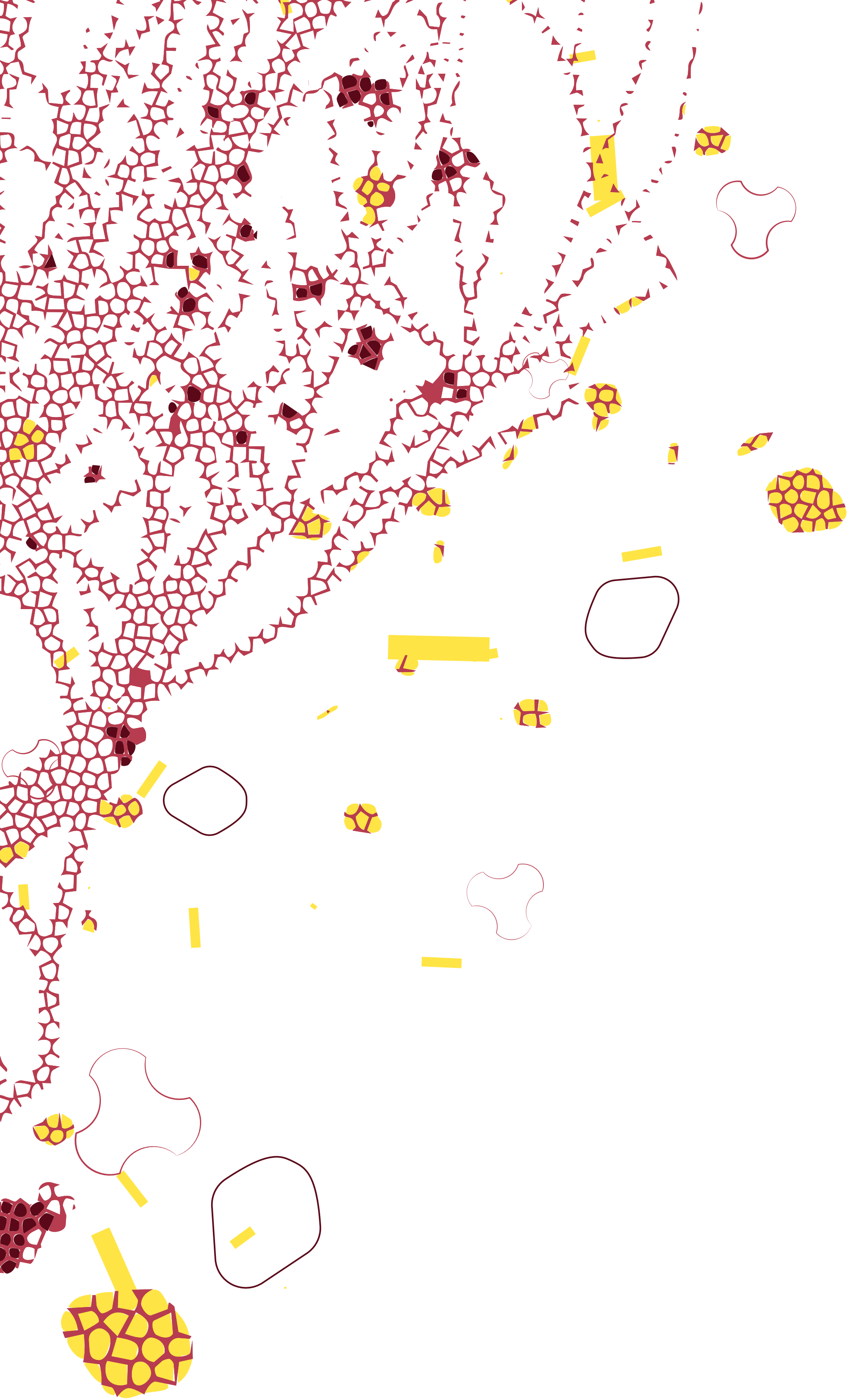
LIVING MATTERS

How to grow housing

California College of the Arts - Architecture Division | UCSF

2026



“If we learn to build with local materials, we have a future.”

Diébédo Francis Keré, Burkinabé-German architect director of the firm Keré Architecture. Awarded Pritzker Architecture Prize in 2022.

Biodesign Challenge 2026

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Contents

Introduction

This project is a research initiative developed by architecture students from the California College of the Arts in collaboration with researchers from University of California, San Francisco. It proposes a modular, bio-based housing construction system aimed at providing affordable housing in California while reducing the environmental impact caused by the construction sector.

Today, the construction industry is highly inefficient and polluting. Roughly half of the raw materials extracted worldwide go into the built environment. Additionally, construction is responsible for an estimated one-third of global waste production and at least 40% of global carbon dioxide emissions. Moreover, the sector remains outdated and incapable of building housing at the speed and affordability required by the population.

In response, we envisioned a system that uses local and underutilized natural materials to create housing with high structural performance and energy efficiency. The proposal is designed to be locally adopted while involving local labor in the prefabrication process, strengthening the regional economy.

The system facilitates low-tech construction techniques through the use of digital fabrication methods, creating a solution that is simple, adaptable, and capable of being implemented by local workshops and communities, avoiding the high upfront costs and risks typically associated with industrial prefabrication.

The components are designed to be prefabricated and delivered to the site ready for assembly. This prefabrication process allows projects to be completed 20% to 50% faster than traditional on-site construction, while also reducing total construction costs by up to 20% when implemented at scale (McKinsey & Company, 2025).

Because the system is composed of smaller, lightweight pieces, it does not require heavy cranes, making construction more flexible and accessible not only to contractors, but also to communities themselves, enabling a bottom-up, community-led assembly process.

Furthermore, the system is designed for disassembly, allowing its components to be reused in the future if the building is no longer needed. This approach minimizes waste, reduces the need for new raw material extraction, and supports a circular economy by closing the material loop.

Living Matters is a system rooted in local materials that seeks to ensure the basic right of everyone to have a healthy and dignified home while minimizing the environmental impact of construction.

33%

of waste generated in the world is due to the construction sector[1]


arjes.de

1 - World Green Building Council, "Thought Leadership" (Accessed 07/05/26)

37%

is the percentage of Global Carbon emissions linked to construction[2]


Kevin Frayer - Getty Images

2 - UN environment programme, "Building Materials And The Climate" (Accessed 07/05/26)


Ryan J. Lane - Getty Images

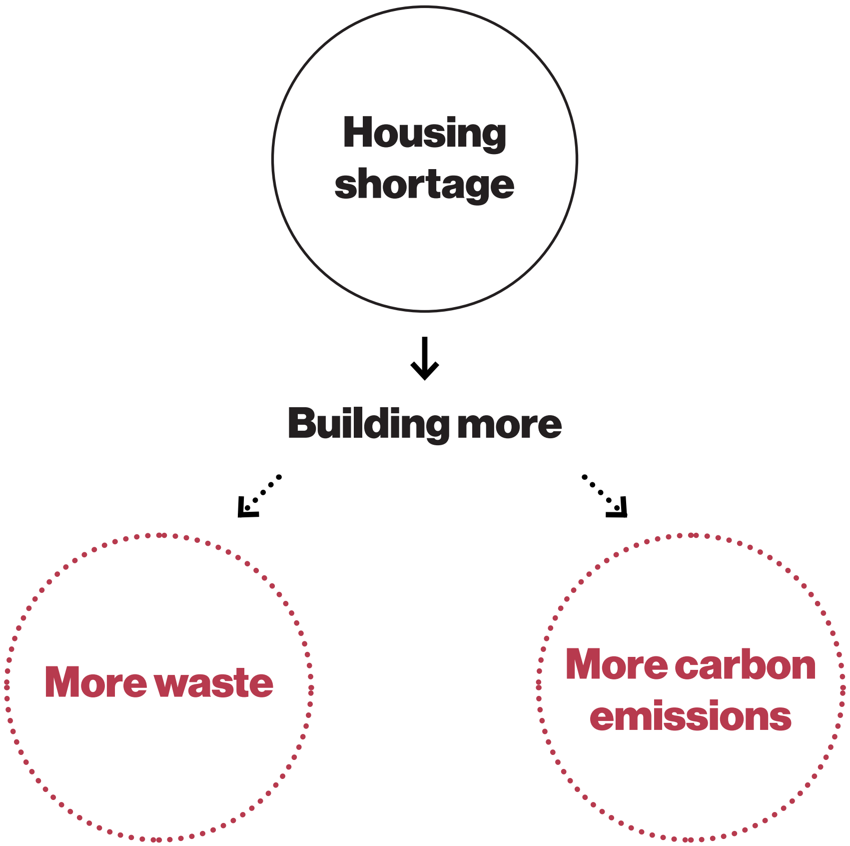
2.5 million is the number of homes California must build by 2030 to meet the state's housing needs[3]

3 - Terner Center Report - "Potential Pathways to Scale Innovative Construction Methods in California" (Accessed 07/05/26)

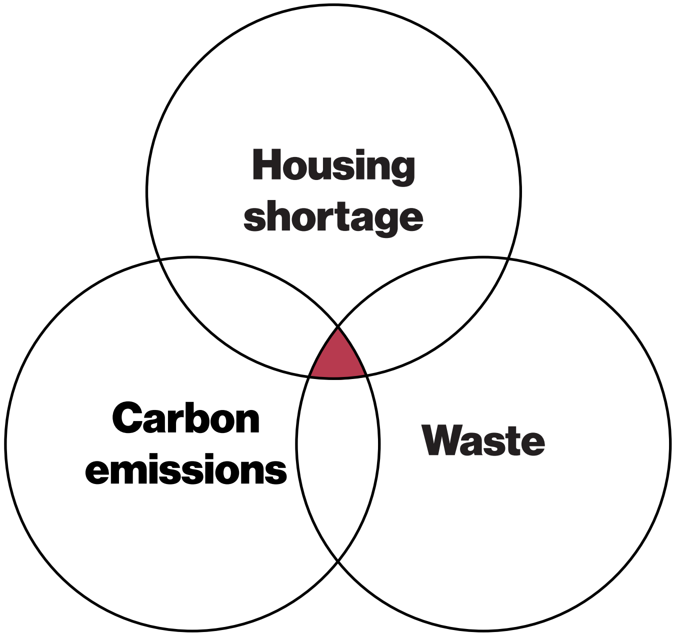
"If we don't build billions of square meters, the humanitarian crisis escalates, but if we build, we worsen the environmental crisis."

Alejandro Aravena, Chilean architect and executive director of the firm Elemental S.A. Awarded Pritzker Architecture Prize in 2016.

An interconnected problem



Addressing only one problem is **not enough**.



It is necessary to adopt a **holistic approach** that considers social, economical, and environmental factors.

