ARCHITECTURE AS (A) CARBON (-BASED) PRACTICE

An Experiment on Biomaterials
A Speculation on Adaptive Reuse

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MArch ‘24 | Rhode Island School of Design
CPHC®

To all those who have contributed to the development of this thesis, in ways large and small, I offer my sincerest thanks. This work would not have been possible without the generous and passionate individuals who accompanied me on this journey.

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ABSTRACT

Carbon serves as both a silent protagonist and a looming antagonist in the narrative of architecture, shaping not only the physical structures we inhabit but also the ecological legacy we leave behind.

Centuries of human exploitation of the environment have led to climate and material crises. Shifting this dynamic requires action at micro (matter), meso (material), and macro (materiality) levels. Biogenic materials offer significant potential for carbon sequestration and present opportunities for the building industry to collaborate with nature rather than merely extract from it.

Demonstrating through Central Falls and Blackstone River, this thesis establishes a research and manufacturing practice that prioritizes material innovations, carbon sequestration, environmental rehabilitation, and adaptive reuse. By strategically sourcing local materials such as water chestnut, sawdust, and automobile tires, this thesis transforms these waste products or carbon-sequestering substances into viable building materials through scientific experimentation and testing, ultimately integrating them into architectural systems.

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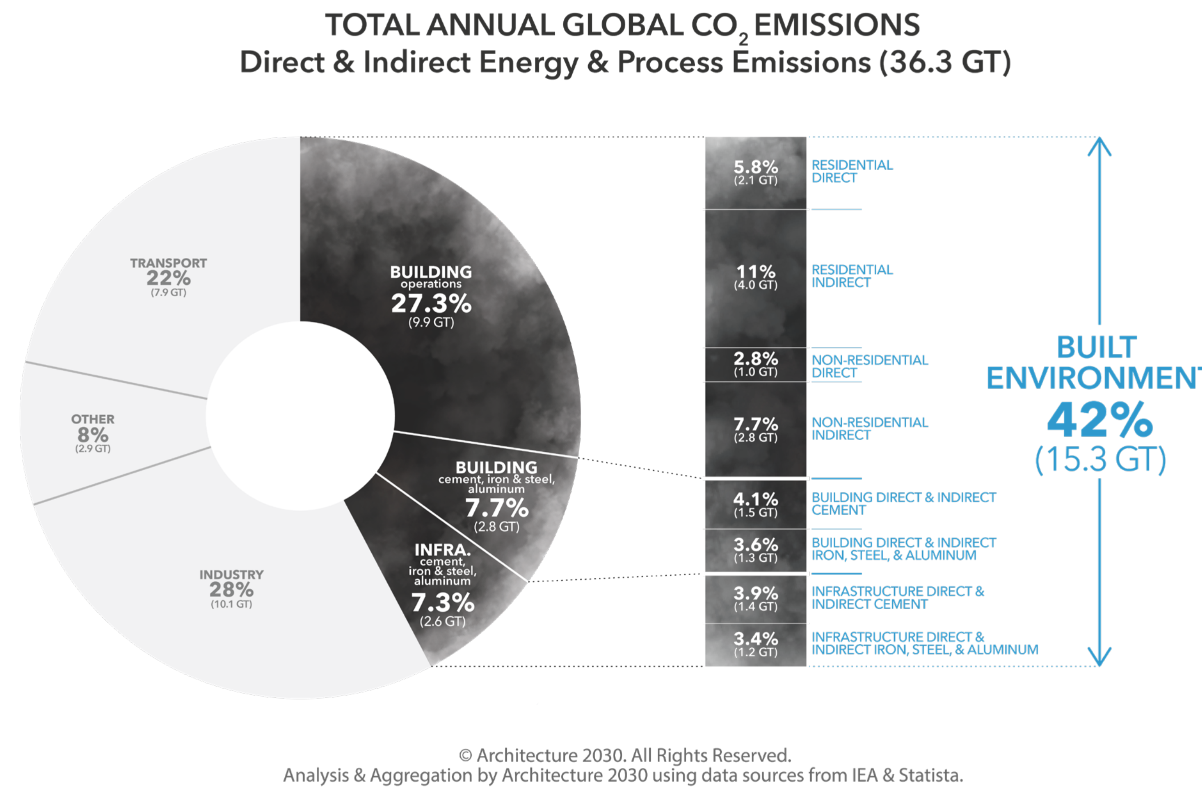
Congressional Budget Office, *Emissions of Greenhouse Gases in the Manufacturing Sector*. 2024.



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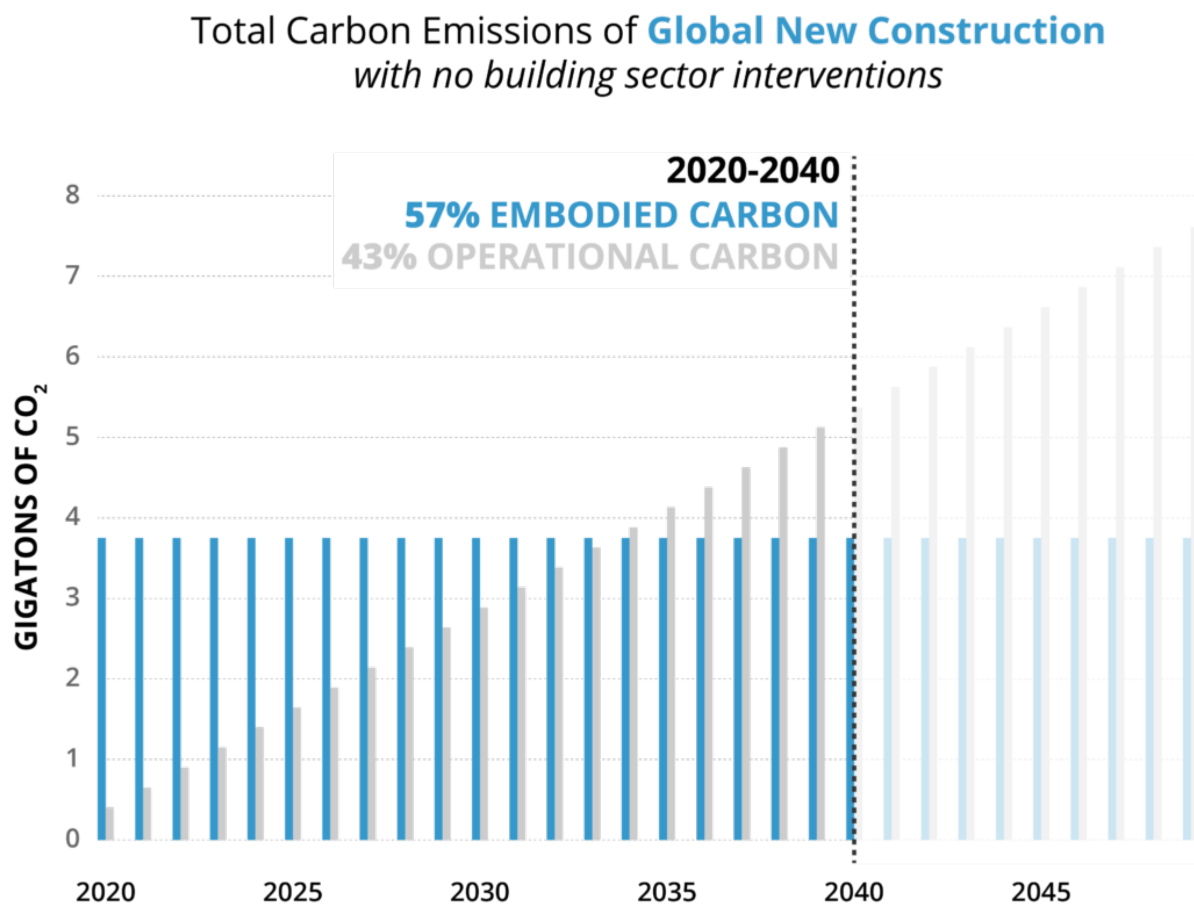

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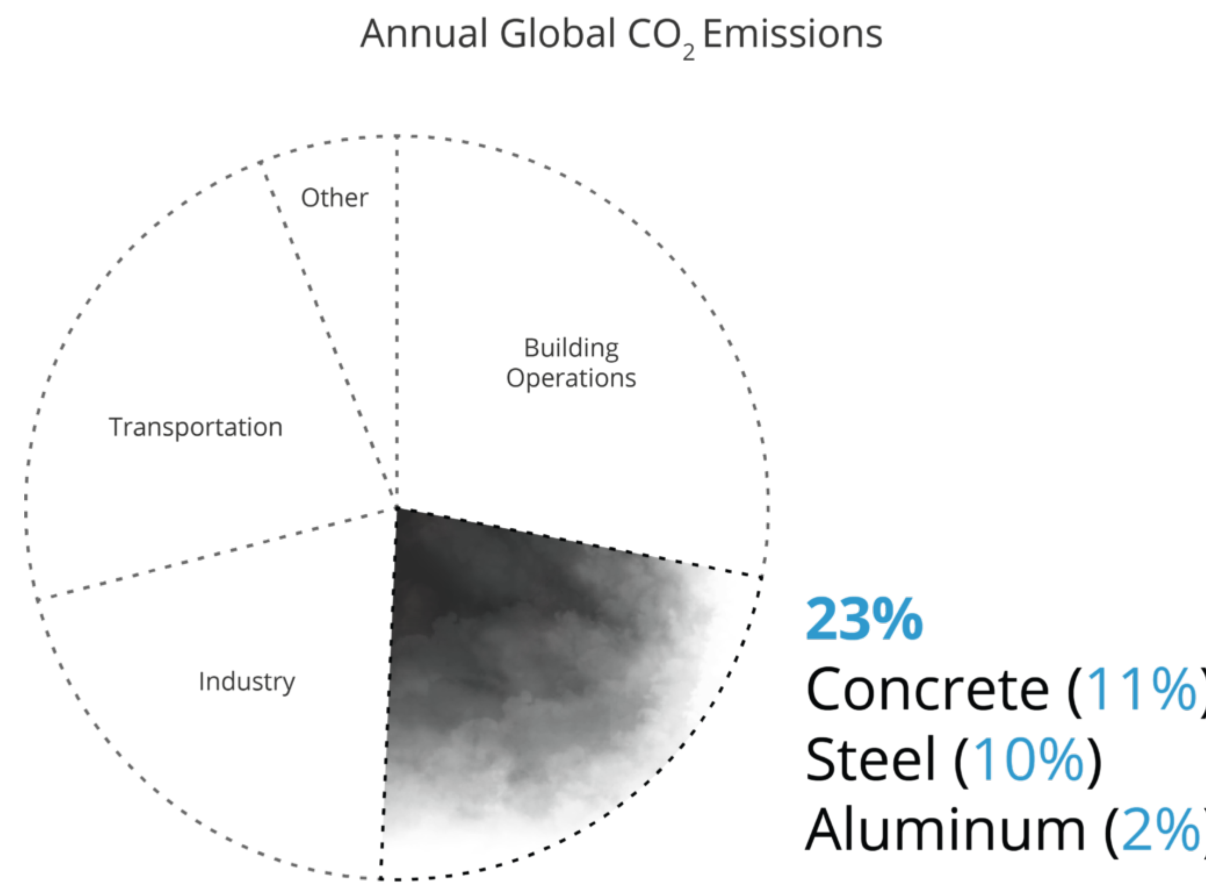

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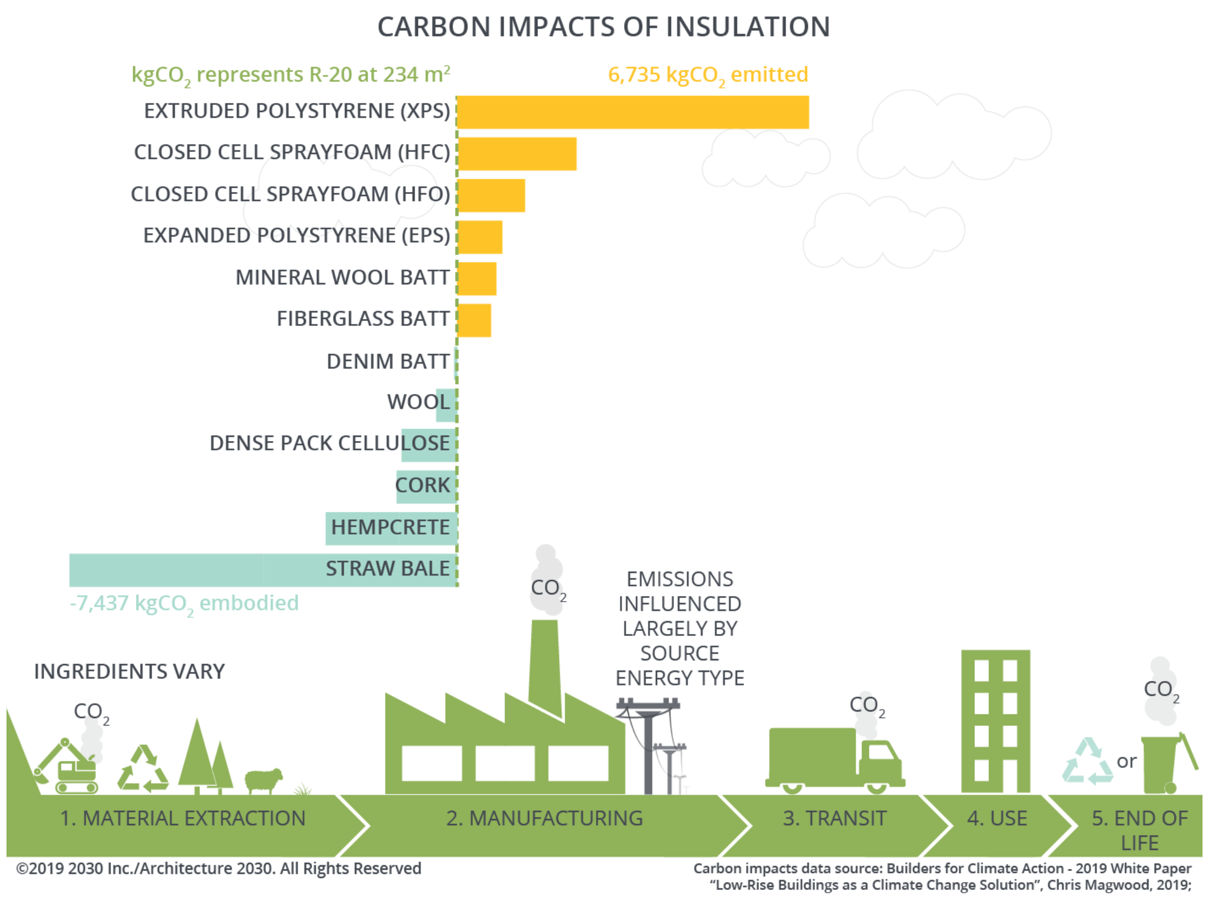

