

living in the sunlight

exploring greenhouses as domestic spaces

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introduction

1. “greenhouse”, *Oxford English Dictionary*, accessed December 23, 2024, https://www.oed.com/dictionary/greenhouse_n?tab=etymology&tl=true#2436995

2. John Hix, *The Glass House* (Cambridge: MIT Press, 1974), 81

The term “greenhouse” originates from the Middle English word grene, meaning “green” or “vegetation,” and the Old English hūs, meaning “house” or “shelter.”¹ This simple combination of “green” and “house” encapsulates the essence of these structures: spaces designed to protect plants by creating a controlled climate. Initially, the term referred specifically to spaces dedicated to cultivating greenery. Over time, however, it has evolved to encompass greenhouses integrated into human living environments, merging nature with human habitation.

This evolution began during the 18th century, when greenhouses gradually merged with domestic architecture. Originally conceived as free-standing structures, they were often positioned away from the main house, serving as independent objects designed solely for botanical purposes. Over time, their potential to enhance everyday life became apparent, leading to their integration with dwellings. As John Claudius Loudon observed in 1832, “According to our ideas of the enjoyments of the green-house, it is essential that it be situated close to the house; not merely near, but immediately adjoining it [...]”.² This integration transformed greenhouses into multifunctional spaces, supporting leisure, extending living areas, and offering new ways to connect with nature within the domestic sphere.

Today, amidst the ongoing ecological crisis, greenhouses continue to be of significant relevance. Far from being simple glass structures, they function as climatic machines, capturing solar heat during the day and releasing it back into the house at night. This passive solar heating process not only reduces energy consumption but also contributes to the overall sustainability of the dwelling. While not an essential room like in traditional housing, greenhouses offer unique opportunities to redefine domestic spaces. They enhance the indoor-outdoor connection, provide thermal and spatial benefits, and accommodate multifunctional uses that enrich living environments.

This study investigates the role of residential greenhouses in small-scale housing projects. It explores several questions: What is the interest of using residential greenhouses in today’s context? What is the value of incorporating greenhouses into houses and in what ways can greenhouses enhance the quality of a dwelling? Finally, how can greenhouses be effectively integrated into residential architecture to ensure optimal functionality?

To address these questions, the study begins by defining key terms related to greenhouses. It then provides an overview of the evolution of residential greenhouses and their changing purposes over time. Next, it examines selected case studies from the 20th and 21st centuries using a comparative framework based on specific criteria: composition principles of the greenhouse, seasonal variations in use, balancing privacy and transparency, climatic systems, functional use of the greenhouse, and presence of vegetation. Finally, the study conducts a comparative analysis of these case studies, focusing on the formal, spatial, and functional qualities of greenhouses to better understand their role in dwellings.

definitions

This chapter provides an overview of core terms related to the study. It explores their evolution and current meanings, establishing a working definition of “greenhouse” that will be used in this research.

The following definitions from the *Oxford English Dictionary* outline the precise meanings of terms relevant to this study:

- **Greenhouse:** A structure with walls and roof made chiefly of glass or translucent plastic in which plants requiring regulated climatic conditions are grown.³
- **Conservatory:** Originally: a greenhouse, either free-standing or attached to a house, for cultivating or keeping delicate flowers or plants; (in modern use) a living room with a glass roof and glass wall panels, often one constructed on the back or side of a house, used as a sun lounge or for growing indoor plants.⁴
- **Winter Garden:** Originally: a greenhouse or conservatory in which plants are kept flourishing in winter. Later: a large enclosed space ornamented with plants and trees and used for public recreation or entertainment.⁵
- **Orangery:** A place in which orange trees are grown or kept. A type of large conservatory or hothouse in which oranges or other delicate fruits can be reared where the climates does not allow them to be cultivated in the open.⁶

The concept of the greenhouse has evolved significantly over time. In the 17th century, greenhouses were basic shelters constructed from brick or timber, incorporating limited windows and heating systems. As glass became more affordable and advanced heating methods emerged, these structures transformed into predominantly glass-enclosed spaces with minimal wooden or metal frames. By the mid-19th century, the greenhouse shifted from merely providing refuge from harsh weather to becoming a controlled environment optimized for specific plant needs.⁷

In modern times, greenhouses serve multiple purposes. In agriculture, they are essential for cultivating plants requiring controlled conditions, often featuring glass, plastic films, or fiberglass coverings supported by aluminum, galvanized steel, or wooden frames.⁸ Prefabricated and industrially produced, greenhouses are designed to maximize exposure to natural light, which is critical for plant growth. Residential integration has also become a significant aspect of modern greenhouses. As architects Lacaton & Vassal describe, the greenhouse is “the minimum, most elegant system to transform the exterior climate to make it liveable.”⁹ Modern residential greenhouses serve multifunctional roles beyond plant cultivation, such as providing social spaces, improving thermal comfort, capturing solar energy, and enhancing hygienic living environments.

In this study, the term “greenhouse” consistently refers to a glass or translucent structure integrated into residential architecture. This definition includes terms such as conservatories, which may better describe some case study projects. However, for simplicity and consistency, the term “greenhouse” will be used throughout this paper. Unlike traditional definitions focusing on plant cultivation, this research emphasizes the greenhouse’s multifunctional roles as residential spaces.

3. “greenhouse”, *Oxford English Dictionary*

4. Ibid., “conservatory”, https://www.oed.com/dictionary/conservatory_n?tab=meaning_and_use#8589758

5. Ibid., “winter garden”, https://www.oed.com/dictionary/winter-garden_n?tab=meaning_and_use#14093974

6. Ibid., “orangery”, https://www.oed.com/dictionary/orangery_n?tab=meaning_and_use#33248916

7. “greenhouse”, *Britannica*, accessed January 5, 2025, <https://www.britannica.com/science/greenhouse-effect>

8. Ibid.

9. Stamina Kousidi, “On Greenhouses and the Making of Atmospheres” in *Ardeth* (March 2023), 102

role and evolution of residential greenhouses

This chapter traces the evolution of the role of residential greenhouses by examining key aspects of the greenhouse: the greenhouse as a home for plants, the greenhouse as a social space, the greenhouse as a passive energy system, and the greenhouse as a hygienic space. Examining these perspectives reveals the conditions that influenced the development of residential greenhouses, providing insight into the specific needs and circumstances behind the case study projects.

greenhouse as a home for plants

Greenhouses were originally conceived as agricultural structures, designed to provide plants with protection and a controlled environment to support their growth. Their history dates back to the 16th century, a time of expanding international trade and exploration, which introduced many exotic plants to Europe. Among these were citrus trees, particularly orange trees, which became symbols of prestige. However, the European climate posed challenges for these delicate species, as they were unable to survive harsh winters. This prompted the development of greenhouses specifically designed to protect frost-sensitive plants by replicating their native conditions. Over time, these shelters evolved into spaces for botanical experimentation and research.¹⁰

From their starting point, greenhouses acted as intermediaries between architecture and nature, facilitating the integration of vegetation into human environments while moderating climatic extremes. In the 19th century, a new role for greenhouses emerged as they were increasingly connected to residential buildings. This integration redefined domestic spaces, establishing a stronger bond between homes and the surrounding landscape. The definition of greenhouses expanded from utilitarian plant shelters to architectural features that brought nature directly into the dwelling.¹¹

Greenhouses symbolized humanity’s ability to control and replicate exotic natural habitats. They showcased rare exotic plants, reflecting status and mastery over nature. However, as their popularity grew, the residential greenhouse evolved into a space where people could gather, relax, and admire the beauty of exotic vegetation. Plants remained a key element, but more for their sensory qualities of the space—its light, warmth, and fragrance— than for active cultivation. The greenhouse became less about cultivating plants but more about admiring them, serving as a space for leisure and socialization.¹²

10. Duncan Fouchet, *Jardin d'Hiver* (Master's thesis, EPFL, 2023), 16

11. Philippe Mourelle, *La Serre Domestique* (Master's thesis, EPFL, 2023), 8

12. Margaux Verve, "Habiter la serre: comment la serre peut-elle contribuer à générer une architecture sensitive et un espace aux appropriations multiples selon les principes développés par Philippe Rahm?" in *HAL* (January 2019), 76

greenhouse as a social space

The two World Wars marked a decline in the cultural prominence of greenhouses. Faced with the challenges of survival, society deprioritized such luxuries, and alternative forms of recreation emerged in the 20th century.¹³ Today, greenhouses are finding renewed significance within the green building movement and biophilic design. Biophilic architecture emphasizes reconnecting people with nature to promote well-being, ecological balance, and sustainability.

Current approaches integrate greenery seamlessly into living spaces, creating environments where architecture and nature coexist. As Zardini and Borasi noted, “green does not stop at a building’s surface: it also penetrates the interior, to give the impression of living everywhere with nature.” (Zardini, Borasi, 2012)¹⁴ A notable example is the Naturhus by Bengt Warne (1974–1980) where the original role of the greenhouse as a home for plants is preserved. In the Naturhus, the greenhouse serves as a space for plant cultivation, fostering a continuous relationship between people and plants. It allows the growth of Mediterranean plants in a Northern European climate and supports self-sufficiency, providing up to 75% of the household’s fruits and vegetables.¹⁵



13. John Hix, *The Glass House*, 94

14. Stamina Kousidi, “On Greenhouses and the Making of Atmospheres”, 112

15. Andrea Antolloni, *Bengt Warne’s Naturhus: sustainable living in a Northern European climate* (Master’s thesis, Politecnico di Torino, 2017), 5

Fig. 1: *Das Innere des Palmenhauses* (Source: Blechen, Carl, 1832, oil on canvas, 135 x 126 cm)

The 19th century saw the rise of domestic greenhouses in England. Over time, these spaces shifted from being merely functional structures for cultivating exotic plants and fruits to becoming integral social spaces within residences. This transition marked a significant change in their design and purpose.

As the 19th century progressed, the allocation of space within greenhouses increasingly prioritized human activities over plant cultivation. Residential greenhouses were not only used to grow exotic fruits but also became venues for social gatherings such as elaborate dinners, musical performances, and theatrical events. They served as places of leisure, recreation, and retreat, cementing their status as symbols of elegance and refined enjoyment.¹⁶ According to J. C. Loudon in the 1820s, the greenhouse was “not indeed one of the first necessities, but one which is felt to be appropriate and highly desirable,” reflecting its role as a marker of sophistication and luxury.¹⁷

Greenhouses became central to the lifestyle of the wealthy, often hosting parties meant to showcase the structure itself. These events highlighted the economic power of their owners, with luxurious greenhouses and exotic plants serving as displays of prestige. The physical proximity of greenhouses to the main residence brought also changes in their design, as they adapted to the human scale and domestic functions. This led to smaller, more intimate spaces that were brighter and warmer than the rest of the house.¹⁸

In the second half of the century, advancements in metal and glass manufacturing significantly reduced construction costs. The mass production of materials made greenhouses more affordable, allowing the middle class to own what was previously an exclusive luxury. By the end of the 19th century, greenhouses and winter gardens, once symbols of wealth and status, became accessible to a broader segment of society. The introduction of catalog-purchased greenhouses allowed people to easily add the prefabricated structures to their existing houses. This accessibility made greenhouses a common feature in many households, and they quickly became viewed as essential rather than just an extension of the dwelling.¹⁹

The primary purpose of domestic greenhouses evolved to emphasize their role as spaces for human activity. They were designed to let in light, create displays of plants and flowers, and impress and entertain guests—functions distinct from the practical demands of other parts of the house. Today, this idea continues in projects like the Communal House of Plan Común (2023), where a rooftop greenhouse is a social space where people of the same building can meet and socialize. It serves as a venue for communal dinners, parties, and dancing, fostering encounters and creating a sense of community among residents.²⁰

16. Philippe Mourelle, *La Serre Domestique*, 8

17. John Hix, *The Glass House*, 81

18. Philippe Mourelle, *La Serre Domestique*, 10

19. Ibid. 17

20. “Portfolio: Kim Courrèges, Plan Común”, *The Architectural Review*, accessed December 23, 2024, <https://www.architectural-review.com/awards/w-awards/2024-w-awards/portfolio-kim-courreges-plan-comun>

greenhouse as a passive energy system



Fig. 2: In the Conservatory (Source: Tissot, James, 1875, oil on canvas, 38.4 x 51.1 cm)

21. Duncan Fouchet, *Jardin d'Hiver*, 35

22. Andrea Antoloni, *Bengt Warne's Naturhus: sustainable living in a Northern European climate*, 16

23. Philippe Mourelle, *La Serre Domestique*, 20

24. Anthony Denzer, *The Solar House: pioneering sustainable design* (New York: Rizzoli, 2013), 153

25. Günter Pfeifer, "Das Haus als solares System" in *Die Architekt*, n. 2 (2022), 15

The greenhouse effect is the principle behind passive solar design. When solar radiation passes through the glass of a greenhouse, it changes wavelength and becomes thermal radiation. This thermal energy, unable to escape through the glass due to its longer wavelength, becomes trapped, raising the temperature inside. The extent of this temperature rise depends on the amount of solar radiation entering, which can be maximized by carefully angling the glazing to capture sunlight most effectively. This natural process allows greenhouses to function as passive solar systems, optimizing solar gains during winter while minimizing them in summer through ventilation and shading.²¹

While greenhouses for plant cultivation often rely on mechanical systems, such as heating, cooling, and ventilation equipment powered by external energy sources, residential greenhouses have been widely studied and employed as passive energy solutions. From the postwar period until the 1970s, Europe experienced rapid economic growth, technological advancements, and improved living conditions. This era of prosperity led to rapid urbanization and population growth, resulting in the construction of numerous new buildings across cities. However, this rapid expansion placed increasing pressure on the planet's resources, as rising consumption became a growing concern.²²

The global oil crisis of the 1970s brought an economic downturn that had a major impact on architecture. Architects were forced to rethink technical systems reliant on oil and gas, which had become costly, scarce, and highly polluting. This period marked a shift toward renewable energy sources, including passive solar strategies, driven by both economic and environmental necessity.²³

Incorporating renewable energy solutions into buildings became a focus for architects, with greenhouses emerging as a key strategy. The idea of 'solar house', first used in 1940 to describe buildings designed to use solar energy for heating, gained widespread attention after 1973. The solar house became both a cultural movement and a distinct architectural style. Franklyn M. Branley expressed this urgency in *Solar Energy* (1957): "Whether we like solar houses or not is beside the point. As our supply of fuels grows slimmer we shall be forced to design and live in houses that put the energy of the sun to work. Perhaps you will be designing and building such houses in the future... chances are, someday you will be living in one of your own."²⁴

Architectural experiments with solar strategies flourished across Europe and in the United States, driven by a desire to enhance indoor comfort without relying on additional energy inputs. Passive solar systems required no technical machinery; instead, buildings themselves became tools for energy efficiency. Placement, geometry, materials, and design were carefully planned to optimize natural solar energy use, integrating it directly into the architecture.²⁵

greenhouse as a hygienic space



Fig. 3: Magazine about solar houses (Source: Popular Mechanics, October 1957)

These dwellings were designed to optimize sunlight year-round, storing solar energy in greenhouses and redistributing the heat to other areas of the dwelling. By integrating greenhouses into domestic spaces, architects created energy-efficient and environmentally conscious solutions to the pressing challenges of the time, as seen in projects like the Solar House by Oswald Mathias Ungers (1980), which served as a model for solar houses throughout Germany. This design encloses a stone house with a greenhouse, providing heat storage in the stone structure during winter. The greenhouse acts as both an energy-efficient system and a transitional space, connecting the indoors with the surrounding environment while enhancing thermal performance.

By the mid-1980s, the urgency of renewable energy disappeared as oil prices fell and conventional energy sources such as nuclear, gas, and coal gained dominance. The focus on solar strategies diminished and was nearly forgotten. However, in the early 21st century, the rising threat of global climate change revived interest in solar energy, now recognized not only as an architectural experiment but as a solution for a sustainable future.²⁶

26. Barbara Penner, Adrian Forty, Olivia Horsfall Turner, Miranda Critchley, *Extinct: A Compendium of Obsolete Objects* (London: Reaktion Books, 2021), 328–331

In 1928, modern architects gathered at La Sarraz, Switzerland for the first CIAM (Congrès Internationaux d'Architecture Moderne) to establish principles of good building practices. Their manifesto emphasized the importance of sunlight, hygiene, and rationalized domestic living, declaring "Through educational work carried out in schools, a body of fundamental truths could be established forming the basis for a domestic science (for example: the general economy of the dwelling, the principles of property and its moral significance, the effects of sunlight, the ill effects of darkness, essential hygiene, rationalisation of household economics, the use of mechanical devices in domestic life, etc.)."²⁷ This call for sunlight and improved living standards laid the foundation for heliotherapeutic and sanatorium architecture, which emphasized the restorative effects of natural light and its role in fostering health and hygiene.²⁸

During the interwar period, architects confronted the urgent housing crisis by focusing on affordable solutions that prioritized the well-being of urban inhabitants. Germany, despite facing severe economic difficulties after World War I, began constructing compact, cost-effective apartments to meet the needs of the population. These efforts coincided with broader trends to rethink urban living, emphasizing not just architecture but also integrating greenery within city boundaries. This period saw the rise of architectural approaches that treated natural light and vegetation as essential components for healthier living environments, particularly in rapidly industrializing urban centers.²⁹

The Lebensreform movement³⁰, which emerged in Germany during this time, supported the idea of healthier lifestyles through the design of hygienic, light-filled homes.³¹ Attention shifted to the intangible qualities of living spaces, such as indoor climate, air quality, and thermal comfort, recognizing their profound impact on comfort and health. Architects explored how incorporating vegetation into residential architecture could improve indoor air quality and regulate thermal conditions, enhancing the overall quality of life.³²

Residential greenhouses became a pivotal solution in achieving these objectives, as exemplified in Martin Wagner's Wachsende Haus (1932). Conceived as a prototype to be replicated throughout Germany, the Wachsende Haus integrated a greenhouse into the dwelling, fostering both physical and psychological well-being. The design allowed spaces filled with natural light, fresh air, and greenery. This approach aligned with a broader trend toward practical design, where functionality took precedence over mere aesthetics.

To ensure homes could make effective use of natural light, sun orientation became a central consideration. In Germany, where winters are characterized by limited sunlight, capturing and utilizing solar energy was especially critical. Greenhouses and other sunlit spaces were designed to make the most of available sunlight, providing warmth and brightness even during the cold months. Combining health, light, and greenery, greenhouses shaped the modernist goals for better living.³³

27. H.-P. Berlage, Victor Bourgeois, Pierre Chareau, "Declaration de La Sarraz" in *Habitation: revue trimestrielle de la section romande de l'Association Suisse pour l'Habitat* (1928), 15

28. Anthony Denzer, *The Solar House: pioneering sustainable design*, 11

29. Jadwiga Urbanik, "The Growing House" - the Way to Solve the Housing Problem in Interwar Germany in *Advances in Human Factors* in *AHFE* (June 2019), 243

30. Lebensreform movement: A series of social reform movements originating in mid-19th century Germany, characterized by criticism of industrialization, materialism, and urbanization, and advocating a return to a more natural way of life.

31. Ibid. 247

32. Stamina Kousidi, "On Greenhouses and the Making of Atmospheres", 112

33. Ken Butti, John Perlin, *A Golden Thread. 2500 years of solar architecture and technology* (Palo Alto: Cheshire Books, 1980), 165–166

introduction to the case studies

In this chapter, nine residential greenhouse projects from the 20th and 21st centuries are examined. The selected projects are notable for their architectural interest and diversity, offering a wide range of approaches to the integration of greenhouses within residential settings.