How to grow a house

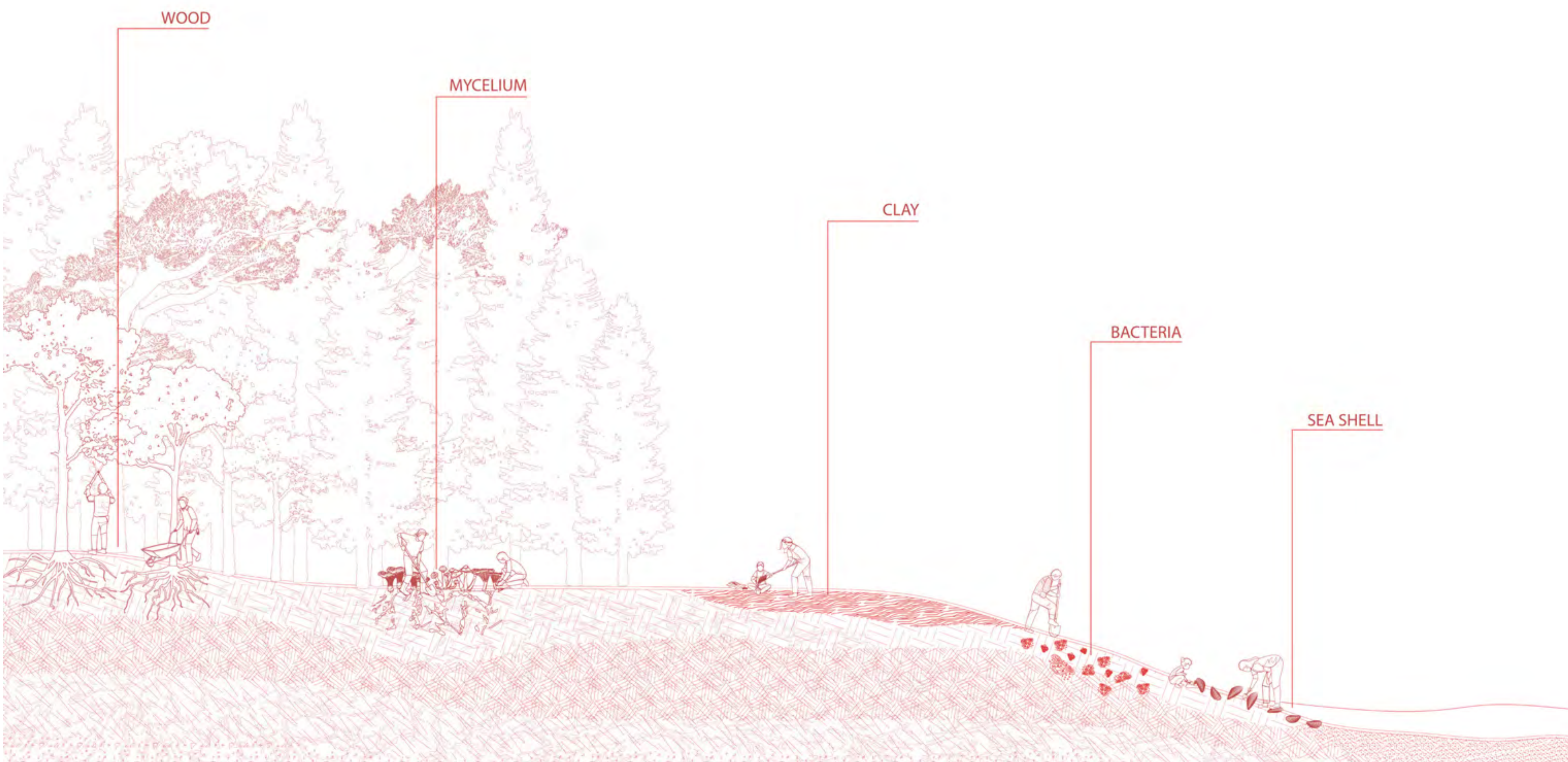
In response to the environmental impacts of conventional construction, the *Living Matters* team began by rethinking how housing is built today. Instead of relying on carbon-intensive materials extracted, processed, and transported through global supply chains, we studied the use of local natural resources that are often overlooked or underutilized.

Our research was guided by a question: **How can we grow a house?** This idea became the foundation of our proposal and is reflected in the project's identity.

The house is built from the resources of its environment: the materials used in the building, such as wood from forest restoration projects, mycelium grown from agricultural and forestry byproducts, clay, crushed shells, and bacteria-based materials, are sourced from the local landscape and transformed into building components.

The section below illustrates this relationship between the building and its territory, mapping the origins of the natural materials that compose the system.

In this way, *Living Matters* proposes an architecture that grows from the place it inhabits, creating housing that is not only affordable and environmentally responsible, but also connected to its context.



Materials

The *Living Matters* system is designed to be built from natural, locally available materials from the California context. The materials below were chosen for their low environmental impact, performance, and accessibility.

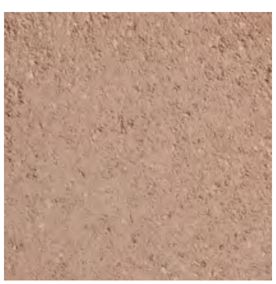
Structural Frame

For the structural frame, locally available and underutilized wood streams are used as resources for a prefabricated mass timber system. These include small-diameter California trees removed through forest restoration projects to help prevent the spread of wildfires. Additional potential wood sources are cut-offs considered “waste” by framing lumber suppliers, as well as salvaged wood.

Insulation

For the insulation, mycelium is used due to its high thermal performance and fire resistance. Mycelium is a fungus that can be sourced locally. To support its growth, sawdust (a byproduct of processing the wood for the structural frame) is combined with hemp. The mycelium is then cast into a PHA (Polyhydroxyalkanoate) 3D-printed mold, a 100% bio-based and compostable 3D printing filament.

Interior Plaster



The interior layer is made of a thin clay plaster composed of clay, crushed seashells as a fine aggregate, water and a mineral paint on top.

For the insulation and skin, these materials could also be replaced with other bio-based alternatives depending on the project location, allowing the system to adapt to different cultural and economical contexts beyond California.

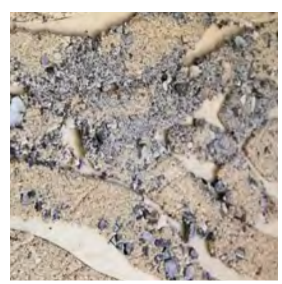
Exterior Plaster

The exterior plaster is the layer responsible for waterproofing and fire resistance. It is made of bentonite clay, crushed shells, water, and the bacteria Sporosarcina pasteurii. The bacteria enhances the durability of the plaster by creating a self-healing material: if cracks appear on the surface and water enters, the bacteria produces calcium carbonate, which seals the cracks.

Rainscreen

The rainscreen is a sacrificial layer, playing a fundamental role in protecting the building from weather exposure as well as fire. It is composed of tiles made of bentonite clay, bacteria, seaweed fibers and crushed shells (fine aggregates).

Roof Tiles

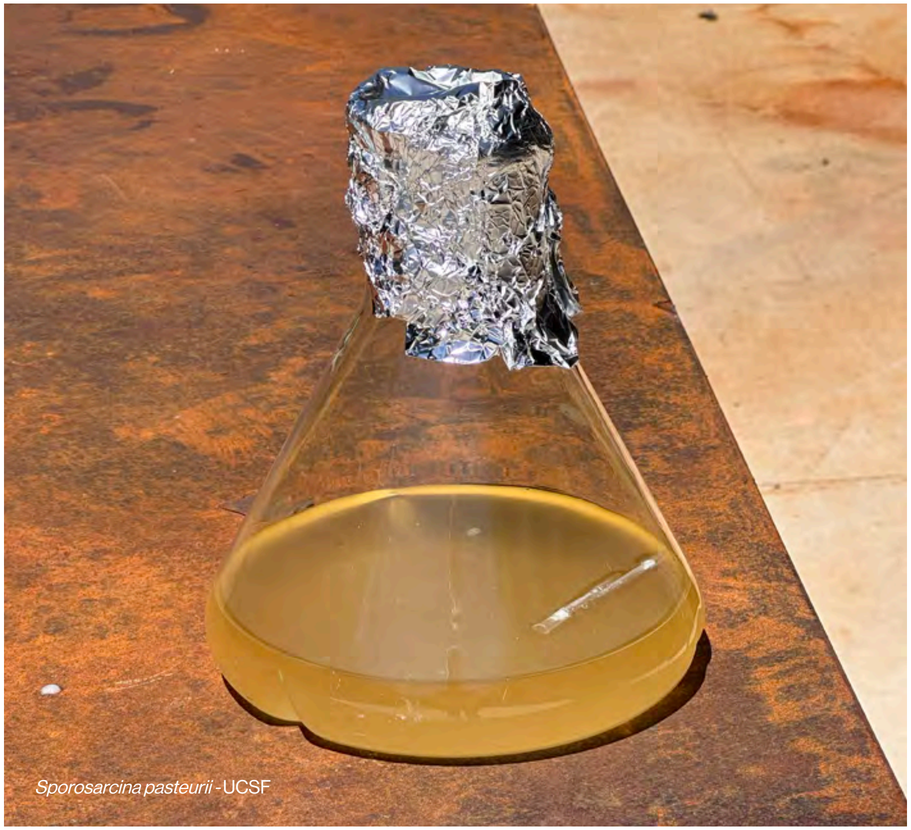


The same tiles used for the rainscreen are also used on the roof, creating a continuous layer of protection around the building.

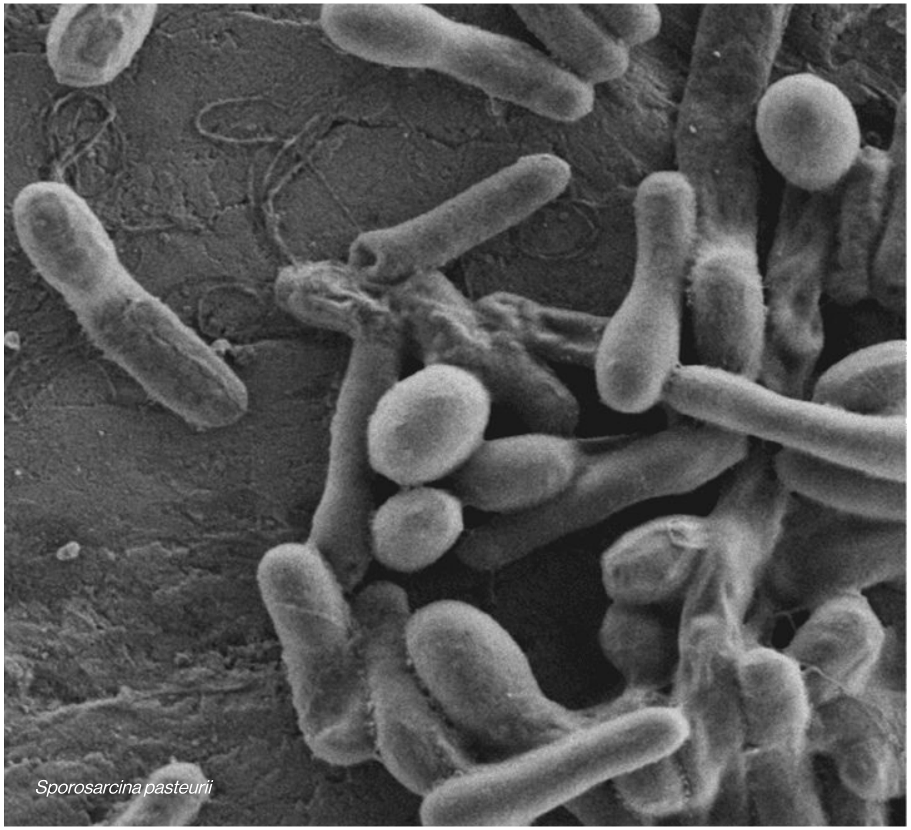
Bacteria and a self-healing material

The project explores the use of bacteria in the exterior plaster and rainscreen tiles to create a self-healing building shell. Both systems incorporate the bacteria *Sporosarcina pasteurii*, which is capable of producing calcium carbonate through a process known as microbial-induced calcite precipitation (MICP). When small cracks appear on the surface and moisture enters the material, the bacteria activates and generates calcium carbonate, gradually sealing the cracks over time.