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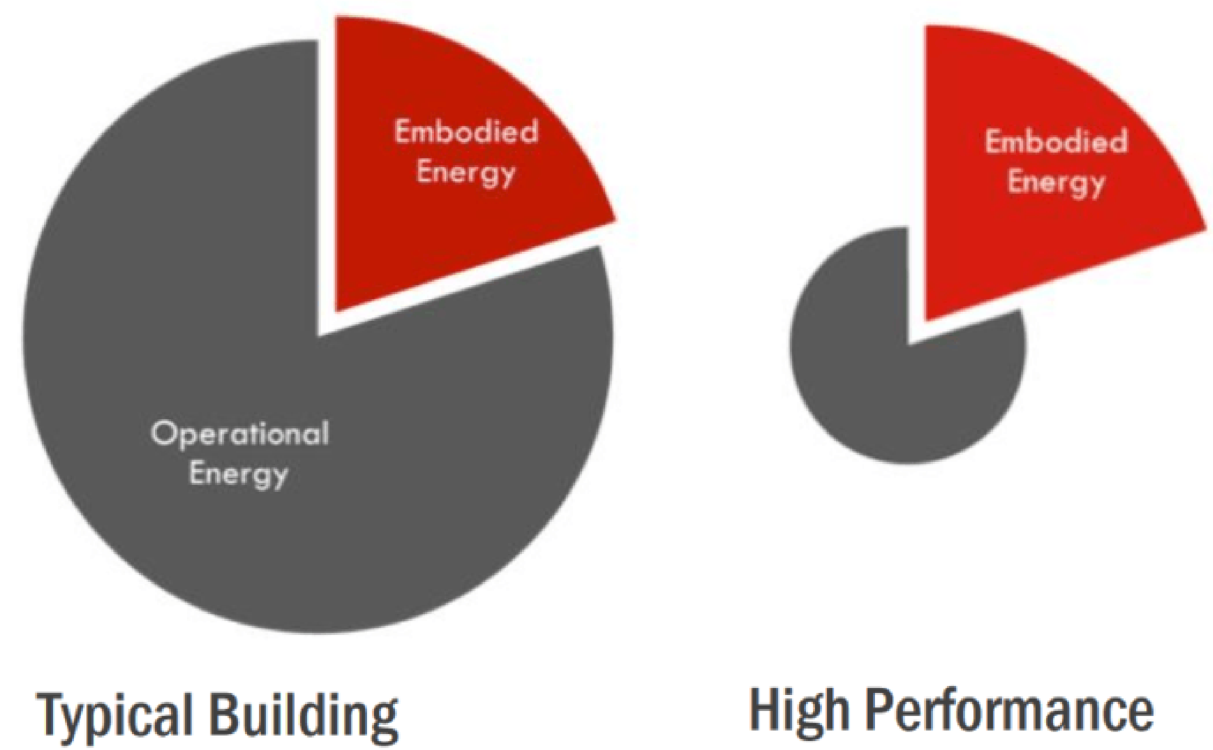

West Coast Climate Forum.

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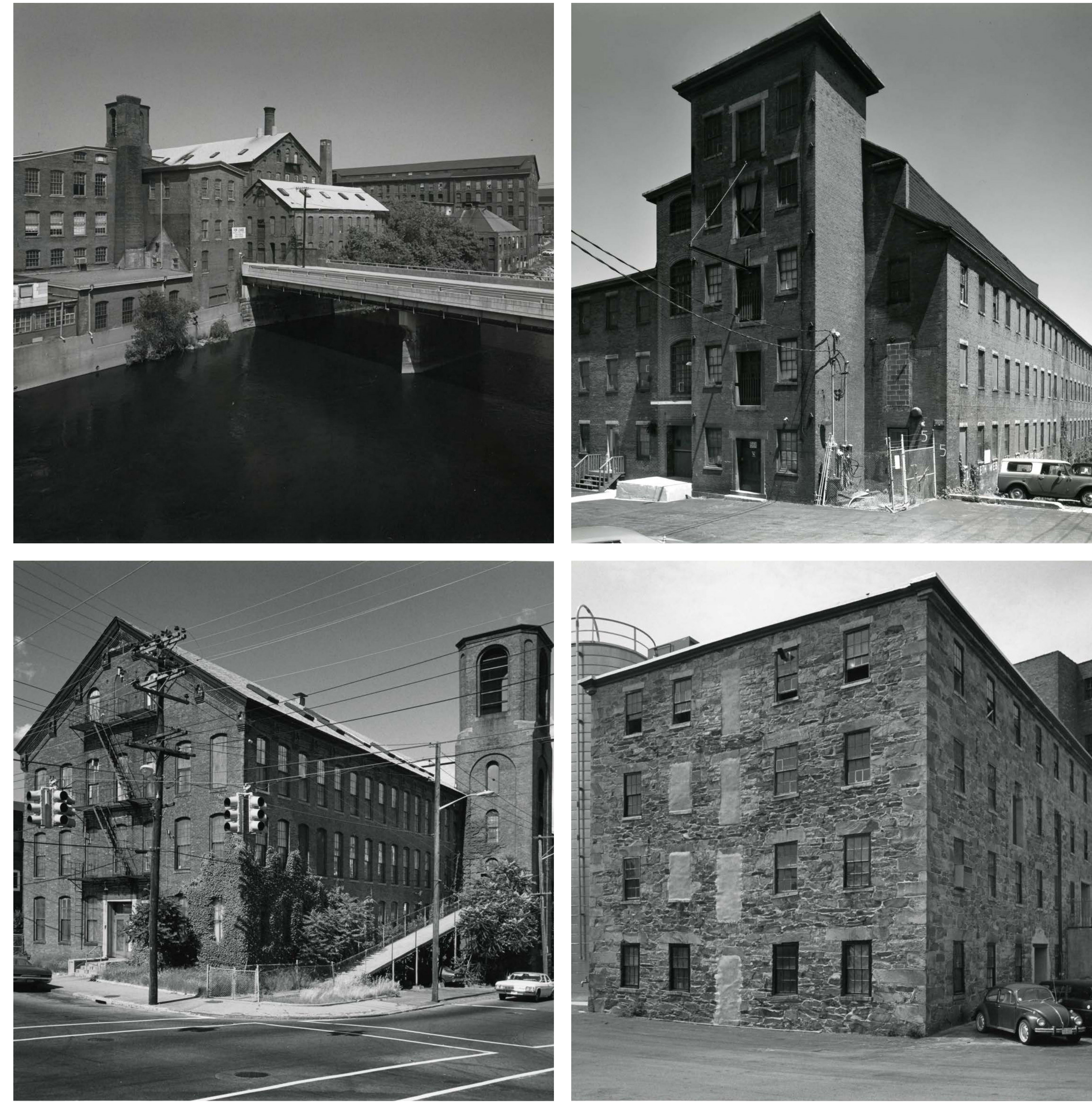
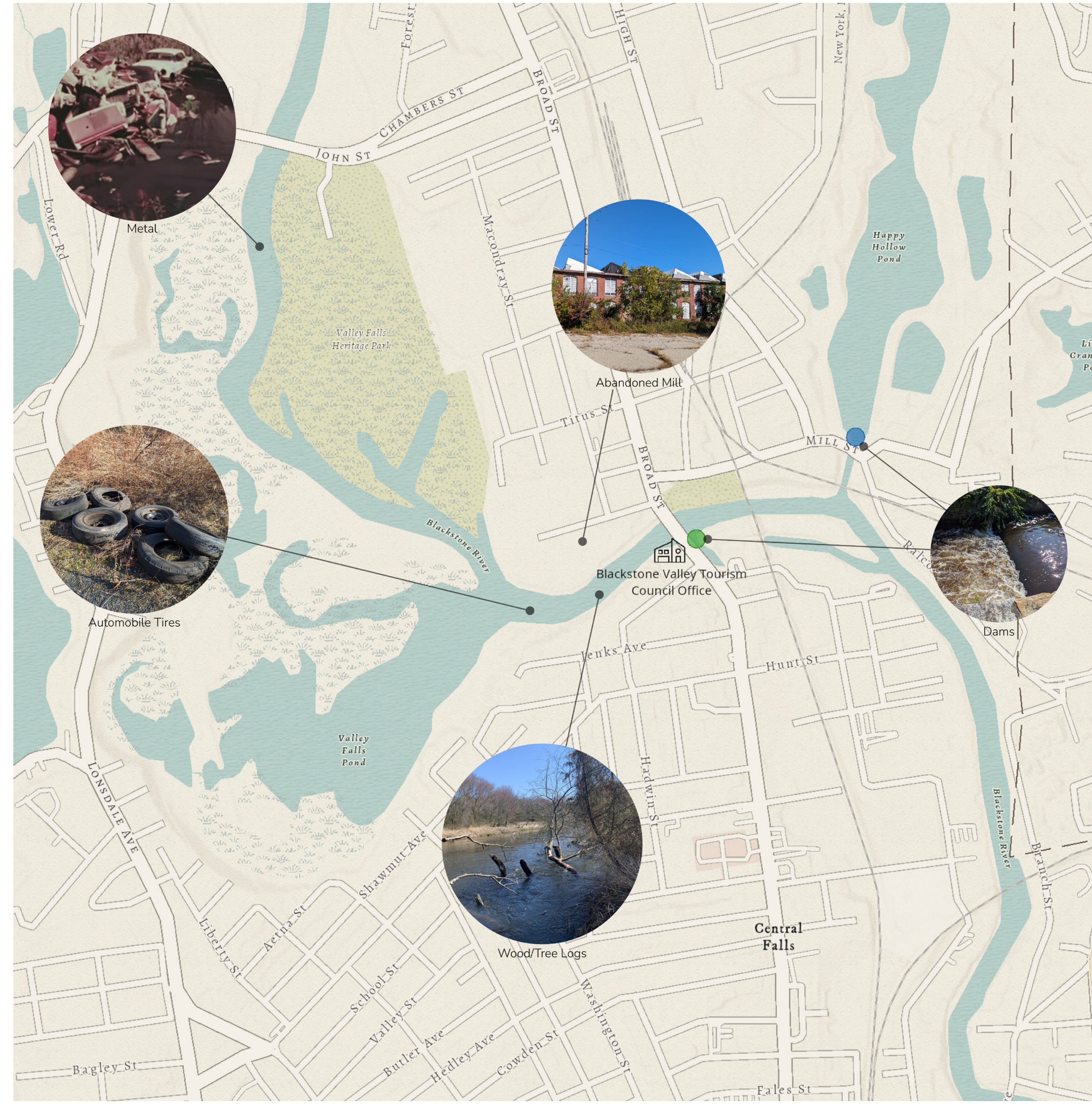

National Register of Historic Places, 1978.



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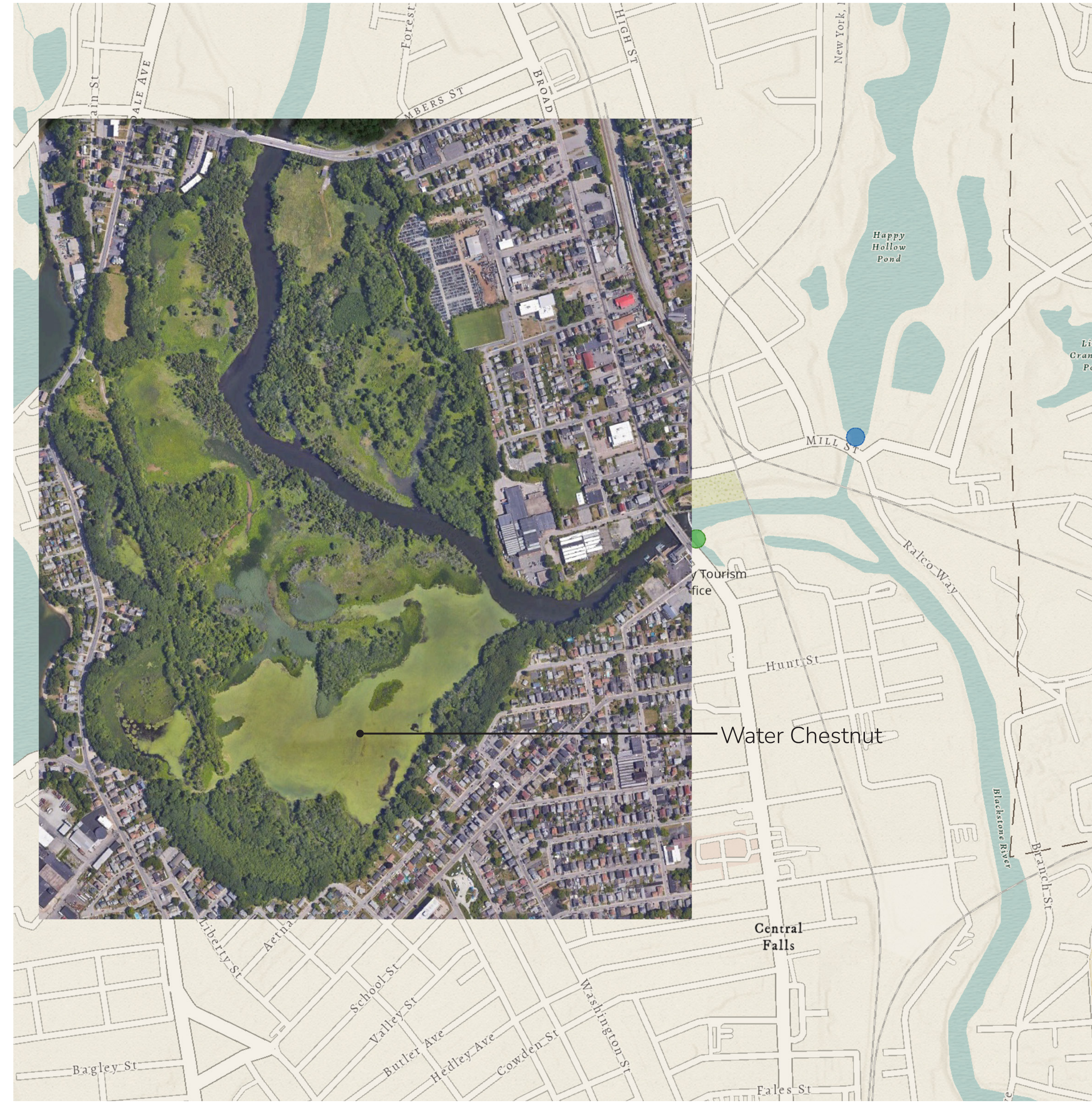