All the chosen projects are located in the northern hemisphere, with six situated in Europe, two in Japan, and one in the United States. While these projects are situated in regions with differing climates, their selection is based on their architectural qualities in the use of residential greenhouses. Each project possesses distinct features and characteristics that justify its inclusion in this study. Furthermore, given the ongoing challenges posed by climate change, exploring how residential greenhouses function in warmer climates, such as the hot and humid summers of Japan, adds an intriguing perspective to the study.

Each project is analyzed through detailed plan and section drawings, as well as an exploration of its context and architectural characteristics. To provide a structured evaluation, the projects are compared based on specific criteria: composition principles of the greenhouse, seasonal variations in use, balancing privacy and transparency, climatic systems, functional use of the greenhouse, and presence of vegetation. These criteria were chosen by considering the themes most pertinent to understanding the role—both in form and usage—of residential greenhouses, ensuring a comprehensive framework for analysis.

explanation of the criteria for analysis

Composition Principles of the Greenhouse

This criterion examines the spatial relationship between the greenhouse and the insulated living space of the dwelling. It considers how the greenhouse is positioned—whether attached, surrounding, or enclosing—and how this spatial arrangement affects its use and quality. Understanding the composition principles helps clarify how the greenhouse and living spaces are linked and how these design choices influence their functionality.

Seasonal Variations in Use

Greenhouses are dynamic spaces with usage that changes with the seasons, often shaping the rhythms of domestic life. This analysis compares how the greenhouses and dwellings function during different seasons, focusing specifically on winter and summer. In winter, greenhouses function as buffer zones that capture solar heat and help warm the insulated areas of the home, where most activities take place. Conversely, in summer, when equipped with proper ventilation and shading, greenhouses can serve as complementary living spaces. By analyzing how domestic life adapts to these variations, this study highlights the seasonal rhythm inherent in greenhouse living.

Balancing Privacy and Transparency

Greenhouses, being transparent or translucent structures, often pose challenges regarding privacy. While their openness allows for ample light and a connection to the surroundings, it also means that visibility from outside can be an issue. This criterion examines the strategies employed in each project to balance transparency with privacy.

Climatic Systems

The climatic adaptability of greenhouses is crucial to their success. This criterion evaluates how well each project addresses seasonal challenges, concentrating specifically on winter and summer. In winter, retaining heat becomes critical, as greenhouses rely on the greenhouse effect to trap solar radiation and increase interior temperatures. During summer, addressing the challenge of daytime overheating requires measures such as solar shading and natural ventilation. This analysis explores how each project manages these climatic challenges to maintain comfort and energy efficiency throughout the year.

Functional Use of the Greenhouse

The role of a greenhouse within a dwelling varies widely depending on its size and spatial configuration. Some greenhouses primarily serve as living spaces for people, while others are designed for vegetation or as climatic buffer zones to enhance energy efficiency. This analysis considers how each greenhouse is used, shedding light on its contribution to the dwelling's overall functionality and purpose.

Presence of Vegetation

Vegetation is a defining element of traditional greenhouses, and its presence or absence in a residential context plays a significant role in shaping the greenhouse's atmosphere. This criterion investigates whether the projects incorporate vegetation, examining whether the original concept of plant cultivation remains integral to these adaptations.

wachsende haus

1:150



architect martin wagner

year 1932

place berlin, germany

state built

greenhouse floor area 58 m2

isolated floor area 109 m2

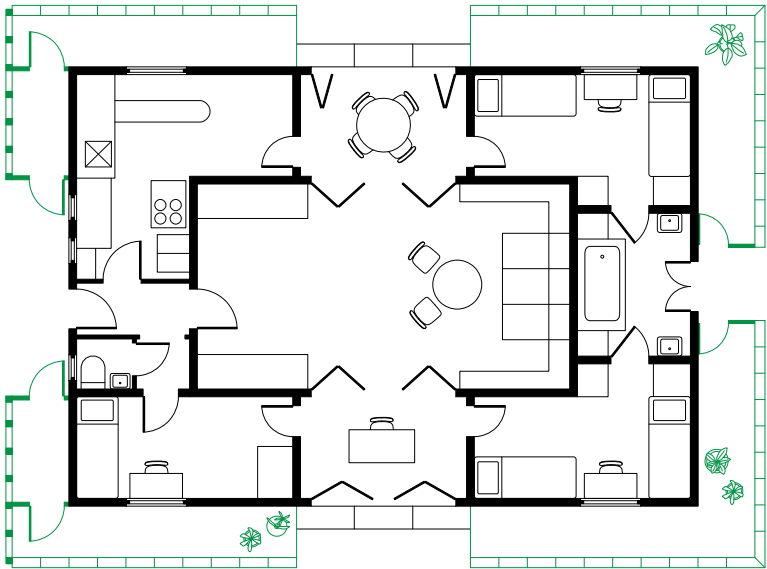
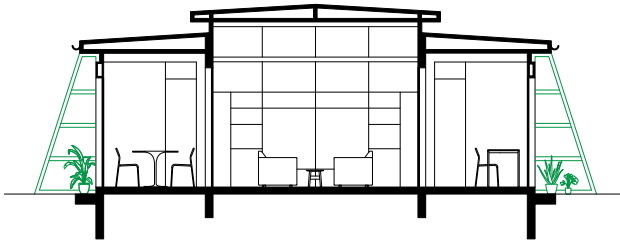


Fig. 4: Exterior view of the Wachsende Haus (Source: Wagner, M., *Das Wachsende Haus* (Berlin: HKW, 2015), 149)



34. Jadwiga Urbanik, "The Growing House" – the Way to Solve the Housing Problem in Interwar Germany in *Advances in Human Factors*, 245

In 1932, Martin Wagner, the city architect of Berlin, publishes *Das Wachsende Haus. Ein Beitrag zur Lösung der städtischen Wohnungsfrage* (The Growing House: A Contribution to the Solution of the City Housing Problem), introducing a new concept for housing that emphasizes ergonomics, ecology, economy, and flexibility. This book summarizes the results of the competition on housing solutions started by Hans Poelzig and includes Wagner's own project alongside contributions from 24 other architects.³⁴ This initiative came in response to the global economic crisis of 1929, and the project was realized in 1932 as a prototype house for the Berlin Summer Exhibition at the Radio Tower.

The central idea behind Wagner's proposal is to provide inhabitants with plots of land that can be adapted to their individual needs. The house's design revolves around a "core house" concept, which allows for gradual growth through modular additions. Expansion can occur in several ways: by adding floors, extending rooms, or through concentric growth around the original structure. This was achieved through the use of prefabrication and standardization of construction elements, with plans to mass-produce houses in the future. It was even possible to order the house from a catalog.³⁵

35. Bettina Schlorhauser, "Growing House. "The "rationalisation of happiness" was not born in the concept of "incremental housing" (March 2020), 9

The project features a rectangular plan with dimensions of 11 by 15 meters, organized into three distinct layers. The innermost layer, the core, houses the living room. The second layer surrounds the core and includes essential functions such as the kitchen, bedroom, bathroom, and workspace. Finally, the outermost layer consists of a greenhouse, approximately one meter wide, which provides climate control and space for growing plants. The greenhouse mainly serves as a source of passive solar energy, helping to warm the main living space and reduce energy costs—an important consideration during the interwar period when affordability was essential. According to Wagner, a modern house should also include a large garden as an extension of the living space, enabling activities such as working, playing with children, eating, and even sleeping during the summer.³⁶ These three layers are interconnected, with the option to separate them using folding doors, allowing for spatial flexibility. The greenhouse, with its triangular cross-section and glass walls, envelops the building, acting as a buffer zone for thermal regulation. The structure of the house relies on tongue-and-groove wooden walls, ensuring efficient construction and insulation.³⁷

36. Jadwiga Urbanik, "The Growing House" – the Way to Solve the Housing Problem in Interwar Germany in *Advances in Human Factors*, 247

37. Martin Wagner, *Das wachsende Haus* (Berlin: HKW, 2015), 144

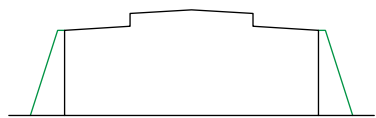
The design not only allowed the house to grow in size but also in quality, as it could adapt to the changing needs of a family over time. However, the design was criticized as being too fancy and for its central living room, which lacks natural light from the large exterior windows, relying instead on small roof windows.³⁸ Nonetheless, the Wachsende Haus introduced a forward-thinking vision for housing that combined modularity, affordability, and sustainability.

38. Jadwiga Urbanik, "The Growing House" – the Way to Solve the Housing Problem in Interwar Germany in *Advances in Human Factors*, 252



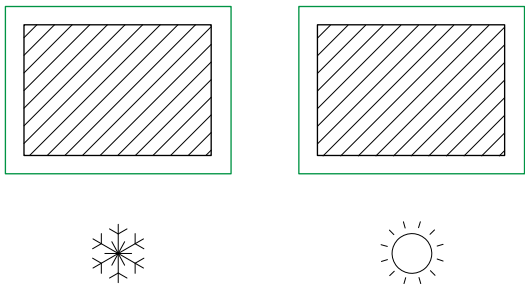
Fig. 5: View of the central living-room (Source: Wagner, M., *Das Wachsende Haus* (Berlin: HKW, 2015), 149)

composition principle of the greenhouse



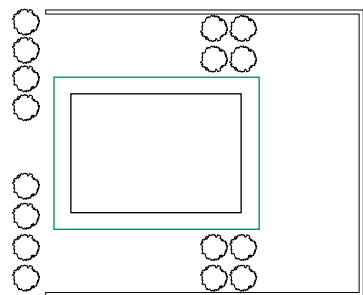
The Wachsende Haus adopts a compositional principle where the greenhouse surrounds the facades of the main living space. This design creates a buffer zone that mediates between the interior and exterior, acting as both a visual and thermal filter. The main living space is a rectangular box, with the greenhouse volume featuring a triangular section that surrounds the facade, except for the entries to the building.

seasonal variations in use



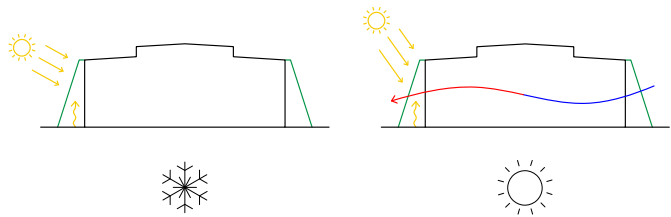
Daily life primarily unfolds within the insulated living space, regardless of the season. The greenhouse, designed with only a 1-meter width, is too narrow to function as an additional living area. As a result, there are no seasonal variations in its use.

balancing privacy and transparency



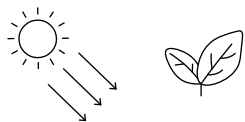
The house is surrounded by a fence and trees, which provide privacy by protecting it from external views. Moreover, the greenhouse, made entirely of glass, does not host any activities inside, making the question of privacy less important. The transparent nature of the greenhouse does not detract from the sense of privacy as it remains unused for daily living.

climatic systems



The climate system of the greenhouse relies on passive principles to regulate temperature throughout the year. During winter, the greenhouse captures passive solar energy, warming both the greenhouse and the central living area. In summer, cross ventilation helps decrease the temperature of the greenhouse. This flow of air cools and refreshes the space, allowing warm air to exit the house. However, the absence of a shading system means the greenhouse depends entirely on natural ventilation for temperature control during the warmer months.

functional use of the greenhouse



The greenhouse serves a dual purpose: it is used for growing plants and plays a key role in the house's climate control. The greenhouse acts as a buffer zone, utilizing passive energy to help heat the main living space, enhancing the house's energy efficiency. However, the greenhouse's dimensions are too small for human use, with only a 1-meter width.

presence of vegetation



Vegetation is present in this project, primarily in the form of potted plants within the greenhouse. However, the main function of the greenhouse is not centered around vegetation; rather, it primarily serves a climatic control role, helping to regulate the temperature and contribute to the energy efficiency of the house.

naturhus

1:150



architect bengt warne

year 1974-1980

place saltsjöbaden, sweden

state built

greenhouse floor area 220 m2

isolated floor area 263 m2

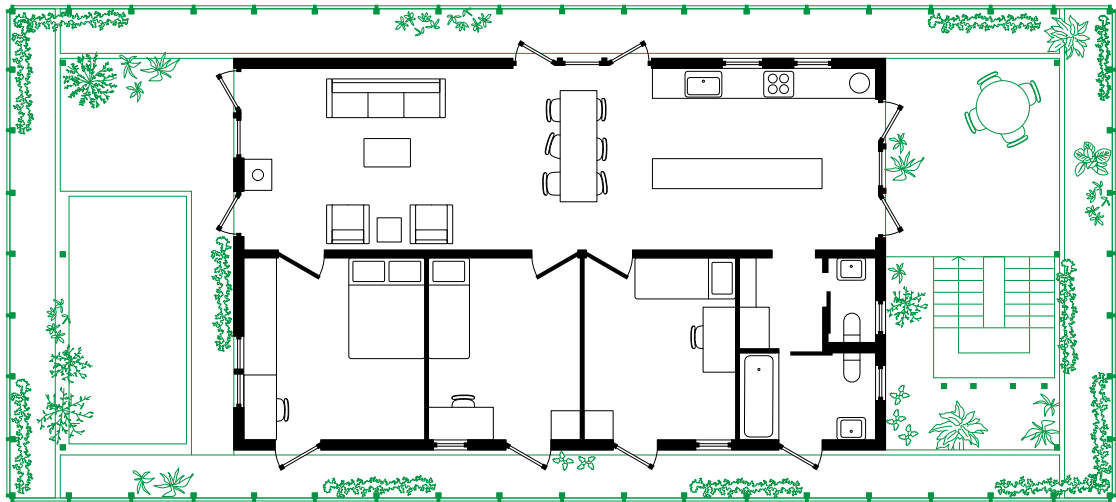
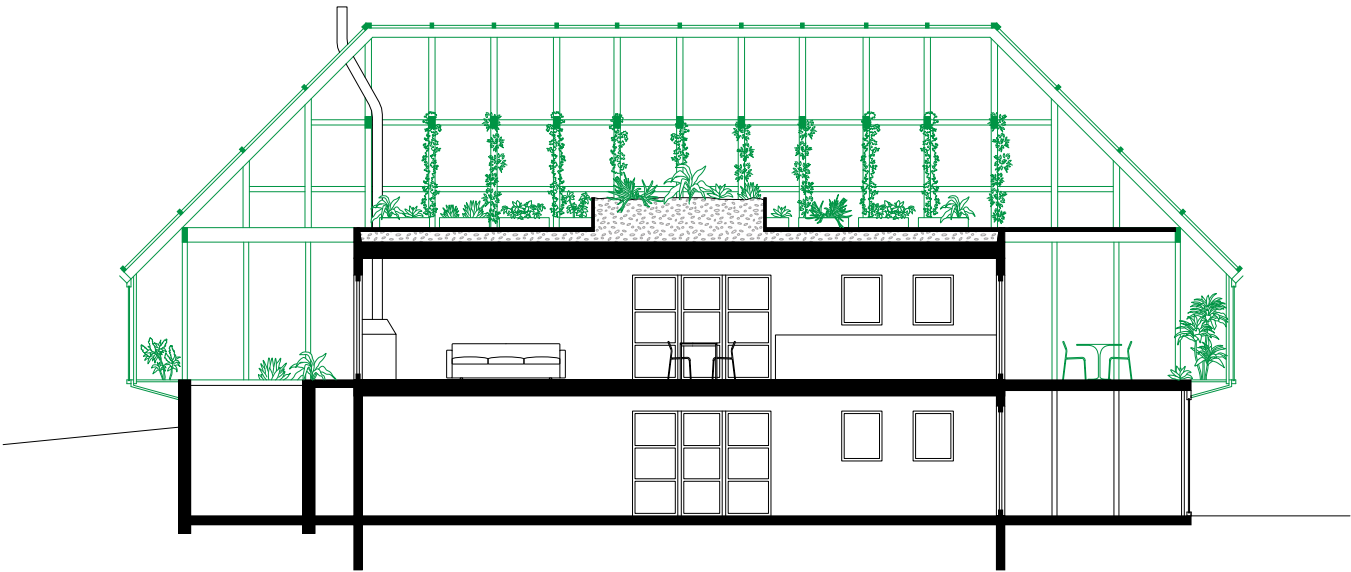


Fig. 6: Exterior view of the Naturhus (Source: Fredriksson M., Warne B., På akacians villkor (Sweden: Warne Förlag, 1993)



39. Andrea Antolloni, *Bengt Warne's Naturhus: sustainable living in a Northern European climate*, 20

40. Ibid. 43-44

41. Ibid. 23

42. Philippe Mourelle, *La Serre Domestique*, 34-36

43. Andrea Antolloni, *Bengt Warne's Naturhus: sustainable living in a Northern European climate*, 73-74

44. Ibid. 62

45. Ibid. 60

Bengt Warne introduces the concept of Symbio Housing, a vision of living in harmony with nature while ensuring sustainability for future generations. This approach relies on passive systems powered by natural elements such as the sun, wind, rain, and soil, emphasizing sustainability and the use of local resources.³⁹

The Naturhus project is an application of the principles of Symbio Housing. Located in the suburban area of Saltsjöbaden, Sweden, the design integrates a wooden core house within a glass-enclosed greenhouse. This structure enables residents to cultivate Mediterranean fruits and vegetables, even in Sweden's cold climate, while protecting both people and plants from snow, rain, and wind. The Swedish magazine *Allt i Hemmet* collaborated with Bengt Warne to design this nature-friendly house, which was built as a prototype of the future dwelling for Warne himself and his family.⁴⁰ This period of economic growth was beginning to have significant effects on natural resources, prompting a shift towards the conservation of nature and the development of environmentally conscious architecture. Unlike ordinary houses that keep the outside out, the Naturhus creates a new relationship between people and nature by keeping the outside in.⁴¹

The dwelling features a half-sunken basement and a ground floor that includes a living room and kitchen on the north side, with three bedrooms facing south along the building's two longest facades. Surrounding the ground floor is a balcony within the greenhouse, where grass and flowers grow between the wooden boards, creating a semi-outdoor environment. On the shorter facades, large greenhouse extensions provide additional usable space, while on the north and south sides, smaller extensions of about one meter act as corridors connecting the larger greenhouse areas. Above the core house, a roof garden enclosed by the greenhouse is covered with 10 centimeters of soil and initially intended for growing plants.⁴² Vines climb along the wooden framework of the greenhouse, offering some shade. However, due to excessive heat during the summer, the original roof garden was later modified, and an additional floor was built above it.⁴³

On the eastern side of the balcony, a large staircase connects the spaces, alongside a small garden. The absence of an internal staircase requires movement between floors via the greenhouse. On the western side, a pool designed to collect rainwater was initially planned but ultimately excluded due to budget issues.⁴⁴

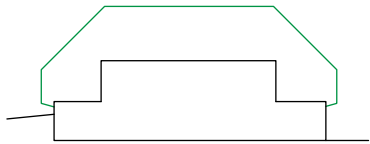
In the basement, a Clivus Multurum composting system processes toilet, kitchen, and greenhouse waste. Purified rainwater is used for bathing, laundry, and dishwashing, with the filtered water returning to nourish the greenhouse plants, completing the cycle of resource use.⁴⁵

The Naturhus exemplifies how sustainable design can integrate natural cycles, provide efficient resource use, and create a productive environment that harmonizes human habitation with the natural world.