This self-healing mechanism increases the durability and lifespan of the building envelope while reducing maintenance needs and material deterioration caused by water infiltration. In addition to improving performance, the use of bacteria-based materials proposes an alternative approach to construction in which biological processes become part of the strength of the building system itself.



Sporosarcina pasteurii - UCSF



Sporosarcina pasteurii

PHA filament

PHA (polyhydroxyalkanoate) is a biodegradable biopolymer produced by bacteria that use methane as a carbon source. In the Living Matters system, PHA filament is used to 3D print both the molds for growing mycelium insulation panels and the rainscreen tiles. The tiles also have a pattern over the top which helps keep the tiles from cracking as they cure.

The digital fabrication of these components enables precise production while minimizing material waste. As a bio-based and biodegradable material, PHA aligns with the project's goal of creating a construction system rooted in circular material flows and renewable resources.


3D Printing with PHA


3D Printing with PHA

Underutilized wood from California

Despite California's abundant forest resources and the growing demand for engineered wood products, local mass timber production remains extremely limited. As a result, most design teams must source mass timber products internationally or from other locations in the U.S. The high investment costs, certification requirements, and skilled labor needed to establish conventional mass timber manufacturing facilities , particularly for products such as Cross-Laminated Timber (CLT) , have contributed to years of stalled or unsuccessful production efforts within California. [4]

At the same time, California forests are overstocked with low-value biomass, especially small-diameter trees removed through forest restoration and wildfire prevention projects. Currently, the economic return from forest thinning and controlled burns rarely offsets the costs of extraction and management. Existing markets such as firewood, dimensional lumber, or biomass energy production do not generate sufficient added value to make these restoration processes economically sustainable. [4]

Mass timber construction presents an opportunity to support forest management efforts while providing low-carbon structural materials for housing. In addition to forest biomass, salvaged timber and wood cut-offs from lumber suppliers can also serve as valuable material streams for construction.

Living Matters proposes a smaller-scale, lower-tech, and decentralized approach to the production of structural mass timber systems. Rather than relying on highly industrialized facilities with large upfront investments, the system is designed to be manufactured through local workshops and small carpentry shops, allowing production to be rapidly deployed in regions with limited industrial infrastructure and skilled labor.

This approach creates higher-value products from underutilized wood resources generated through forest restoration projects. By enabling production through family-owned or community-scale carpentry workshops, the system also contributes to strengthening local economies and creating distributed networks of sustainable construction production that can gradually scale over time.

4 - Mayencourt, P., & Swagemakers, J. (2025). DIY mass timber: Development of low-tech and low-cost structural mass timber manufacturing to support forest utilization in California. Architecture, Structures and Construction, 5(37).


Kari Greer/ USFS

A low-tech mass-timber system

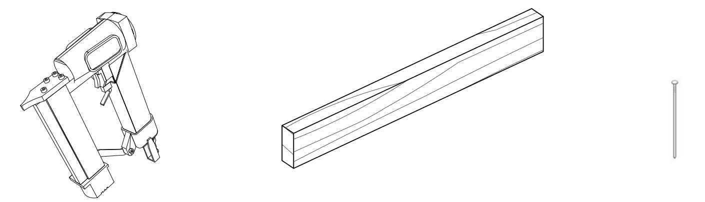
The structural system is based on a low-tech mass timber approach that utilizes underused wood resources, such as small-diameter California trees removed through forest restoration projects and cut-offs from the lumber industry. These smaller wood pieces are combined to form structural mass timber elements. The system is created by stacking and nailing timber elements according to requirements established by the California Building Code and the International Building Code, including specifications for nail diameter, spacing, type, and timber grading. The result is a series of modular components that function as a kit of parts for the house, including columns, beams, slabs, and rafters.

The construction process relies on a small set of accessible tools and materials: a pneumatic nail gun, construction-grade nails, and kiln-dried, structurally graded lumber boards cut to length and surfaced according to national construction standards. Different wood species, grades, and moisture contents can be mechanically assembled using nails or dowels, although these variables influence the performance and quality of the final product. The use of commercially available wood species commonly found in the construction market is therefore recommended.[4]

The system is designed to be prefabricated in local woodshops, allowing for faster construction timelines while minimizing waste generated on-site. By relying on simple assembly methods and locally available resources, the proposal reduces the need for highly industrialized manufacturing processes and expensive infrastructure. This decentralized prefabrication approach also supports scalable housing production, contributing to the development of more affordable and environmentally responsible housing solutions.

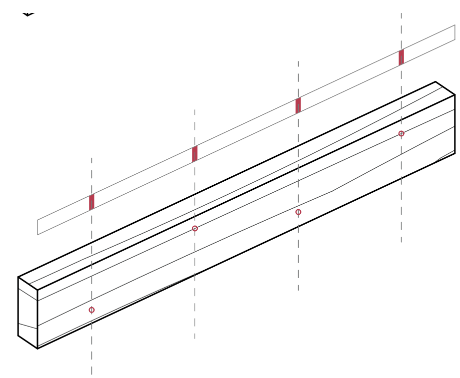
4 - Mayencourt, P., & Swagemakers, J. (2025). DIY mass timber: Development of low-tech and low-cost structural mass timber manufacturing to support forest utilization in California. Architecture, Structures and Construction, 5(37).

Tools

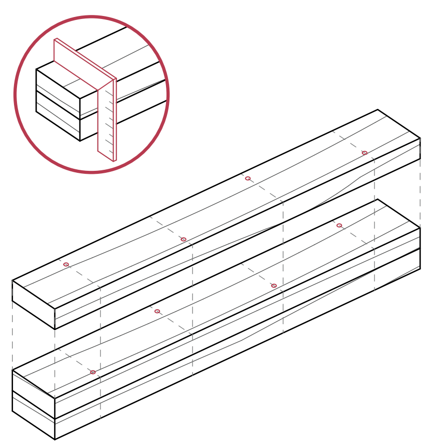


Nailer **Lumber** **Nails**

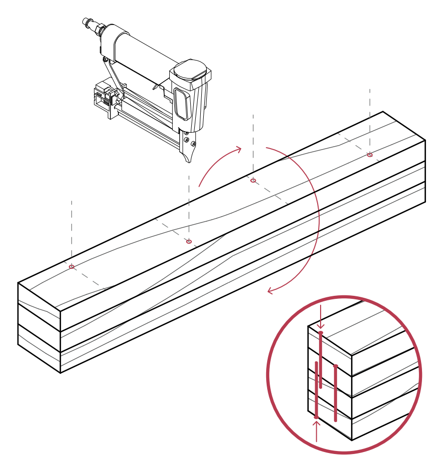
1. Mark nailing pattern



2. Align boards

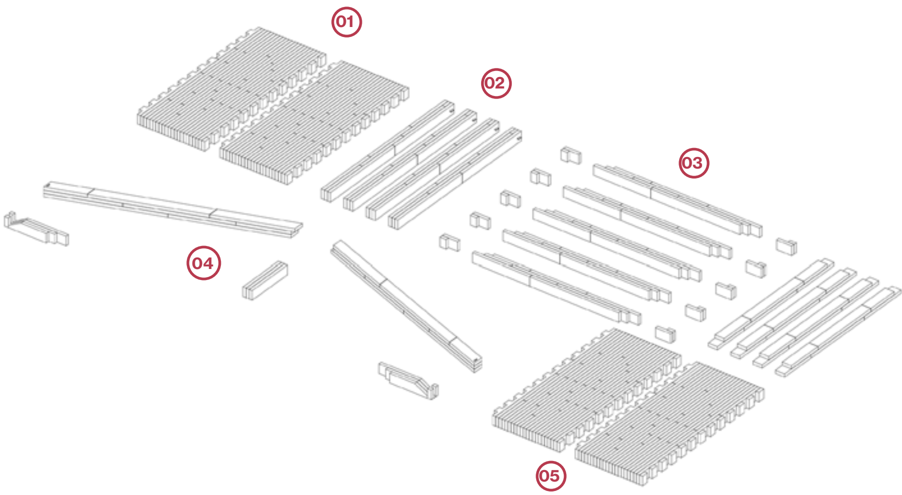


3. Flip and nail from both sides. Add board and repeat



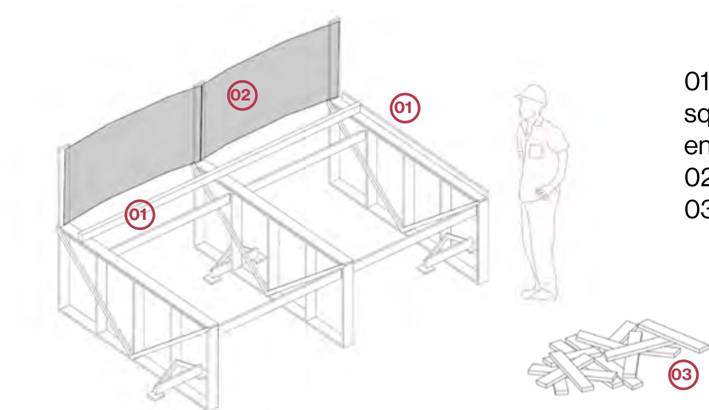
Off-site pre-fabrication | Structural frame

1 - Design of a "Kit of Parts"



01 -Slab | 02- Column | 03- Beam | 04 -Rafter | 05- Roof slab

2- Build a jig for the manufacturing process in local woodshops

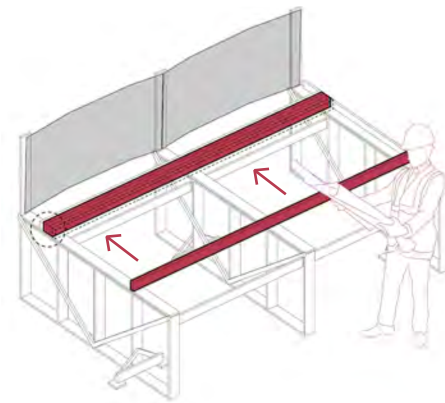


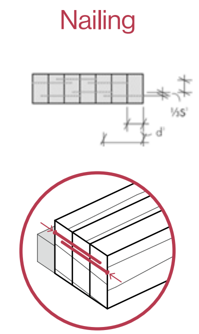
01 -Straight and square back and end stop
02- Back fence
03 - Cut-offs

The construction of a jig simplifies the fabrication of the panel for higher values and quality. The jig design is inspired by the information shared in the U.S. NLT design guide. A pneumatic nail gun and dried, graded, and surfaced structural lumber are all that is required to produce code-compliant mass timber panels in California, according to the California Building Code 2304.9.3 under Mechanically Laminated Decking.[4]

4 - Mayencourt, P., & Swagemakers, J. (2025). DIY mass timber: Development of low-tech and low-cost structural mass timber manufacturing to support forest utilization in California. Architecture, Structures and Construction, 5(37).