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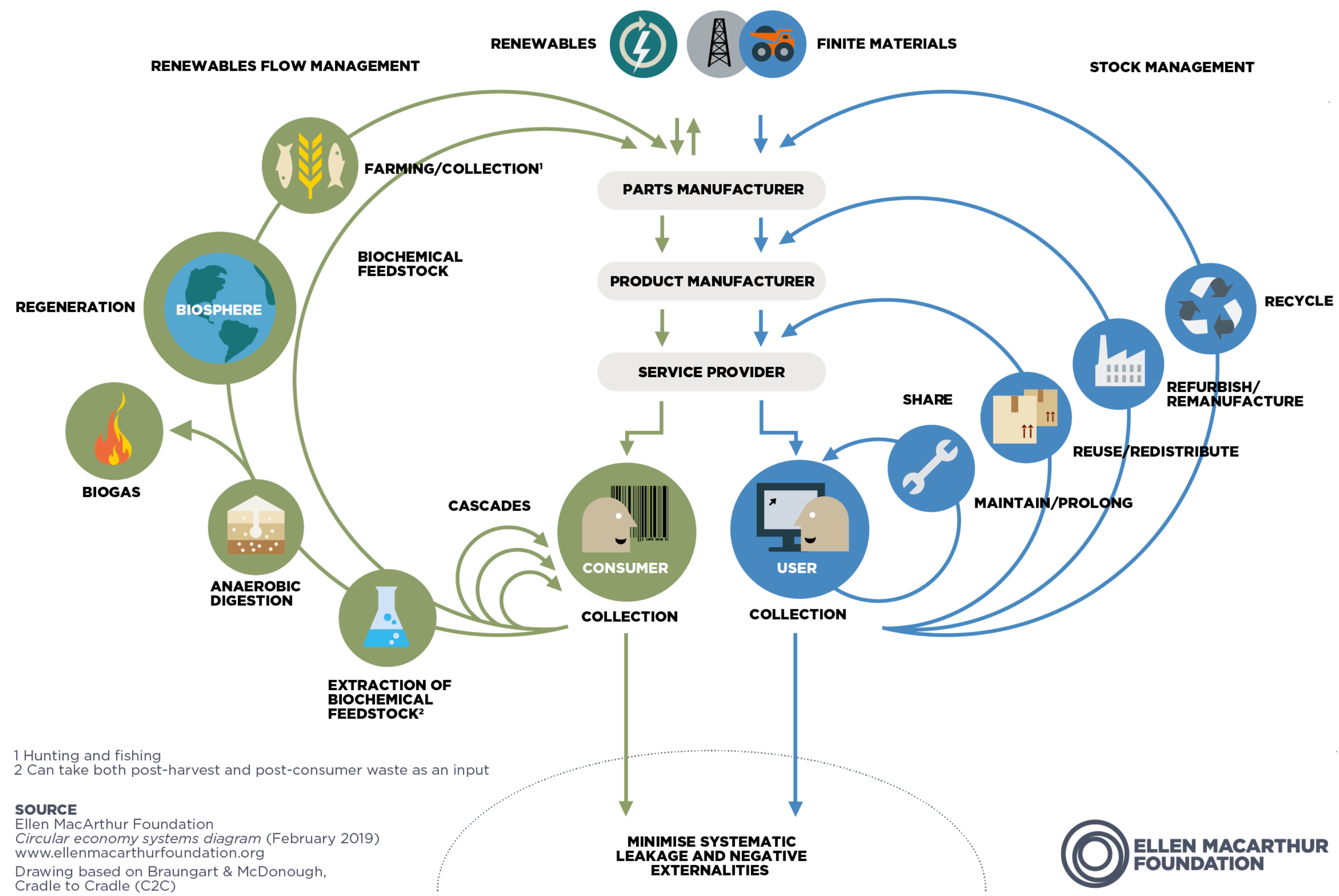
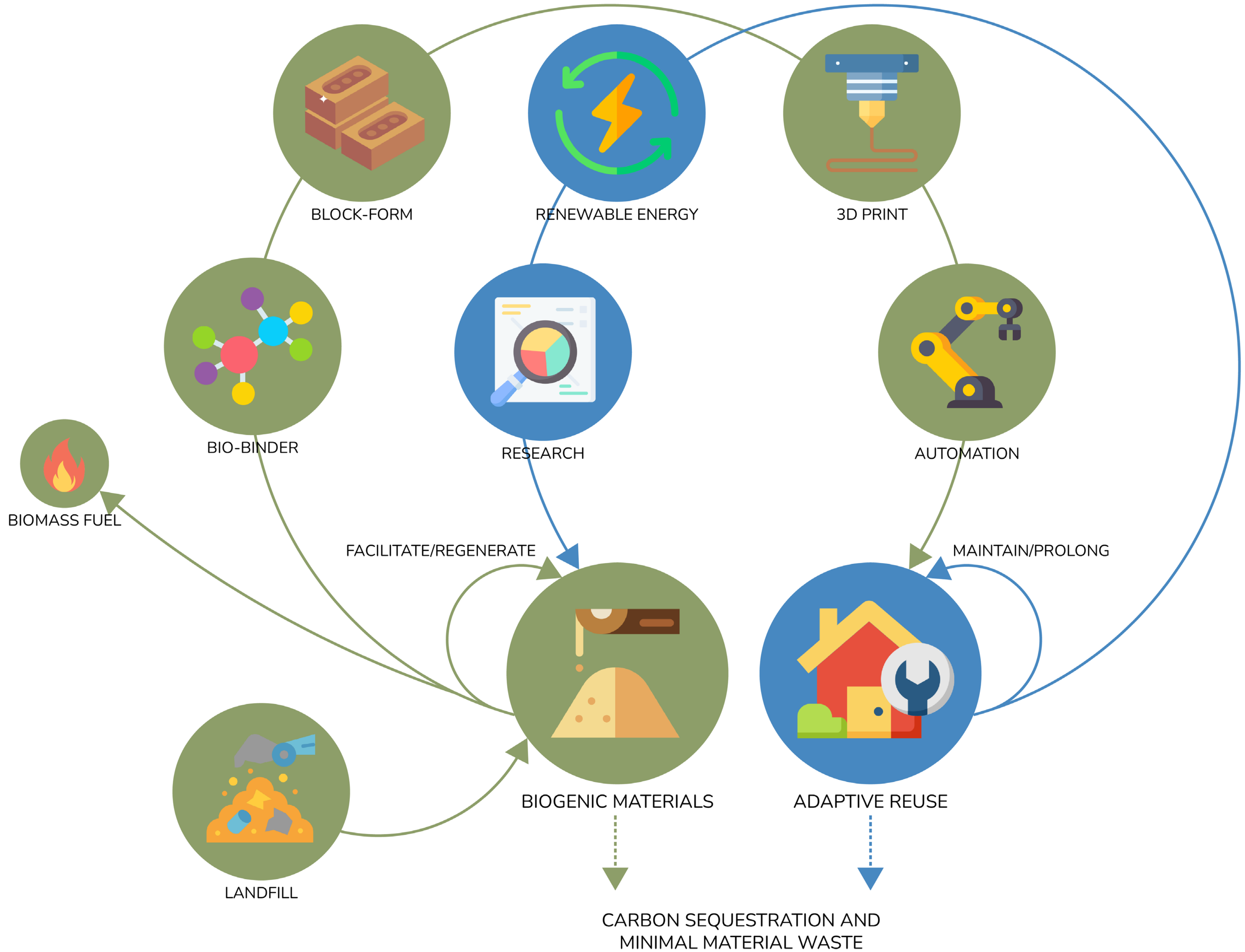
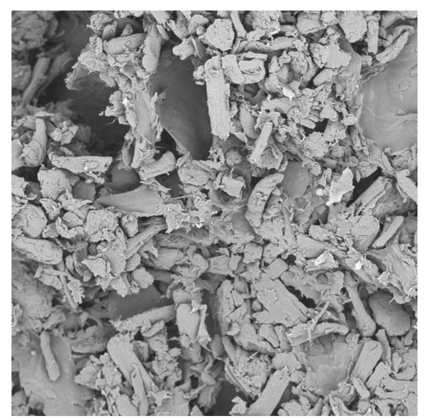

RENEWABLES
FINITE MATERIALS
RENEWABLES FLOW MANAGEMENT
STOCK MANAGEMENT
FARMING/COLLECTION¹
PARTS MANUFACTURER
BIOCHEMICAL FEEDSTOCK
PRODUCT MANUFACTURER
REGENERATION
BIOSPHERE
RECYCLE
SERVICE PROVIDER
REFURBISH/ REMANUFACTURE
SHARE
REUSE/REDISTRIBUTE
BIOGAS
CASCADES
MAINTAIN/PROLONG
CONSUMER
USER
ANAEROBIC DIGESTION
COLLECTION
COLLECTION
EXTRACTION OF BIOCHEMICAL FEEDSTOCK²
1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input
SOURCE
Ellen MacArthur Foundation
Circular economy systems diagram (February 2019)
www.ellenmacarthurfoundation.org
Drawing based on Braungart & McDonough, Cradle to Cradle (C2C)
MINIMISE SYSTEMATIC LEAKAGE AND NEGATIVE EXTERNALITIES
ELLEN MACARTHUR FOUNDATION

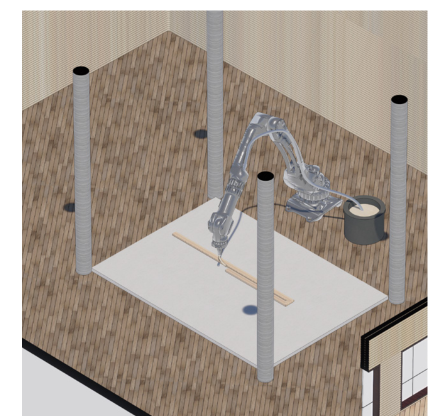

BLOCK-FORM
RENEWABLE ENERGY
3D PRINT
BIO-BINDER
RESEARCH
AUTOMATION
BIOMASS FUEL
FACILITATE/REGENERATE
MAINTAIN/PROLONG
LANDFILL
BIOGENIC MATERIALS
ADAPTIVE REUSE
CARBON SEQUESTRATION AND
MINIMAL MATERIAL WASTE

MATTER



MATERIAL

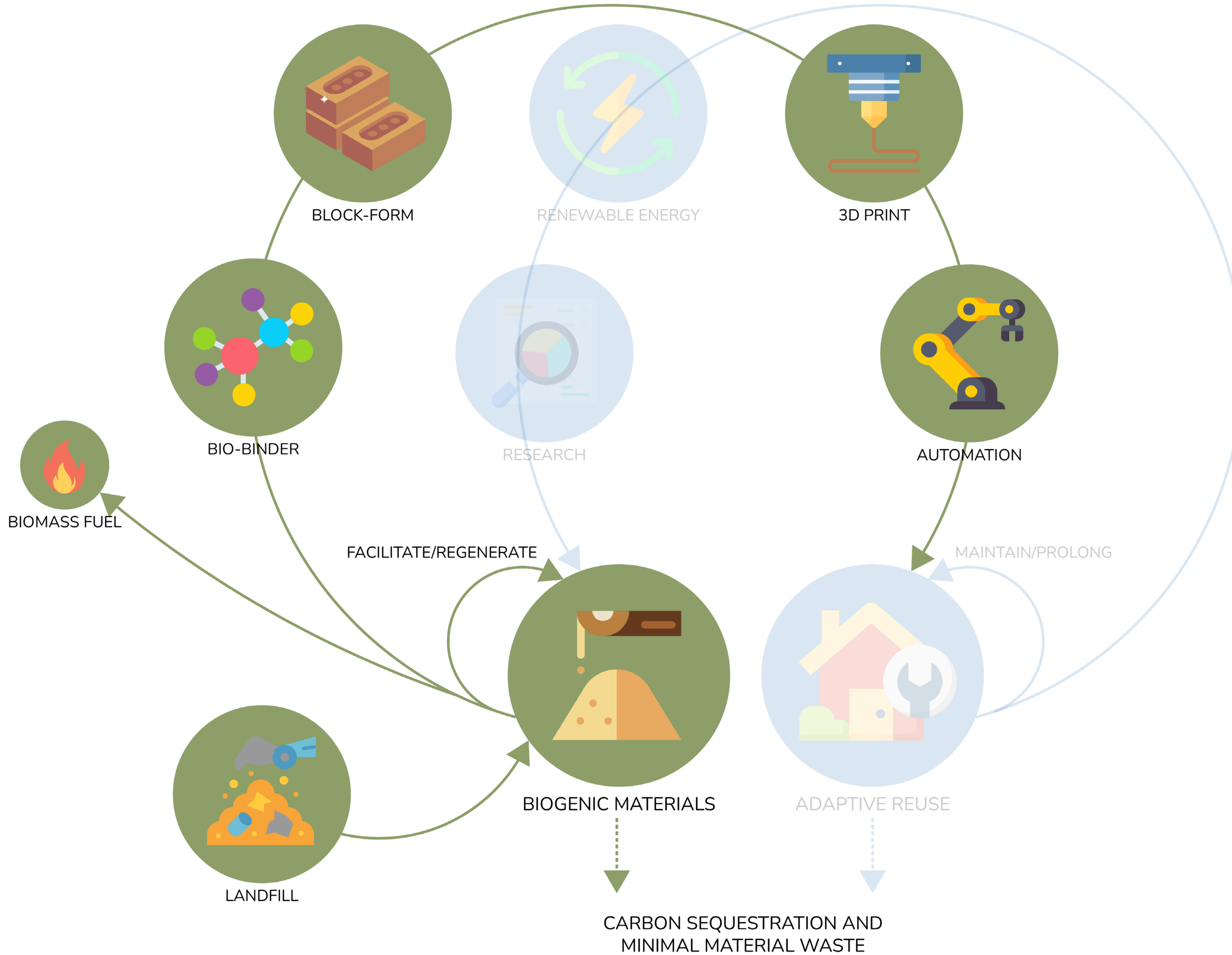
MATERIALITY



Picon, Antoine. *The Materiality of Architecture*. University of Minnesota Press, 2020. https://doi.org/10.5749/j.ctv1dwq1vq.

A Designer is a Scientist.