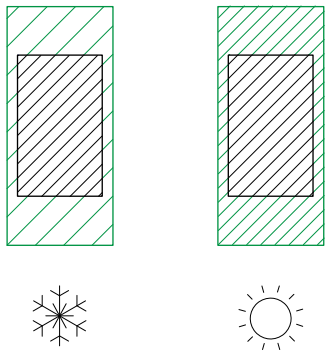
Fig. 7: View of the rooftop garden of the greenhouse (Source: Fredriksson M., Warne B, *På akaciens villkor* (Sweden: Warne Förlag, 1993)

composition principle of the greenhouse



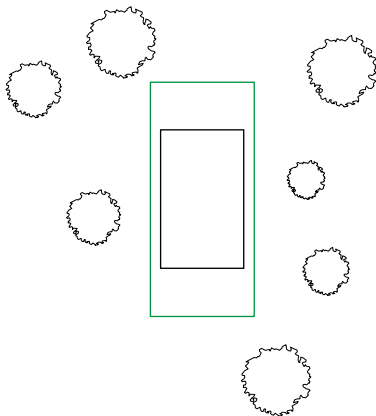
In Naturhus, the greenhouse fully encloses the main living space, covering both the facade and the roof. This design creates a protective envelope around the house, resulting in no direct view or access to the exterior from the main living space.

seasonal variations in use



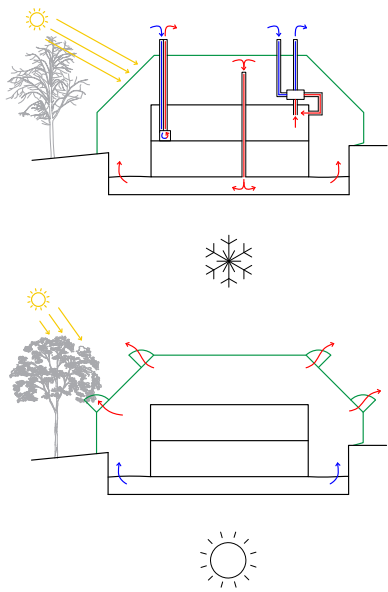
During winter, the family confines their activities to the most essential rooms, staying close to heat sources like the fireplace for warmth. In summer, the dwelling opens up, allowing the use of both the greenhouse and the insulated living areas. However, since the stairs are located in the greenhouse, the family also needs to pass through the greenhouse in winter to access all floors. The greenhouse is also used in winter for the rooftop garden.

balancing privacy and transparency



The project is situated on the outskirts of Saltsjöbaden, in a sparsely built area, where privacy is more naturally achieved. Despite the use of a glass greenhouse, privacy is effectively maintained by the trees surrounding the building, which shield it from street-level views and create a natural barrier, enhancing the sense of seclusion.

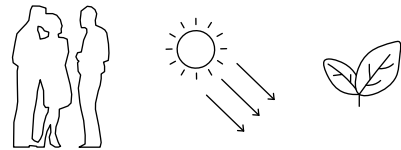
climatic systems



The project incorporates specialized climatic systems to ensure comfort throughout the year. In winter, fresh air is drawn into the core living space through a heat exchanger, before being sent out through the roof.⁴⁶ A combitherm stove further contributes to heating efficiency, with outdoor air supplied to the fireplace via a chimney. The chimney functions as a heat exchanger, warming the incoming air. The ground floor has pebbles, which are used to store heat or cold. The heat stored in the ground can be used when needed, taken up by fans.⁴⁷ During summer, ventilation is achieved through roof windows in the greenhouse, facilitating airflow to prevent overheating. The cold stored in the ground is also used to cool the greenhouse. Additionally, the trees provide natural shading, blocking direct sunlight.

⁴⁶ Andrea Antolloni, Bengt Warne's Naturhus: sustainable living in a Northern European climate, 57-58
⁴⁷ Ibid. 64

functional use of the greenhouse



The greenhouse serves multiple functions: it provides space for people, supports plant growth, and contributes to climate regulation. On the rooftop, the greenhouse primarily functions as a space for gardening. On the ground floor, the greenhouse incorporates the stairs and acts as a circulation space around the main living area, creating a continuous flow between indoor and outdoor environments. Although a pool was originally designed within the greenhouse, it was not built. Instead, the space serves as a place to sit and rest, much like a balcony, but enclosed within the greenhouse.

presence of vegetation



Vegetation is present in the greenhouse, with grass and flowers growing between the wooden boards of the balcony and plants cultivated on the rooftop. However, changes have occurred over time. An additional floor has been constructed above the roof terrace because the original roof garden became too hot in summer, making plant growth difficult. Grass around the balcony has been removed due to unpleasant odours, and now plants grow exclusively in pots.⁴⁸

⁴⁸ Ibid. 73-74

kelbaugh house

1:150



architect douglas kelbaugh

year 1975

place princeton, united states

state built

greenhouse floor area 20 m2

isolated floor area 72 m2

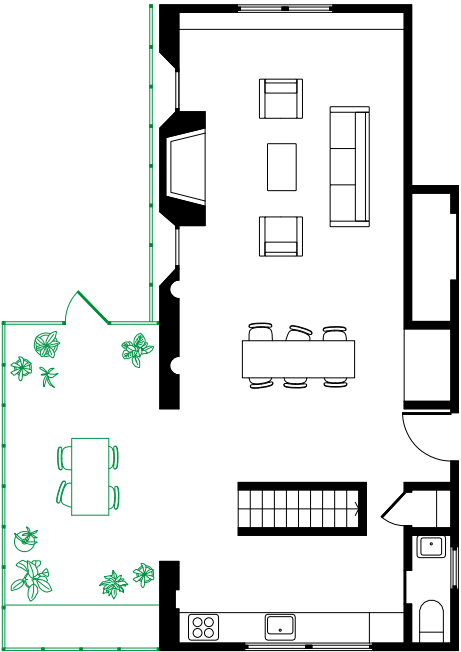
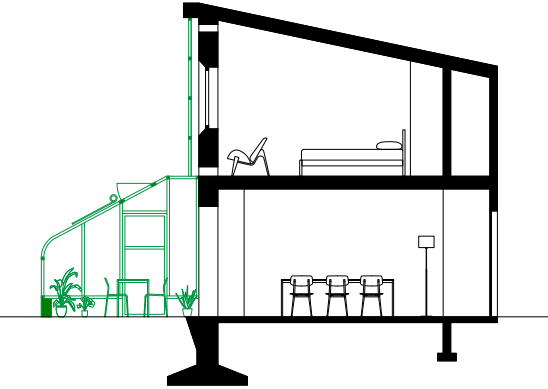


Fig. 8: Exterior view of the Trombe wall and greenhouse (Source: Kelbaugh, D., 1975)



49. Pierre-Edouard Latouche, "The Kelbaugh House", *The Planet Is the Client*, accessed December 23, 2024, <https://www.cca.qc.ca/en/articles/issues/19/the-planet-is-the-client/33741/the-kelbaugh-house>

50. Robert W. Craig, *The Report of the Princeton Architecture Survey* (Princeton: Princeton Joint Historic Sites Commission, 1981)

51. Pierre-Edouard Latouche, "The Kelbaugh House"

52. Ibid

53. Ibid

54. Ibid

55. Barbara Penner, Adrian Forty, Olivia Horsfall Turner, Miranda Critchley, *Extinct: A Compendium of Obsolete Objects*, 328-331

56. Pierre-Edouard Latouche, "The Kelbaugh House"

The Kelbaugh House, located in a residential neighborhood of Princeton, United States, was designed by American architect Douglas Kelbaugh as a residence for himself and his family. This two-story home, featuring three bedrooms, was constructed on the only sunny section of a mostly shaded plot—the northeast corner.⁴⁹ While the main entrance is situated on the northern side, the house's eastern facade faces the street.

Designed during the period following the oil crisis, the dwelling incorporates innovative passive energy solutions. Initially designed with a rectangular plan, the house was modified in 1976 with the addition of a southern-facing greenhouse.⁵⁰ This greenhouse serves multiple purposes: it houses potted plants and a seating area, and has a door on its western side providing access to the garden.

A defining feature of the house is its Trombe wall, a passive solar system named after French inventor Félix Trombe. This system, popular in Europe, was first introduced to the United States by Kelbaugh. The Trombe wall consists of a thick southern-facing masonry wall painted black, an air gap, and double layers of glass mounted in aluminum channels typically used in greenhouses. This allows the wall to collect solar energy in winter, and acts like a cooling mass in summer. Remarkably, Kelbaugh implemented two Trombe walls stacked vertically, a new method at the time.⁵¹

The south-facing glass facade, spanning two floors, maximizes sunlight penetration into the house, helped by the building's slim floor plan. The masonry wall is built from poured concrete, 38 cm thick, coated in black, and paired with double-pane glass set 15 cm in front of it.⁵² The masonry has six openings ensuring natural light for every room, while colored blinds add character. This thermal system initially faced challenges that affected the building's overall performance. Over the years, modifications were made to address and minimize these issues, gradually enhancing its efficiency.⁵³

The greenhouse addition transforms the southern face into both a solar collector and an inviting extension that connects to the garden. Meanwhile, the house's wood frame structure leans against the concrete wall, with its roof sloping downward to the north. The facade, made from unpainted plywood, offers a dark but textured appearance with irregularly placed windows.⁵⁴

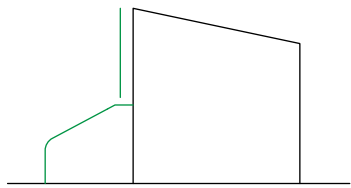
Despite early thermal performance challenges, the Kelbaugh House becomes a symbol of solar architecture. Living in this dwelling required the family to adapt to seasonal changes as it was an ongoing project with continuous experiments to achieve comfortable indoor temperatures. Over 75% of the dwelling's heating needs were met by solar energy.⁵⁵

Kelbaugh's admiration for Le Corbusier is evident in the house's details, including colorful interior blinds, cedar plywood siding, and niches and shelves cast into the Trombe wall's interior, blending solar architecture with modernist aesthetics.⁵⁶



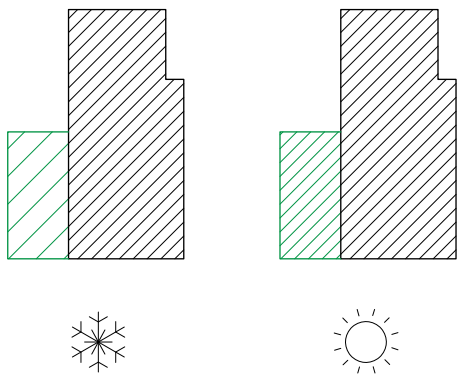
Fig. 9: Interior view of the Trombe wall from the bedroom (Source: Kelbaugh, D., 1975)

composition principle of the greenhouse



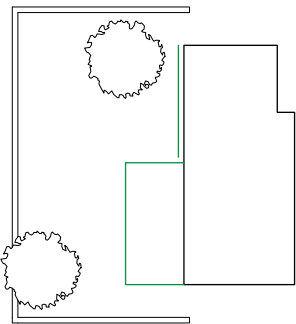
In the Kelbaugh House, the greenhouse is attached to the southern facade of the main living space. The greenhouse consists of two components: a Trombe wall and a small greenhouse structure attached to the southeastern corner of the masonry. This small greenhouse was a later addition, constructed one year after the main building was completed.

seasonal variations in use



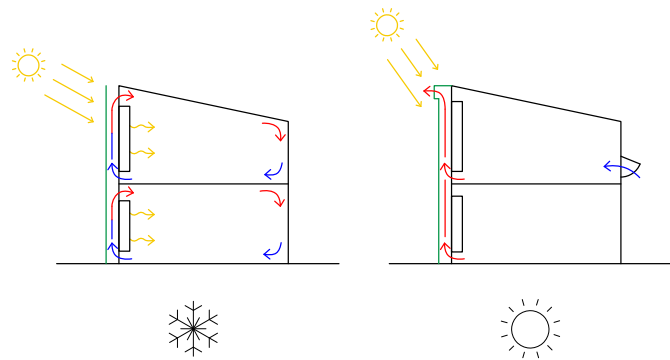
During winter, the heated living space is primarily used, while in summer, the small greenhouse becomes an additional area for the household. The greenhouse is however used year-round for plant growth, providing space for cultivating greenery throughout all seasons.

balancing privacy and transparency



The small greenhouse, not facing the street and designated for secondary use, makes privacy a less critical concern. Additionally, the Trombe wall, with its thick masonry and small openings, ensures further privacy. Both the greenhouse and Trombe wall face south to maximize sunlight exposure, reducing direct views from the street on the east side.

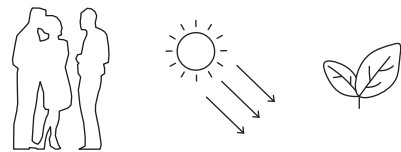
climatic systems



During the winter months, sunlight enters through the glass of the Trombe wall, heating the air inside. This warm air rises and flows through the vents near the ceiling of both stories, circulating into various rooms where it mixes with cooler air, descends, and returns through lower vents to continue the cycle. At night, the masonry releases the heat it absorbed during the day, radiating warmth into the dwelling. In summer, the Trombe wall serves as a cooling element, counteracting the solar energy that reaches the building. Sunlight reflects off the structure, while cool air enters from the north side, circulates through the rooms, and exits via the Trombe wall vents. To enhance this process, small electric fans at the top of the Trombe wall exhaust the hot air collected in the system.⁵⁷

57. Pierre-Edouard Latouche, "The Kelbaugh House"

functional use of the greenhouse



The small greenhouse serves multiple purposes: it is a space for people, for plants, and a climate controller. The greenhouse supports plant growth and includes a table where occupants can sit and enjoy the greenery and sunlight. An opening in the greenhouse also provides direct access to the garden. The Trombe wall functions merely for climate control of the main living space.

presence of vegetation



The greenhouse is filled with numerous potted plants, making vegetation a central feature and main protagonist of the space.

