

Sketching Structural Lightness: Frei Otto and the Treehouses (1959-1987)

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Abstract

Frei Otto's treehouse projects offer his vision through their detailed drawings and unbuilt architecture's structure hybrids. These works echo the ecological and anatomical analogies proposed by Philip Steadman, underscoring the deep connection between the built environment and natural systems. The concept of the 'treehouse' or Baumhäuser, and its intrinsic relationship with architecture and nature, was a consistent theme in Otto's work from 1959 to 1989. The treehouse is a timeless architectural idea, found across cultures and centuries from Papua New Guinea to modern designs by Baumraum studio. These structures blend structural design, nature, and spatial adaptability. The objective of this research focus in Otto's 'treehouse' concept through four key case studies from New York to Berlin. It begins by examining interviews, drawings and literature on his philosophy, tracing the concept's evolution from early unbuilt proposals to the Ökohaus in Tiergarten. This project, the most comprehensive built expression of these principles, was studied via fieldwork and drawing analysis to understand its materialization. Otto's earlier works –including watercolours, sketches, and experimental models– demonstrate his interest in architecture rooted in the genius loci and a holistic ecological vision. His treehouse projects exemplify a synthesis of form, construction, and environmental awareness, an approach that remains pertinent to contemporary architectural discourse.

Keywords: Frei Otto, treehouse, ecological architecture, Ökohaus, architectural drawings.

Introduction: drawing architecture and ecology, a symbiotic evolution

The complex relationship between architecture and nature, and the broader dialogue concerning ecology and the environment, has been a consistent thread in both theoretical research and applied projects. This fruitful discourse spans decades, encompassing pivotal works from Reyner Banham's *Four ecologies* philosophy [Banham 1971] and Murray Bookchin's *For an ecological society* [Bookchin 1978], to Philip Steadman's classification of architecture and nature [Steadman 1982] or Juhani Pallasmaa's research and exhibition in Helsinki published under *Animal Architecture* [Pallasmaa 2020]. More recent contributions include Kenneth Frampton's *Seven points for the new millennium* [Frampton 2003], Eduardo Prieto's

Historia medioambiental de la arquitectura [Prieto 2019], Philippe Rahm with his *Natural history of architecture* [Rahm 2020] or Neri Oxman's *Biomorphism and Material ecology* [Antonelli 2020].

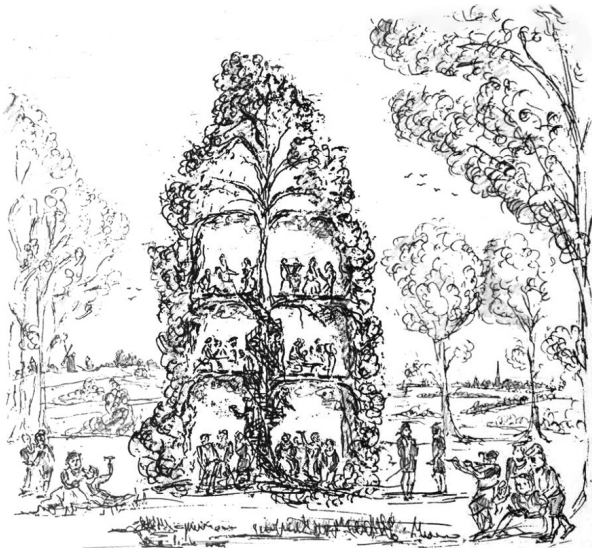
Steadman's 1982 framework provides a valuable lens, classifying this multifaceted dialogue into five key analogies: organic, classificatory, anatomical, ecological, and Darwinian. This research specifically focuses on the case of treehouses and the architecture of Frei Otto, emphasizing its strong ties to ecological and anatomical analogies. Otto's approach is characterized by two distinct yet interconnected 'ways of thinking'. The first, often termed 'thinking diagrammatically', involves his detailed study of

organic forms and their inherent relationship to climate. The second, 'thinking by modelling', centers on his exploration of ultra-lightweight structures, drawing inspiration from the skeletal forms of prototypes developed at his Institut für Leichte Flächentragwerke (IL). Both models are fundamental to his conceptualization of treehouses, linking a profound respect for trees with the innovative idea of their structure resembling an inverted catenary. On this basis, the treehouse operates as a model for an ecological architecture of adaptability.

Frei Otto's advanced treehouse projects, discover for his sketches, diagrams and models, draw from a valuable history of examples and design strategies. The concept of arboreal dwellings has European roots stretching back to the Roman Empire in the province of Lycia and monasteries during the Middle Ages [Aikman 1988]. Beyond Europe, precedents like the Airy dwellings nestled among the Itá palm trees in the Orinoco Delta and Kenya's renowned Treetops Hotel also stand out. A particularly significant historical reference is the Parco Mediceo in Pratolino, near Florence, established in the mid-17th century by the de' Medici ducal family (fig. 1).