An interative process that is full of failures.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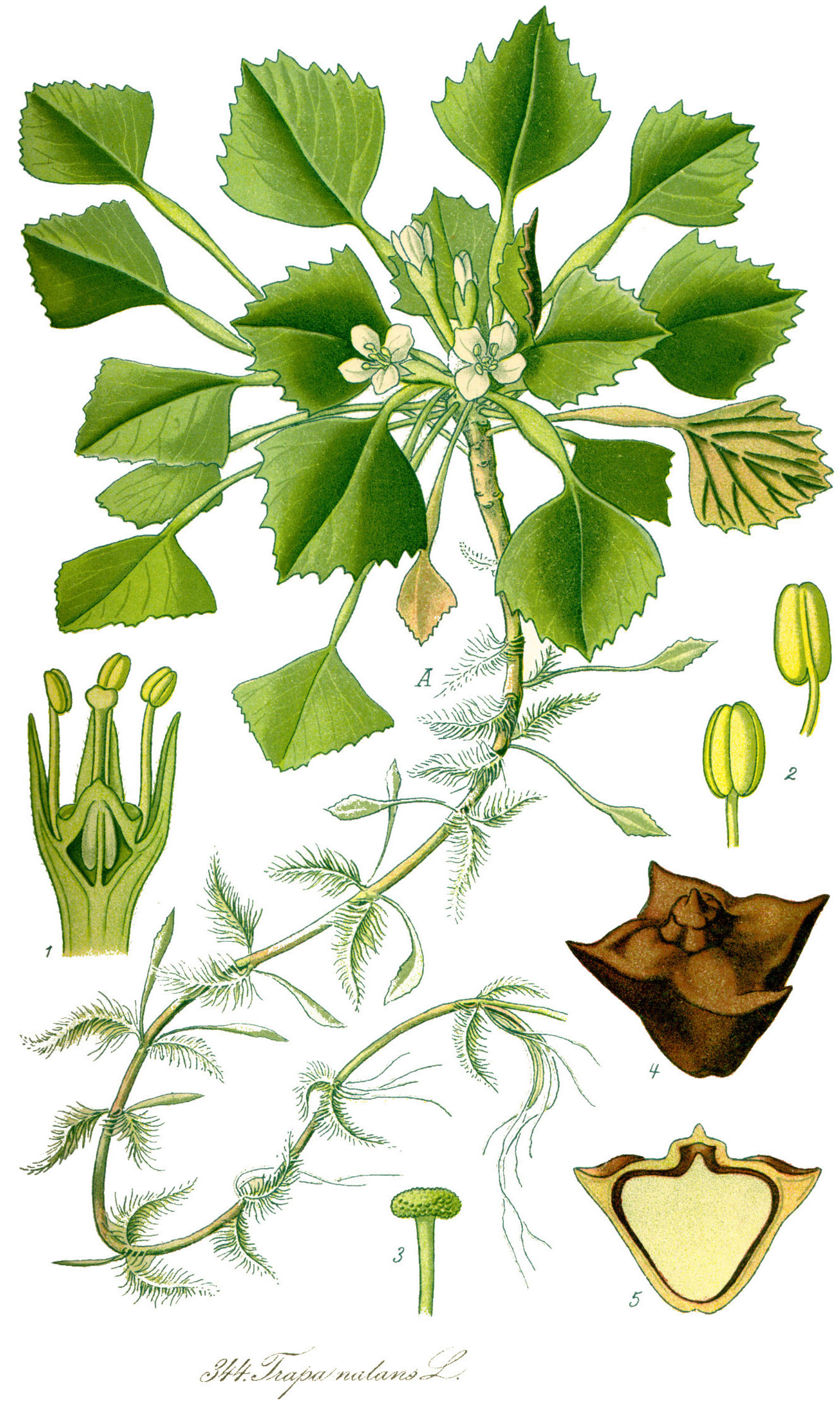
MATTER | MATERIAL | MATERIALITY



Water chestnut is a rooted floating aquatic plant with both floating and submerged leaves. Reproducing rapidly, water chestnut displaces native species and provides little to none nutritional and habitat values to fish and other aquatic animals. The polluted and toxic breeding ground of the Blackstone River also prevents it from being further processed for food or fertilizers, resulting in an enormous amount of landfill associated with labor and resources. However, the main components of chestnut shell are Klason lignin and carbohydrates, which represent 41.7% and 41.6% oven-dry basis. Specifically, cellulose is the predominant carbohydrate, reaching up to rates of 28.4% such as glucose. This is a similar component profile to the tree bark, making it a potential source for wood/sawdust based building materials.

GRINDING

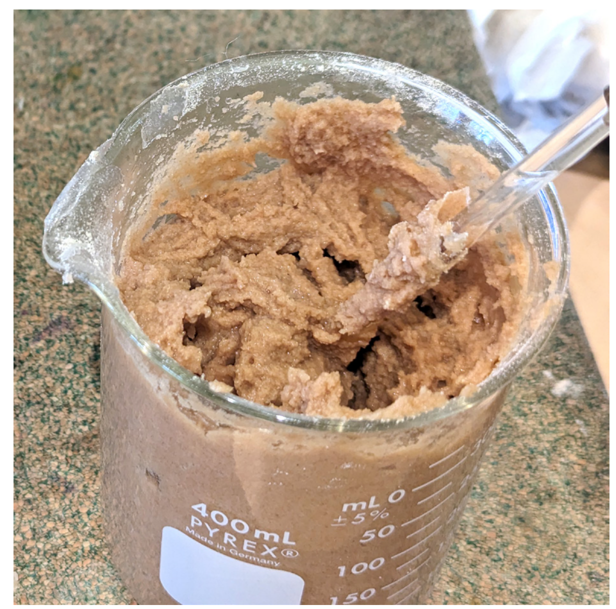
Water chestnut and sawdust are ground to different mesh sizes to produce material mixes with varying densities.

HEATING

Agar and glycerin are heated with water to undergo gelation, creating the polymer binder.

MIXING

FORMING

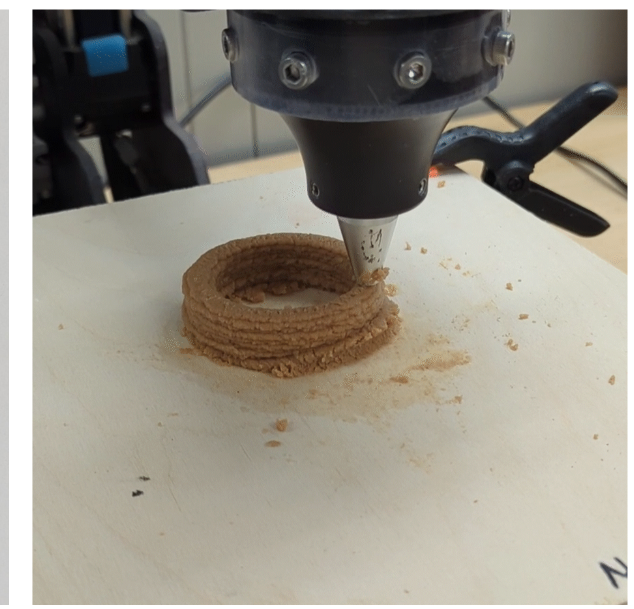


MIXING

The binder is mixed with the fiber-based powder to form a paste-like texture that is easy to shape and manipulate.

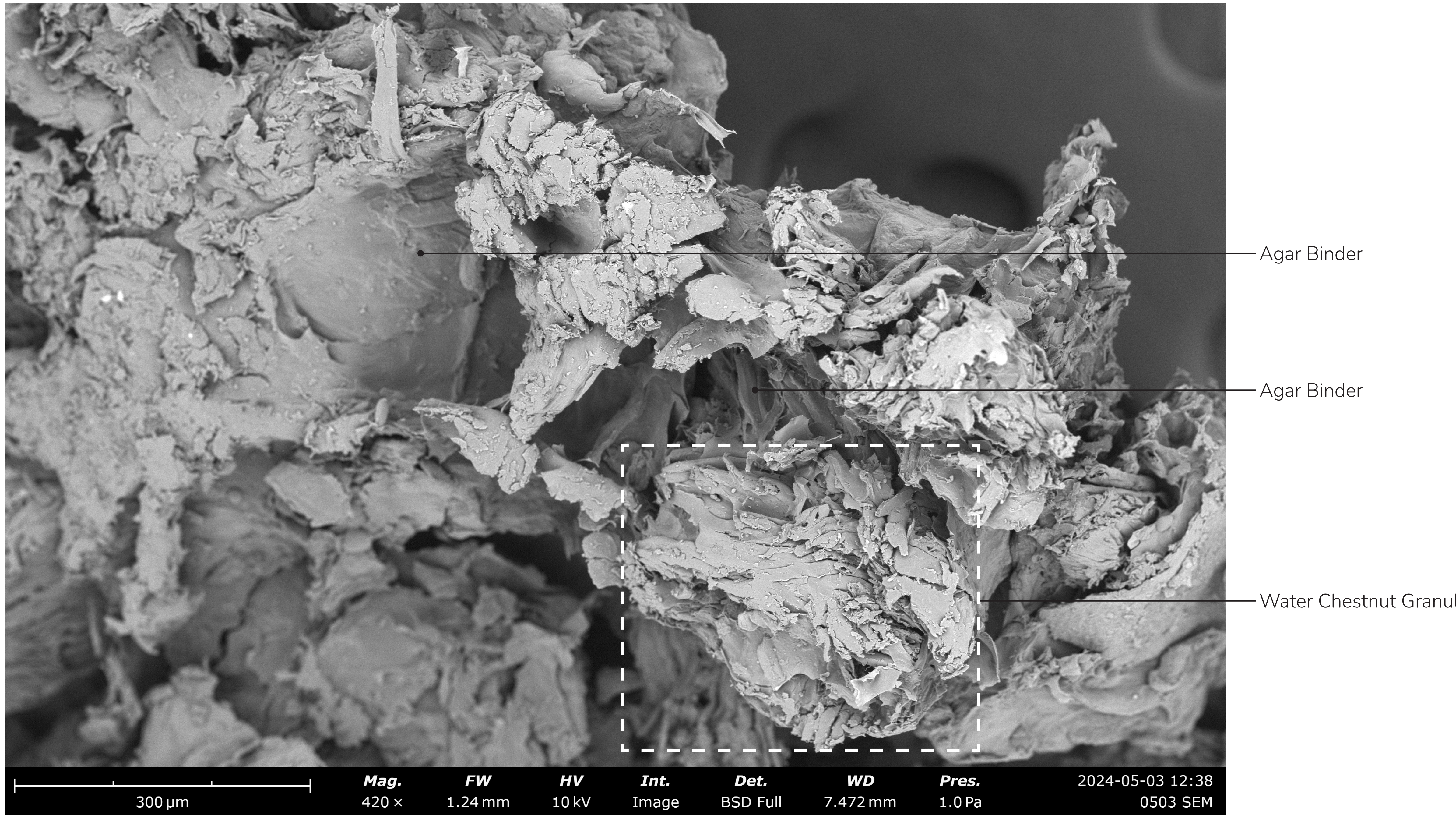
SYRINGE TEST

The pastes can be pressed into molds to create various shapes or injected with a syringe to test their viscosity.