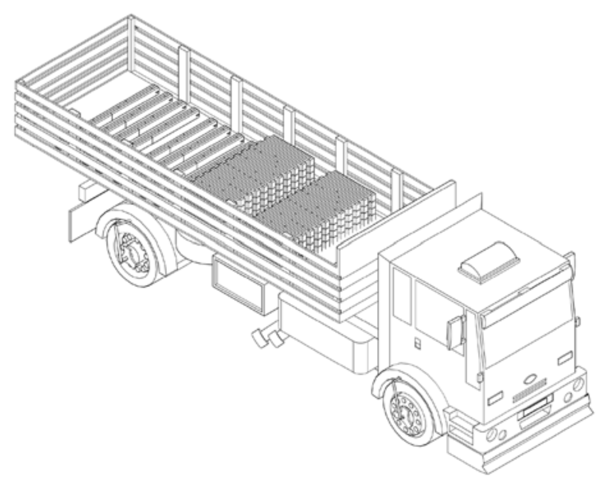
Stacking and nailing through the jig





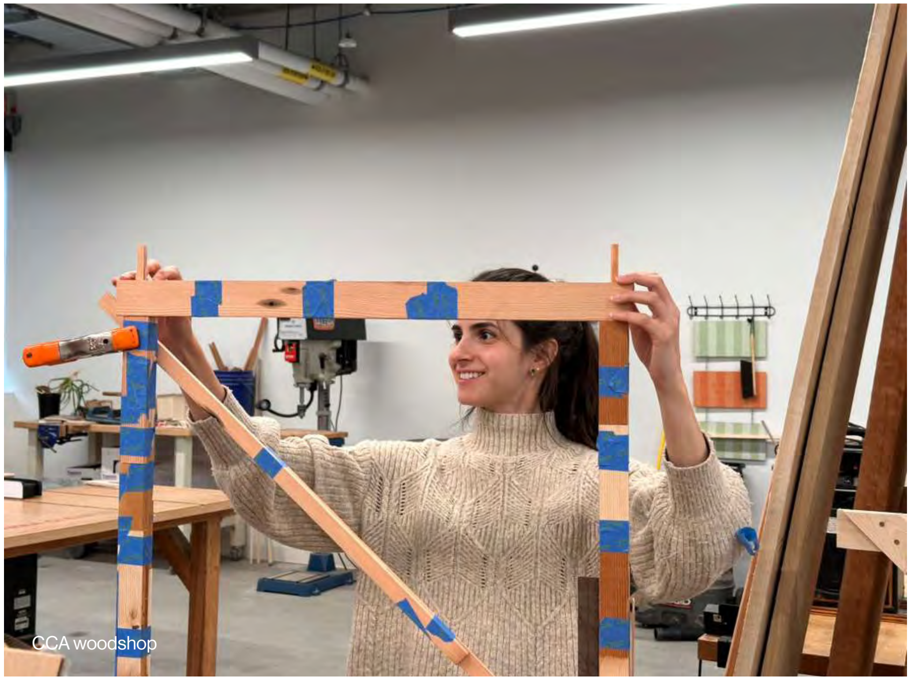
The boards are stacked and nailed according to the pattern defined by the California Building Code 2304.9.3, accessible for free online. The required nail type and nail pattern is defined in Table 2304.9.3.2 depending on the nail diameter, nail length, board thickness, and the support condition of the panel.[4]

Packing and preparing for transportation

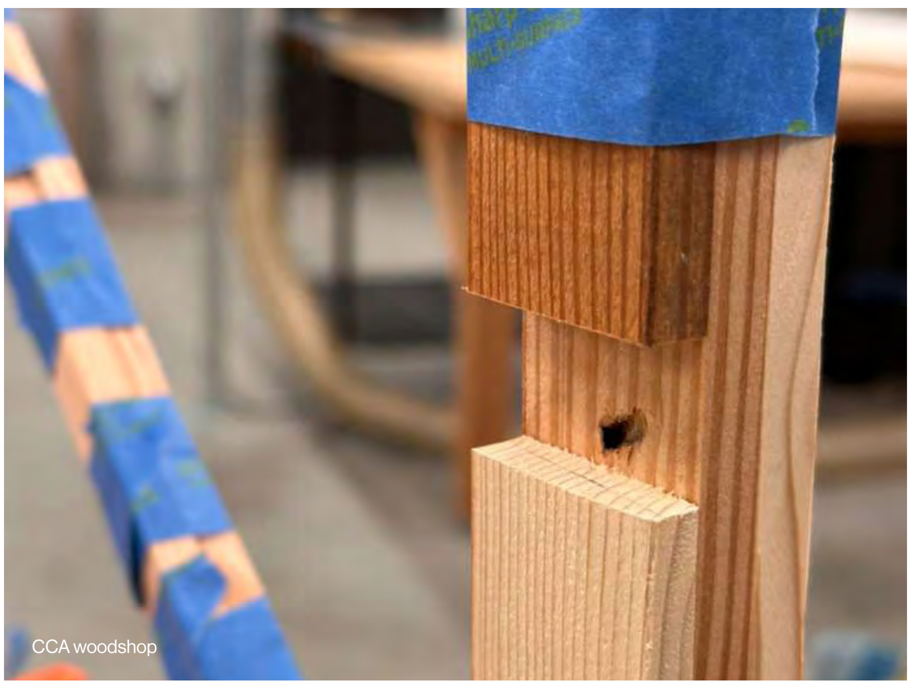


After the structural components are built, they are packed and sent to the construction site.

Structural frame | Prototype



CCA woodshop

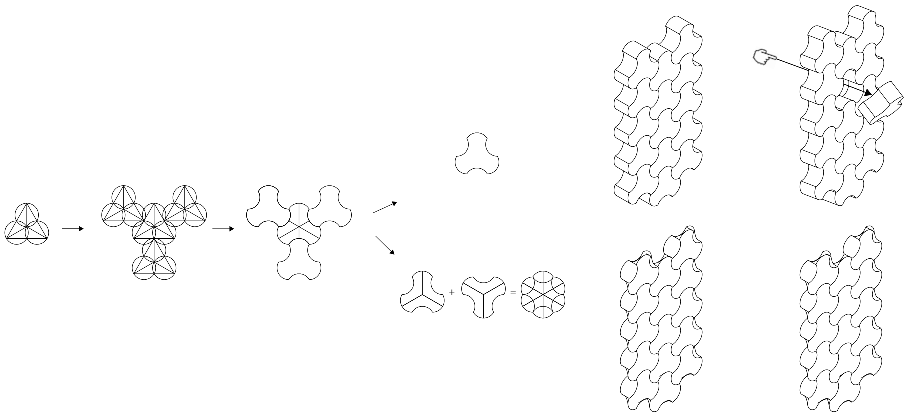


CCA woodshop

Workshop/ CCA + UCSF

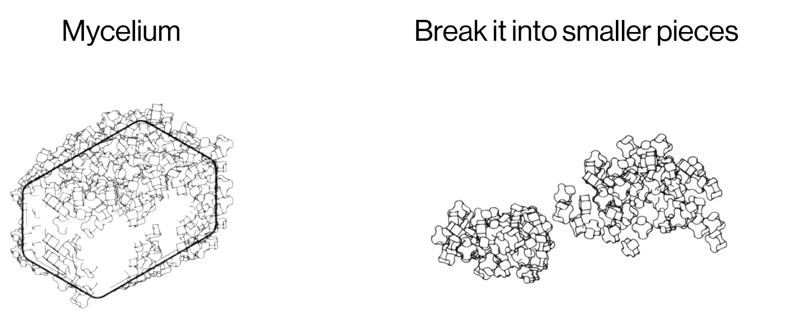
Off-site pre-fabrication | Insulation

1 - Design of a mold



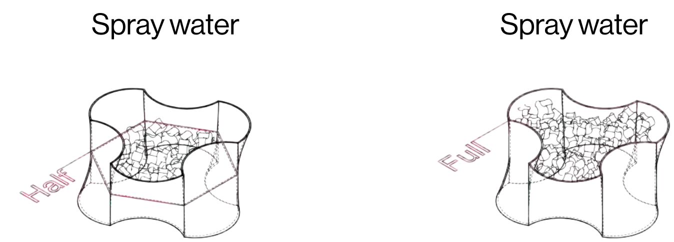
The form is created using a custom mold that is 3D-printed from PHA material and then filled with the mycelium mixture. This shape provides stability across all three dimensions (X, Y, and Z axes), simplifying the assembly process and significantly enhancing the overall structural stability.

2 - Prepare the mycelium + hemp mix



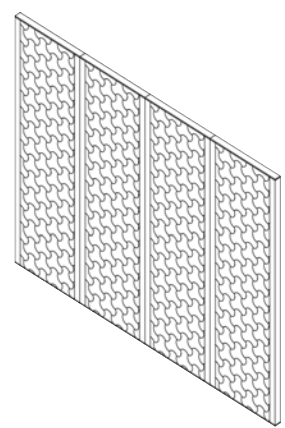
The mycelium material is thoroughly crumbled into fine pieces, making it easy to fill the mold evenly.

3 - Adding water and backing



To promote mycelium growth, lightly spray water into the mold when it is half full and again when it is completely filled. Next, place the filled block in a plastic bag and store it in a cool, humid environment for 3 to 5 days, away from direct sunlight and excessive heat. Once the mycelium blocks have fully grown, bake them at a low temperature to halt further growth and prevent mold formation.

4- Stacking the blocks to creat a pre-fab panel



Once completely dry, the blocks are assembled into panels for easier transportation and on-site installation. The blocks are stacked within a wooden frame, which holds them in place and forms the panel system.

Insulation | Prototype

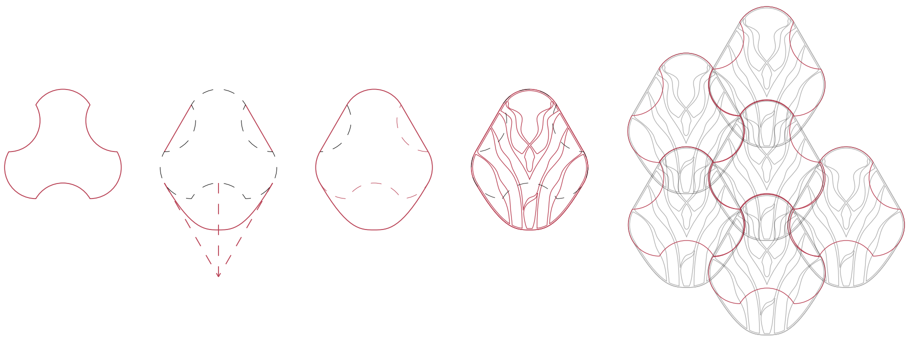
Workshop/ CCA + UCSF

Workshop/ CCA + UCSF

Workshop/ CCA + UCSF

Off-site pre-fabrication | Skin

1 - Design of a mold



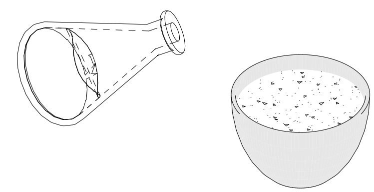
The tile geometry is designed based on the insulation blocks. This approach provides more systematic and coherent coverage of the wall surface, while the overlapping logic of the tiles aligns with the interlocking assembly logic of the blocks, creating a consistent relationship between the exterior cladding and the underlying insulation system.

2 - 3D print the mold with PHA

The embedded surface patterns on the tiles are created using 3D-printed PHA components. Taking advantage of PHA's biodegradable properties, these inserts gradually decompose, leaving behind a network of natural textures on the tile surfaces. The patterns are intentionally designed to capture and retain moisture from both atmospheric humidity and residual rainwater following precipitation. Combined with the nutrients released during the degradation of the PHA, these textured surfaces create favorable microclimatic conditions for moss growth. Over time, the facade evolves into a dynamic living system, transforming the building envelope into a responsive layer that continuously adapts and develops through its interaction with the surrounding environment.