This project showcases a double spiral staircase winding around a tree, providing access to hanging gardens and platforms at various heights for social gatherings. An engraving by Stefano della Balla vividly illustrates this structure, depicting a wide-trunked tree with two staircases coiling around its expansive central trunk. This imagery is further contextualized by the 1599 lunetta by Giusto Utens of 1599, offering a glimpse into the historical design. The historical lineage of treehouses, and their function as elevated social spaces, provides vivid context for understanding Frei Otto's projects. Anthony Aikman's work developed on treehouses [Aikman 1988], for instance, recreates the intricate spiral staircases of the Fontana della Rovere, an example seemingly in dialogue with other early references like those at Cobham Hall and nearby Plessey. These structures illustrate a shift from utopian ideals to practical, elevated platforms for gathering, playing, eating, and debating, offering families a retreat from urban life, particularly near Paris. The 17th-century diarist John Evelyn, a keen observer of gardens and woodlands, was so captivated by Lord Cobham's treehouse that it inspired his treatise *Silva* and led him to construct his own treehouse in 1646. Beyond

Fig. 1. Medicean tree house in Pratolino and the Tree house at Cobham Hall (redrawing by the author after Anthony Aikman) [Aikman 1988, p. 44].



European examples, diverse global precedents exist, such as the dwellings of the Koiari people in Papua New Guinea, the temporary shelters crafted from felled trees by settlers in Klallam lands in Washington, and the bamboo structures built by residents around a central tree near Aldeia Marakanã [Beaumont 2021]. Contemporaries of Frei Otto also explored the symbiotic relationship between trees and architecture. Notable examples include 1951 Glass house by Lina Bo Bardi, 1962 Venezia Pavilion by Sverre Fehn, and the Smithsons' work, exemplified by the tree integrated into the Wayland Young Pavilion in 1959 [Fernández, Jiménez 2020]. These diverse projects highlight a shared fascination with integrating nature and built environments, a theme central to Otto's own architectural philosophy. This paper analyses Otto's unbuilt and built treehouse projects, exploring their potential to redefine a type of collective housing through the lens of the human ecology approach [Boughey 1973]. The paper is structured as follows: behind an introduction that establishes the historical background and context of treehouses, it details the methodology used in this research. Next, it introduces a part of the pivotal work done at the IL Institute and delves into the symbiosis between architecture and biology. The core of the paper then focuses on an in-depth analysis of Frei Otto's treehouse case studies, concluding with the findings and insights derived from the research.

Methodology

Fieldwork, handmade drawings and interviews

This research employs a qualitative and graphic-based methodology [De Jorge-Huertas 2019a], primarily centred on a detailed analysis of specific case studies (fig. 2). This first phase of the research begins by examining diagrams and interviews with Frei Otto himself [AA. VV. 1994; Lendt 2011; Escher, Förster 2012], providing invaluable insights into his foundational thinking. This phase is complemented by second one, a comprehensive review of existing literature, specifically focusing on the broader concept of treehouses [Aikman 1988; Martínez 2015; Nugraha 2023], Otto's own philosophical framework of *Occupying and Connecting* [Otto 2009], and the overarching principle of lightness as it permeates his architectural work.

The third phase involves a selection and analysis of all type of drawings (diagrams, sketches, watercolours, etc.), of both built and unbuilt treehouse case studies by Frei Otto,

from 1959 to 1989. This comparative approach allows for a nuanced understanding of how the treehouse concept evolved and ultimately materialized, particularly in the context of the Ökohaus in Berlin. As the only constructed example among the studied projects, this casestudy became the subject of intensive fieldwork. This included on-site visits to directly observe its design and integration, conceptual diagrams, handmade sketches, digital redrawing and interpretation of the architecture along with interviews with its inhabitants to gather firsthand accounts of living within Otto's vision.

The four specific Otto treehouse projects under study in this third phase are: the 1959 visionary, yet unbuilt project for New York; the collaborative design of "a funicular model of a tree-like structure" that emerged from a student workshop at Yale University in 1960 [Roland 1970, p. 123]; the theoretical case study at Askanischer Platz in Berlin; and finally, the 'tangible' Ökohaus in Berlin, completed in 1991. This comprehensive selection aims to provide a robust framework for tracing the conceptual and material trajectory of Frei Otto's enduring interest with the relationship of ecology, the tree-like concept together with branched structures, and lightweight architecture.

Frei Otto's research: dragonflies, lightness and future housing

Dragonflies as bio-indicators: Otto's lightweight structures

In his key work, *Occupying and Connecting: Thoughts on Territories and Spheres of Influence with Particular Reference to Human Settlement* [Otto 2009], Frei Otto structured with drawings and geometrical diagrams each section around a concept or case study directly tied to human habitat networks within their ecosystems. This approach underscored the inherent connection between habitat design, architectural ecology, and the exploration of non-permanent forms [Ciezadlo 2013]. A particularly compelling example of this is Otto's use of the dragonfly as a metaphor and as structural micro-scale research (fig. 3). Dragonflies hold significant ecological importance; they are remarkably sensitive indicators of shifts in the health of aquatic ecosystems. Their rapid response makes them invaluable bio-indicators, capable of signalling both current environmental well-being and predicting future changes. Furthermore, their role as efficient predators, especially of mosquitoes, contributes significantly to environmental balance.

Fig. 2. Diagram of tree house projects and influences related to the projects (elaboration by the author).