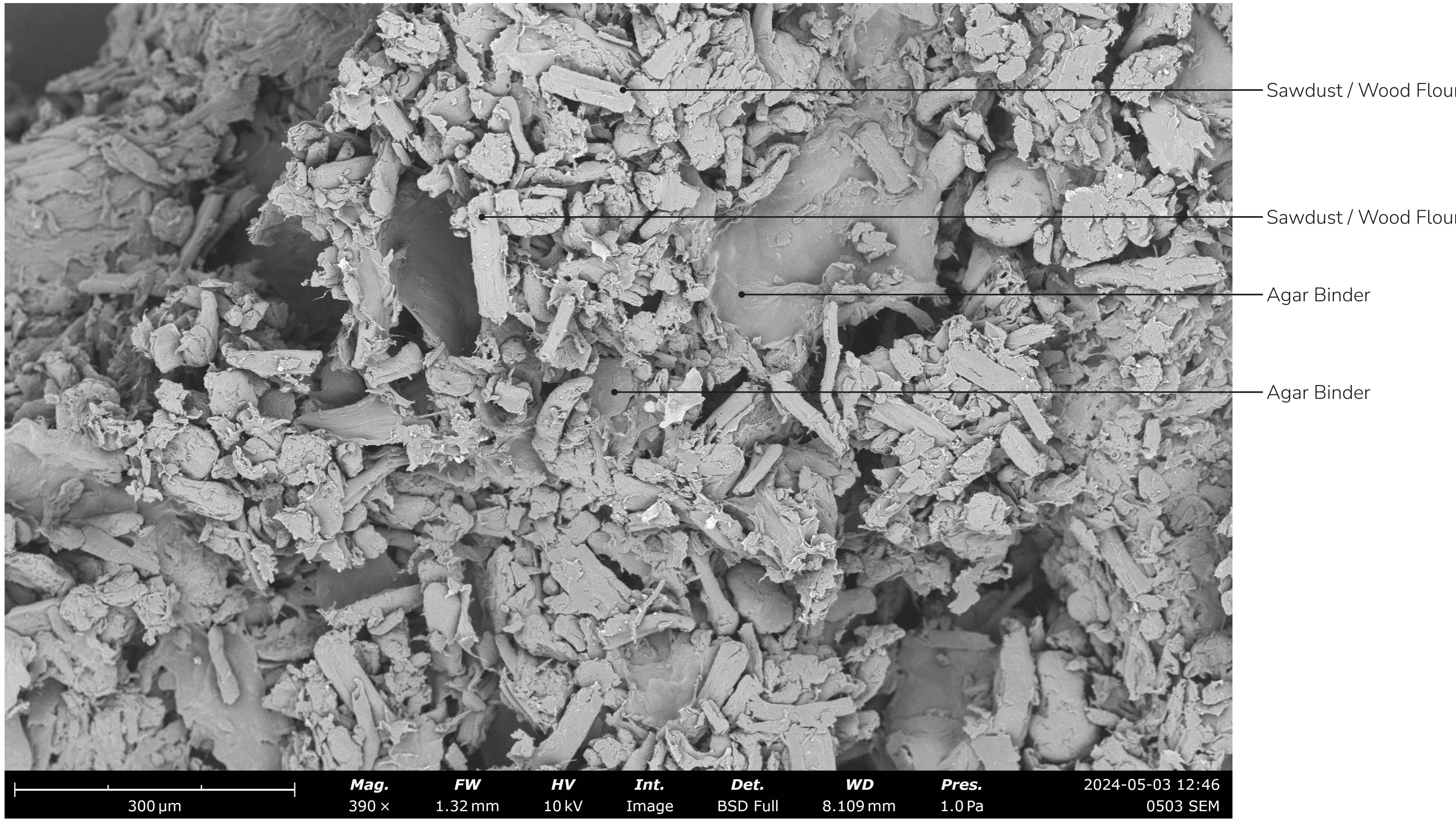


3D PRINTING

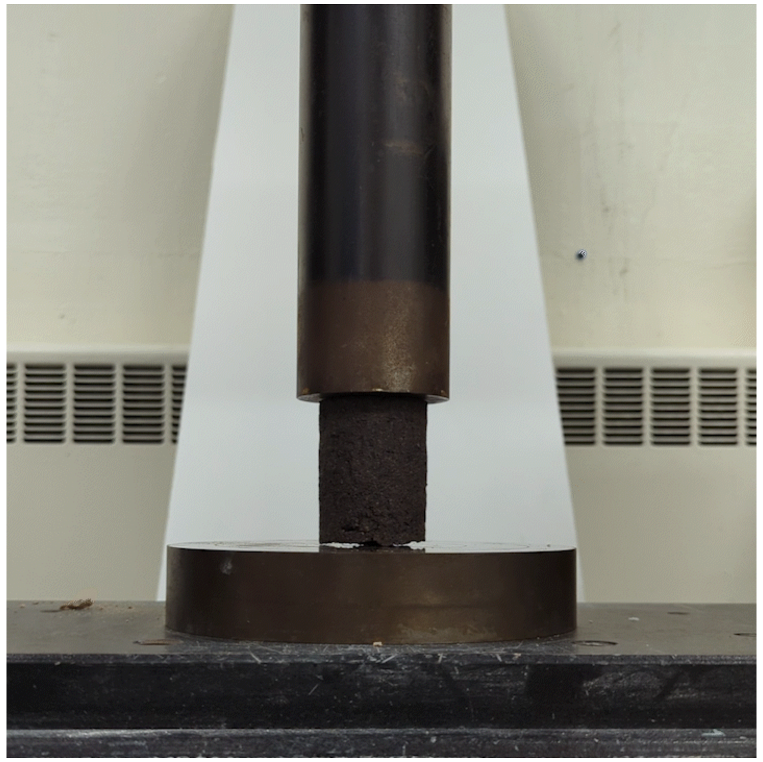
With the appropriate viscosity, the material can be loaded into the paste extruder for 3D printing.



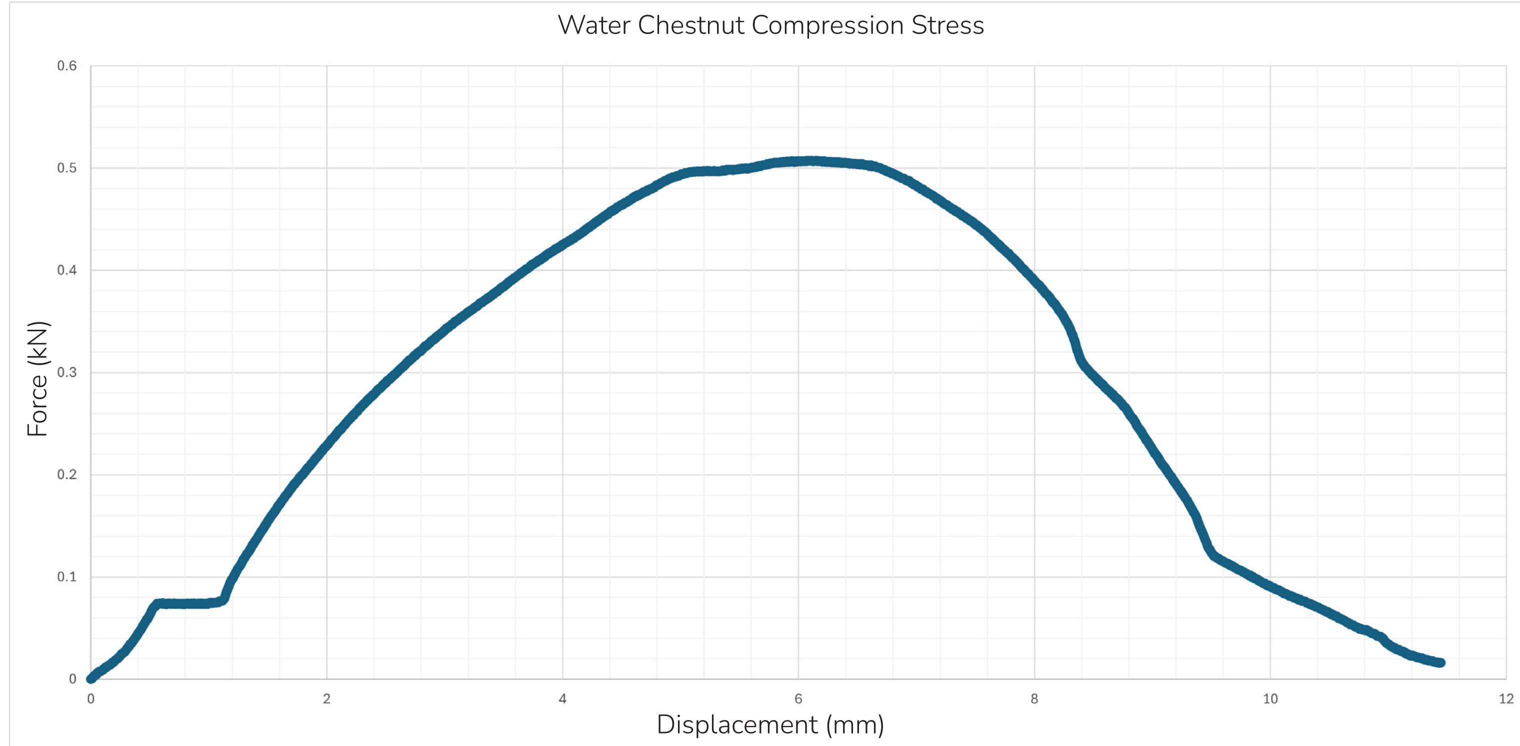
SEM Image of Water Chestnut Mix, May 2024.



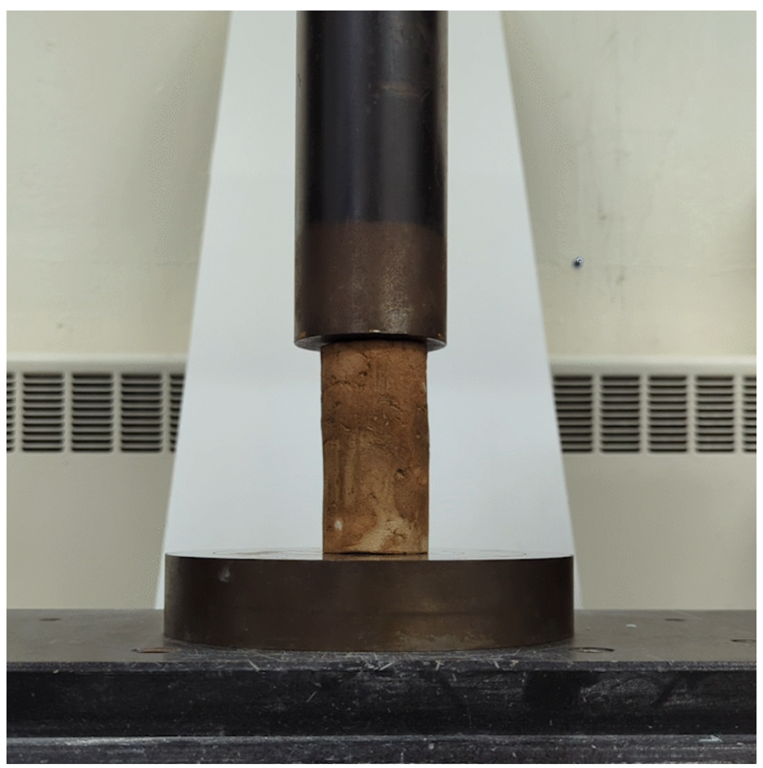
SEM Image of Sawdust Mix, May 2024.



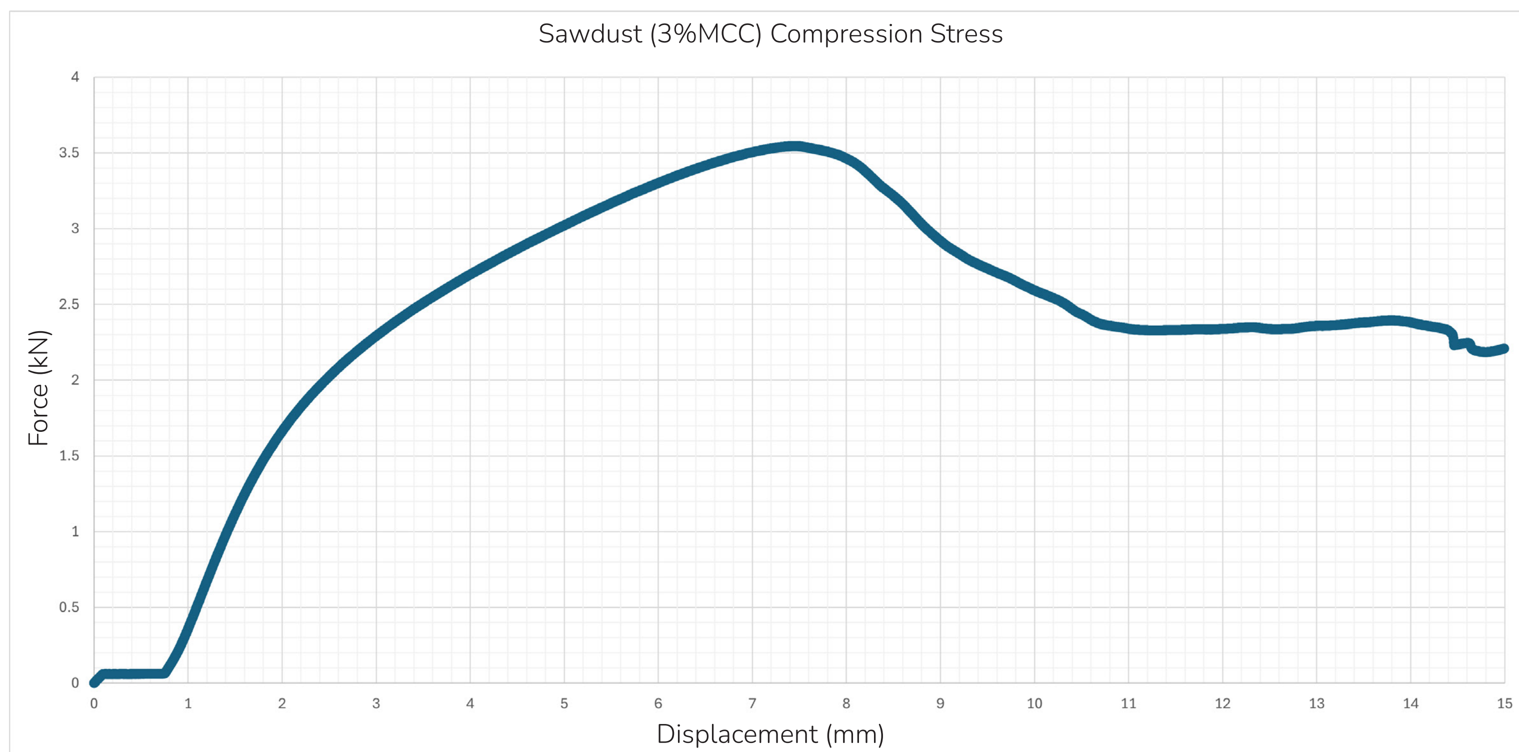
WATER CHESTNUT
Low Density Sample



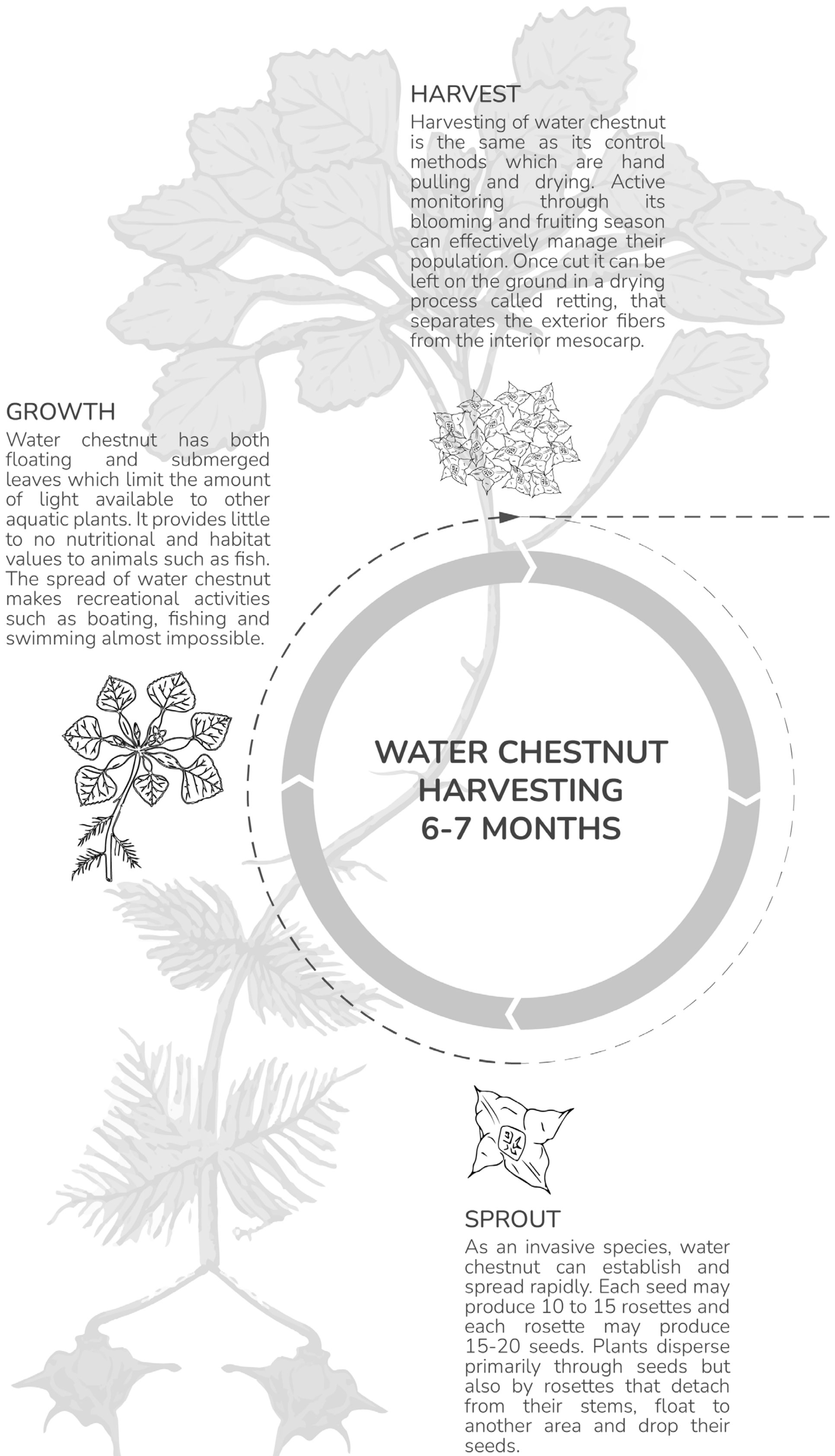
Maximum Force = 0.5075 kN = 114.09 lbs
Area = 2.4 in²
P = 47.5 psi* = 6840 psf



SAWDUST
High Density Sample



Maximum Force = 3.5458 kN = 797.13 lbs
Area = 2.4 in²
P = 332.1 psi* = 47827.8 psf



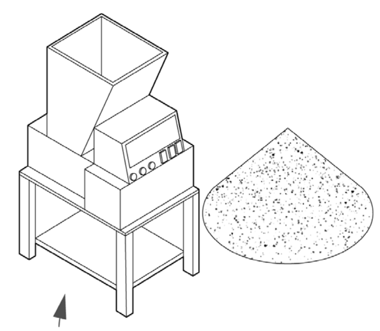
HARVEST
Harvesting of water chestnut is the same as its control methods which are hand pulling and drying. Active monitoring through its blooming and fruiting season can effectively manage their population. Once cut it can be left on the ground in a drying process called retting, that separates the exterior fibers from the interior mesocarp.