solar house

architect oswald mathias ungers

year 1980

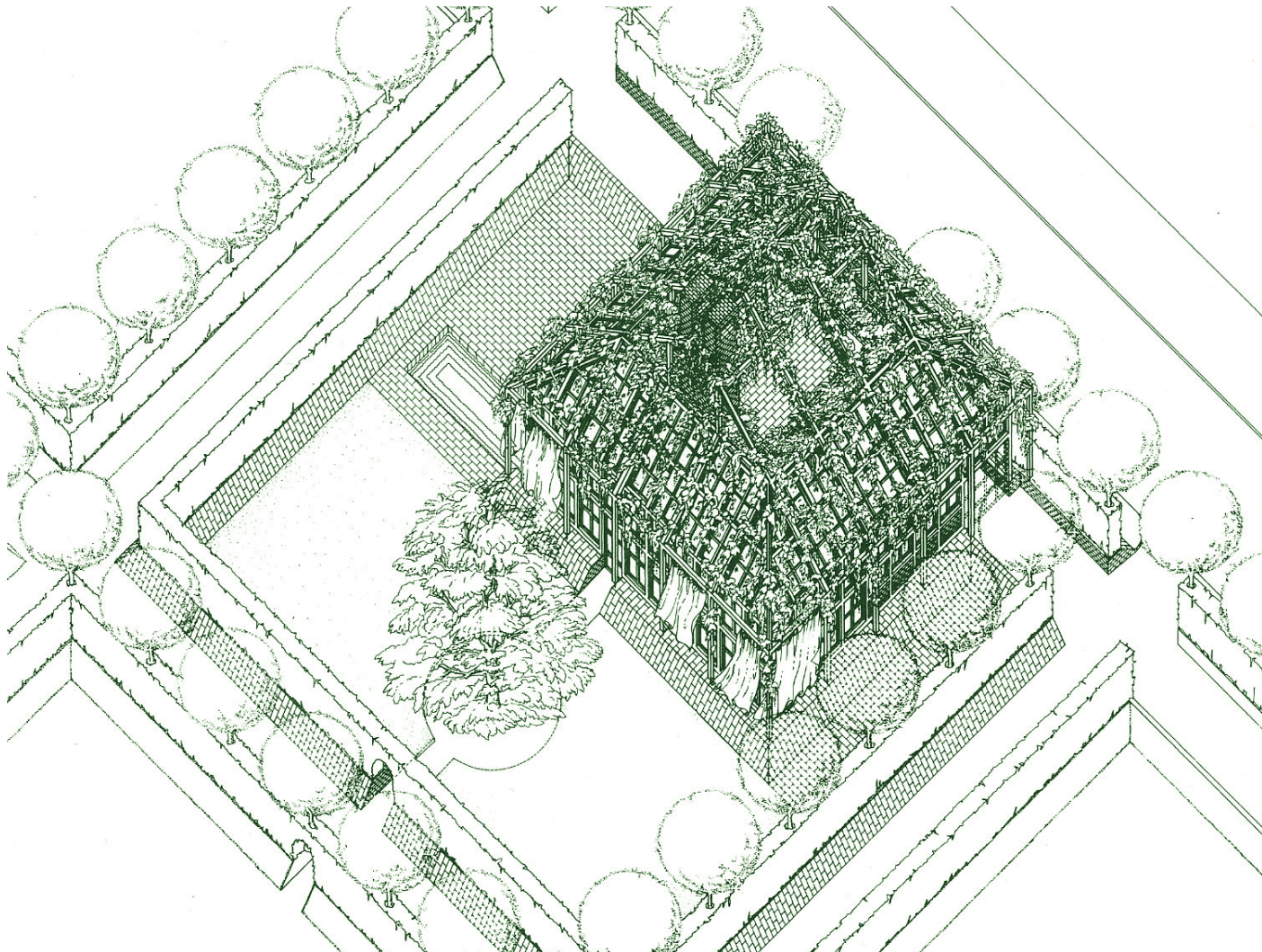
place landstuhl, germany

state not built

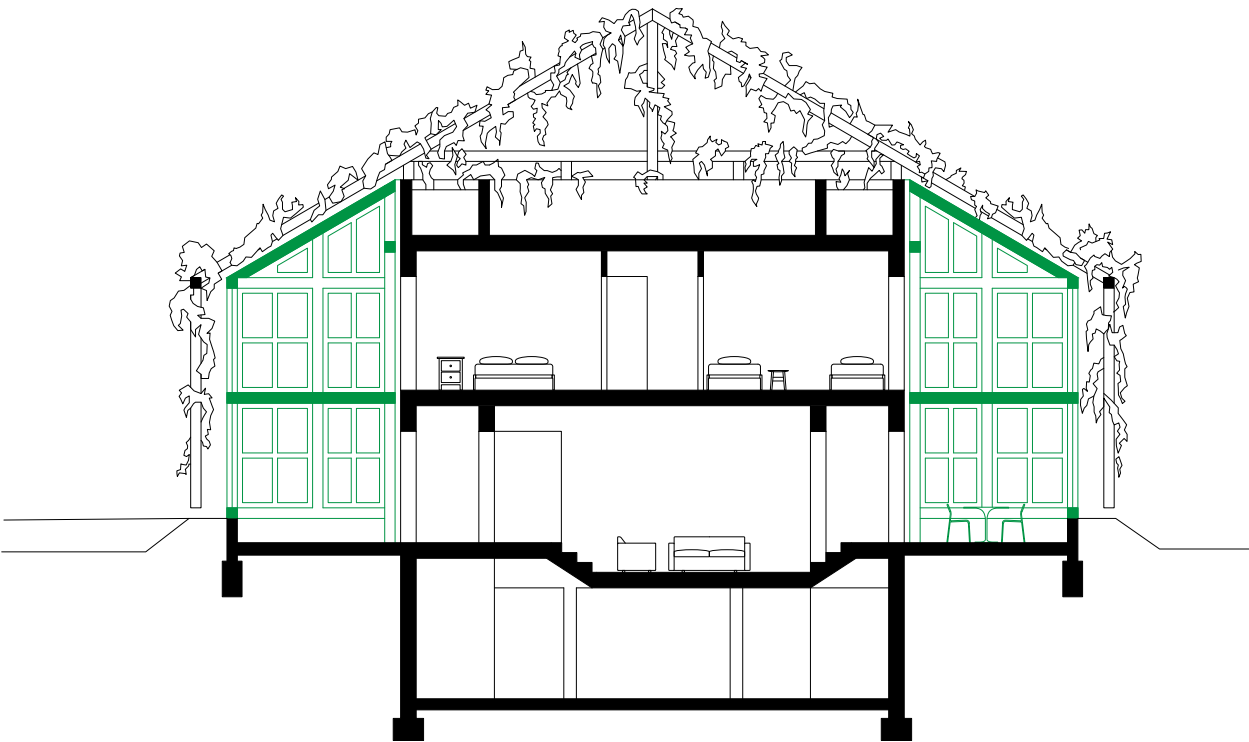
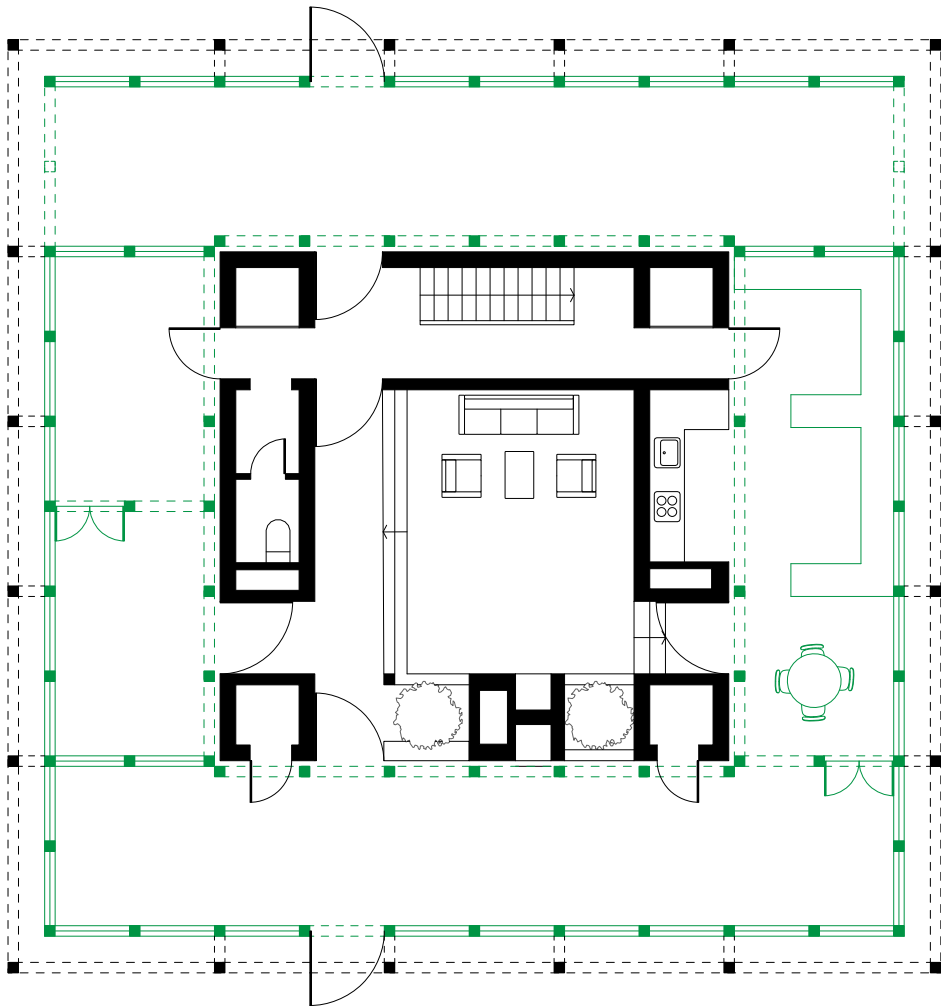
greenhouse floor area 378 m2

isolated floor area 305 m2

Fig. 10: Axonometry drawing of the Solar House (Source: Ungers, O. M, 1980)



1:150



1:150

58. Cornelia Escher, Lars Fischer, *Negotiating Ungers: the Aesthetics of Sustainability* (Brussels: Common Room, 2019), 18

59. Ibid. 23

60. Mariabruna Fabrizi, "Energy as Architectural Matter: Oswald Mathias Ungers' Solar House (1980)", *SOCKS*, accessed December 23, 2024, <https://socks-studio.com/2021/06/27/energy-as-architectural-matter-oswald-mathias-ungers-solar-house-1980/>

61. Cornelia Escher, Lars Fischer, *Negotiating Ungers: the Aesthetics of Sustainability*, 24–25

62. Ibid. 24

63. Ibid. 34–35

64. Mariabruna Fabrizi, "Energy as Architectural Matter: Oswald Mathias Ungers' Solar House (1980)"

Designed as part of a competition in Landstuhl, Germany, Solar House was intended as a model for solar housing across the country. The competition, titled *auf der Melkerei*, focused on solar housing solutions.⁵⁸ Oswald Mathias Ungers' proposal, known as "the house within the house," earned a special prize and public praise, although it was never built. Ungers designed five variants of houses as part of this competition. The project was later showcased in the 1980 exhibition *Houses for Sale* at the Leo Castelli Gallery in New York.⁵⁹

The building's plan is a perfect square with dimensions of 19 by 19 meters. The design features one underground floor, two above-ground floors, and a rooftop terrace designed for planting, which contributes to thermal insulation, moisture control, and noise protection. The house's square floor plan minimizes its exterior surface area, enhancing energy efficiency—a central concern in the broader context of architectural debates on environmental sustainability and the decarbonization of energy during the period.⁶⁰

The house has a simple volume with a rectangular base and a gabled roof. It is set on a square plot, enclosed by a brick wall and a hedge, with trees planted inside the garden. The design has a self-contained character, emphasizing privacy rather than openness to the surroundings.⁶¹

The interior spaces follow a day-night arrangement: the ground floor contains the living room and kitchen, while the first floor houses the bedrooms. The house is organized into concentric zones, each defined by its material and function. At the core is a stone structure that serves as a thermal mass, storing heat and hosting essential living spaces. Surrounding this is a greenhouse layer that acts as a buffer zone, mediating the temperature between the interior and exterior. A wooden framework encloses the greenhouse, supporting an outer layer of greenery that provides shade in the summer.⁶²

The design adapts to changing seasons and conditions. In winter, activity is concentrated in the stone core, while in summer, the living spaces expand into the glasshouse. From the outside, the seasonal changes are visually apparent, as if staged. In summer, the dwelling appears lively and open, with greenery enveloping the structure. In winter, the greenery recedes, revealing only the wooden framework, resembling a skeleton.⁶³

Ungers' project rethinks the fundamental design of the house, addressing environmental sustainability without relying on added technologies. Instead, he employs spatial and formal solutions, such as the layered volumes and thermal mass, to integrate energy efficiency into architecture.⁶⁴

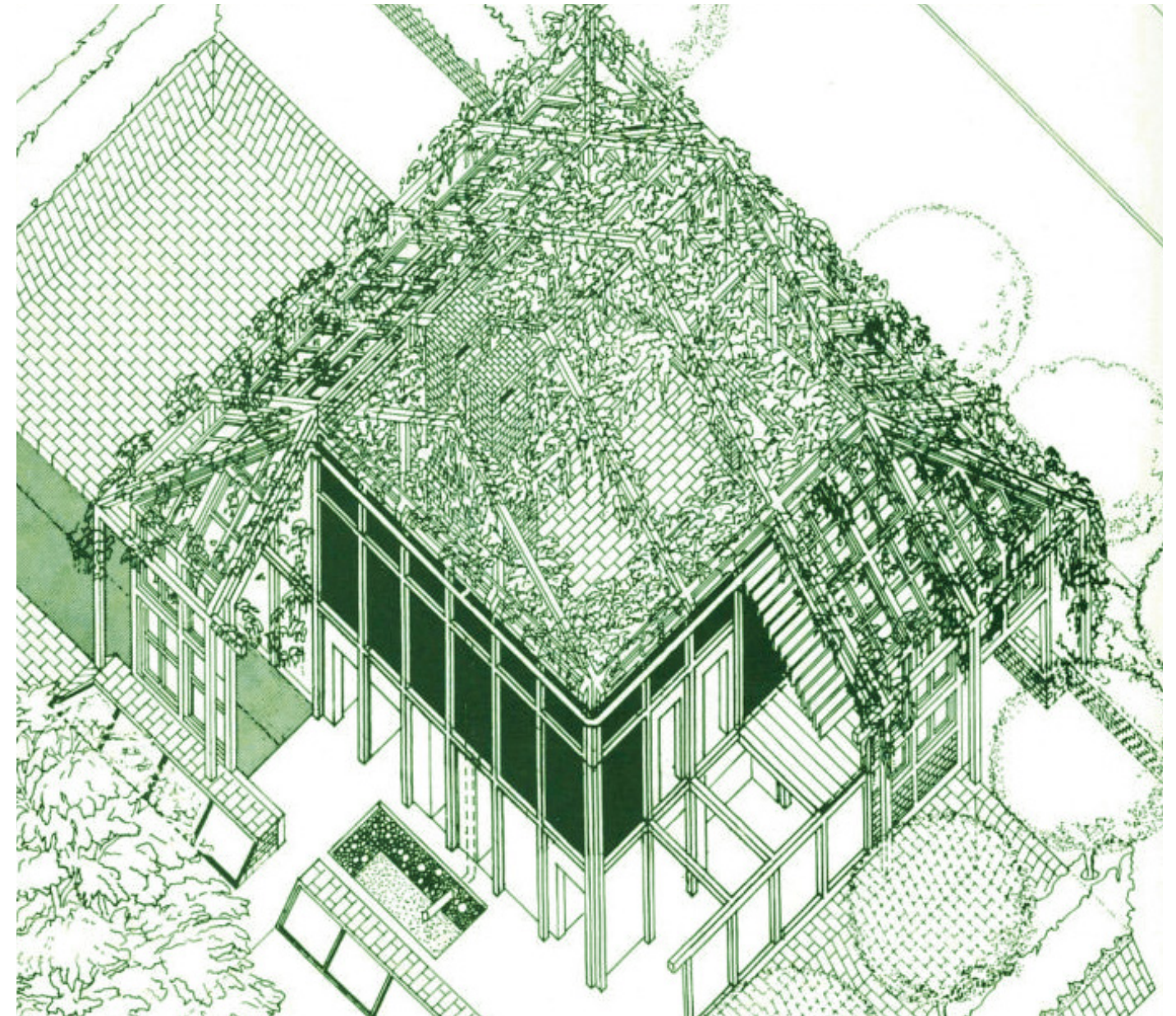
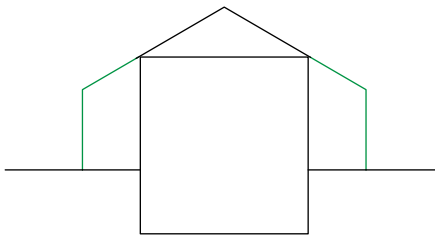


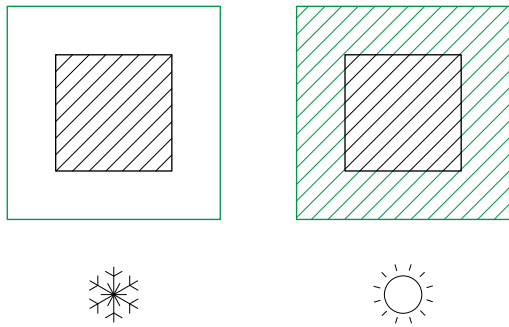
Fig. 11: Axonometry drawing of the Solar House (Source: Ungers, O. M, 1980)

composition principle of the greenhouse



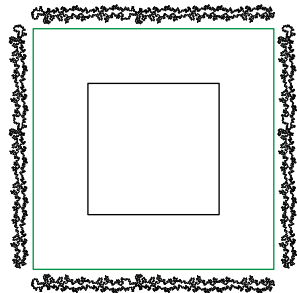
In the Solar House, the greenhouse encircles the facades of the insulated living space, creating an additional layer that acts as a buffer between the interior and exterior environments. The main living space is designed as a rectangular volume, while the greenhouse features a shed roof.

seasonal variations in use



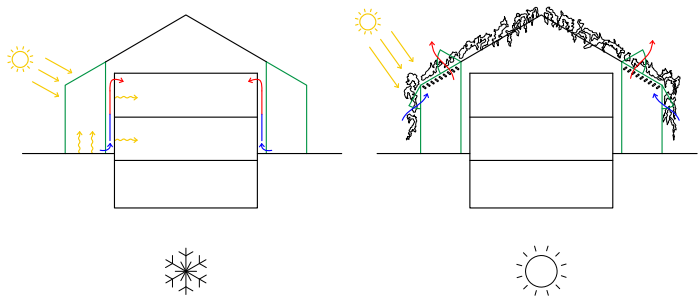
During winter, daily activities are concentrated in the heated central space, ensuring comfort during colder months. In summer, the use of space expands to include not only the greenhouse and central living area but also the outdoor rooftop, offering a versatile environment for seasonal living.

balancing privacy and transparency



The greenery on the wooden framework blocks the view to the greenhouse and enables privacy. The glass facade of the greenhouse, though transparent, is complemented by the framework to maintain a sense of seclusion. Even when the greenery is absent, the wooden framework itself provides an additional layer of privacy.

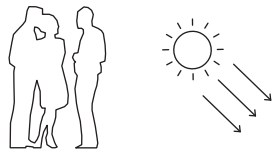
climatic systems



The Solar House employs an efficient climatic system to adapt to seasonal changes. In winter, a thick stone storage wall absorbs heat during the day and releases it at night, contributing to a stable indoor temperature. A glass facade positioned in front of the storage wall creates a thermal buffer, allowing cold air to flow between the glass and the wall, where it warms as it rises before entering the living space at the top. During this season, the absence of greenery allows passive solar energy to penetrate fully into the greenhouse.⁶⁵ In summer, greenery on the wooden framework provides natural shading, blocking direct sunlight and reducing overheating. Cold air enters the greenhouse through facade windows, while warm air exits through roof windows, ensuring effective ventilation. Additionally, blinds installed on the roof offer extra shading.

65. Mariabruna Fabrizi, "Energy as Architectural Matter: Oswald Mathias Ungers' Solar House (1980)"

functional use of the greenhouse



The greenhouse serves as both a space for human use and a functional element in climate control. While much of the greenhouse lacks a specific designated purpose, the area near the kitchen features furniture drawn by the architect, suggesting its use as an extension of the kitchen and dining room. Accessible from both the ground floor and the first floor, the greenhouse enhances connectivity within the house, creating opportunities for flexible use while also contributing to the overall environmental performance of the building.

presence of vegetation

There is no vegetation inside the greenhouse; instead, greenery grows on the wooden framework that surrounds the structure. This vegetation originates from rooftop pots, cascading down along the framework to create a natural screen. While the design allows for the addition of potted plants within the greenhouse, the architect chose not to incorporate them, focusing instead on the exterior greenery as the primary natural element.

latapie house

1 : 150



architect lacaton & vassal

year 1993

place floirac, france

state built

greenhouse floor area 63 m2

isolated floor area 120 m2

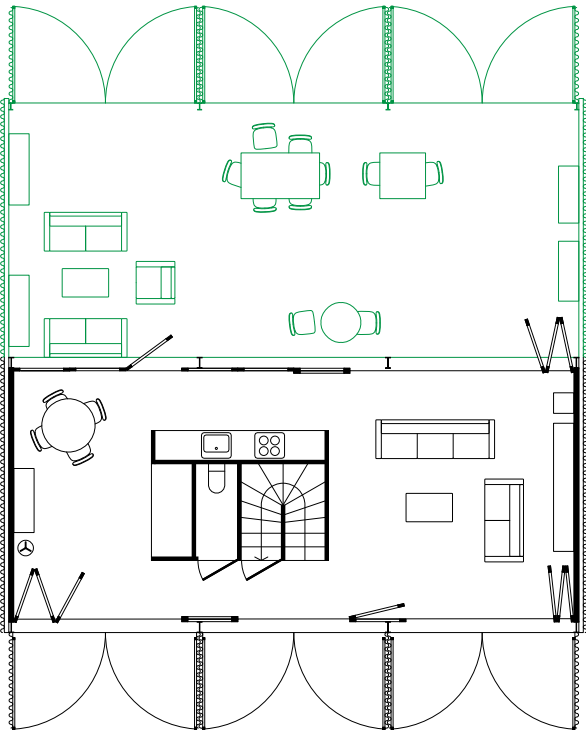
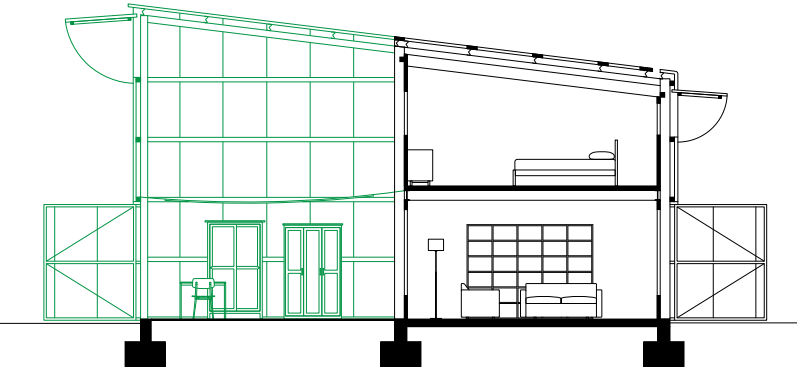


Fig. 12: Exterior view of the greenhouse of Latapie House (Source: Ruault, Philippe)



66. Andreas Ruby, Ilka Ruby, *Lacaton & Vassal* (Barcelona: Editorial Gustavo Gili, 2007), 27

67. Philippe Mourelle, *La Serre Domestique*, 46

68. Tiago P. Borges, "Does it make sense to talk about type today? On typology, climate and the work of Lacaton & Vassal" in *Burning Farm* (October 2023), 6

69. Olivier Darmon, "Serre et habitat" in *Archi pas chère* (October 2013), 21

70. Philippe Mourelle, *La Serre Domestique*, 50

71. Andreas Ruby, Ilka Ruby, *Lacaton & Vassal*, 27

72. Olivier Darmon, "Serre et habitat", 20

The Latapie House, located in a residential area of Floirac, France, was designed as a low-budget home for a couple with two children. The house features an almost square plan measuring 11 by 12 meters, divided into two distinct rectangular areas: an opaque wooden volume facing the street on the west and a greenhouse facing the garden on the east.⁶⁶

The insulated wooden volume serves as the main heated living space and contains conventional domestic spaces. At its center is a technical core that houses the staircase, bathroom, kitchen, and storage. This central core is the only separator, with no additional partitions defining the surrounding spaces.⁶⁷ On the ground floor, the living room and a multipurpose area, which can also function as a garage, are located. The first floor contains two bedrooms of different sizes. The house's structure is supported by a metal frame, a construction method inspired by industrial structures.⁶⁸

The greenhouse, built with translucent polycarbonate sheeting, is a double-height space equipped with ventilation panels for comfort during summer. This inclusion of extra space is crucial to making the dwelling comfortable, providing what normal houses often lack: a flexible, adaptable space that occupants can use according to their desires and needs. The greenhouse, which receives morning sun and opens to the plot's garden, functions as a thermal buffer zone and serves multiple purposes. It can be used as a summer dining room, additional lounge, workshop, play area, garage, or other uses.⁶⁹ The architects, Lacaton & Vassal, deliberately left out furniture in their plan and section drawings, inviting users to imagine and appropriate the space as they see fit.⁷⁰