3 - Mix the ingredients

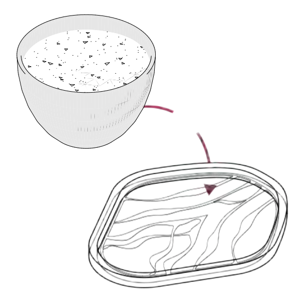
Mix the clay with Bacteria



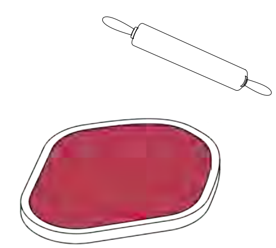
The tiles are made from a mixture of clay, sand, water, bacteria, and algae fibers. For each batch, 500 ml of clay is mixed with 500 ml of sand, 100 ml of bacterial solution, 100 ml of water, and approximately 10 ml of algae fibers cut into 1–2 inch lengths. The algae fibers help reduce cracking, while the bacteria contribute to the self-healing and strengthing properties of the tile.

4 - Cast the mix into the mold

Place the clay into the mold



Roll the surface until it is flat



Once mixed, the material is placed into molds. The upper surface is rolled flat and the tile is then left to dry.

Skin | Prototype

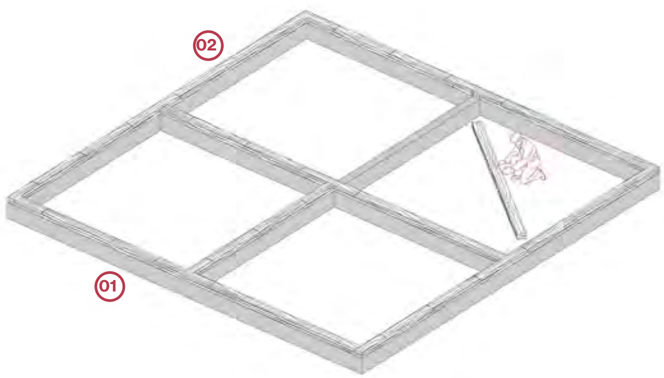
Workshop/ CCA + UCSF

Workshop/ CCA + UCSF

Workshop/ CCA + UCSF

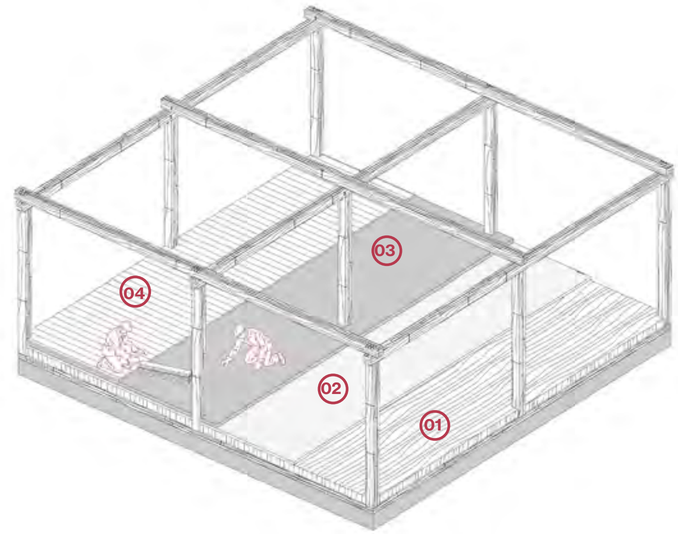
On-site installation

1 - Foundation + Sill Plate



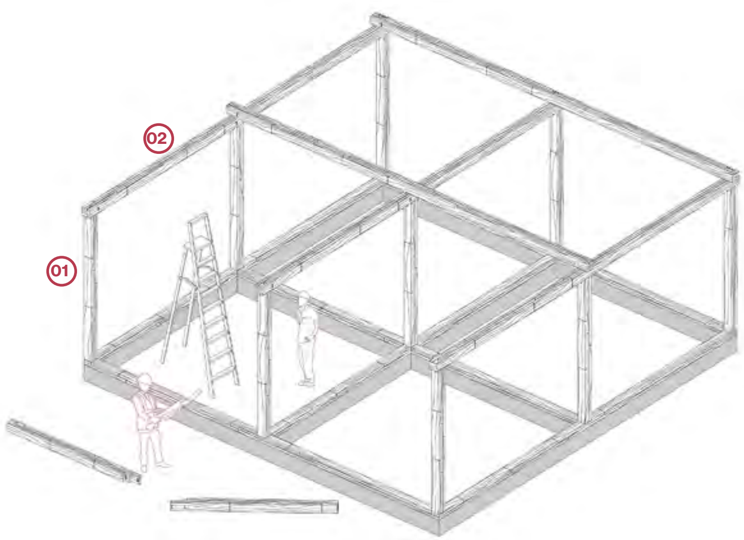
01 -Wood beams connected to helical piles foundation | 02- Sill plate

3- Floor Slab + Insulation



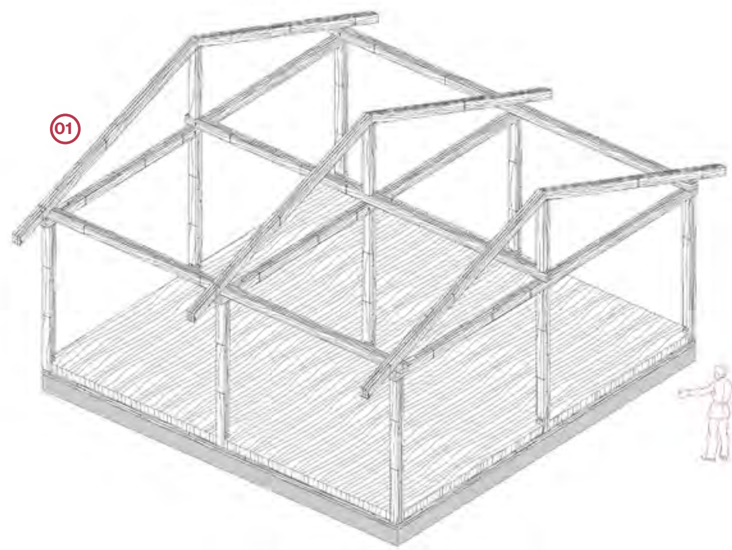
01 -Mass-timber slab | 02- Acoustic insulation | 03- Concrete layer | 04- Wood flooring

2 - Columns + Beams



01 -Column | 02- Beam

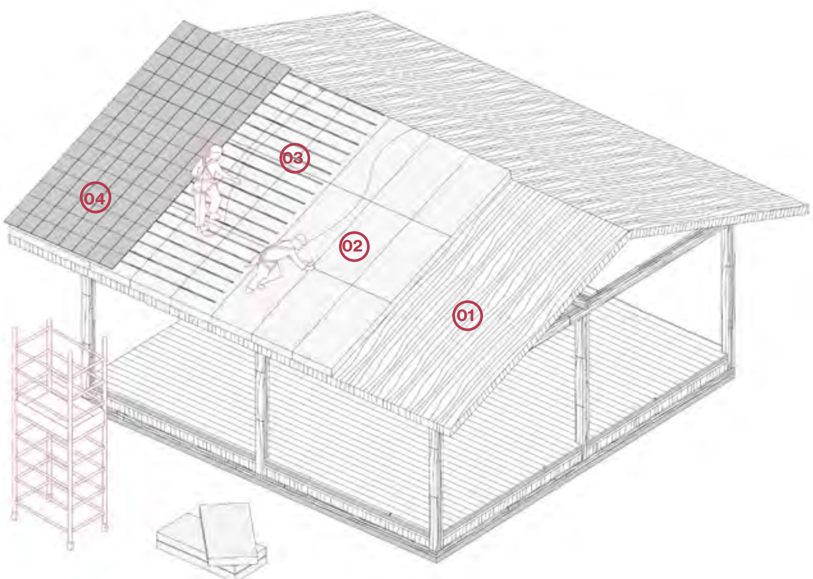
4- Roof Structure



01 -Rafter

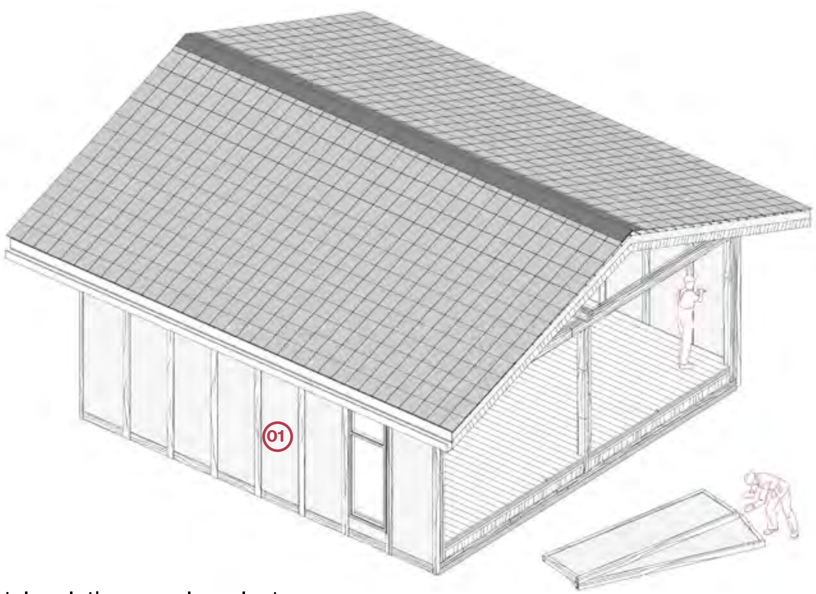
On-site installation

5 - Roof Slab + Insulation + Tiles



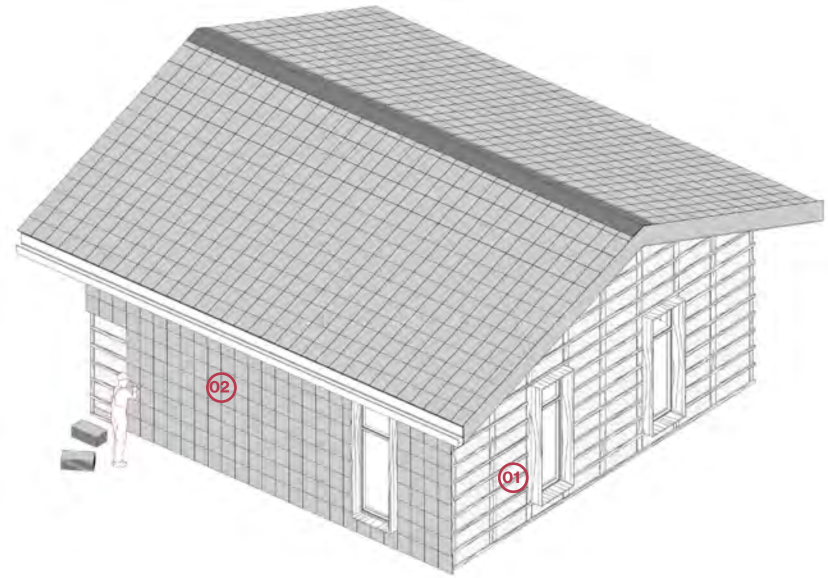
01 -Mass-timber slab | 02- Insulation panel | 03- Battens | 04- Roof tiles