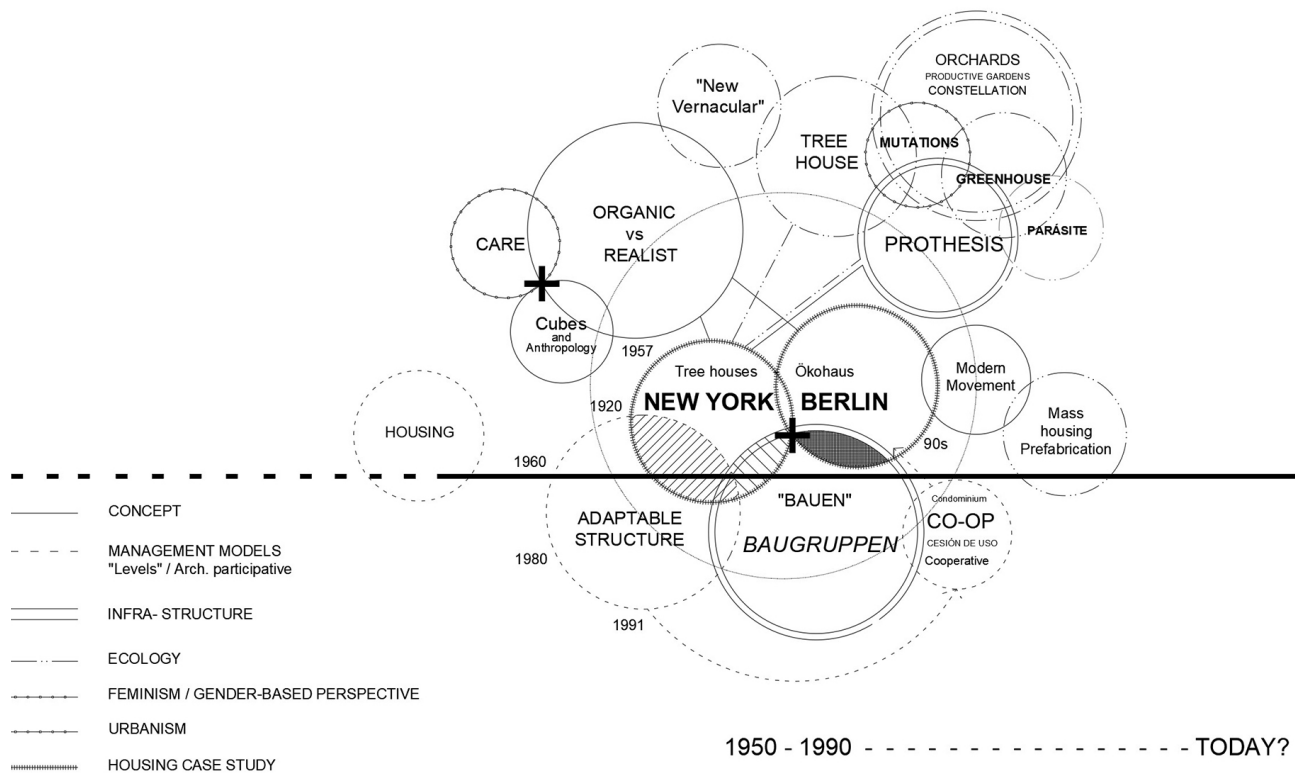
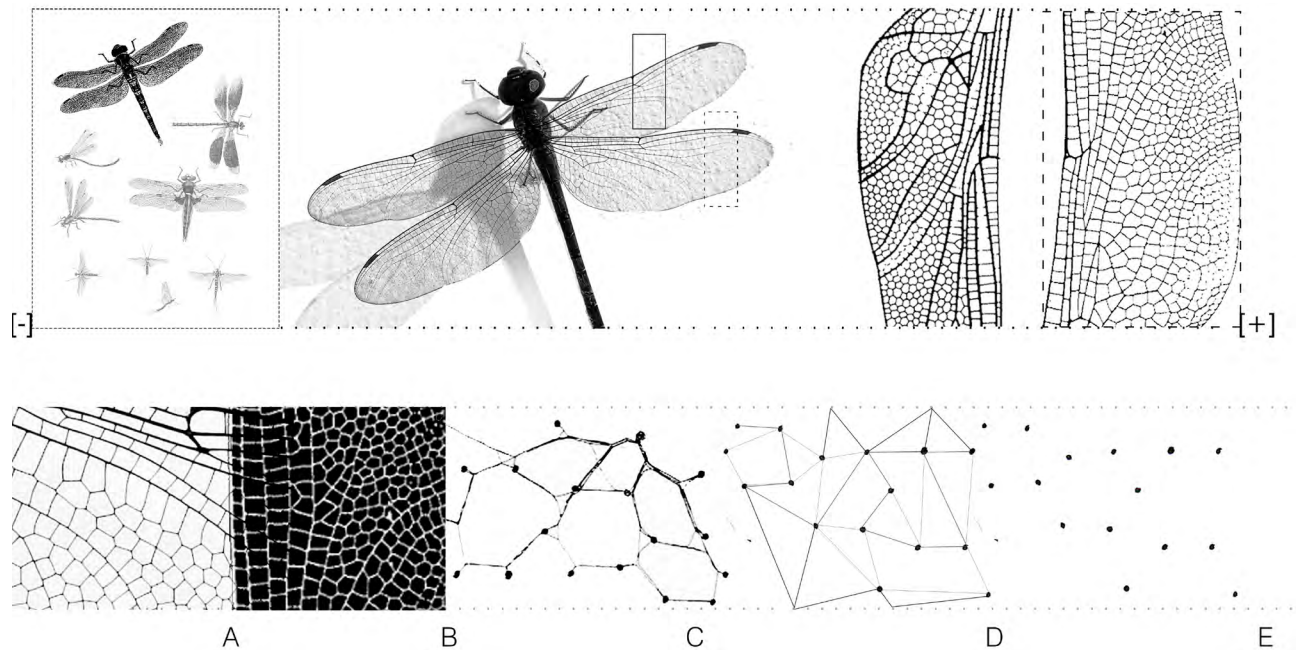


Fig. 3. Evolution and scalar structures (A-E) of the dragonfly and the wings geometry (A-B) towards patterns of occupation (D-E) (elaboration by the author).