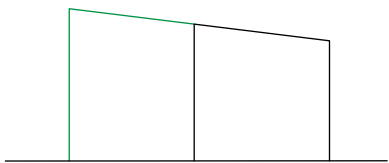
The east and west facades are designed with mobile openings, allowing the house to transform based on the occupants' needs. These openings enable the house to alternate between being fully enclosed or entirely open, offering a direct view from the street to the garden when desired. They also regulate light, ventilation, and intimacy, enhancing the adaptability of the house. The street-facing facade includes large doors made of fiber cement.⁷¹

The greenhouse and the overall design reflect the architects' exploration of non-traditional construction methods for housing. The project draws inspiration from two industrial construction types: horticultural greenhouses and metal structure buildings.⁷²



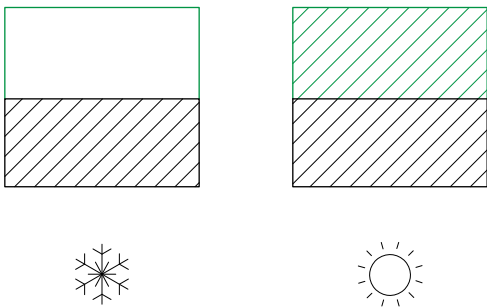
Fig. 13: Interior view of the greenhouse (Source: Lacaton & Vassal)

composition principle of the greenhouse



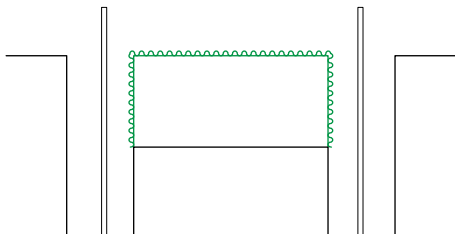
In the Latapie House, the greenhouse is attached to the insulated living space on the east side. The main dwelling consists of a rectangular volume, mirrored by the attached greenhouse, featuring a shed roof and of a similar size.

seasonal variations in use



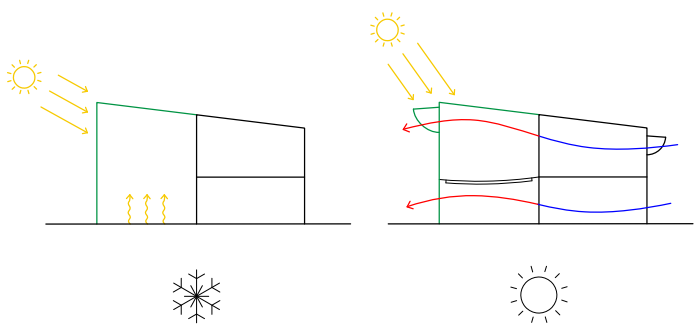
In winter, the family confines their activities to the heated living space for warmth and comfort. In summer, the usage of the dwelling expands to include both the greenhouse and the insulated living space, effectively doubling the ground floor area as the greenhouse becomes an extension of the living environment.

balancing privacy and transparency



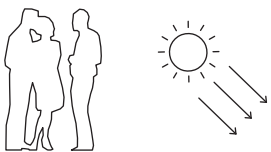
The waves of the polycarbonate panels act as a filter, enhancing privacy while allowing natural light to enter the space. Additionally, a fence separates the houses along the street, offering further protection from external views. The greenhouse faces the private garden to ensure an intimate environment for the residents.

climatic systems



The greenhouse relies on passive solar energy for heating during winter, with no shading system in place, allowing direct sunlight to fully penetrate the space and maximize warmth. In summer, the greenhouse remains comfortable through a combination of cross ventilation facilitated by ground-floor doors, upper-floor windows, and ventilation panels. This airflow system effectively refreshes the space as warm air exits the building. Additionally, a shading system mounted at mid-height of the greenhouse protects the interior from direct sunlight, preventing overheating during the warmer months.

functional use of the greenhouse



The greenhouse serves a dual purpose: it is used by people and plays a role in the house's climate control. As an extension of the living space, the greenhouse offers adaptability to suit the users' needs. This extra space can serve as a summer dining room, additional lounge, workshop, play area, garage, or other functions, depending on the requirements of the residents. The flexibility of the space allows it to be used for various purposes throughout the year.

presence of vegetation

This project does not include any vegetation. Although it is possible to introduce greenery, the users chose not to include any in the greenhouse area. The greenhouse is primarily used for human activities.

f3 house

1:150



architect koh kitayama + architecture workshop

year 1995

place yamato, japan

state built

greenhouse floor area 92 m2

isolated floor area 43 m2

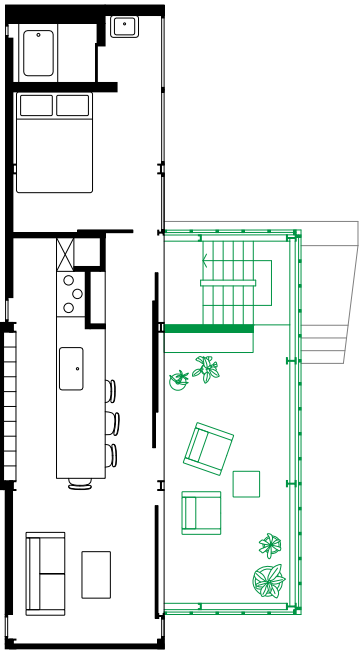
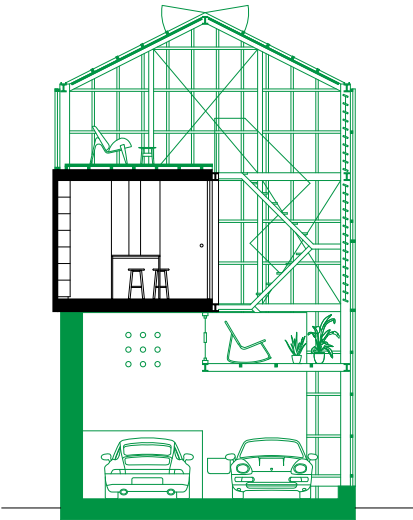


Fig. 14: Exterior view of the F3 House (Source: Fujitsukaz, Mitsumasa)



73. "F3 House", Archws, accessed December 23, 2024, <https://archws.com/architecture/1292/>

The F3 House is located in the densely built environment of Yamato, Japan, with a distant view of Mount Fuji. Designed for a single resident, the dwelling moves away from traditional family-oriented layouts, focusing instead on personal hobbies. The owner wanted a house that could accommodate a garage for two cars and a large party space, prioritizing these elements over conventional domestic functions.⁷³

The main living space is a white industrial container, insulated and waterproof, floating within a greenhouse structure. This minimalist white box is slightly extended toward the north side of the greenhouse. On the south side, the white container extends beyond the greenhouse volume, where its roof becomes an outdoor terrace with views of Mount Fuji. Despite its industrial style, the container incorporates traditional Japanese elements such as a traditional bathroom and shoji screens. The white container is a protected, secluded space—minimally detailed and scaled—offering a sense of quiet introspection. In contrast, the surrounding greenhouse, constructed from prefabricated agricultural components, is open and transparent, creating an outward-facing space that captures the surrounding environment.⁷⁴

74. "F3 House" in *UME Magazine* 3 (1997), 18–21

The greenhouse's transparent glass facade and roof invite light into the structure, while the ground floor features translucent glass to enhance privacy. The greenhouse is used for hobbies, providing a flexible, open space for various activities. At night, the illuminated greenhouse highlights the activities within, creating a glowing presence in the neighborhood.⁷⁵

75. Philippe Mourelle, *La Serre Domestique*, 55–56

A staircase within the greenhouse connects the levels, from the garage below to the terrace on the top floor. The house is composed of one story below ground and three above ground, with a half-storey difference between the white container and the greenhouse platform. The toilet room, located below the white box, requires moving through the greenhouse to access it, further integrating the greenhouse into daily life. The bedroom, placed in the north section, escapes from the greenhouse volume, creating a private retreat away from the more public and social spaces of the house.⁷⁶

76. Ibid. 52–54

The house faces the west side, towards the street, and benefits from afternoon sun. The design plays with the contrast between the private, inward-focused white container and the transparent, outward-facing greenhouse. As the architect describes, this juxtaposition is a proposition about the inevitable cultural shifts in modern Japan, combining the stillness and composure of traditional values with the dynamic, open approach to modern global living.⁷⁷

77. "F3 House" in *UME Magazine* 3, 18–21

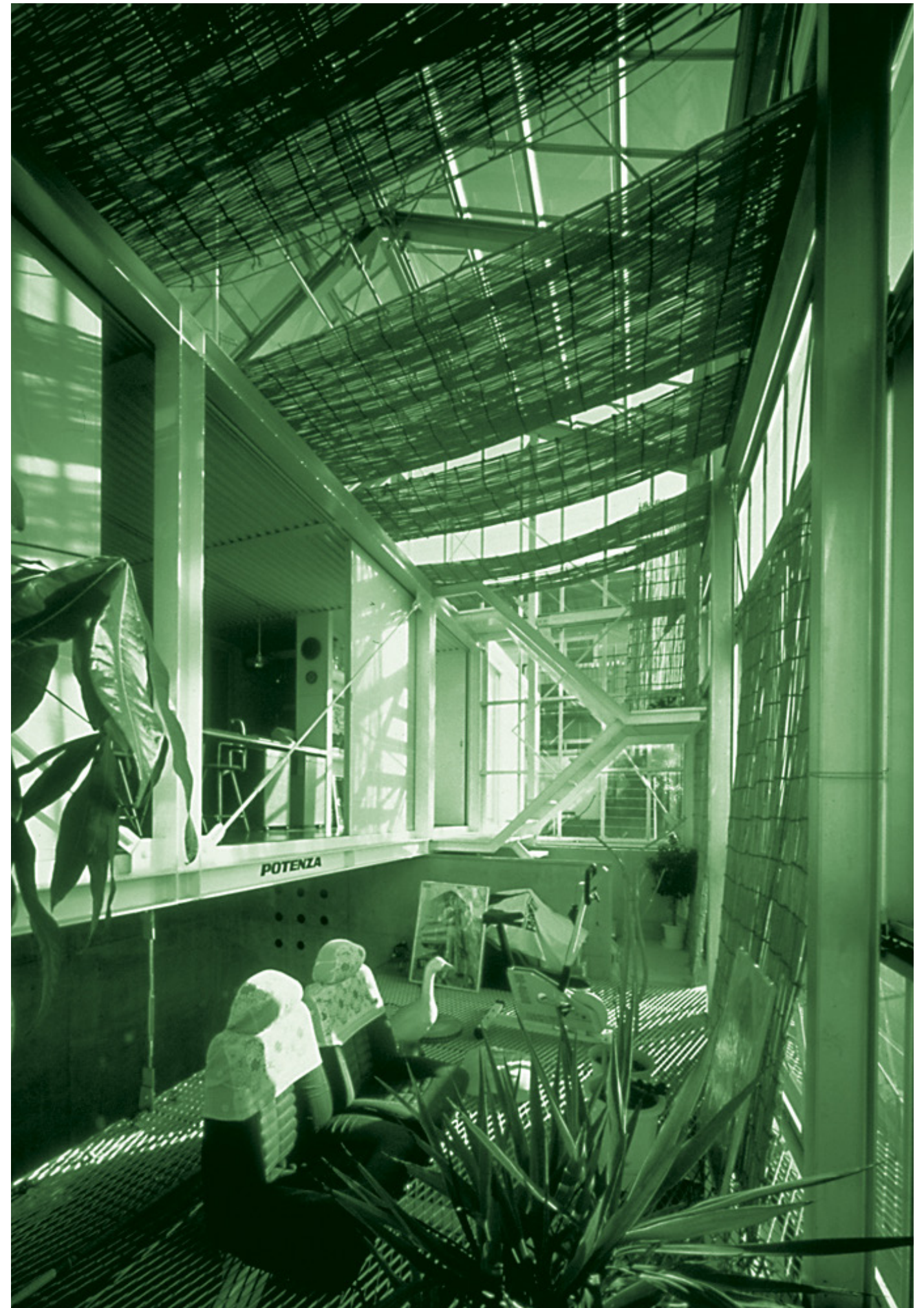
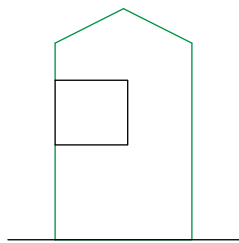


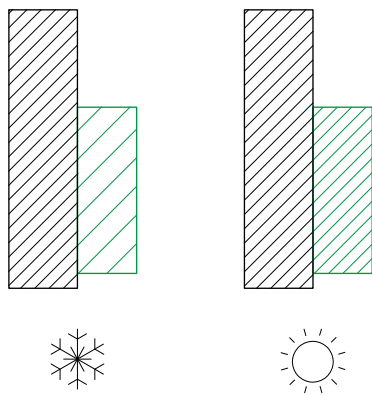
Fig. 15: Interior view of the greenhouse (Source: Nakagawa, Nobuaki)

composition principle of the greenhouse



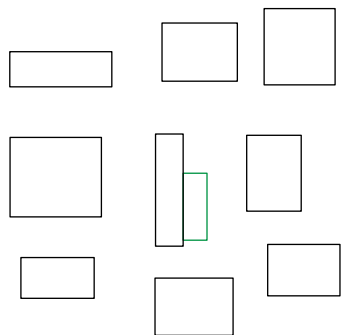
In the F3 House, the greenhouse encloses the insulated living space, providing a protective buffer between interior and exterior. However, the main living space extends beyond the greenhouse on the south side and slightly on the north side. The main living space is a small rectangular container volume, while the large gable roof greenhouse completely encloses it.

seasonal variations in use



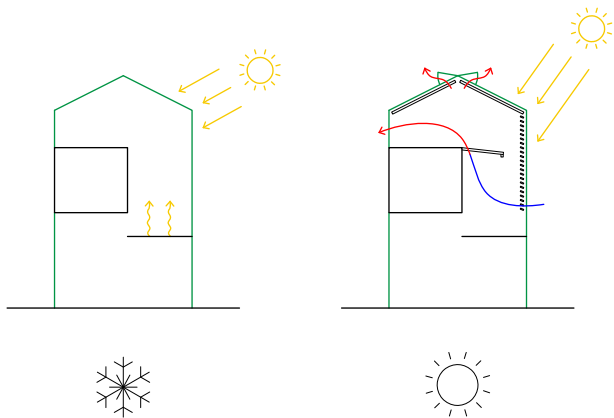
During the colder months, life takes place in the heated container, except for the toilet room located beneath the main living space. However, stairs accessing the different floors are located in the greenhouse, so it is necessary to use the greenhouse even in winter to enter and exit the house, as well as to access the toilet room. When the weather warms up, the greenhouse becomes an additional usable living area.

balancing privacy and transparency



The spaces beneath the greenhouse suffer from a lack of privacy, as the house is located in a densely built area. This issue also affects the living room and kitchen when the sliding doors are open, which is necessary to bring in natural light. In recent images, blinds cover the facade of the greenhouse to address these privacy concerns. On the ground floor, translucent materials are used to provide more privacy, while glass is used in all other parts of the greenhouse. The greenhouse itself, with its transparent facade, showcases life inside, almost like a theater, making the activities within visible to the outside.

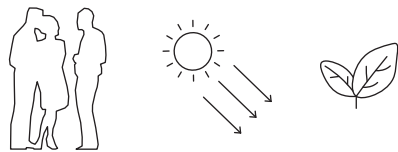
climatic systems



In winter, the greenhouse relies on passive solar energy for heating. In the warmer months, ventilation is facilitated through openings in the facade and roof windows. To address overheating, the greenhouse's glass roof was covered by an opaque wooden roof. In earlier photos of the building, light shading elements can be seen hanging between the roof of the main living space and the facade of the greenhouse. However, in more recent images, these elements have been replaced with an awning and blinds for better control of light and temperature.⁷⁸ In summer, the use of an air conditioner in the main living area helps maintain comfort.

⁷⁸ Philippe Mourelle, *La Serre Domestique*, 56

functional use of the greenhouse



The greenhouse is used for people, for plants, and plays a role in climate control. It is mainly used as a party room, bringing people together in a social space. On the ground floor, the translucent part of the greenhouse serves as space for two cars.

presence of vegetation



The greenhouse features potted plants, but only on the ground floor, where there is no overload of light. The primary purpose of the greenhouse is human use, serving as a space to host parties and gatherings.

camouflage house III

1:150



architect hiroshi iguchi

year 2008

place karuizawa, japan

state built

greenhouse floor area 101 m2

isolated floor area 79 m2

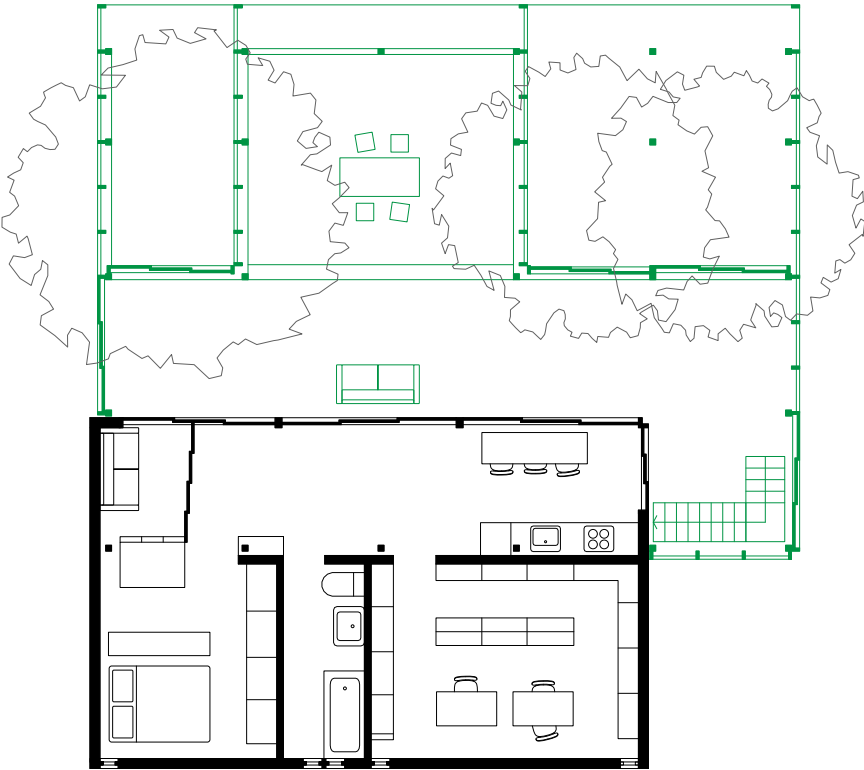
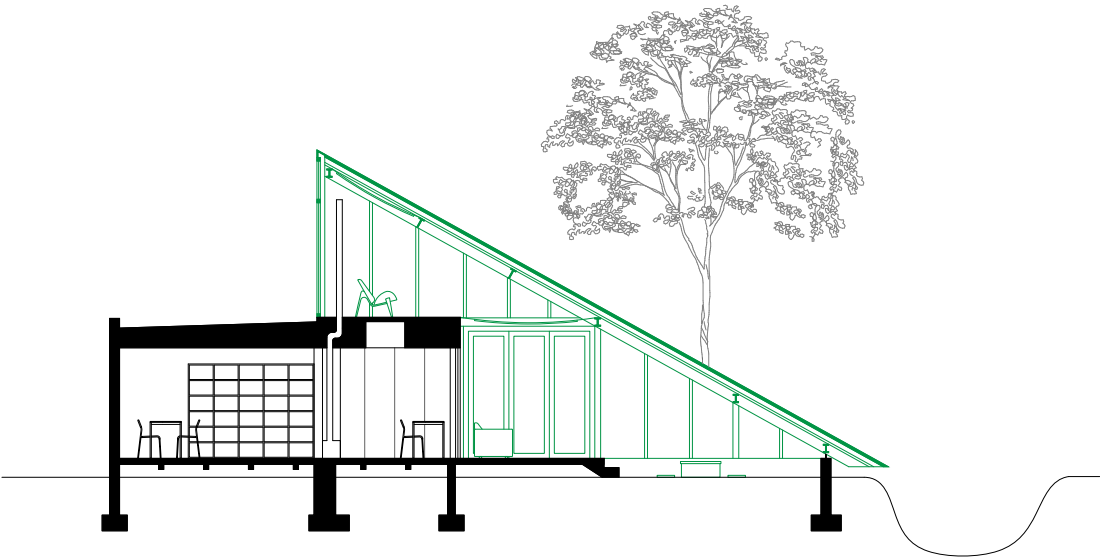


Fig. 16: Exterior view of the Camouflage House III (Source: Divisare, A. G. v.)