6 - Wall Insulation + Windowns



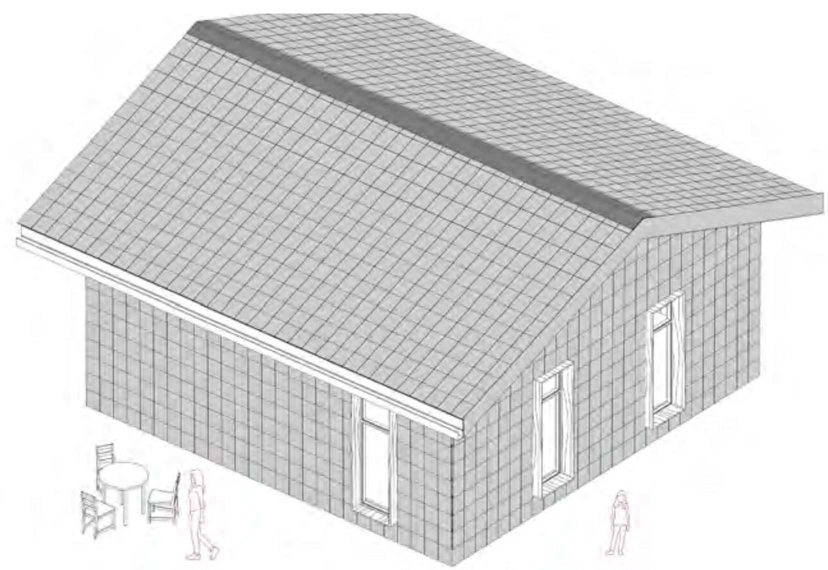
01 -Insulation panels + plaster

7- Rainscreen

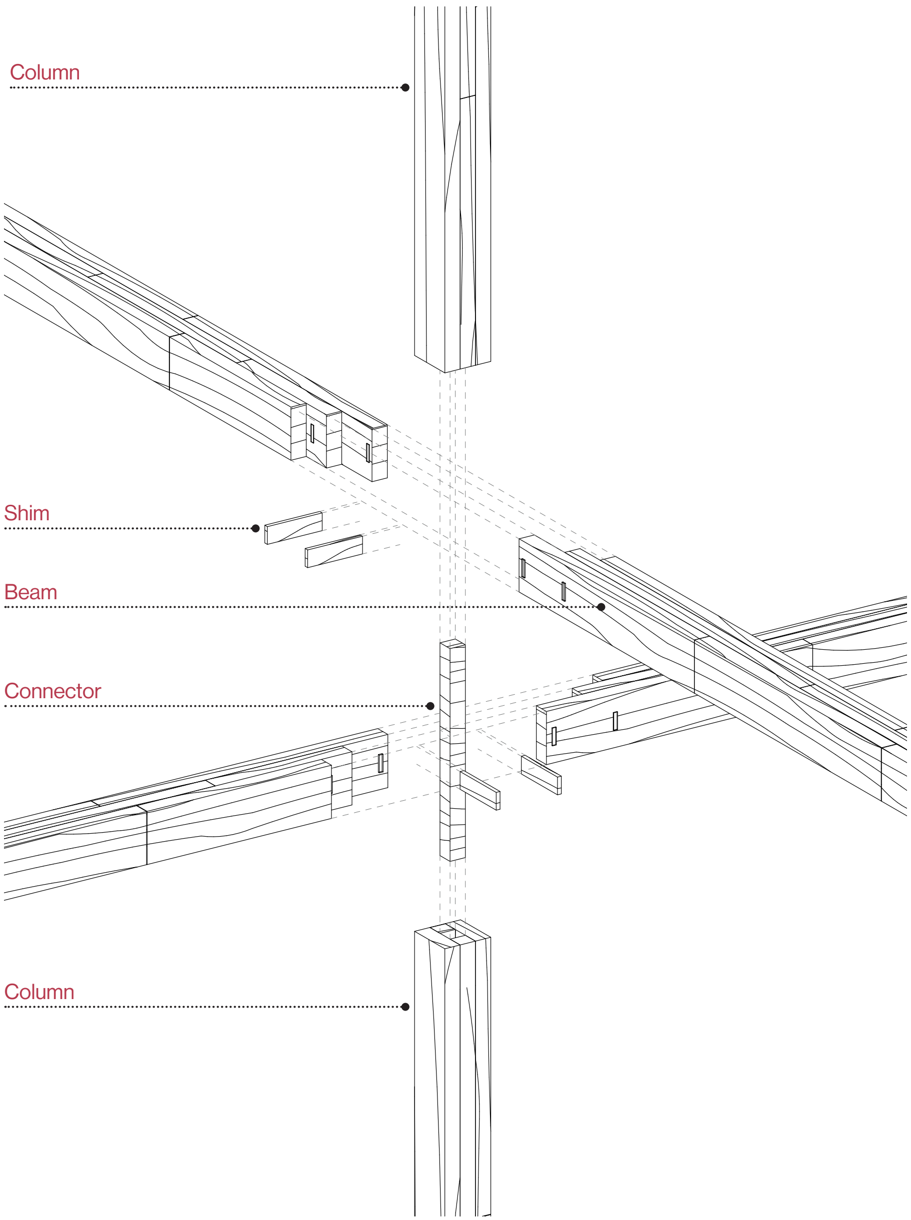


01 - Battens | 02- Wall tiles

8- Move-in



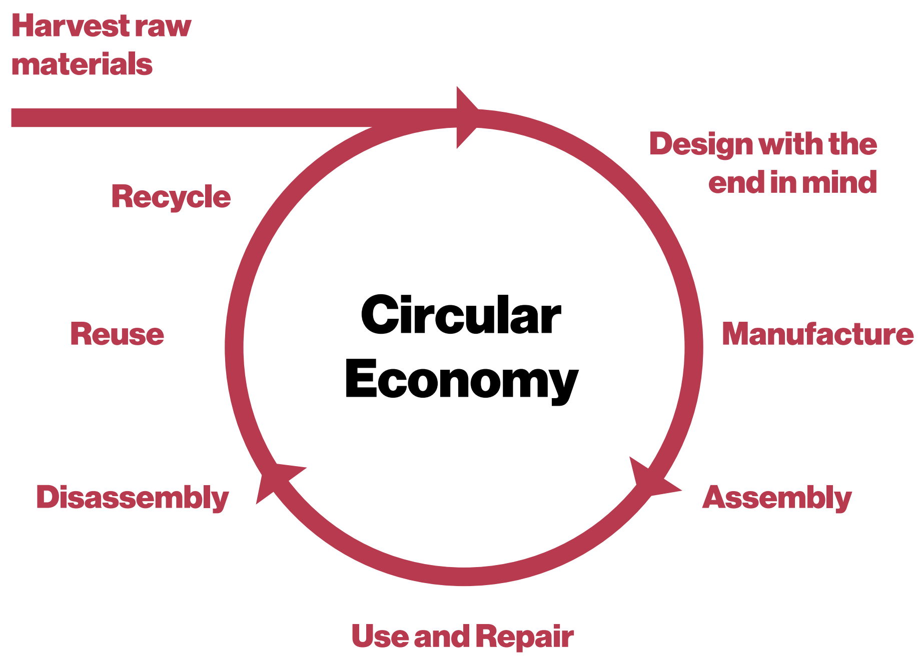
Design for disassembly



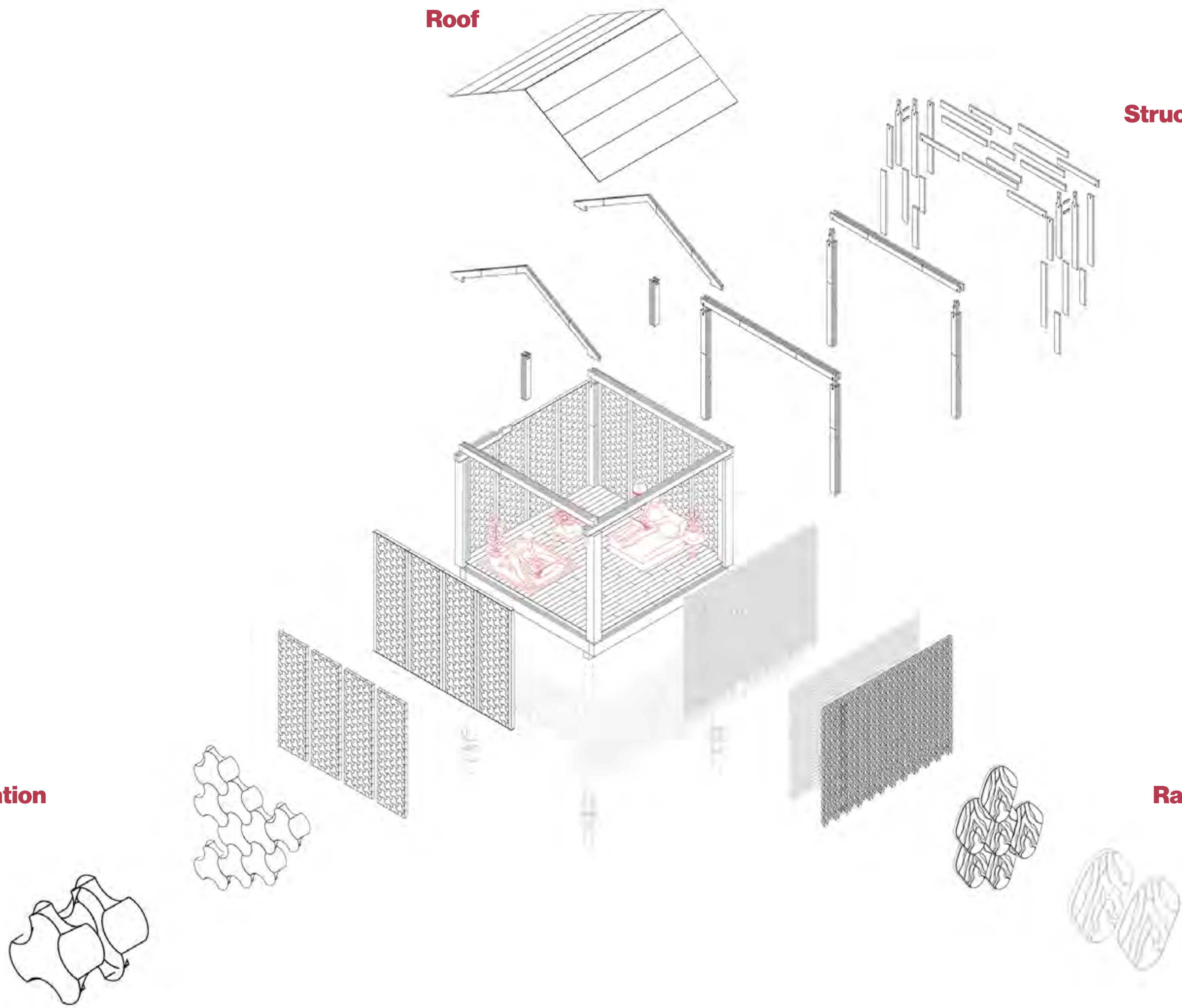
Connection Beam X Column

Design for disassembly(DfD) is a key principle of the *Living Matters* system. The structural connections takes inspiration from traditional Japanese joinery. This ancient technique uses interlocking wooden configurations to fit pieces together without relying on nails, screws, or glue. Therefore, elements are assembled in a way that allows them to be taken apart without damaging the components. The goal is to enable repair, replacement, and reuse throughout the building's lifespan.