GROWTH
Water chestnut has both floating and submerged leaves which limit the amount of light available to other aquatic plants. It provides little to no nutritional and habitat values to animals such as fish. The spread of water chestnut makes recreational activities such as boating, fishing and swimming almost impossible.

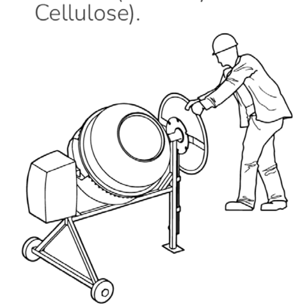
SPROUT
As an invasive species, water chestnut can establish and spread rapidly. Each seed may produce 10 to 15 rosettes and each rosette may produce 15-20 seeds. Plants disperse primarily through seeds but also by rosettes that detach from their stems, float to another area and drop their seeds.

WATER CHESTNUT MANUFACTURING

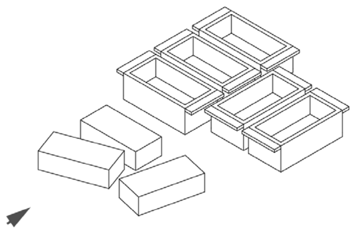
GRINDING
Water chestnut seeds are milled into granules and powders for mixing.

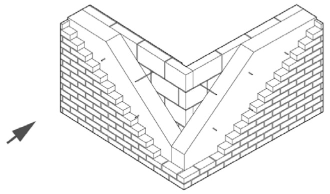


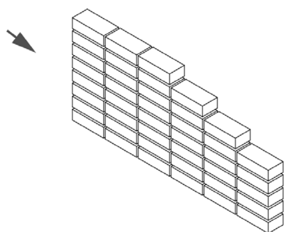
MIXING
Water chestnut shell consists of 80% of lignin and carbohydrates. After being ground, it is mixed with glycerin, agar, and MCC (Microcrystalline Cellulose).

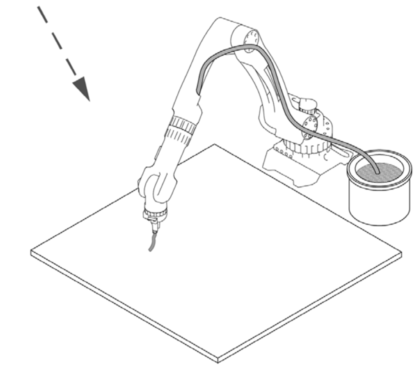


FORMING
The water chestnut-based paste can be pressed into molds and formed into bricks. The modular-sized bricks air dry over 5-7 days, depending on temperature and humidity.

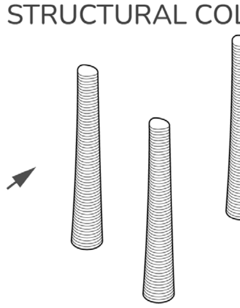


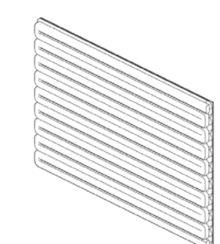
BRICK VENEER


STACKED WALL


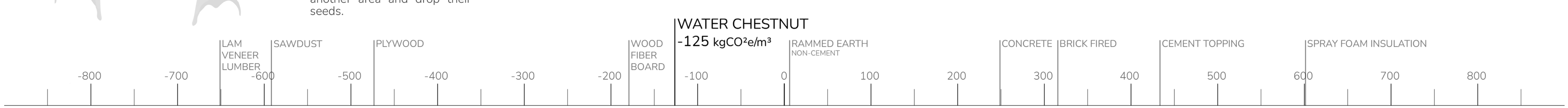


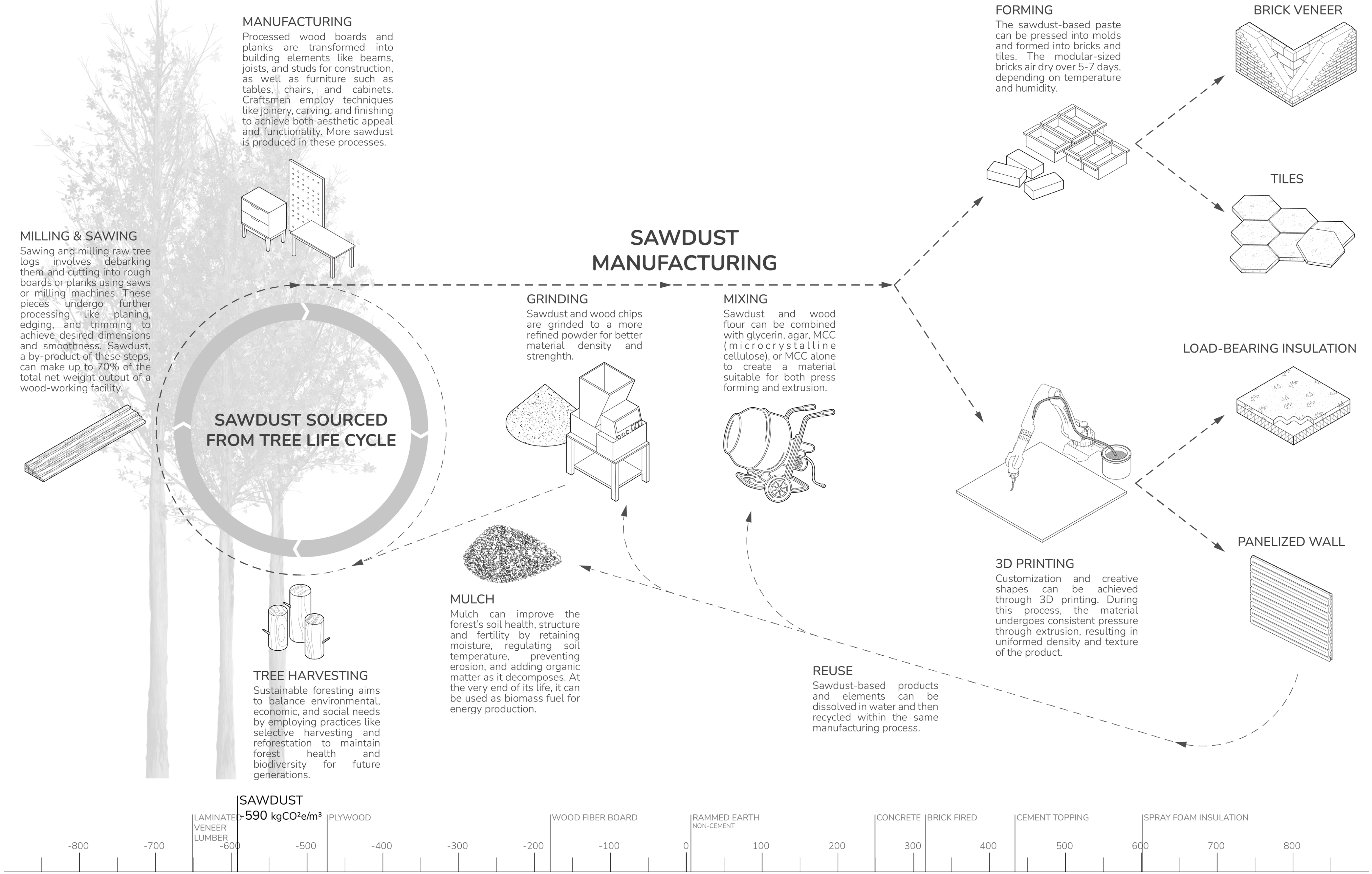
3D PRINTING
The water chestnut-based paste is extrudable and highly capable of customization to create different architectural forms and systems.

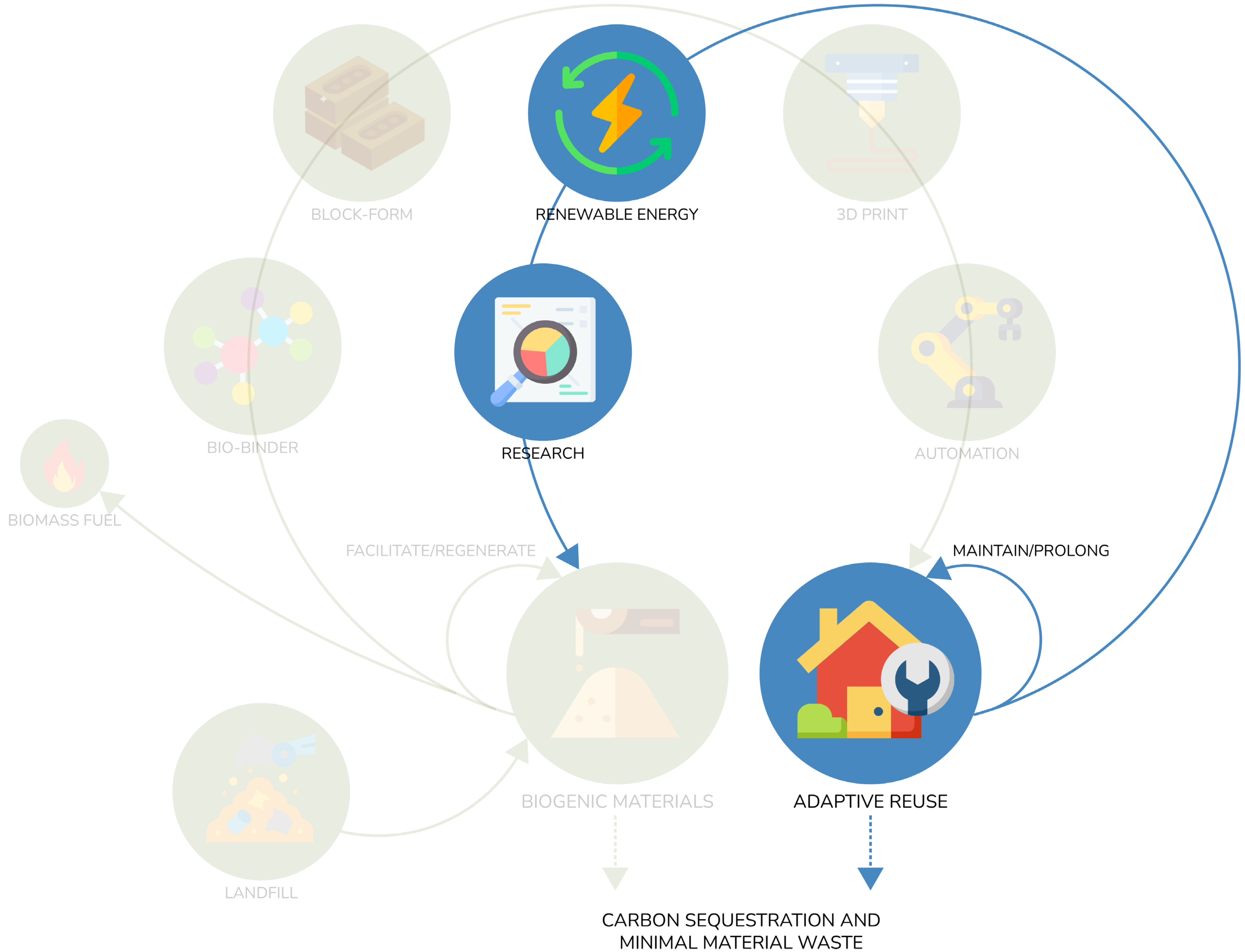
STRUCTURAL COLUMN


PANELIZED WALL


REUSE
Upon appropriate disassembly and sorting, water chestnut-based elements can be soaked in water re-mixed with more polymer binders.