Thinking by sketching: thinking diagrammatically and thinking by modelling

Dragonflies, which need stable oxygen levels and clean water, are also considered reliable bio-indicators of ecosystem health [Córdoba-Aguilar et al. 2023]. This ecological significance made them a key *leitmotif* in the analyses at Otto's institute for Structures and Conceptual Design (IL). This focus is a prime example of Otto's 'thinking diagrammatically' approach, a cornerstone of his extensive work and unbuilt projects known [De Jorge-Huertas, De Jorge-Moreno 2024] and handed down to other generations by his drawings and pre-parametric diagrams. In his *Occupying and Connecting* [Otto 2009] illuminates, with handmade drawings and models, how various projects are crucial for understanding alternative methods of creating collective housing that prioritize lightness and customizability, contrasting sharply with traditional compact, serialized, and homogeneous designs. His experiments, theories, and prototypes reveal other ways to conceive collective housing from an 'ultra-light' perspective, as opposed to heavy and mass-produced solutions.

Otto's dragonfly structures are infra-light in time and ultra-light in matter, much like the soap bubbles extensively studied by the IL Institute. Both offer insights into developing experimental and alternative methods of eco-prefabrication and mass housing within Otto's broader research. The experimental essence of projects like the tree-house is further showcased in the IL's 'thinking by modelling' section, where Otto and his team experimented

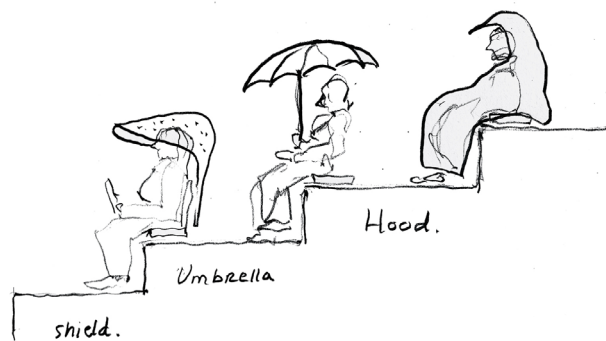


Fig. 4. Small adaptable roofs: shield, umbrella, hood and lightweight structures (elaboration by the author after Frei Otto) [Otto 2009].

with ultra-thin membranes using physical models and line drawings. Dragonfly structures, light membranes and roofs, soap bubble assemblies and processes of occupation and connection [Otto, Nerdinger 2005; Otto 2009], as seen in the diagrams in (fig. 3), were central to Frei Otto's Atelier's studies from the 1950s to the 1970s. Their research explored flexible territories within self-constituting triangular grids, allowing for variable spatial sizes. Otto's drawings consistently feature three categories of light structures: small adaptable roofs, 'shield, umbrella, hood' (fig. 4) and numerous designs emphasizing lightness, a concept he intrinsically linked to saving material and, consequently, energy.

Ökohaus' organic genesis: biology, architecture and art

"Biology has become indispensable for architecture, but architecture has also become indispensable for biology" [Otto 1971b, p. 8]. The organic principles embodied in the Ökohaus likely stem from a confluence of influences: the interconnected diagrams analysing organic occupation patterns in Otto's research at his Institute, and the profound discussions between Otto and German anthropological biologist Johann-Gerhard Helmcke during the 1950s [Helmcke 1963]. Their conversations explored the intricate symbiosis between biology, architecture, and anthropology. Helmcke, a specialist in microorganisms, particularly skeletons of radiolarians and diatoms (a type of algae with silicified walls), introduced Otto to the concept of 'building form' in biology through the stereoscopic observation of these minute organisms. As Otto recounted in an interview [Escher 2012], Helmcke's insights came partly from his time as an unpaid tutor with professor Hans Pözelzig, a close friend of Konrad Wachsmann's in Berlin. It was through a pair of students that Otto was introduced to Helmcke, who subsequently became a regular visitor to Otto's studio in Warmbronn and the Stuttgart department. Within this rich constellation of influences, Frei Otto also frequently cited Constantin Brancusi as the sculptor he most admired, recognizing Brancusi's exceptional mastery of plastic forms and craftsmanship [Glaesser 1972]. Otto systematically analyzed Brancusi's surfaces through a scientific process. These analytical processes were directly reflected in the seminars organized by the IL Institute for professionals and academics, where the focus was on the relationship between biological structures (animals and

Fig. 5. Stairs structure around the existing trees in the garden of the Ökohaus in Berlin (drawing and photos by the author).