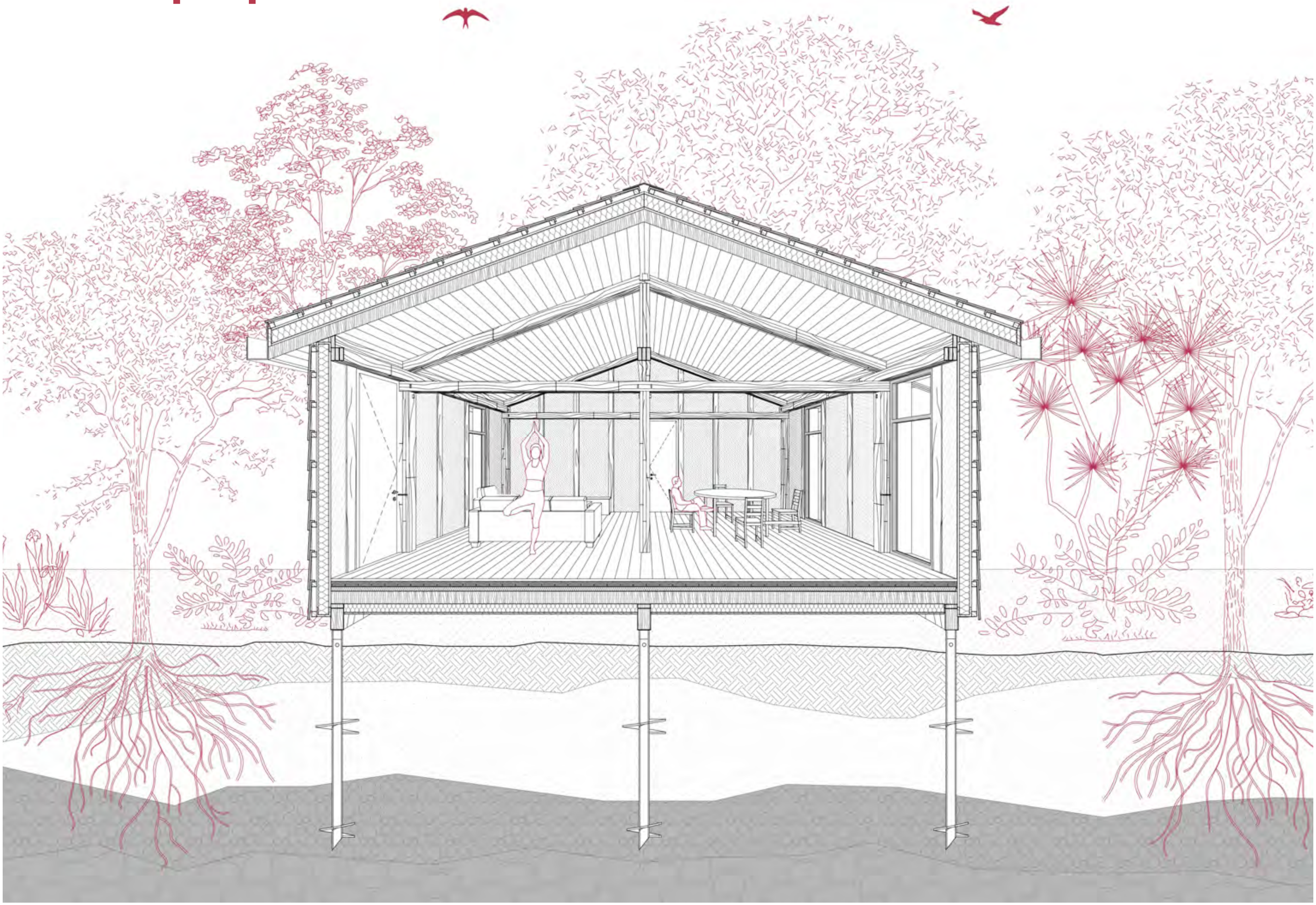
Once a building reaches the end of its service life, the structural elements can be disassembled, recovered, and incorporated into new constructions. This process reduces waste, limits the extraction of new raw materials, and keeps materials circulating within the economy for longer periods of time.

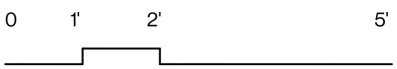


Exploded axonometric

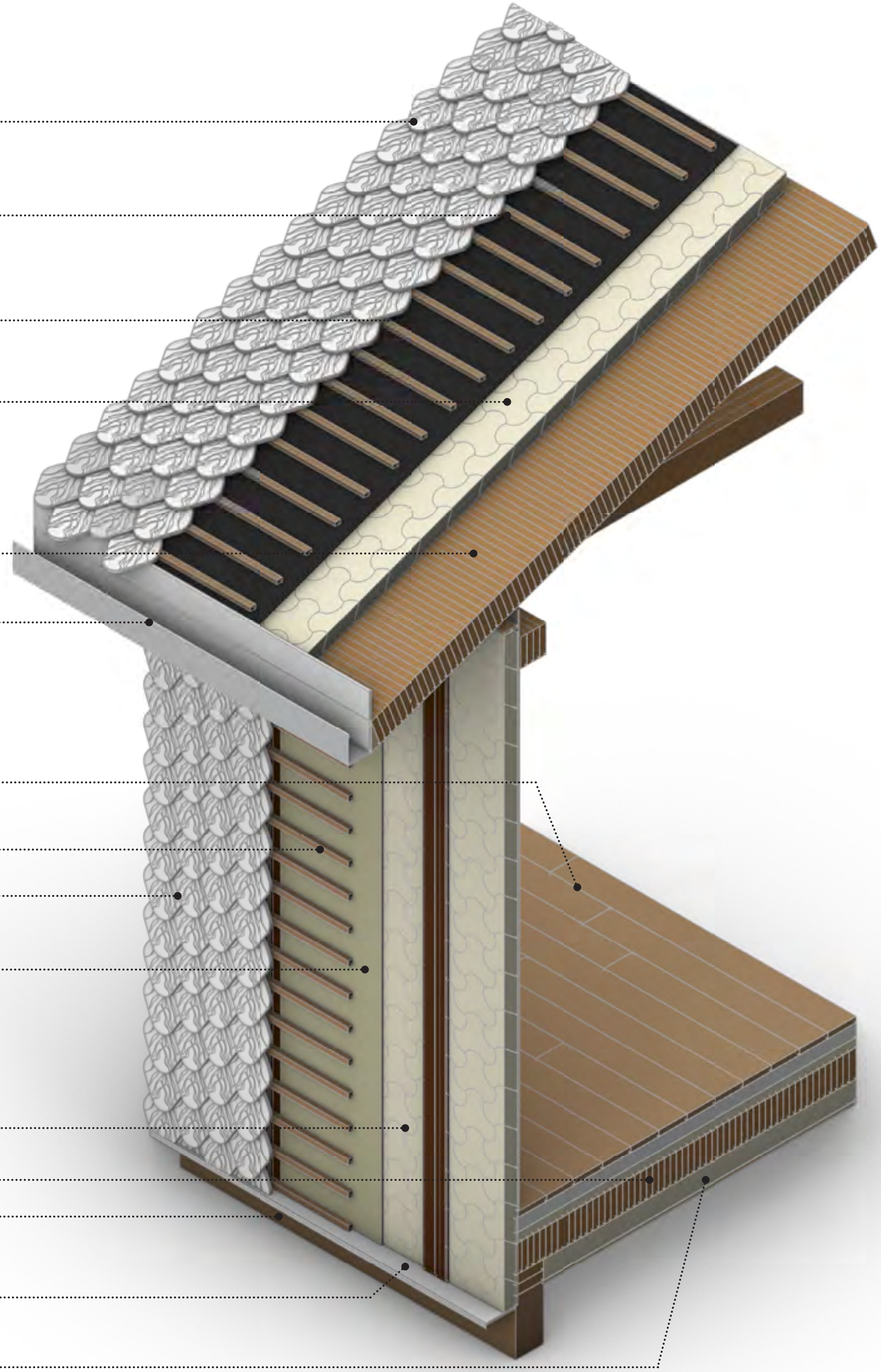


Section in perspective





Wall composition



Roof Tiles

Tiles made of clay + bacteria (*Sporosarcina pasteurii*), seaweed fibers + seashells

Wood Battens

Elevate, anchor, and provide an even surface for the tiles

Waterproofing Membrane

A critical shield, preventing water infiltration, structural damage, and mold

Insulation

A layer made of Mycelium blocks that regulate temperature, reduce energy costs, and prevent moisture build-up

Mass-timber Slab

A slab made of wooden cut-offs

Rain Gutter

Collects rainwater runoff and direct it away from the building to protect the roof, walls and foundation from water damage

Wood Flooring

Wood Battens

Rainscreen

Weather-resistant barrier/ Sacrificial Layer

Plaster

A layer responsible for waterproofing and fire resistance. It is made of clay, crushed shells, water, and the bacteria Sporosarcina pasteurii

Wall Insulation

Floor Slab

Foundation

Beam connected to the helical piles foundation

Base flashing with drip edge

Prevents water damage

Floor Insulation

Modularity - Small, Medium, Large

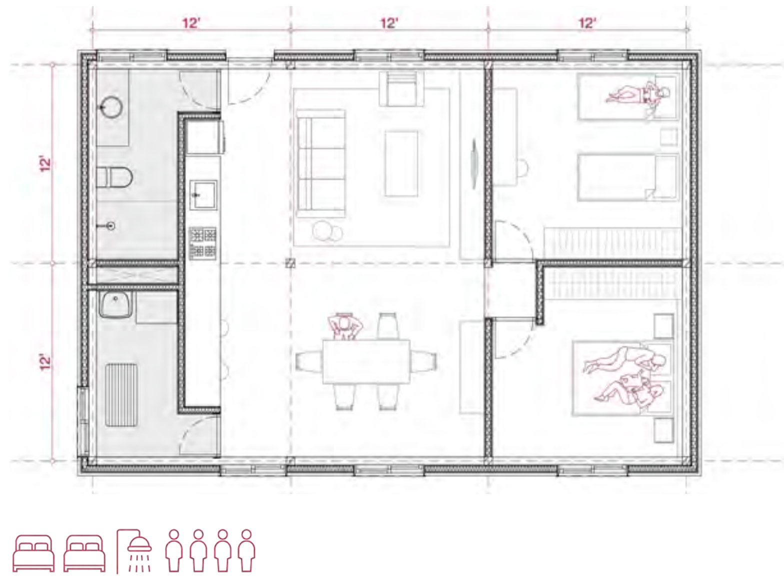
Flexibility and adaptability are central to the project's design, allowing the system to respond to the diverse needs and aspirations of different families and communities. The proposal is based on a modular kit-of-parts system composed of standardized structural and enclosure elements. Through the combination of the same modular components, buildings of different sizes, layouts, and spatial configurations can be created. This flexibility allows the system to adapt to a variety of cultural, social, and environmental contexts.

The modular approach also simplifies prefabrication, transportation, assembly, maintenance, and future disassembly. The use of repeated components also reduces material waste, streamlines construction processes, and increases efficiency.