MANUFACTURING
Processed wood boards and planks are transformed into building elements like beams, joists, and studs for construction, as well as furniture such as tables, chairs, and cabinets. Craftsmen employ techniques like joinery, carving, and finishing to achieve both aesthetic appeal and functionality. More sawdust is produced in these processes.
MILLING & SAWING
Sawing and milling raw tree logs involves debarking them and cutting into rough boards or planks using saws or milling machines. These pieces undergo further processing like planing, edging, and trimming to achieve desired dimensions and smoothness. Sawdust, a by-product of these steps, can make up to 70% of the total net weight output of a wood-working facility.
SAWDUST SOURCED FROM TREE LIFE CYCLE
TREE HARVESTING
Sustainable foresting aims to balance environmental, economic, and social needs by employing practices like selective harvesting and reforestation to maintain forest health and biodiversity for future generations.
SAWDUST MANUFACTURING
GRINDING
Sawdust and wood chips are grinded to a more refined powder for better material density and strenghth.
MIXING
Sawdust and wood flour can be combined with glycerin, agar, MCC (microcrystalline cellulose), or MCC alone to create a material suitable for both press forming and extrusion.
MULCH
Mulch can improve the forest's soil health, structure and fertility by retaining moisture, regulating soil temperature, preventing erosion, and adding organic matter as it decomposes. At the very end of its life, it can be used as biomass fuel for energy production.
REUSE
Sawdust-based products and elements can be dissolved in water and then recycled within the same manufacturing process.
FORMING
The sawdust-based paste can be pressed into molds and formed into bricks and tiles. The modular-sized bricks air dry over 5-7 days, depending on temperature and humidity.
BRICK VENEER
TILES
3D PRINTING
Customization and creative shapes can be achieved through 3D printing. During this process, the material undergoes consistent pressure through extrusion, resulting in uniformed density and texture of the product.
LOAD-BEARING INSULATION
PANELIZED WALL
SAWDUST
-590 kgCO²e/m³
LAMINATED VENEER LUMBER
PLYWOOD
WOOD FIBER BOARD
RAMMED EARTH
NON-CEMENT
CONCRETE
BRICK FIRED
CEMENT TOPPING
SPRAY FOAM INSULATION
-800
-700
-600
-500
-400
-300
-200
-100
0
100
200
300
400
500
600
700
800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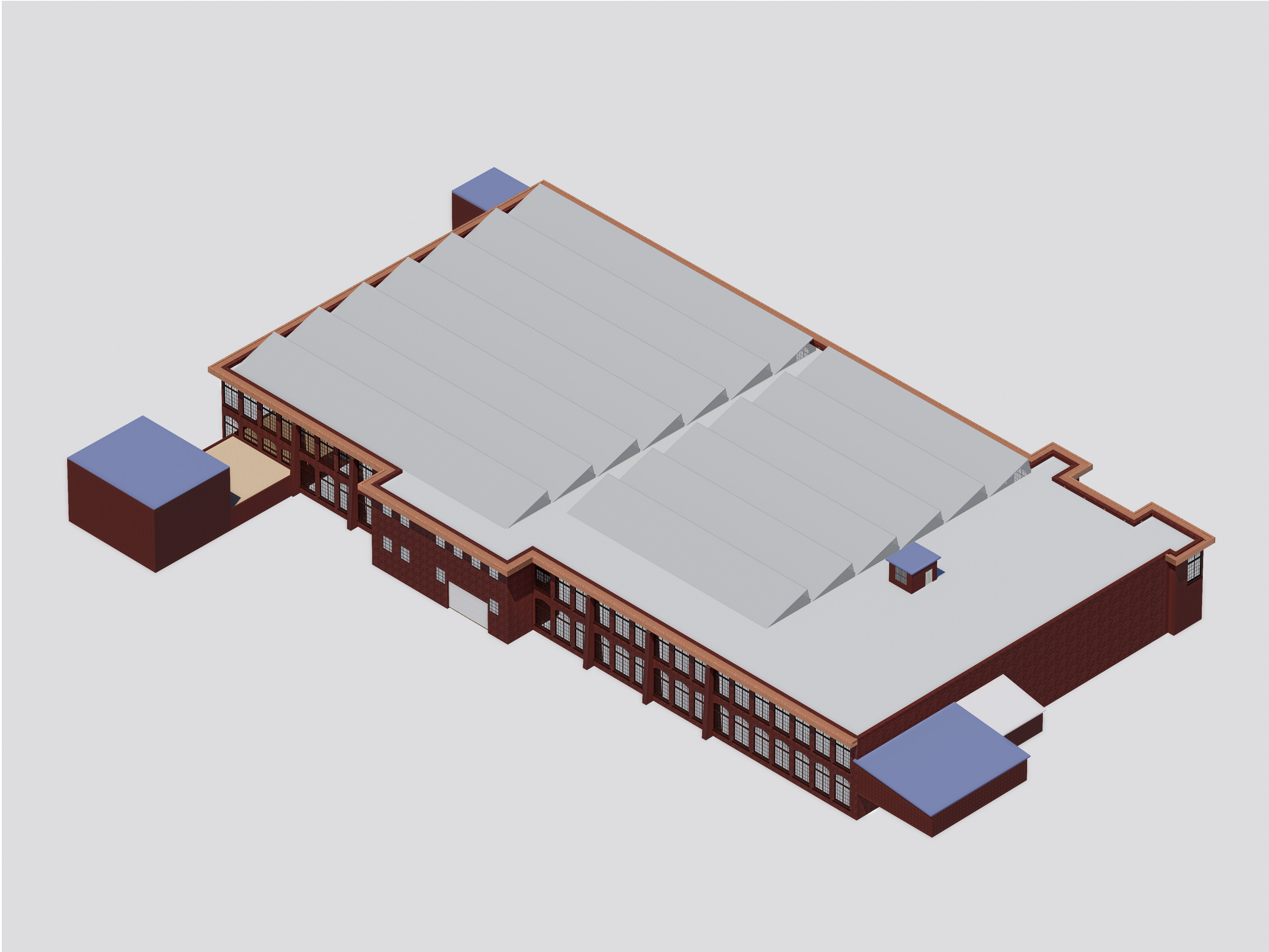
FACILITATE/REGENERATE
MAINTAIN/PROLONG
LANDFILL
BIOGENIC MATERIALS
ADAPTIVE REUSE
CARBON SEQUESTRATION AND
MINIMAL MATERIAL WASTE

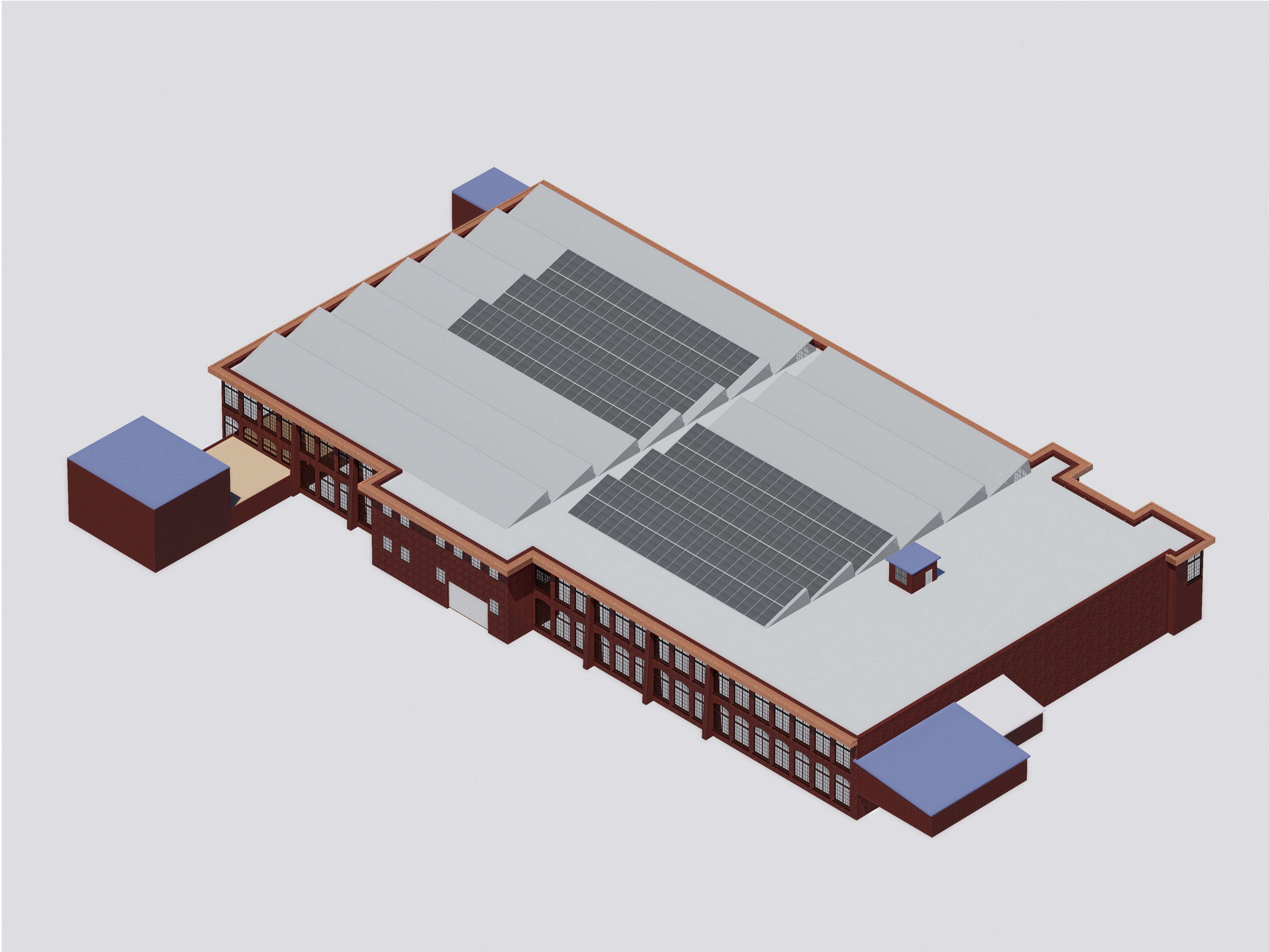
- 1902-1908 Operated by the Naushon Company.
- 1909-1914 Tilton Mills.
- 1915-1928 Hansahoe Manunfacturing Company.
- 1928-1937 Worcester Textile Company.
- 1937-1959 Sidney Blumenthal, Inc.
- 2016 The property was listed in the National Register of Historic Places.