79. "Camouflage House 3" in *Jutakuotokushu* (April 2010), 112

80. "Camouflage House III", Hiroshi Iguchi & Fifth World Architects, accessed December 23, 2024, <https://fifthworld.jp/2021/11/11/camo3/>

81. Ibid.

82. "Camouflage House 3" in *Jutakuotokushu*, 112

83. "Camouflage House III", Hiroshi Iguchi & Fifth World Architects

Camouflage House III is located in Karuizawa, Japan, and designed for a couple, their child, and two dogs. The house has two stories above ground and combines an insulated living space with a greenhouse structure, emphasizing environmental coexistence. The building is designed as a passive solar house, following the rhythm of nature to optimize energy use and maintain comfort.⁷⁹

The ground floor contains a bedroom, library, guest room, living room, kitchen, and bathroom. The second floor is left open, with no specific function aside from a few chairs for sitting, and it provides access to the roof terrace. The house integrates seamlessly into the surrounding terrain, using the gentle slope of the southern landscape as part of its design. The building appears to merge with the slope, blending architecture and nature like a work of land art.⁸⁰

The greenhouse, constructed using agricultural greenhouse elements such as a metallic structure and a glass roof and facade, is embedded into the main living space. With a triangular section, the greenhouse serves as both a functional and aesthetic element of the house. Trees planted in pockets on the large glass roof provide privacy and enhance the connection to nature.⁸¹ Despite its orientation toward the north, which limits its exposure to sunlight, the greenhouse features a sunken sitting area on the northern side, offering a space to relax and enjoy the natural view. The greenhouse also functions as a circulation space, with stairs connecting the two floors.

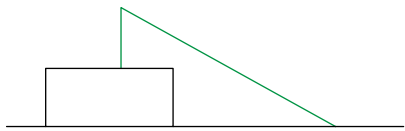
Shoji screens with insulation separate the greenhouse from the main living space, providing subtle control of the indoor heating environment. When the shoji screens are closed in winter, access to light in the kitchen and living room is mainly through the ceiling window, with some additional light entering through the translucent shoji screens. The wooden main box has walls filled with insulation and is covered with glass clapboard, allowing the silhouette of the trees to be seen from inside the house through the translucent insulation.⁸²

The design reflects the architect's search for environmental symbiosis with architecture, without neglecting design as a means of expressing beauty. The integration of the building into the landscape is achieved by lowering the roof of the greenhouse until it touches the ground, enhancing the connection between the structure and the surrounding landscape. Considering the two dogs, the internal and external floors are continuous, with the wood deck blending seamlessly with the wooden floor inside, ensuring a harmonious flow between the indoor and outdoor spaces.⁸³



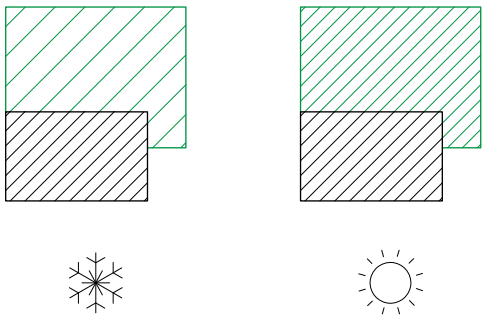
Fig. 17: View of the kitchen, dining-room and greenhouse (Source: "Camouflage House 3" in *Jutakuotokushu*, 1980)

composition principle of the greenhouse



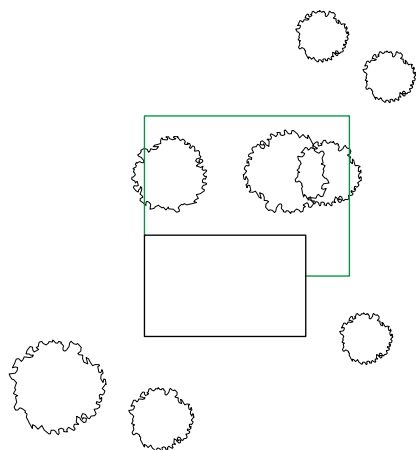
In Camouflage House III, the greenhouse is attached to the isolated living space. The main living space has a rectangular volume, while the greenhouse features a single-slope triangular section, creating a distinct contrast in form.

seasonal variations in use



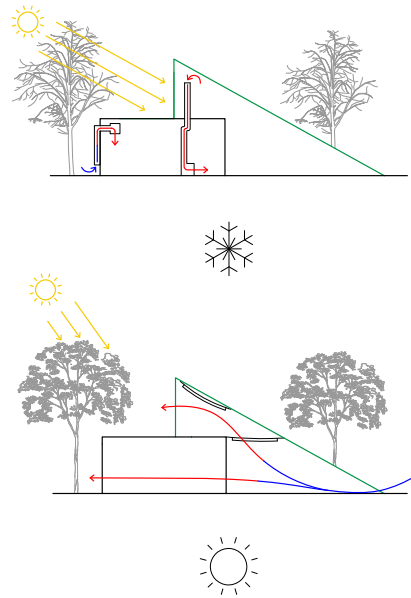
During winter, living occurs within the heated main space. However, even in winter, the greenhouse is used for circulation, providing access to the two entries of the house and the stairs leading upstairs. In the summer months, both the main living space and the greenhouse are utilized, expanding the usable area.

balancing privacy and transparency



Privacy is enhanced through the use of trees, which help control the view from the front road. The trees act as a natural barrier, limiting visibility into the dwelling. The glass greenhouse further supports this privacy, as the sky and trees are reflected on the glass roof from the neighboring area, ensuring that the interior remains shielded from view.

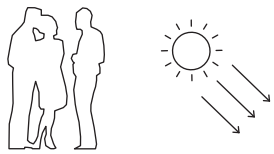
climatic systems



The walls of the main living space are constructed with a combination of translucent insulation and glass, known as the ‘solar wall.’ This wall serves a dual purpose: it collects solar heat while maintaining thermal insulation. The air inside the wall, heated by sunlight, is drawn into the interior by a fan activated by a temperature sensor.⁸⁴ Additionally, warm air from the top of the greenhouse is circulated into the living room, dining room, and kitchen through a fan. In winter, as there are no leaves on the trees, maximum solar energy penetrates the greenhouse.⁸⁵ In summer, the trees block sunlight, helping to maintain a cooler environment. Moreover, shading elements are installed at mid-height and at the ceiling of the greenhouse. Cross ventilation is employed to ensure air circulation and an air-conditioner is used in the main living area.

⁸⁴ “Camouflage House III”, Hiroshi Iguchi & Fifth World Architects
⁸⁵ “Camouflage House 3” in Jutakuotokushu, 112

functional use of the greenhouse



The greenhouse serves a dual purpose: it is used for people and plays a role in the dwelling’s climate control. It acts as a circulation space, with stairs providing access to the first floor and the terrace, as well as to the entries of the building. Additionally, the greenhouse features a few seating areas, offering a place to rest and enjoy the natural views surrounding the building.

presence of vegetation

Vegetation is present in the greenhouse through the planting of three trees in the pockets of the greenhouse roof. However, there are no plants directly inside the greenhouse, although it would be possible to place potted plants. The terrace on the first floor also features vegetation.

penthouse berlin

1:150



architect raumlabor

year 2010

place berlin, germany

state built

greenhouse floor area 101 m2

isolated floor area 59 m2

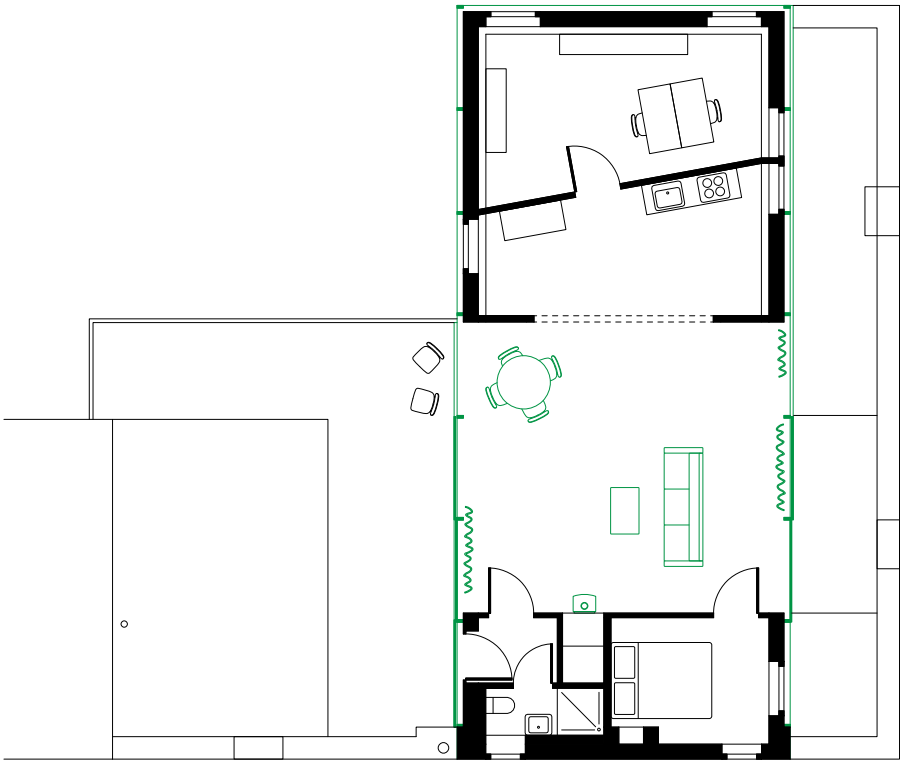
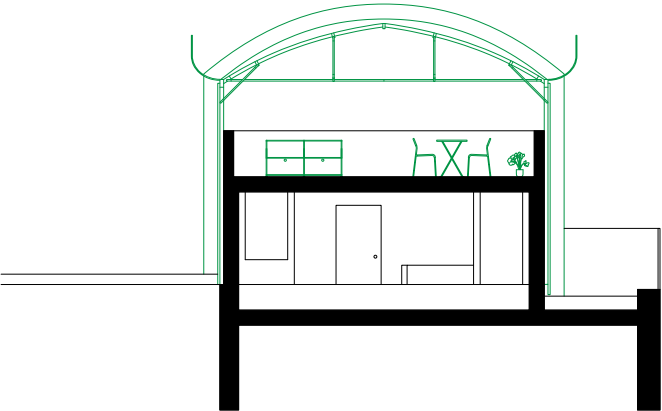


Fig. 18: Exterior view of the Penthouse Berlin (Source: Hülsbörner, Frank)



86. Jan Gympel, "Leben im Gewächshaus" in *Metamorphose* (February 2010), 47

Penthouse Berlin is a residential and studio house located on the rooftop of a former commercial building in Berlin's Wedding district. Designed as a temporary home, the project involves renting the roof space for a 30-year period. The project was designed with a low budget in mind. The construction, which took less than six months, demonstrates a creative response to urban housing challenges. The dwelling is situated on the southern part of the roof, maximizing sunlight exposure.⁸⁶

87. Ibid. 47

The main structure is built using aerated concrete and enclosed within a standard French greenhouse framework, transported from the south of France. The greenhouse forms the outer layer, with two minimal living space volumes positioned inside. Its steel skeleton is complemented by double-walled translucent polycarbonate panels with air inclusions. Roof windows, which span the entire length of the greenhouse, can be opened electrically to enhance ventilation. Sliding doors on the building's long sides provide access to a balcony and a large terrace, seamlessly extending the living space.⁸⁷

88. Thomas Drexel, "Wohn-Experiment über den Dächern von Berlin" in *Neue Low-Budget-Häuser* (2010), 45

The interior is organized around a central living room, flanked by two rooms on the east—a working space and a kitchen—and a bedroom, bathroom, and vestibule on the west. While the studio and living room are open and exposed, the sunken kitchen and dining area, along with the workspace, offer more intimate spaces. A movable aluminum ladder connects the main floor to the upper level.⁸⁸ The house is designed to respond to seasonal changes. In winter, the heated spaces serve as the primary living area, while the central greenhouse, as a secondary space, can be used when warmed by the fireplace and with the addition of warm clothing. In summer, the terrace and balcony expand the usable space, and the mobile kitchen can be relocated outdoors, creating a flexible, open-air living experience.⁸⁹ At night, the house glows softly, with its translucent walls transforming it into a luminous beacon on the urban rooftop.

89. Kaye Geipel, "Aufgesetztes Dachhaus" in *Bauwelt* (June 2010), 23

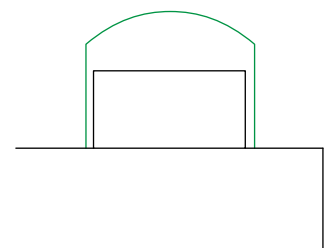
The house, sized at 14 by 6 meters, rests on three external walls of the commercial building. The commercial building's staircase serves as access to the house. The advantages of building on the roof include no additional land required, with the development and security already taken care of. It is also less expensive to connect to existing infrastructures such as heating, water and electricity. The rooftop location allows for a closer connection to the changing seasons and weather compared to other dwellings in the middle of a big city. Roof spaces, typically less developed except for expensive apartments in old buildings, offer the brightest spaces in cities with long winters.⁹⁰

90. Ibid. 22–23
61



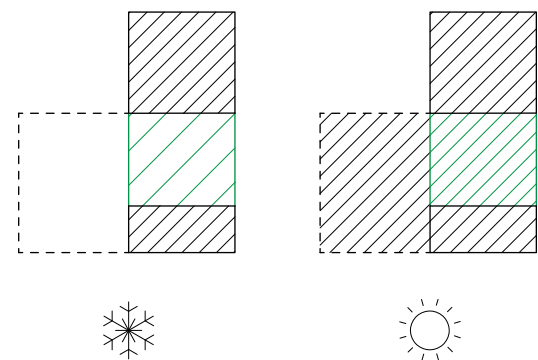
Fig. 19: Interior view of the central greenhouse space (Source: Hülsebörner, Frank)

composition principle of the greenhouse



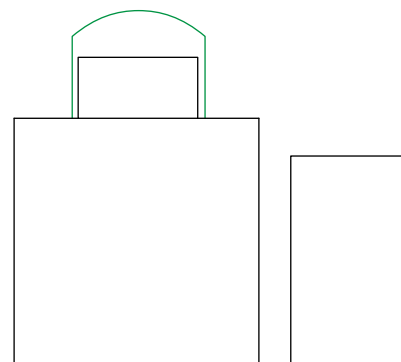
The greenhouse fully encloses the isolated living space, covering both the facade and roof of the main structure. Located on a rooftop building, the main living space consists of two rectangular volumes, while the greenhouse features an oval-shaped roof.

seasonal variations in use



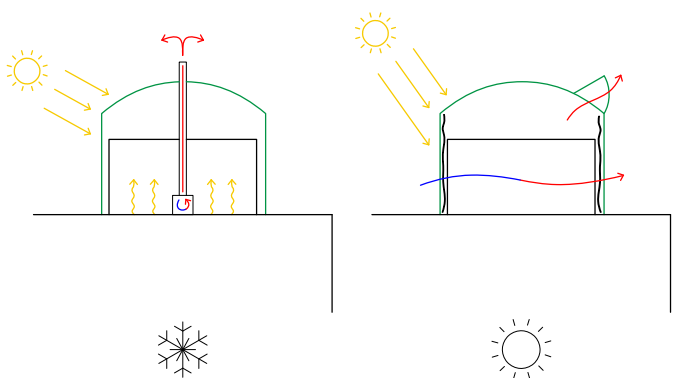
During winter, both the isolated living space and the central open area are used. The open area is heated by a wood fireplace and can be occupied with warmer clothing. However, it remains an additional space. In summer, the isolated living space, greenhouse, and terrace become part of the habitable space, with life extending to the terrace through the use of movable furniture.

balancing privacy and transparency



Privacy is maintained, as the rooftop is not visible to others. The use of polycarbonate, a translucent material, further enhances privacy by obscuring clear views into the space. At night, the greenhouse appears as a softly illuminated structure, visible from the surrounding area.

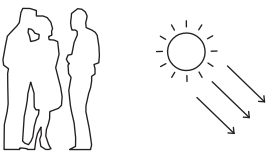
climatic systems



In winter, the greenhouse is passively heated by the sun through its translucent surfaces. The curtains are drawn to allow maximum sunlight to enter and heat the space. Additionally, the greenhouse benefits from the warmth of its fireplace. To prevent overheating in summer, a specialised greenhouse film provides shading and maintains comfortable temperatures. A second layer of curtains made from heat-reflecting fabric has been installed inside the greenhouse. For ventilation, sliding doors and ventilation gaps in the roof ensure effective airflow and cooling during the warmer months.⁹¹

91. "Penthouse Berlin", *Raumlabor Berlin*, accessed December 23, 2024, <https://raumlabor.net/penthouseberlin/>

functional use of the greenhouse



The greenhouse serves both as a functional space for the inhabitants and as a tool for regulating the indoor climate. The central greenhouse space is used as a living room, dining room, and studio, accommodating a variety of daily activities. On the second floor of the greenhouse, the space is more secondary and accessible only via movable stairs, offering a less frequently used but versatile area.

presence of vegetation

There is no vegetation inside the greenhouse, meaning the project does not incorporate the greenhouse's original intended use for plant growth. While it would be possible to add potted plants, the users chose not to do so. Instead, the greenhouse is primarily utilized as a space for human activities.