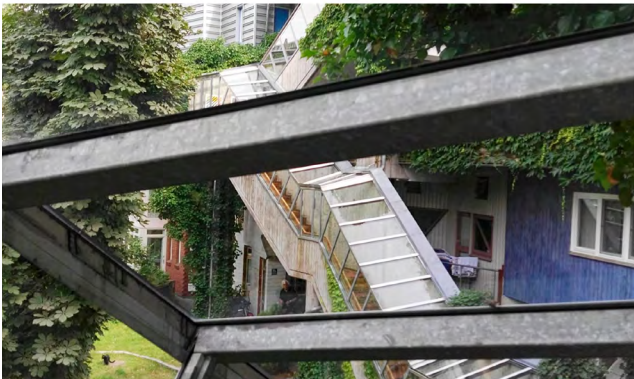
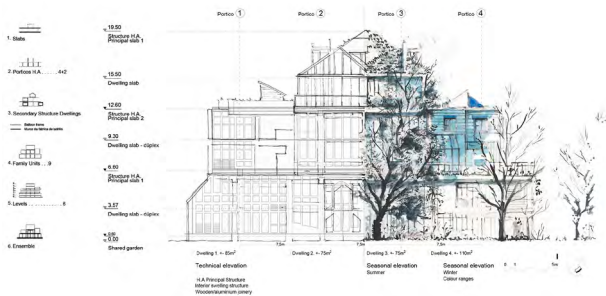
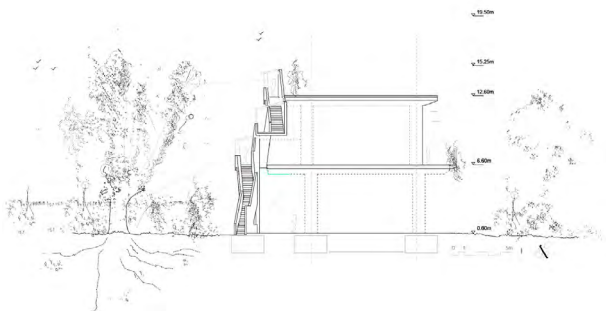


Fig. 6. Exterior stairs and concrete skeleton structure section near the existing trees (drawing by the author).

Fig. 7. The Ökohaus elevation juxtaposes a structural line drawing with a phenomenological depiction (drawing by the author).



plants) and architectural design through drawings and models. These investigations, often captured in Otto's detailed diagrams, ultimately defined the highly spatial and organic character of the arboreal structures and frameworks that are hallmarks of his influential work.

A multidisciplinary manifesto for organic living. "A tree is not a tool for a living being, it is a living being itself" [Helmcke, Otto 1962, p. 856]. The Ökohaus in Berlin (fig. 5), co-directed by Frei Otto and its inhabitants, stands as a tangible manifestation of a multidisciplinary approach that bridges biology, sculpture, art, anthropology, and architecture. This concept finds its broader expression within the Baugruppe movement [De Jorge-Huertas 2019b] and is intimately connected to Otto's earlier, unbuilt experimental projects where the organic played a central role. These designs were infused with a utopian vision, which Otto articulated in his writings to improve future living conditions. This wasn't achieved through rigid, complete designs and drawings, but rather by establishing a foundational 'game board' with flexible guidelines and subtle rules, positioning architecture as a guiding framework rather than a prescriptive blueprint.

From microorganisms to mass housing. The Ökohaus, with its distinctive 'empty' structural section (fig. 6) and complete elevation (fig. 7), embodies the treehouse concept as an aggregation of diverse 'micro-organisms' within a single infrastructure. The Atelier Warmbronn and the IL research Institute meticulously analyzed the organic structures of various insects, such as the mathematically precise, unequal wings of anisoptera or zygoptera dragonflies. Their studies also extended to deformed meshes based on biological patterns, observing these not only in nature but also in the spatial arrangements of people around corners, analyzing their associative behaviors. While the Munich Pavilion remains a well-known example of a Voronian pattern application, the aim in the Baugruppe Ökohaus and its unbuilt treehouse predecessors was the abstraction and creation of a space entirely personalized by its inhabitants, where the structure and architecture recede into the background.

The Ökohaus's proximity to the Philharmonie and the Scharoun Library—a seminal figure in organic architecture—underscores the Warmbronn Atelier's deliberate move to create a built manifesto. This manifesto stands on the very edge of their experimental work with ultra-light structures. The Ökohaus's role as a 'drawing-built manifesto' and a political statement reflecting public engagement

within the context of the IBA Berlin (*Internationale Bauausstellung Berlin*) also formed a crucial part of the research conducted by the Atelier and the IL Institute. This research focused on developing millimetric, almost imperceptible, living, and extremely slender envelopes for a new generation of building materials. For Frei Otto, these structures and materials were the driving force, enabling matter to lose thickness and mass while consistently prioritizing internal, adaptable, and mobile use.

Evolving conceptually through drawing

From Central Park in New York to Tiergarten in Berlin

Dreams, ecologies, and growth are core concepts underlying Frei Otto's projects and drawings centered on the 'tree house' or 'Baumhäuser'. These include the New York project from the late 1950s with green roofs arranged like the branches of a growing tree (fig. 8), the 1960 Tree Structures Project (fig. 9), the unbuilt Berlin precedent at Askanischer Platz, and the, previously analyzed, 1989 Ökohaus in Tiergarten. Collectively, these works served as a laboratory for experimenting with the concept of the house, vertical density, and the multifaceted nature of the tree, as a metaphor and in its direct applicability.