Type 01 - Small

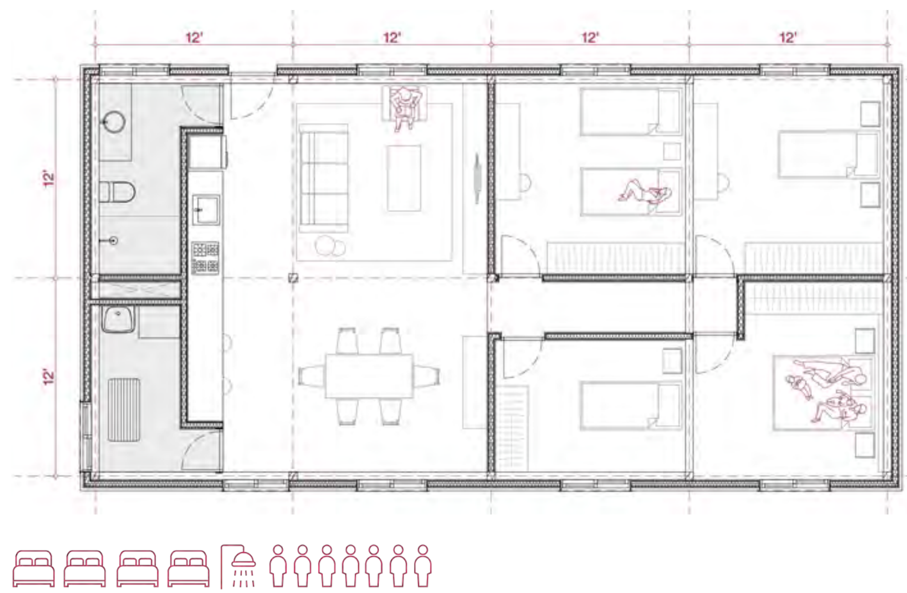
1xBedroom | 1x Bath | 2 People 576sqf

Type 02 - Medium



2xBedrooms | 1x Bath | 4 People 864sqf

Type 03 - Large



4xBedrooms | 1x Bath | 7 People 1152sqf

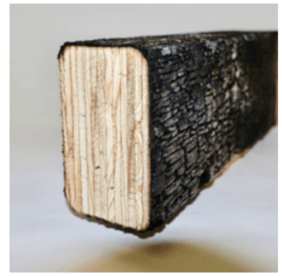
Fire safety

The building is designed with fire protection as a central consideration. In California, wildfires remain one of the greatest environmental risks, with climate change significantly increasing both their frequency and intensity in recent years. In response to this context, the bio-based materials selected for the project were chosen not only for their low environmental impact, but also for their fire-resistant properties. The assembly incorporates protective exterior layers, including fire-resistant plasters and rainscreen systems, while the mass timber structure is designed to achieve predictable fire performance through controlled charring. Together, these strategies aim to create a resilient building system adapted to California's environmental conditions.


AP Photo/Noah Berger

Biomaterials and their natural resistance

Wood



As wood burns, it forms a carbonaceous layer that insulates the unburned interior, slowing charring to a predictable rate. This mechanism allows heavy timber to maintain structural integrity during fires.

Mycelium

Mycelium is natural fire-resistant material. When exposed to fire, it forms a protective, carbonized char layer that prevents flame spread and insulates underlying materials. Studies show it excels in fire safety testing.

Clay

Clay materials provide superior fire safety in construction due to their non-combustible nature, typically earning an A1 fire rating. They do not burn, ignite, or produce toxic smoke.

Exterior view


Interior view


Interior view

Interior view

Interior view - exposed mycelium blocks

Scaling -up /Collaborators

Upscaling sustainable construction systems requires long-term collaboration between public institutions, private industry, and civil society [5]. Recognizing the overlapping interests among these different actors creates opportunities for partnerships capable of addressing complex environmental and housing challenges. Living Matters was developed with this collaborative approach in mind. Throughout the research process, feedback and contributions were gathered from a diverse network of stakeholders, including representatives from the California government, local corporations, researchers, designers, and community actors. By building coalitions around shared goals and complementary expertise, the project aims to create synergies that can support the broader adoption of low-carbon, decentralized construction systems. The project also seeks to engage different stakeholders through aligned incentives, framing sustainability not only as an environmental necessity, but also as an opportunity for economic development, local job creation, and community resilience.

Government

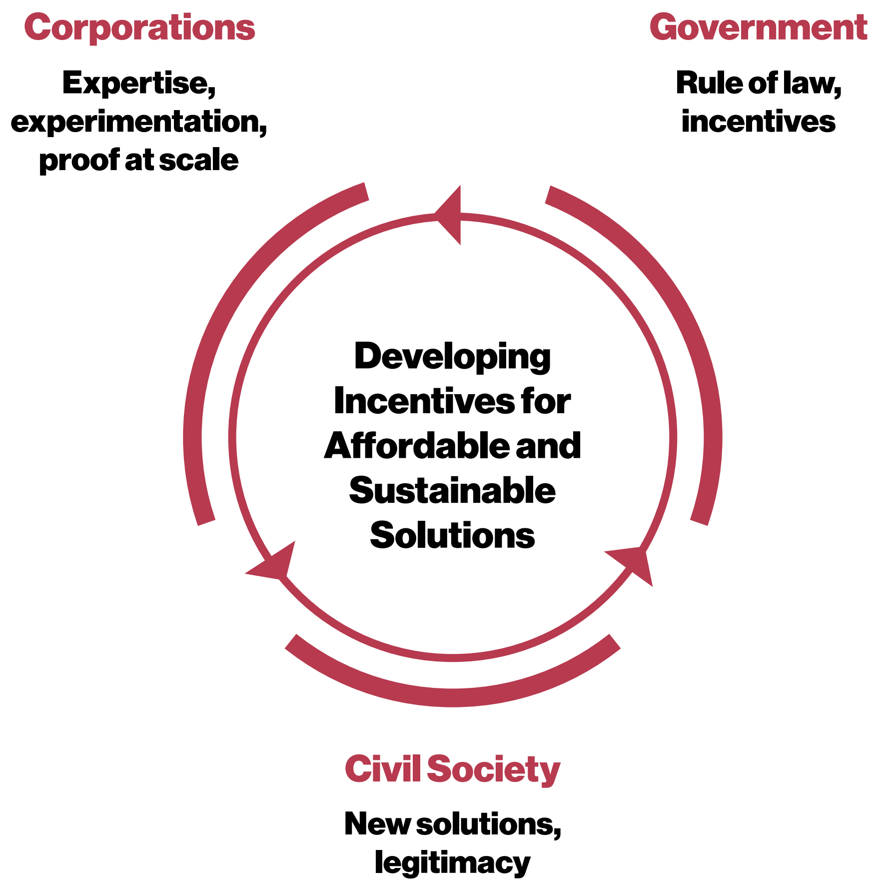
- California Assembly Select Committee on Housing Construction Innovation (Buffy Wicks, Assembly member)
- Terner Center for Housing Innovation
- City of San Francisco Department of the Environment

Corporations

- Arup (Francis Yang)
- Autodesk Research (Arthur Harsuvanakit)
- Far West Fungi

Civil Society

- Alireza Borhani Haghighi (CCA Architecture)
- Massey Burke (California Straw Building Association)
- Creative Citizens in Action Award (CCA)
- Eric Lambin (Université catholique de Louvain and Stanford University)
- Paul Mayencourt (UC Berkeley Wood Lab)
- Dr.-Ing. Andrea Rossi (The Computational Hive, University of Applied Arts Vienna)
- Dyche Mullins (Mullins Lab, UCSF)



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Conclusions

Living Matters proposes an alternative approach to housing construction that addresses both the environmental impacts of the building industry and the growing housing crisis in California. By combining locally sourced bio-based materials, decentralized prefabrication, and low-tech mass timber systems, the project explores how housing can be produced in a way that is environmentally responsible, economically accessible, and socially adaptable.

Rather than relying on highly industrialized construction models, the proposal demonstrates the potential of smaller-scale and community-oriented production systems that can utilize underused local resources, reduce waste, and strengthen regional economies. The modular nature of the system allows it to adapt to different spatial, cultural, and environmental conditions while supporting flexibility, scalability, and future disassembly.

The research also highlights the importance of collaboration between public institutions, private industry, researchers, designers, and local communities in order to scale sustainable construction solutions. Through these collective efforts, Living Matters aims to contribute to new models of housing production that are resilient, circular, and rooted in local ecologies and communities.

Ultimately, the project envisions housing not only as shelter, but as an opportunity to rethink the relationship between construction, natural resources, and social well-being, proposing a system that seeks to provide healthy and dignified homes while minimizing environmental impact.

This project is aligned with the following UN Sustainable Development Goals

SUSTAINABLE DEVELOPMENT GOALS

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Francis Yang (ARUP)

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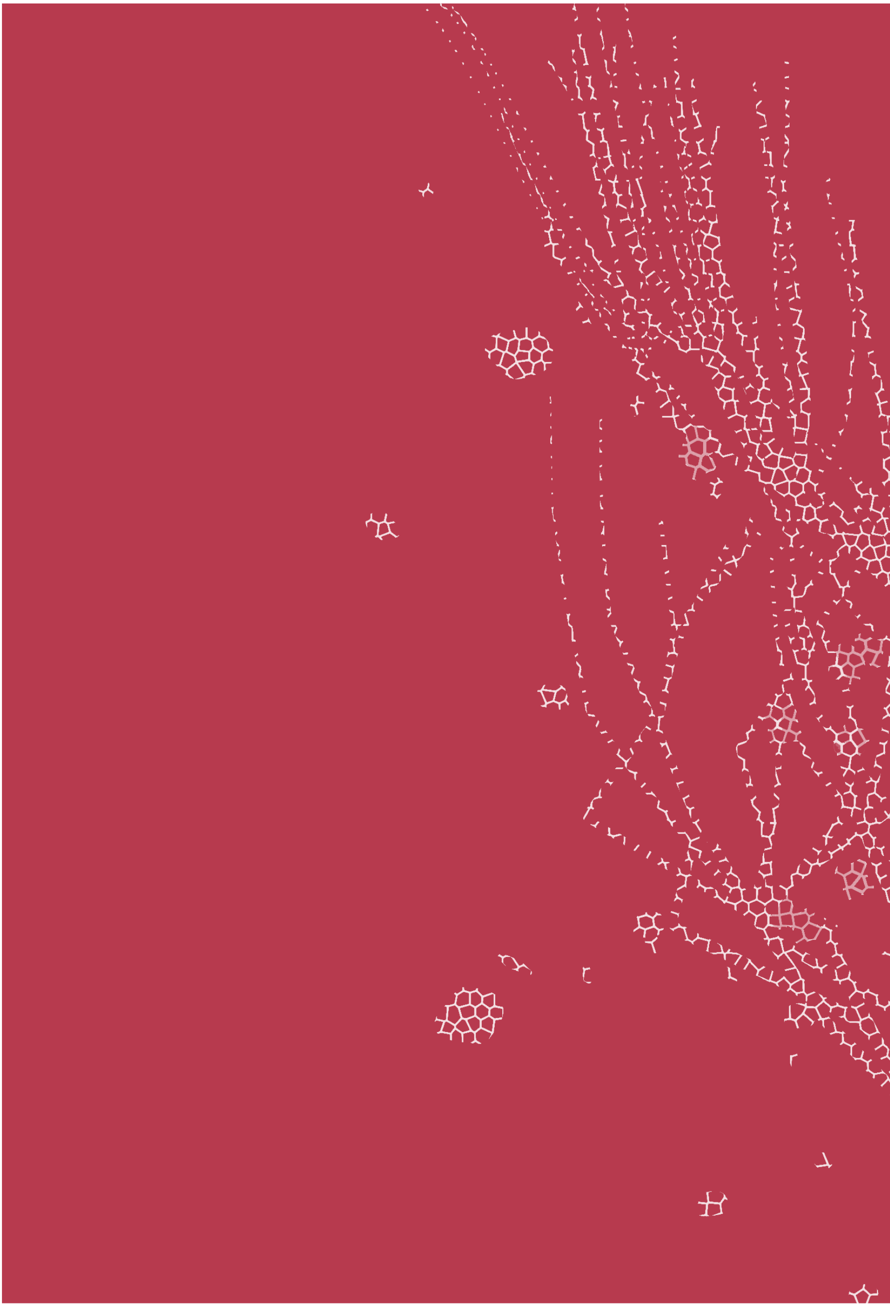
For more information about this project:
seashift.org



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