communal house

1:150



architect plan común

year 2023

place pantin, france

state built

greenhouse floor area 68 m2

isolated floor area 367 m2

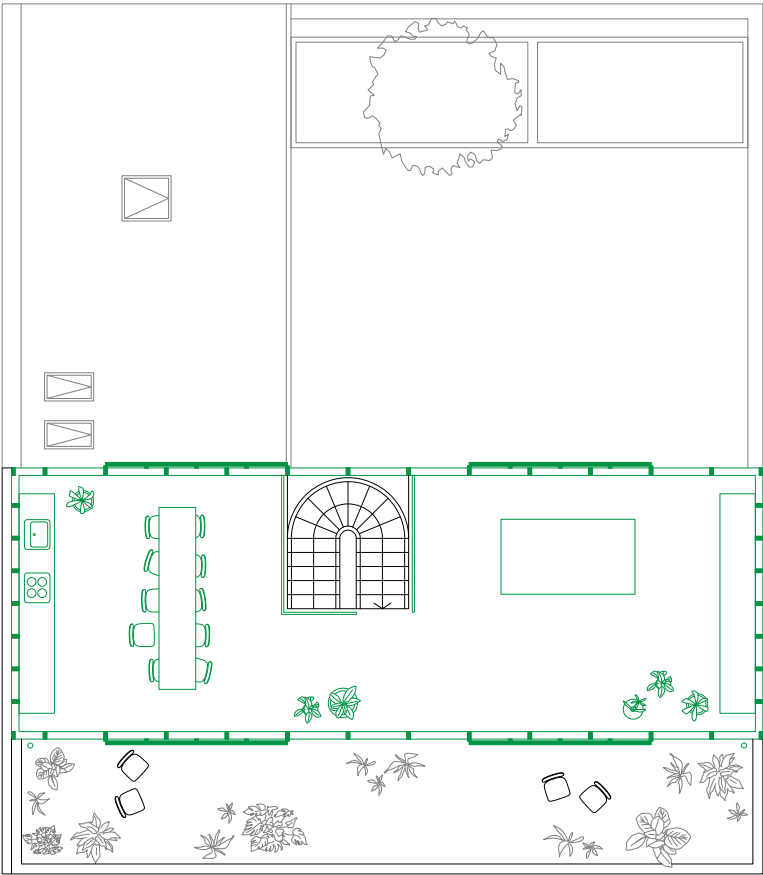
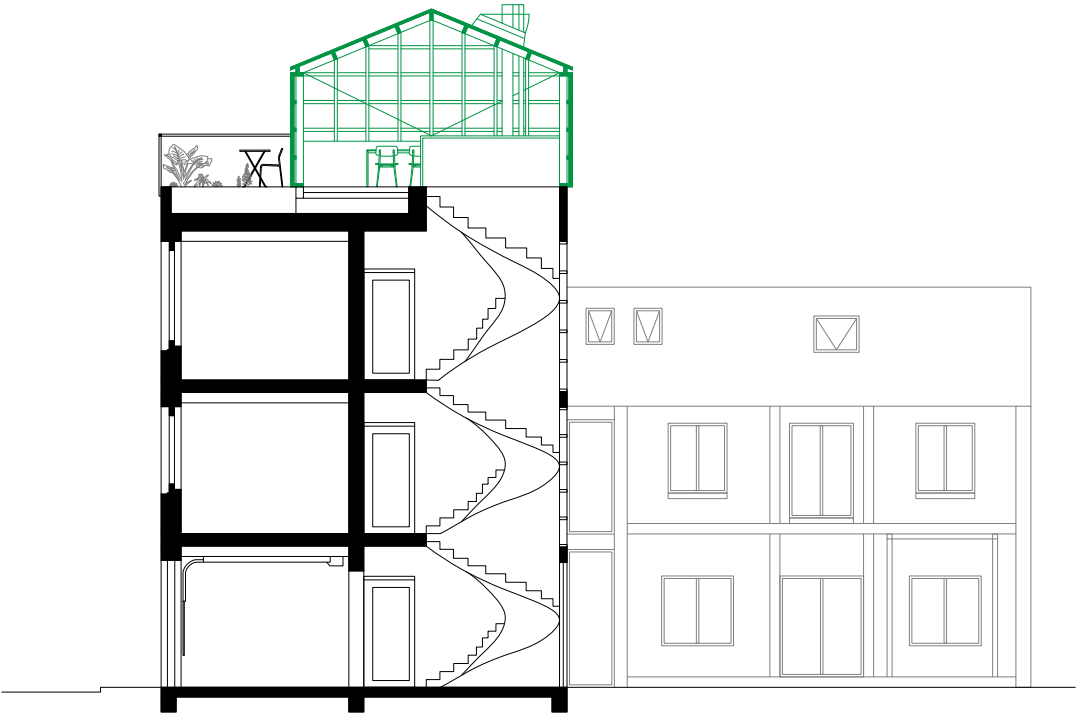


Fig. 20: Exterior view of the rooftop greenhouse of Communal House (Source: Rojas, J. A.)



92. "PANTIN: A Common House / Plan Común", *Archdaily*, accessed December 23, 2024, <https://www.archdaily.com/1020388/pantin-a-common-house-plan-comun>

93. "Residential Building near Paris by Plan Común", *DETAIL*, accessed December 23, 2024, https://www.detail.de/de_en/wohnhaus-bei-paris-von-plan-comun?srltid=Afm-B0oq7QeD0lunOLnVePAunyKwOVsLxtsqW55hgF-nPH62xzLAGVnBb5

94. "PANTIN: A Common House / Plan Común"

95. Ibid.

96. "Portfolio: Kim Courrèges, Plan Común", *The Architectural Review*

97. Ibid.

The Communal House is located in a low-density industrial neighborhood of Pantin, France, on a plot that includes a two-story L-shaped house and a new building facing the street. Initially, the project planned to extend the existing house toward the street, but after studies of the fragility of the ground and the existing structure, it was decided to demolish the old structure and construct a new one.⁹²

Commissioned by Plan Común, the project was self-initiated, giving the architects significant freedom in both design and financial decisions.⁹³ The new building consists of three floors with a concrete skeleton and a brick finish, using reclaimed bricks from Belgium. Although local regulations allowed for four floors, the architects chose to limit the height to three. This decision avoided blocking sunlight for neighboring buildings and created space for a shared rooftop area. While this meant reducing private living space, it allowed for the addition of generous communal spaces.⁹⁴ The building includes five living units, with the greenhouse on the roof serving as a visible statement promoting collective housing in the area.

The design includes a sequence of shared, non-heated spaces that link all levels of the building. Polycarbonate panels, which are used in the greenhouse, are also used along the staircase and in the shared spaces on the ground floor, creating a cohesive connection between the community spaces on the ground floor and the roof.⁹⁵ The greenhouse has become a place for community activities, hosting parties, dinners, and everyday interactions. Its design includes sliding doors on each side, opening the space to its surroundings.⁹⁶ Since the design phase, shading elements were deliberately excluded; instead, the residents' laundry, hung to dry, naturally provides shade. The terrace around the greenhouse is used for growing plants.

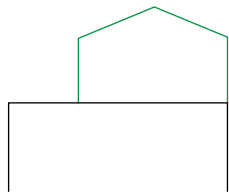
The rooftop features a wooden greenhouse structure that includes a communal kitchen and laundry area, as well as a terrace with views of Pantin and Paris. The greenhouse serves as a multifunctional space—a communal room, utility area, and even a dance floor. The greenhouse and terrace are like a garden on top, emphasizing the project's communal and collective nature, which is also reflected in the firm's name, Plan Común, and the project's name.⁹⁷

On the ground floor, a large hall with direct links to the street blurs the boundaries between city and building, bringing the outside in. Outdoor extensions are all shared spaces, as evidenced by the absence of private balconies in the apartments. The communal space is an important aspect of the project, embodying the collective values of the design and the intent to foster community living.



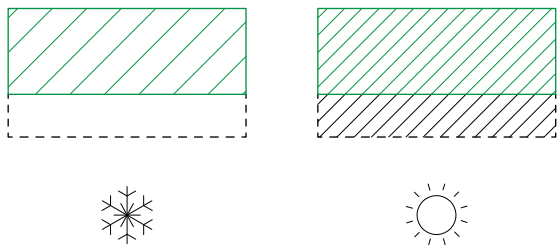
Fig. 21: Interior view of the rooftop greenhouse (Source: Rojas, J. A.)

composition principle of the greenhouse



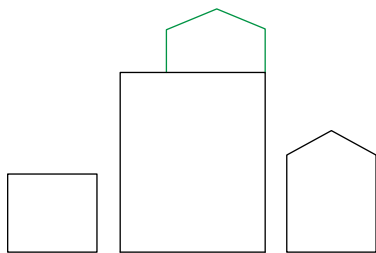
In the Communal House, the greenhouse is situated on the rooftop of the dwelling, serving as a shared space for the residents. The main volume of the building has a rectangular volume and comprises four floors, while the rooftop greenhouse features a gable roof.

seasonal variations in use



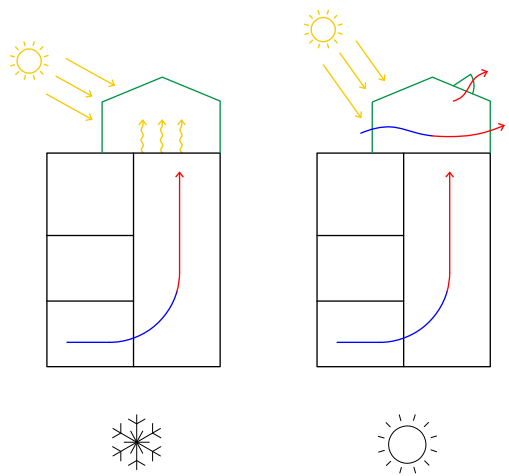
During winter, the rooftop greenhouse is too cold for regular use, limiting its function primarily to laundry. In contrast, during summer, with the sliding doors open and shading elements in place, the space can be used more frequently for various activities.

balancing privacy and transparency



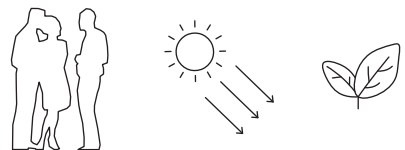
Privacy is ensured by the rooftop location, which limits visibility from the surrounding area. Additionally, as the space serves as a communal secondary area rather than a primary living space, privacy becomes a less critical concern. The use of translucent polycarbonate panels further enhances privacy by obscuring clear views into the interior. At night, the greenhouse appears as a glowing form from the surrounding area.

climatic systems



In winter, the greenhouse relies on passive energy for heating. The design also takes advantage of the chimney effect created by the stairs: cold air enters from the ground floor, rises through the stairwell, and warms as it reaches the greenhouse. In summer, cross ventilation is achieved through the two sliding doors and the roof windows. Additionally, the users' hanging laundry naturally serves as shading elements, aiding in cooling the space.

functional use of the greenhouse



The primary function of the rooftop greenhouse is to serve as a shared, social space for the residents of the apartment building. It functions as a multipurpose area, accommodating a variety of communal activities such as hosting gatherings, laundry, and even serving as a dance floor for celebrations. The space brings people together, fostering community interaction. Moreover, it also accommodates plant growth.

presence of vegetation



The greenhouse features potted plants, with the users currently growing tomatoes, thereby aligning with its original intended use for vegetation. However, the majority of the greenery is located on the terrace, emphasizing the terrace as the primary space for vegetation in the project.

comparative analysis of case studies

This chapter analyzes and compares the nine case studies to uncover both similarities and differences among them. The analysis focuses on identifying the essence of each project and the core concepts driving the design of the greenhouses. The comparison is structured around seven topics: experimental greenhouses, climatic systems, presence of vegetation, seasonal variations in use, greenhouse integration, social space, and space for appropriation.

experimental greenhouses

The integration of greenhouses into domestic spaces often carries an experimental dimension, as these projects frequently serve as studies or research initiatives to test the feasibility and performance of residential greenhouses. These experiments are typically led by architects, either for themselves, as part of a competition, or for a specific client. Such projects push the boundaries of domestic living by exploring new solutions.

Designed by Douglas Kelbaugh for himself and his family, the Kelbaugh House exemplifies the experimental nature of solar architecture. As the earliest project in the United States featuring a Trombe wall, it market a significant step in solar housing which were still relatively unexplored. At the time, Kelbaugh, a young architectural graduate, was captivated by the potential of the Trombe wall and implemented it in his family's dwelling.⁹⁸ The house faced early performance challenges, including reverse convection and heat loss through the staircase. These issues were addressed through ongoing modifications, reflecting the trial-and-error process inherent in experimental design. The project also required the family to adapt their habits and routines to the changing seasons, actively engaging in the continuous effort to optimize indoor comfort.

Similarly, the Naturhus designed by Bengt Warne for himself and his family was conceived as an experimental prototype to realize his Symbio Housing philosophy. Developed in collaboration with the Swedish magazine *Allt i Hemmet* to celebrate its 20th anniversary in 1976, the house aimed to demonstrate how an ordinary family home could utilize natural resources, recycle them, and achieve near self-sufficiency.⁹⁹ Over the first five years, Warne conducted continuous experiments, collecting data on energy savings, types of plants best suited for cultivation in the greenhouse, and the overall efficiency of the system. This initial Naturhus became the foundation for several subsequent nature houses commissioned after its success.

In Germany, the Solar House by Oswald Mathias Ungers was conceived as a prototype for solar typologies intended for mass production. The competition for which the house was designed sought to pave the way for market-ready solar housing solutions.¹⁰⁰ This project emerged during a time when ecology was just beginning to emerge in Germany, and Ungers had no prior experience with alternative energy systems. Ungers adopted an experimental approach, designing five variants of solar houses to test energy concepts. These designs explored variations in shape, spatial organization, orientation, and materials, showcasing the experimental level of the project.¹⁰¹

These projects highlight the experimental potential of residential greenhouses as spaces for testing new ideas, systems, and materials. They demonstrate how architects have used greenhouses as tools for exploration, pushing the boundaries of what is possible in residential buildings.

98. Barbara Penner, Adrian Forty, Olivia Horstall Turner, Miranda Critchley, *Extinct: A Compendium of Obsolete Objects*, 329

99. Andrea Antolloni, *Bengt Warne's Naturhus: sustainable living in a Northern European climate*, 13

100. Cornelia Escher, Lars Fischer, *Negotiating Ungers: the Aesthetics of Sustainability*, 40

101. Ibid. 44-45

climatic systems

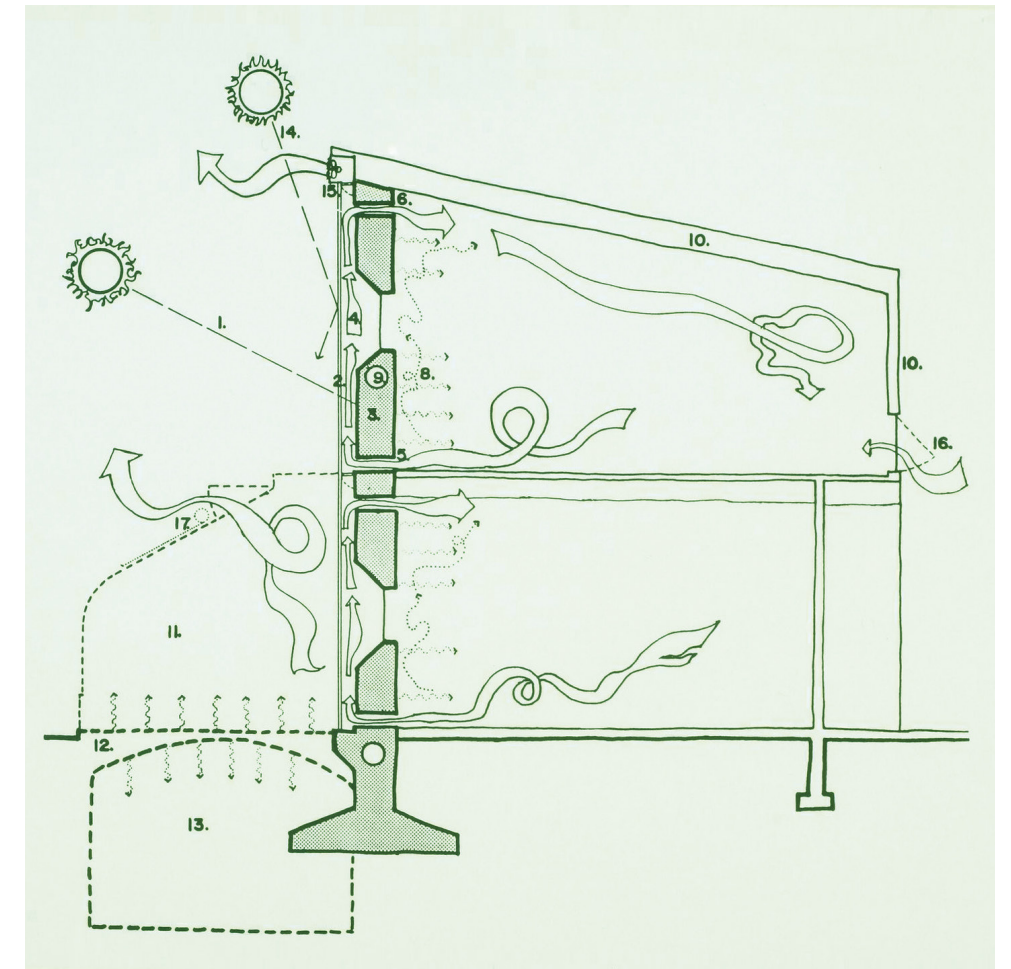
While all greenhouses naturally regulate climate, this role is not always the primary focus in every project. In some cases, the climatic function of the greenhouse becomes the central intention of the architect, prioritizing the use of solar energy to heat both the greenhouse and the main living spaces. Passive solar systems rely on the natural properties of a building and its surroundings to capture and store solar energy without mechanical or electrical devices. These systems make use of solar radiation, which, upon passing through the glass of a greenhouse, changes wavelength and becomes thermal radiation. This heat energy, unable to escape due to its longer wavelength, becomes trapped, creating a warmer environment inside.

The broader social and economic context at the time of construction often influenced this focus on climate control. For instance, the Wachsende Haus by Martin Wagner, built in Germany after the economic crisis of 1929, responded to the need for affordable housing by incorporating passive solar energy. This was used to create healthier, light-filled dwellings while reducing energy costs. The greenhouse of this project surrounds the entire main living space allowing sunlight to enter throughout the day from the west, south, and east sides. During winter, the sun's warmth heats both the greenhouse and the main living areas, while in summer, cross ventilation helps to cool the dwelling and reduce the greenhouse's internal temperature. With a narrow, 1-meter-wide triangular section, the greenhouse serves exclusively as a climate controller, without human access or spatial integration. It operates independently of the dwelling's interior, highlighting its role as a functional energy solution rather than a spatial extension. The project's essence lies in its climatic focus, using the greenhouse solely to regulate temperature and improve living conditions efficiently.

In contrast, the Kelbaugh House by Douglas Kelbaugh, built after the oil crisis, illustrates a shift towards renewable energy solutions to reduce dependency on finite, costly, and polluting resources. This focus on sustainability was driven not only by the energy crisis but also by the rise of the environmental movement, which further drove the adoption of solar housing solutions. The greenhouse incorporates a Trombe wall—a system that traps solar energy using a southern-facing masonry wall, an air gap, and glass—to heat the home in winter and cool it in summer. Kelbaugh strategically built the house on the sunniest section of a shaded plot and oriented it southward, even though the street faced east. Solar energy met over 75% of the dwelling's heating needs, reducing reliance on external energy sources.

Initially, the greenhouse served purely as a climate controller with limited integration into the dwelling's spatial quality. However, a year later, a small greenhouse was added to the south-facing Trombe wall. This transformed the greenhouse into a multifunctional space—a climate controller and a usable space for people and plants. The addition integrated the greenhouse into daily life, extending its role beyond climate control to a space of spatial significance.

Fig. 22: Section drawing of the climatic system of the Trombe wall of Kelbaugh House (Source: Kelbaugh, D., 1975)



presence of vegetation

In some of the case studies, greenhouses maintain their original purpose as spaces for plants, fostering a deep connection with nature. These projects emphasize the integration of greenery as a central focus, aiming to bring nature indoors and facilitate human interaction with natural elements. The greenhouse becomes an intermediary between architecture and nature, strengthening the relation between the dwelling and its surrounding landscape.

Two distinct examples of how nature is integrated into the dwelling are the Naturhus and Camouflage House III. These projects present different approaches to blending nature and architecture.

Naturhus by Bengt Warne embodies the concept of Symbio Housing, where the focus is on living in harmony with nature while ensuring sustainability. Warne emphasizes the importance of allowing residents to maintain direct contact with nature. The architecture itself interacts ecologically with the local landscape. As the name suggests, Naturhus is a “Nature House”, where plants are grown in the greenhouse. Grass and flowers grow between the wooden floorboards on the ground floor, a rooftop garden is cultivated year-round, and vines grow up the roof structure. The residents are primarily connected to nature by cultivating and tending to the plants in the greenhouse.