The 'tree structure' of 1960 directly stemmed from Frei Otto's research into minimum surfaces and spatial relationships. Collaborating with students at Yale University, this experiment focused on multiplying compression elements to reduce individual buckling lengths, thereby decreasing both material use and structural thickness. Once the interconnected chords were stiffened and the model inverted, its organic configuration transformed into a tree-like structure [Glaesser 1972]. Parallel to this, a 1959

Fig. 9. Theoretical Tree-Structure Project, 1960. Funicular model (1). Once stiffened, the model is inverted (2-3) (drawing by the author).

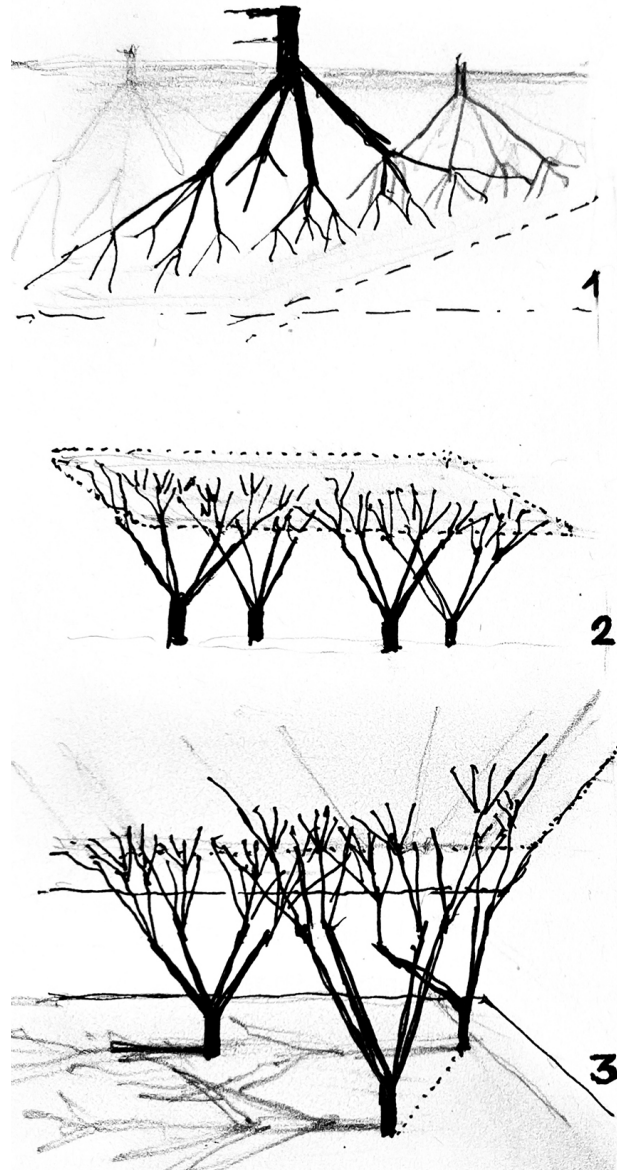


Fig. 8. Structure and construction process of the New York treehouse, 1958 (drawing by the author).

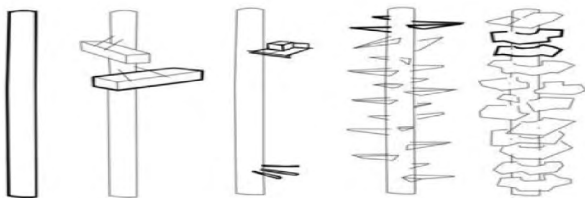
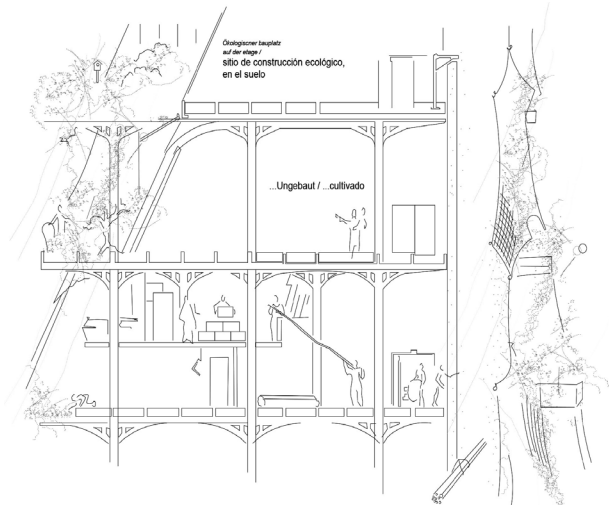
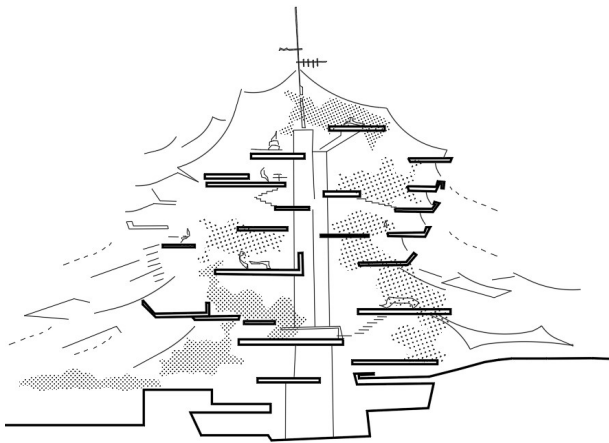


Fig. 10. Structure diagram of the Baumhäuser watercolour in 1980 (redrawing after Frei Otto by the author).

