhirtella*
15. *Prunus subhirtella autumnalis*

Small trees and large shrubs:

16. *Arbutus unedo*
17. *Cotinus coggygria*
18. *Lagerstroemia indica* (white)
19. *Magnolia stellata*
20. *Stewartia pseudocamellia*

21. *Olea fragrans*

22. *Punica granatum*

23. *Prunus progressiflora*

Shrubs and trailing plants:

24. *Abelia x grandiflora* ‘Prostrata’

25. *Clematis recta*

26. *Deutzia gracilis*

27. *Euonymus fortunei radicans*

28. *Hedera helix*

29. *Jasminum primulinum*

30. *Lonicera pileata*

31. *Salix purpurea* ‘Gracilis’

32. *Rosa banksiae*

33. *Spiraea decumbens*

34. *Desmodium penduliflorum*

35. *Viburnum opulus* ‘Compactum’

36. *Ceanothus x delilianus* ‘Gloire de Versailles’

37. *Ceanothus* ‘Autumnal Blue’

38. *Aronia melanocarpa*

39. *Hydrangea serrata*

40. *Ribes sanguineum* ‘King Edward VII’

41. *Exochorda x macrantha* ‘The Bride’

42. *Hydrangea quercifolia*

⁷¹ Enrico Pinto, “A House for Trees, Animals, and (also) Humans,” in *Bosco Verticale: Morphology of a Vertical Forest*, ed. Stefano Boeri Architetti, trans. Sylvia Adrian Notini (New York: Rizzoli, 2025), 10.

43. *Spiraea arguta*
44. *Colutea arborescens*
45. *Camellia japonica*
46. *Deutzia scabra*
47. *Cornus stolonifera* 'Flaviramea'
48. *Camellia sasanqua*
49. *Cotoneaster lacteus*
50. *Sambucus racemosa*
51. *Osmanthus heterophyllus*
52. *Philadelphus x lemoinei* 'Dame Blanche'
53. *Prunus lusitanica*
54. *Sorbaria sorbifolia*
55. *Viburnum plicatum* 'Watanabe'
56. *Viburnum tinus* 'Gwenllian'

Ground cover plants:

57. *Aegopodium podagraria*
58. *Agastache aurantiaca*
59. *Agastache rupestris*
60. *Alchemilla mollis*
61. *Astilbe japonica* 'Ellie'
62. *Brunnera macrophylla*
63. *Campanula poscharskyana*
64. *Ceratostigma plumbaginoides*
65. *Dicentra spectabilis*
66. *Epimedium perralderianum*
67. *Euphorbia cyparissias* 'Clarice Howard'
68. *Euphorbia polychroma*
69. *Euphorbia amygdaloides*
70. *Filipendula ulmaria*

71. *Fuchsia magellanica* 'Pumila'
72. *Gaura lindheimeri* 'Short Form'
73. *Geranium wallichianum* 'Buxton's variety'
74. *Helleborus orientalis* (white)
75. *Heuchera* 'Brownies'
76. *Heuchera* 'Citronelle'
77. *Liriope muscari*
78. *Liriope spicata*
79. *Matteuccia orientalis*
80. *Penstemon digitalis* 'Husker Red'
81. *Perovskia atriplicifolia* 'Little Spire'
82. *Rodgersia henricii*
83. *Pachisandra terminalis*
84. *Polygonatum falcatum* 'Variegatum'
85. *Rosmarinus officinalis* 'Porto Alabe'
86. *Salvia farinacea* 'Rhea'
87. *Stipa tenuissima*
88. *Veronica* 'Kellereri'
89. *Vinca minor* 'Marie'
90. *Vinca minor alba* 'Gert. Jekyll'
91. *Sarcococca hookeriana* var. *humilis*

ANIMALS

Birds:

1. Condor
2. Parrot
3. Pigeon
4. Blackbird
5. Falcon

6. Swift
7. Blackcap
8. Chaffinch
9. Collared dove
10. Wren
11. Rock pigeon
12. Dove
13. Goldfinch
14. Great spotted woodpecker
15. Great tit
16. Greenfinch
17. Hooded crow
18. House martin
19. Jackdaw
20. Italian sparrow
21. Kestrel
22. Little ringed plover
23. Nightingale
24. Pallid swift
25. Common redstart
26. Robin
27. Serin
28. Sotted flycatcher
29. Swallow
30. White wagtail

Others:

31. Dog
32. Cat
33. Rabbit

34. Hamster
35. Greater noctule bat
36. White-striped freetail bat

Insects:

37. Western honeybee
38. Yellow meadow ant
39. Ladybug (Ladybird in British English)
40. Two-spotted ladybug (Ladybird)
41. Earthworm
42. Horseflies (listed twice in source text)
43. Worms (listed twice in source text)
44. Snail
45. Common spider
46. European hornet
47. Moth
48. Migrant hawk
49. Large red damselfly
50. Violet dropwing
51. Hummingbird hawk-moth
52. Bee-fly
53. Green rose chafer
54. Antlion adult

Butterflies:

55. Lesser purple emperor
56. Silver-washed fritillary
57. Spotted fritillary
58. Black-veined white
59. Brimstone

60. Green-veined white
61. Large white
62. Wall brown
63. Map butterfly
64. Brown argus
65. Small tortoiseshell
66. Queen of Spain fritillary
67. Comma butterfly
68. Scarce swallowtail
69. Swallowtail
70. Clouded yellow
71. Peacock butterfly
72. Common blue