The greenhouse is divided into different temperature zones to accommodate various types of plants. At ground level, the temperature is around 20°C, ideal for growing lettuce and root vegetables. At two meters, the temperature rises to 30°C, ideal for cultivating cucumbers, tomatoes, grapevines, paprika, and fig trees.¹⁰² The benefits of incorporating greenery into the dwelling are evident, improving air quality, mental well-being, and providing a source of food for the residents, with 75% of the household’s fruits and vegetables produced within the greenhouse.

However, over time, the house changed hands, as new occupants replaced Warne, and they modified the space in ways that deviated from his original vision. The rooftop garden became too hot in summer, making it difficult for plants to grow, and it evolved into an additional living space. The grass around the balcony was removed due to unpleasant odors, and now plants grow exclusively in pots. Despite these changes, Naturhus remains a space where the boundary between indoors and outdoors is blurred, allowing for an ongoing relationship with nature. Unlike traditional houses that keep the outside out, Naturhus creates a new dynamic by keeping the outside in.

Comparably, Camouflage House III, designed during a period of global environmental concern, places a strong emphasis on balancing and harmonizing architecture with its environment. The architect’s exploration of environmental symbiosis is at the heart of the project, reflecting a search for solutions to global ecological problems. The house integrates with the landscape, using the gentle slope of the southern terrain as part of its design. The building appears to merge with the slope, blending architecture and nature like a work of land art.

Fig. 23: View of the northern seating area of the greenhouse in Camouflage House III (Source: Divisare, A. G. v.)



The greenhouse in Camouflage House III does not integrate greenery directly inside the greenhouse, but brings nature inside by linking residents to the surrounding landscape. The roof of the greenhouse features pockets for trees, connecting the structure to the natural elements of the site. The greenhouse faces north, meaning it is not intended for climate control, but instead serves as a space for observing changing seasons and the surrounding nature. This allows the residents to experience the environment visually, enhancing their connection to nature. The residents can also observe the silhouettes of the trees when they are inside the main living space, through the walls made of translucent insulation. Through its design, the project illustrates the architect’s intent to achieve environmental symbiosis with the architecture. The integration of the greenhouse further integrates the building into the landscape, serving as a space for admiring nature rather than cultivating it.

¹⁰² Andrea Antoloni, *Bengt Warne’s Naturhus: sustainable living in a Northern European climate*, 69

seasonal variations in use

Unlike conventional, insulated living spaces, the climate within a greenhouse changes with the seasons, directly affecting how it is used by the inhabitants. The seasons impact the domestic life, influencing how residents adapt their activities and interact with the greenhouse space. When the greenhouse provides comfortable conditions, it can become a central living space. However, during periods when the climate is less suitable, the greenhouse may shift to a secondary role, with the main living areas taking precedence.

In some projects, these seasonal rhythms of use are highly visible. For example, in Latapie House by Lacaton & Vassal, the family's interaction with the greenhouse space adapts dramatically between winter and summer. In winter, the family confines their activities to the heated indoor living areas, as the cold temperatures limit the greenhouse's direct usability. While the greenhouse still supports heating by acting as a thermal buffer and capturing heat, the greenhouse mainly serves a supporting role without being a primary area of use. The residents can sometimes enjoy the passive solar heat of the greenhouse with warm clothes.

In contrast, in summer, the greenhouse becomes a central part of daily life. With the doors between the greenhouse and the main living space open, the two areas blur together, effectively doubling the ground floor area. The comfortable summer climate in the greenhouse invites residents to spend more time there, transforming it into a dining room, lounge, workshop, or play area. The flexible use of space allows the inhabitants to rearrange furniture and adjust to the warmer weather, making the greenhouse an integral part of their lifestyle.

Similarly, in Solar House by O. M. Ungers, the seasonal rhythms of use are pronounced. The house consists of distinct climate zones that expand or retract in response to exterior conditions, creating a continuous presence of change. During winter, living is confined to the building's core—the stone house—where warmth is concentrated, and the glass house takes on a more passive role. In summer, however, the greenhouse becomes an extension of the living spaces, with activities like cooking and dining expanding into the greenhouse, as envisioned by the architect. The house's inhabitants adapt to these changing zones, experiencing a home that evolves with the weather, the seasons, and the shifting greenery. On the exterior, this transformation is also visibly staged. In summer, the house appears open and vibrant, filled with greenery and activity, while in winter, the vegetation is removed, revealing its wooden structural frame like a skeleton.

These examples show how the rhythm of use in greenhouse spaces varies greatly depending on the seasons, highlighting the adaptability of such spaces in relation to environmental changes.



Fig. 24: View of the living room and greenhouse of Latapie House when the doors are open in summer (Source: Ruault, Philippe)

greenhouse integration

The greenhouse is not an optional addition but an integral, mandatory component of the dwelling in some of the case study projects. Unlike secondary greenhouses that can be added or removed based on design preferences, these structures are essential to the functionality of the main living spaces. The greenhouses incorporate key functions, such as circulation and environmental protection, making it an indispensable element for the effective operation of the dwelling. In these cases, the greenhouse and the primary living space are so closely connected that one cannot function without the other.

For example, in the F3 House, Naturhus, and Camouflage House III, the greenhouse plays a vital role in circulation. Residents must pass through the greenhouse to access different parts of the dwelling. The greenhouse is used throughout the year, no matter the seasons and temperature. The greenhouse serves as a functional hub, facilitating movement between spaces and ensuring that all areas of the house are accessible. These three examples incorporate horizontal and vertical circulation within the greenhouse, making it a transitional and interactive space.

In F3 House, for instance, the stairs are located within the greenhouse, which is necessary to access the toilet room and the main entrance. This constant interaction with the greenhouse encourages residents to experience a seamless connection between the indoor and outdoor environments, ensuring the greenhouse is used year-round, regardless of the season or temperature.

Similarly, in Penthouse Berlin, the greenhouse is indispensable, but its function is slightly different. In this case, the greenhouse envelops the living spaces, with the roof and walls forming a crucial part of the building's habitable environment. The greenhouse provides protection from external weather conditions, acting as a thermal buffer that stabilizes the indoor climate. There are no doors separating the greenhouse from some main living areas, meaning the greenhouse is required to use spaces such as the kitchen. The greenhouse essentially creates a "thermal bubble" around the living spaces, allowing the residents to use the main living areas without being affected by outside temperatures. Moreover, the greenhouse itself becomes a mandatory space for the daily activities of the household, welcoming a living room, dining room, and studio that would otherwise be absent in the insulated living spaces.

However, not all greenhouses are indispensable to the functioning of the dwelling. In projects such as the Latapie House and the Communal House, the greenhouse is secondary and can be removed without interrupting the use of the main living areas. In these examples, the greenhouse primarily accommodates secondary functions, such as leisure activities, storage, or summer dining. All essential functions of the dwelling, such as the living room, kitchen, bedrooms, and bathrooms, are located within the insulated living spaces, making the greenhouse an optional, though valuable, extension. This distinction highlights the flexibility of greenhouses in dwellings, demonstrating how their role can vary from being integral to merely supplementary.

social space

In some of the case studies, the greenhouse functions as a space for social interaction and community engagement. These greenhouses are designed with the intention of serving as social hubs, where human activities and relationships take center stage. By blurring the traditional boundaries between private and public spaces, greenhouses allow for public life to unfold within the domestic environment. They create an environment where residents can engage not only with their immediate family but also with their wider community. This approach encourages opportunities for social exchange, unlike the more traditional, segmented layouts of dwellings, where public and private spheres are kept distinctly separate. Greenhouses are adaptable, multifunctional spaces that can easily accommodate a variety of social activities, making them integral to the way inhabitants interact with their surroundings.

The transparency and openness of these structures enhance their role as a stage for social interaction, almost like a theater that showcases the activities within. This openness also means that the social interactions occurring inside the greenhouse are visible to the outside world.

For example, in the F3 House, the greenhouse is explicitly designed as a gathering space, fitted to the user's desire for a space to host parties. Moving away from conventional family-oriented layouts, the dwelling prioritizes personal hobbies and social activities. The greenhouse becomes the public, extroverted area of the house, while private functions, such as the bedroom, extend beyond the greenhouse's boundaries. At night, the illuminated greenhouse creates a warm, glowing presence, drawing attention to the activities inside and further blurring the lines between private and public life. However, despite its intention as a more open and social space, privacy concerns have arisen in more recent images of the project. This is evident in the addition of blinds on the street-facing greenhouse facade, indicating the need for a balance between the openness of the space and the privacy of its inhabitants.

Similarly, in the Communal House by Plan Común, the greenhouse takes on a communal role, serving as a shared space for all the residents of the building. Located on the rooftop, it functions as a multifunctional area that includes a kitchen, dining table, and laundry facilities. Beyond its utilitarian functions, the greenhouse becomes a venue for communal activities such as parties, dancing, and everyday interactions. The greenhouse here is a communal, public space that fosters interaction. Its visibility on the rooftop serves as a statement, promoting the idea of collective housing and reinforcing the architects' emphasis on community-centered living. As the architects note, the communal greenhouse effectively fosters interaction and collaboration among the building's residents.

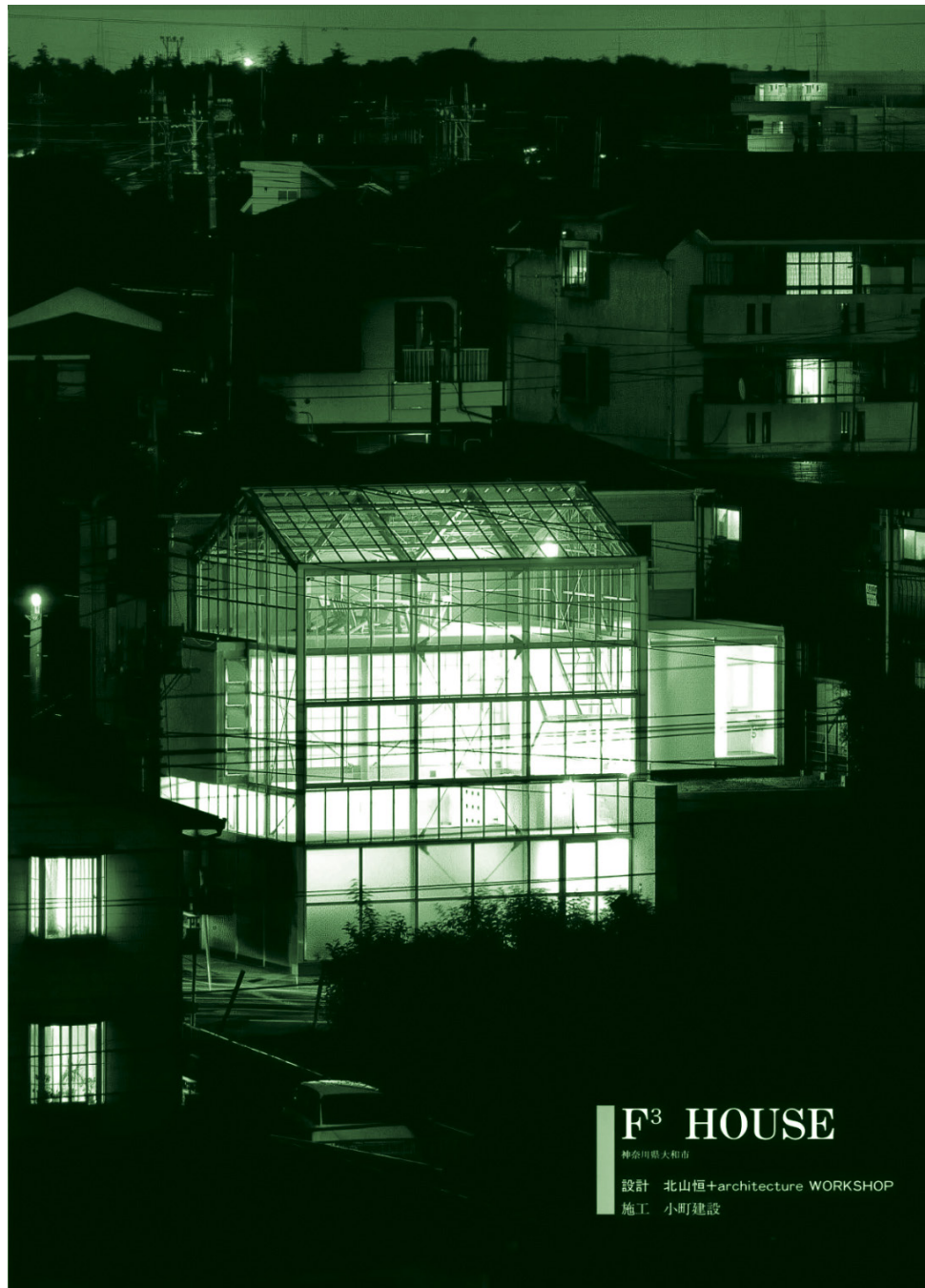


Fig. 25: The F3 House glowing at night as a theater (Source: *Jutakutokushu*, September 1995)

space for appropriation

The greenhouse, sometimes acting as an appropriable space, offers an opportunity for personal adaptation and customization within the dwelling. Unlike traditional spaces with fixed programs, the greenhouse is flexible and undefined, allowing residents to appropriate it in ways that suit their evolving needs and desires. This adaptability fosters a sense of ownership, enabling inhabitants to extend existing domestic areas or create entirely new rooms and activities that would not normally be found in a conventional home. By doing so, the greenhouse transcends its function as an auxiliary space, becoming an integral part of the dwelling's spatial and functional identity.

There are different forms of appropriation, the first being the extension of existing domestic spaces. For instance, the greenhouse can expand the living room, dining area, kitchen, or bedrooms, offering additional space. The second form involves creating entirely new functions within the greenhouse, such as solariums, sports areas, or other spaces that allow for greater flexibility in how the home is used. This flexibility allows the greenhouse to adapt to seasonal or life-stage changes.

In the case of Latapie House, the greenhouse complements the traditional living areas by providing another living room, dining room, and storage space. The greenhouse serves as a versatile extension, accommodating a variety of activities such as summer dining, leisure, workshops, or a garage. The architects, Lacaton & Vassal, deliberately left the design open-ended, excluding furniture from the initial drawings to encourage residents to personalize the space according to their own preferences. This approach allows the greenhouse to evolve over time, as seen in photos taken shortly after completion and several years later, where the space transformed from a simple setup with bikes and small tables to a full outdoor living room with a large dining table and additional storage. This flexibility is crucial in making the dwelling more comfortable and adaptable, providing the extra space that typical homes often lack.

Similarly, in Penthouse Berlin, the greenhouse provides the opportunity to introduce new spaces that aren't found in the insulated living areas. The area beneath the greenhouse becomes an appropriable zone, serving as a living room, studio, or dining room depending on the season. Since the dwelling is inhabited by two artists, the greenhouse can become a creative studio, or simply a comfortable lounge and dining area. In addition to the ground floor, the second floor beneath the greenhouse is also an appropriable space with no fixed function. Photographs reveal how this area acts as an extension of the ground floor studio, incorporating bookshelves and other personal elements. This adaptability of the greenhouse allows the space to constantly evolve, offering a dynamic and personalized environment that adapts to the changing needs of its occupants.

However, not all greenhouses are used as appropriable spaces. In the case of the Solar House, the greenhouse encircles the main living space, making it challenging to appropriate the space. While it primarily acts as a transitional zone, facilitating access to all rooms, its design makes it difficult to place furniture or personalize the space beyond circulation. Apart from a small area near the kitchen, the architect did not include any furniture in the greenhouse space, which has a larger surface area than the insulated living area.

These examples illustrate the diverse roles greenhouses can play in dwellings, ranging from highly flexible spaces for appropriation to more fixed, functional components of a house.



Fig. 26: Interior view of the greenhouse used as a living room and studio in Penthouse Berlin (Source: http://www.reduce-re-use-recycle.info/Projekt_3_0_id_47.html)

This study investigated the role of residential greenhouses in small-scale housing projects, focusing on their integration into domestic spaces. Central to this research were questions such as: What is the interest of using residential greenhouses in today's context? How do they enhance the quality of a dwelling, and what role do they play? How can they be effectively integrated into residential architecture to ensure optimal functionality? To address these questions, nine case studies from the 20th and 21st centuries were analyzed and compared, providing a comprehensive framework for understanding the formal, spatial, and usage qualities of residential greenhouses.

In conclusion, greenhouses offer significant value when incorporated into residential architecture in today's context. As environmental challenges persist and architecture increasingly emphasizes sustainability and green building practices, residential greenhouses remain highly relevant today. Far from being relics of the past, greenhouses contribute unique formal, spatial, and functional qualities that traditional dwellings often lack.

Key benefits of residential greenhouses include their role as passive energy systems, which support sustainable housing by reducing energy costs and enhancing thermal comfort. Greenhouses also strengthen the connection between dwellings and their surrounding environment, blurring the boundary between inside and outside. They create spaces where residents can experience changing seasons, maintain a link with nature, and engage in activities such as plant cultivation. Moreover, greenhouses serve as flexible spaces that can accommodate social activities or be adapted as appropriable spaces to meet the needs of their users.

To successfully integrate greenhouses into domestic spaces, several important considerations must be addressed.

1. Careful design of the climatic system is essential. Factors such as placement, orientation, and geometry must be thoughtfully considered to efficiently utilize solar energy, avoid heat loss in winter, and prevent overheating in summer. This is particularly important in hotter climates, such as Japan, where inadequate design considerations, as seen in the F3 House, can result in overheating and require post-construction modifications. Studies of climatic systems are crucial for understanding how greenhouses function year-round. In winter, it is vital to maximize heat storage so that the heat can be released at night, while in summer, effective ventilation and shading systems must be implemented. When vegetation is integrated into the greenhouse, as in the Naturhus, the importance of the climatic system becomes even more pronounced. Properly designed climatic systems maximize the usability of the greenhouse, allowing it to remain functional and comfortable across as many months of the year as possible.

2. The functionality of greenhouses depends on their integration into the dwelling. Greenhouses that accommodate mandatory functions, such as circulation, ensure continuous interaction with the space, preventing it from becoming underutilized. Alternatively, when designed as appropriable spaces, greenhouses offer users the flexibility to customize their function, creating adaptable environments. The composition of the greenhouse and its relationship with the insulated living area are critical in determining its usability. Greenhouses that entirely surround living spaces face challenges in appropriation, as they often function primarily as circulation zones rather than adaptable environments. To serve as an appropriable space, a greenhouse must include static areas that allow for customization and defined uses. Careful consideration of the greenhouse's function and its composition principles is essential to fully realize its potential within the dwelling.

3. Finally, privacy is a critical factor, given that greenhouses are constructed with translucent or transparent materials. Choosing an appropriate plot and selecting suitable greenhouse materials can reduce privacy concerns. Suburban locations surrounded by natural elements or fencing are effective in addressing these issues. Urban projects, such as the F3 House, illustrate the challenges of integrating greenhouses in densely populated areas. The choice of the greenhouse material, such as glass or polycarbonate, can also enhance intimacy. Effectively addressing privacy concerns can elevate greenhouses from secondary spaces to integrated parts of the home, as seen in successful projects like the Latapie House. Even in greenhouses designed as social spaces, ensuring a minimum level of privacy is vital for user comfort.

This analysis reveals that residential greenhouses offer numerous advantages, enriching traditional dwellings through their diverse applications. Their flexibility makes them particularly interesting, serving purposes such as climate regulation, integration of nature, fostering seasonal awareness, circulation, social interaction, and adaptability as appropriable spaces.

The potential contributions of this research are not only academic but also practical. It aims to contribute to future perspectives and the development of greenhouse design through their integration as domestic spaces. This study focuses on the formal, spatial, and usage qualities of residential greenhouses. However, it must be acknowledged in this conclusion that there are several areas where research on residential greenhouses can be further expanded, such as structural systems, materials, and the plants themselves. These unexplored topics present valuable opportunities for further investigation into the potential of residential greenhouses.

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