Fig. 11. Structure detail of the unbuilt treehouse project in New York, 1959-1960 (redrawing by the author after ARCH+ 57).



research project for a large-scale agricultural canopy, while serving as a greenhouse roof rather than housing roof, also thoughtfully integrated the growth of trees into its design. The genesis of Otto's treehouse ideas and drawings, surprisingly, came from a textile factory in Zehlendorf with a towering 220-meter chimney. As Otto recounted in an interview [Escher 2012], he envisioned drilling horizontal beams, 40 to 50 meters in diameter; into this chimney (fig. 10). This imaginative concept led to an adaptable skyscraper approach, allowing for cantilevered floors of varying sizes. Otto considered where such innovative apartment buildings could be realized, immediately thinking of New York. His familiarity with Central Park, gained through family in the city, provided the ideal backdrop for his conceptual treehouse towers [Escher, Otto 2012].

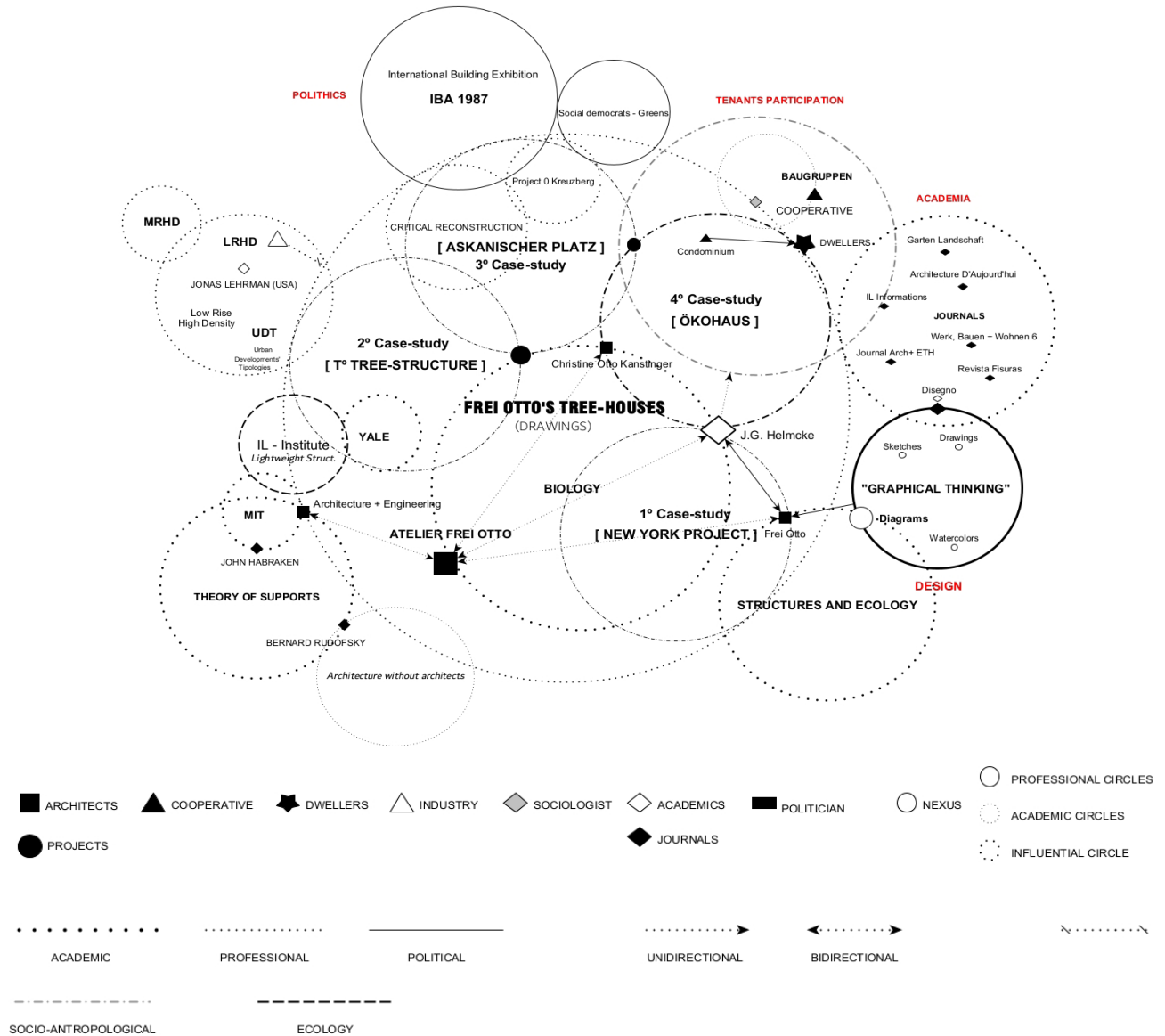
The most recent treehouse experiment, the Baugruppe-based Ökohaus in Berlin, represents a unique construction laboratory [Hamiduddin, Gallent 2016; Urban 2018]. Here, the builders are simultaneously the future tenants, collaborating directly with architectural firms and the construction team in a truly non-hierarchical structure. As we have seen before, this project stands as a powerful manifesto for architecture reimagined as a guide and tool to secure the fundamental right to housing. Frei Otto articulated his distinct views on housing through this innovative approach: "If housing units are taken to the third dimension, the hitherto unsurpassed degree of freedom of the detached single-family house must also be preserved" [Otto 1971a, p. 21].

Results: from tree house sketches to ecological cities

Ecological thinking, tree house conception and experimental housing

Frei Otto, in his correspondence with Giancarlo De Carlo [AA.VV. 1994], articulated a vision for housing units in the third dimension, conceptualizing a 'three-dimensional village' with utopic drawings [1]. This approach, consistently linked to an ethereal or mutable experimental dwelling, emphasized a degree of freedom rooted in ecological characteristics, while crucially preserving the privacy typically afforded by single-family homes. Otto further elaborated on these views in his 1980 lecture, *Natürlich Bauen*, delivered at the IL Institute in Stuttgart. The Ökohaus exemplifies this philosophy, offering an alternative, hybrid experiment between the single-family house and collective

Fig. 12. Network diagram of the research (elaboration by the author).



dwelling. It achieves this through a system of adaptable platforms that allow for mutable domesticity, a concept directly building upon Frei Otto's earlier proposals for New York. Building on these principles, the innovative architect articulated his core perspective regarding housing and its inherent need for adaptation: "What we have not yet had in houses is the adaptable construction, able to follow without delay all the modification of the wishes and needs of the occupant. Adaptable construction represents the total mastery of technique; it is very old and has been proposed. It is only cultivated in mud houses and in modern industrial construction. We know it in its different forms. First, we have the house, but also the large, anonymous, discrete structures, whose shape is not visible, which can grow or shrink, which multiply the area of the building site and which, according to needs and aspirations, can be extended with complete freedom of form inside and outside" [Otto 1971a, p. 21].

In 1959, Otto had already begun researching ecological housing for his New York tree house proposal. Domestic spaces, alongside courtyards, were integrated into branches or slabs, interspersed with raised gardens between dwellings. The design strategy featured a central, vertebral cylinder structure to which irregular floor slabs were anchored. This allowed for free floor plans and varying heights (within limits), where residences would coexist with their own gardens and orchards, as illustrated in the section in figure 11 (fig. 11). Frei Otto's unbuilt proposals for Skyscraper Trees, or three-dimensional garden cities as he termed them in 1958, represent parallel utopias. These concepts predate the Ökohaus and serve as antecedents to the Foundation for Architectural Research (SAR) Support Theory [Habraken 1961]. Both proposals share an initial design strategy centred on the treehouse concept, yet their scale varies significantly: one is a high-density, high-rise macro project for New York, while the other is a medium-to-low-density proposal for Berlin. Both were designed for competitions.

The design and drawing strategy from the New York project found a parallel in the initial 1981 proposal draw for the Ökohaus at Askanischer Platz in Kreuzberg. Here, the vision was to construct two skyscrapers of varying heights, featuring domestic hanging gardens every six meters. Within these intervals, each resident would insert their unique 'nest', a deliberate contrast to the standardized, homogeneous 'honeycomb' housing model. This treehouse project, a precursor to the built Ökohaus in

Tiergarten, was a collaborative effort with Heinz Doster and Johannes Fritz in 1981. The concept centred on a 'three-dimensional garden city' [Archiv für Architektur und Ingenieurbau], reaching a total height of 60 meters and a width of approximately 35 meters. This prototype was designed to accommodate 50 one- or two-story dwellings, primarily powered by renewable energy sources, notably solar. In this early design, Frei Otto was already envisioning a lifestyle that diverged from the traditional single-family house. He sought to reconcile the individual's need for horizontal space and privacy within a domestic setting with the advantages of high-rise buildings. These pioneering ideas, mainly known thanks to the drawings and 'invisible' networks (fig. 12), directly paved the way for the *Baugruppe Ökohaus*, which would be constructed in Berlin a decade later.

Conclusions

The concept of the tree house, or 'Baumhäuser', and its profound link to architecture and nature were constants throughout Frei Otto's work. While the Ökohaus in Berlin stands as the most significant built example of this idea, his earlier studies – captured and known thanks to his diagrams, sketches, watercolours, and experimental models – reveal a long-standing interest in developing an architecture deeply connected to the *genius loci*, or spirit of place. Otto's vision for housing moved beyond traditional forms, imagining a 'three-dimensional village' where mutable dwellings provided freedom and ecological harmony while preserving individual privacy.

The treehouse is a timeless concept, with a history spanning centuries; from the dwellings of the Koiari people in Papua New Guinea to contemporary projects like the one by Baumraum studio in Osnabrück. Ultimately, Frei Otto's treehouse drawn projects are a powerful example of his deep interest in ecology, lightness and the environment. Also, on scientific communication through his IL Institute with the drawings, texts and models published, concepts that remain profoundly relevant in architecture today. These ideas resonate with current debates on participatory, adaptive and lightweight housing. This strength the contemporary relevance of these findings. Future research could be focus on other unbuilt projects and his drawings, examining quantitatively the 'IL Informations' or deep on his watercolour-approach, sketches or diagrams.

Note

[1] For more detail on original sketches, see drawings online: <<https://www.moma.org/artists/66414-frei-otto>> (accessed 1 July 2025), <<https://www.e-flux.com/architecture/housing/332652/apartment-buildings-for-new-york>> (accessed 1 June 2025).

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