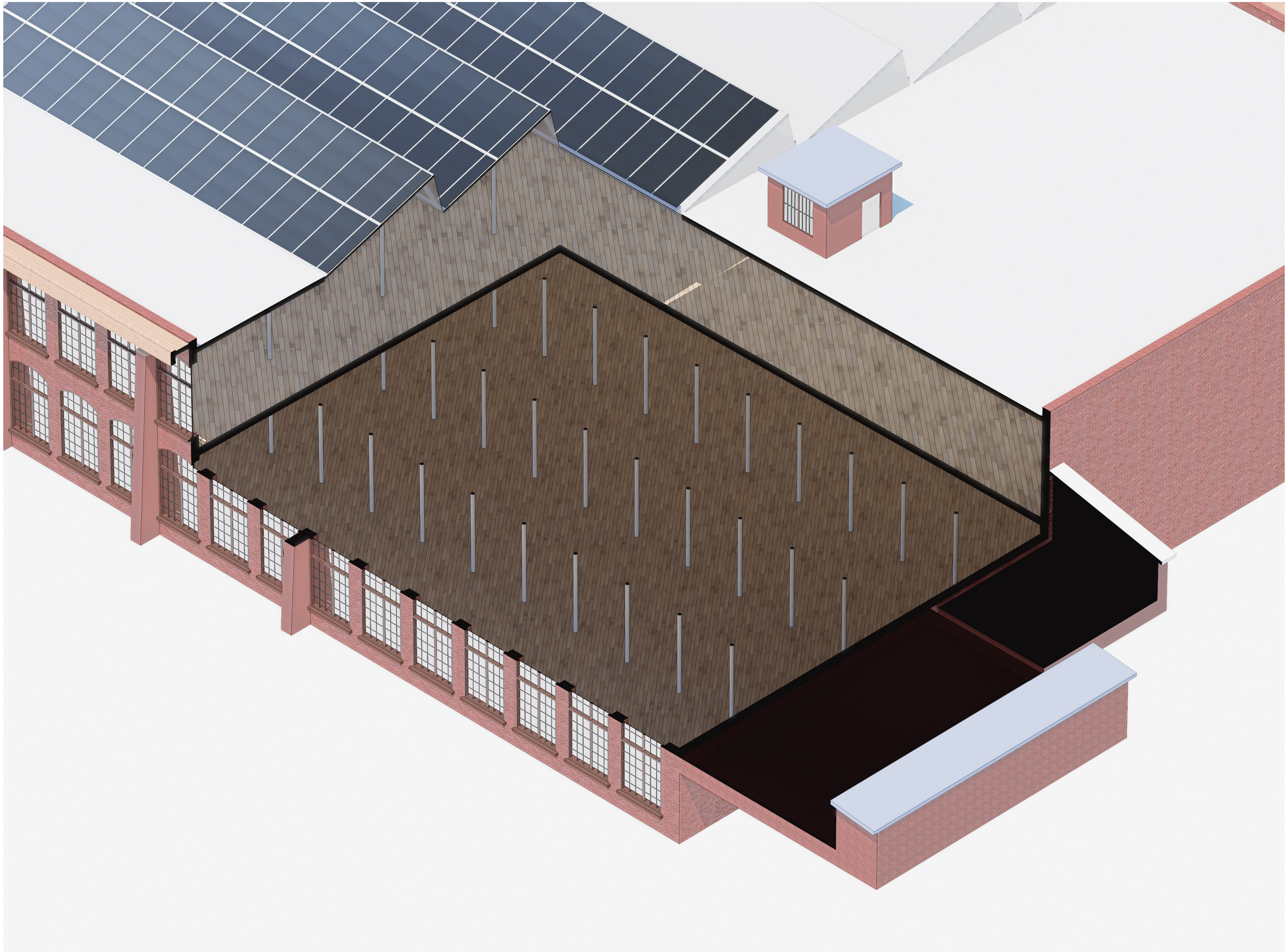
Adaptive Reuse

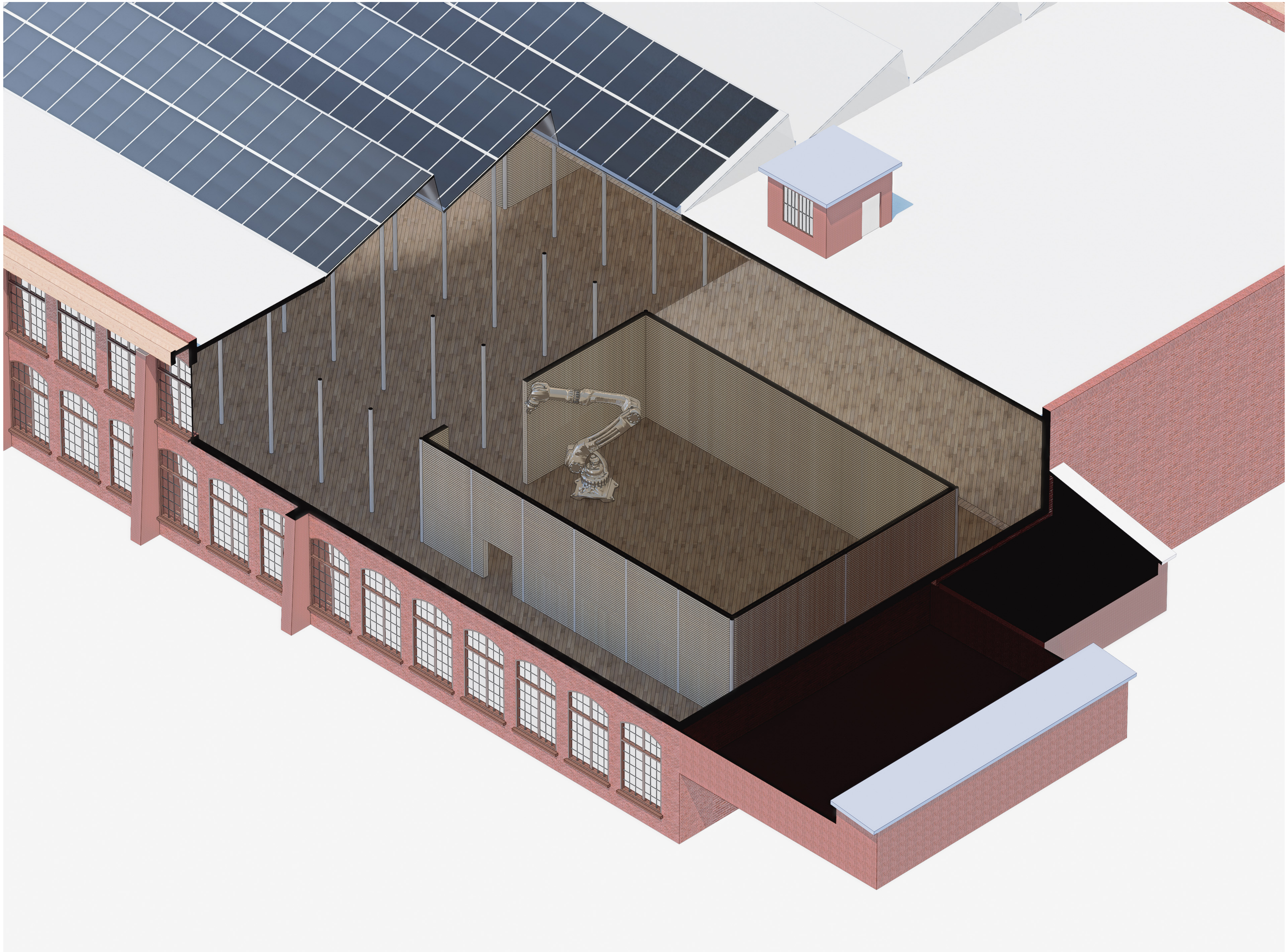
One of the most sustainable building methods today. By retaining the integral structure while retrofitting the building to help it serve a new function, adaptive reuse requires less material than new construction and diverts waste from the landfill. In addition, it helps preserve the historical and social fabric of a neighborhood and community.

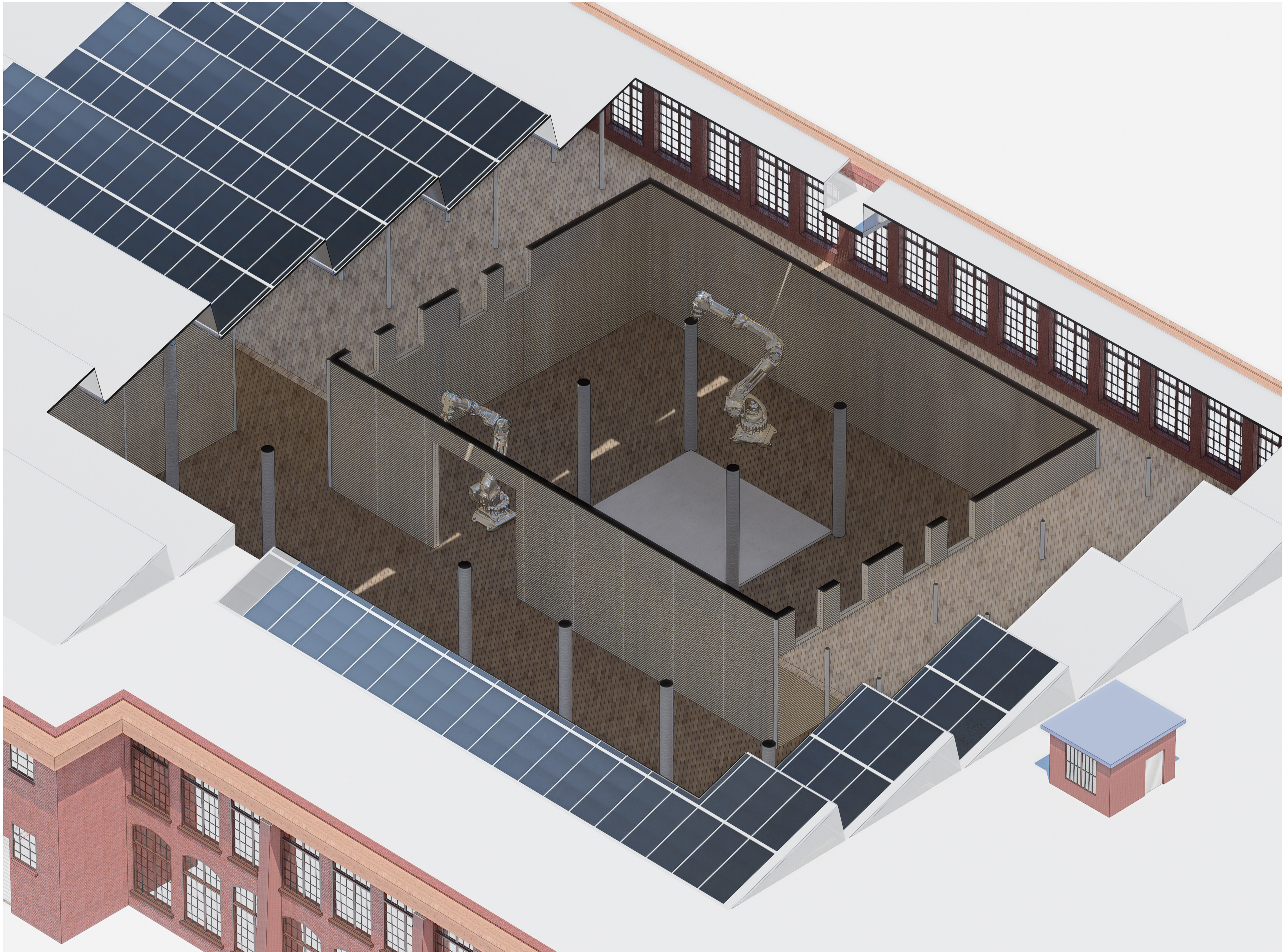
This thesis proposes a non-conventional renovation logic in which the main program (3D print manufacturing factory) begins simultaneously as the renovation process.

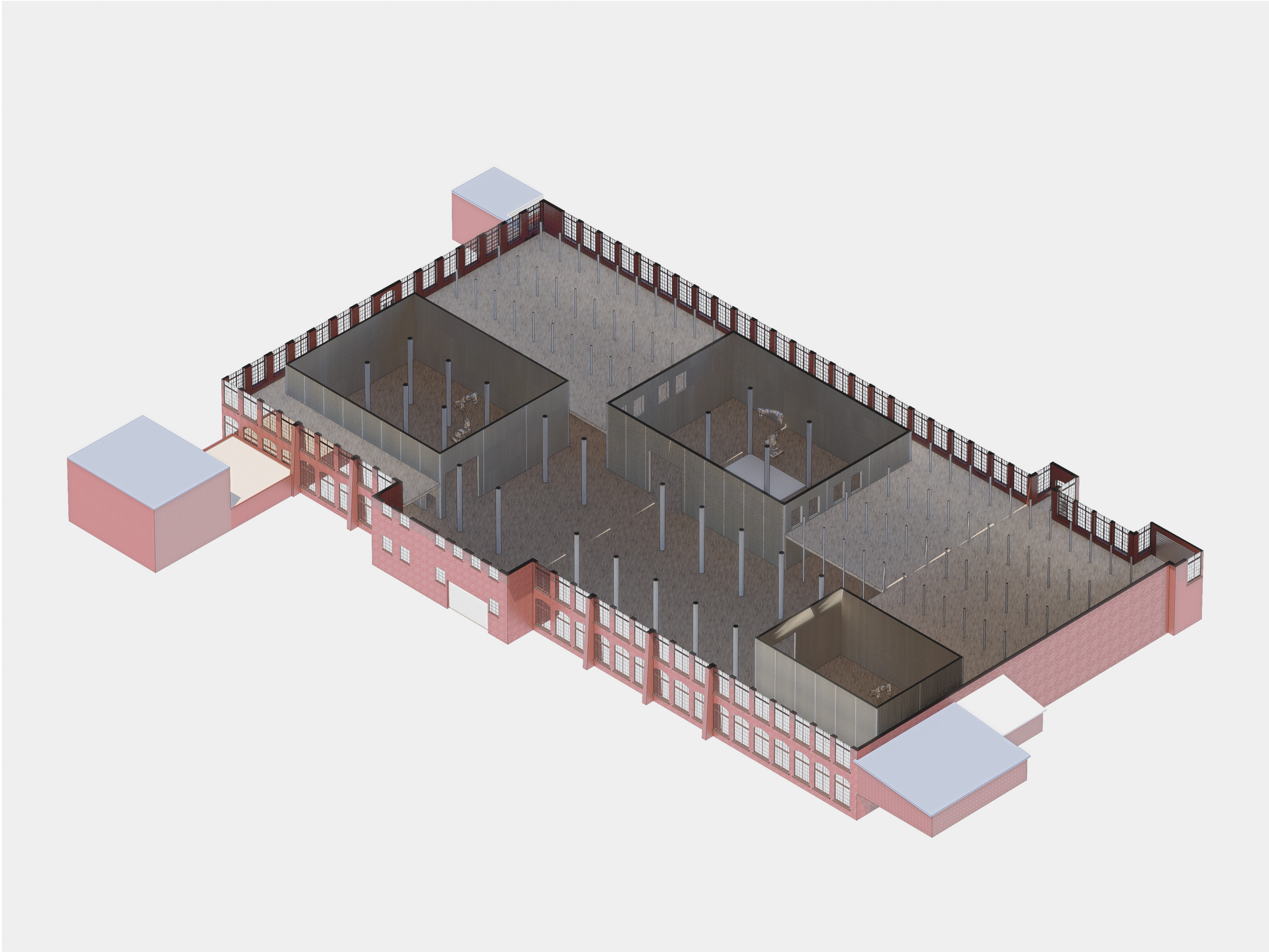


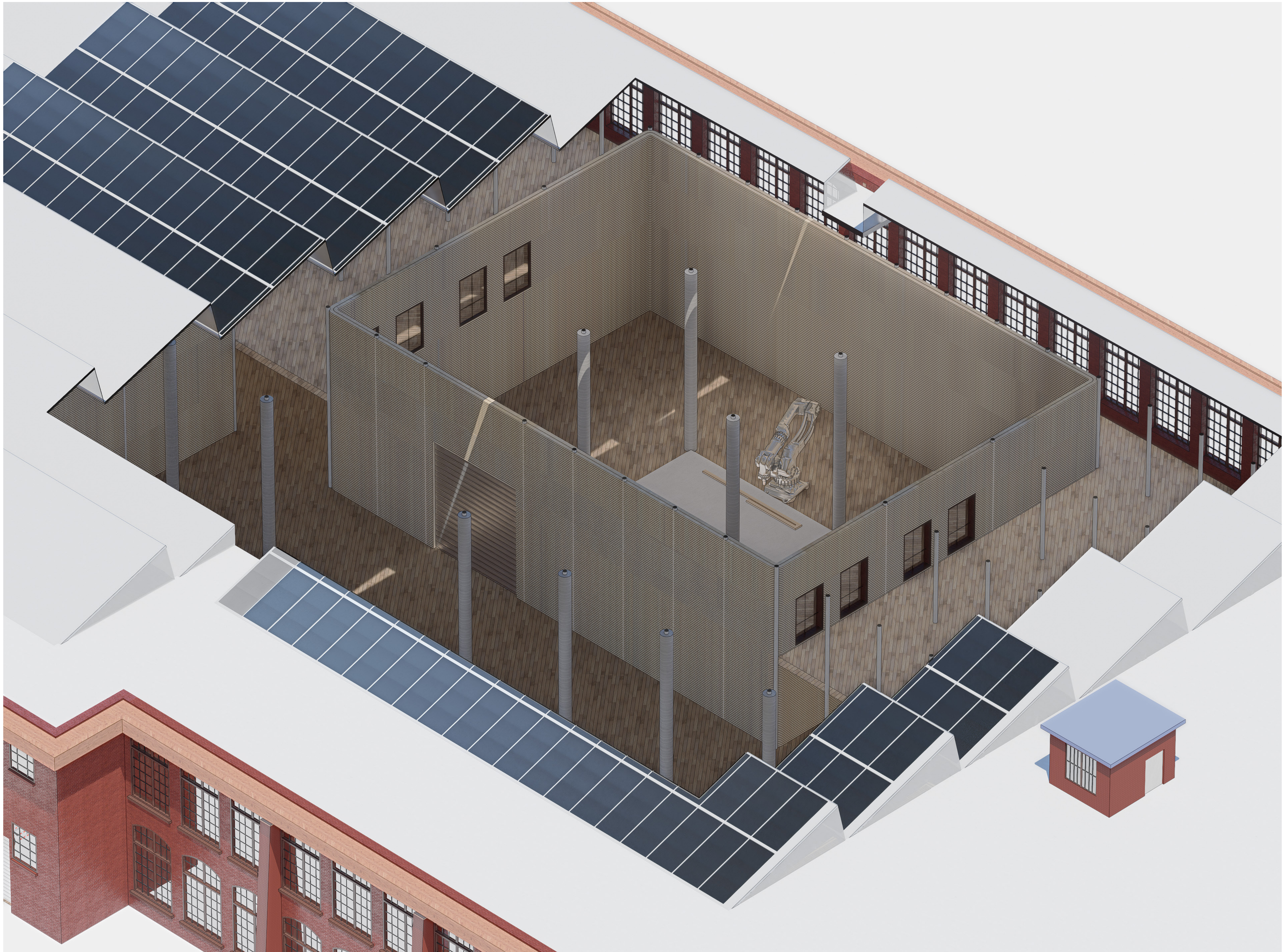


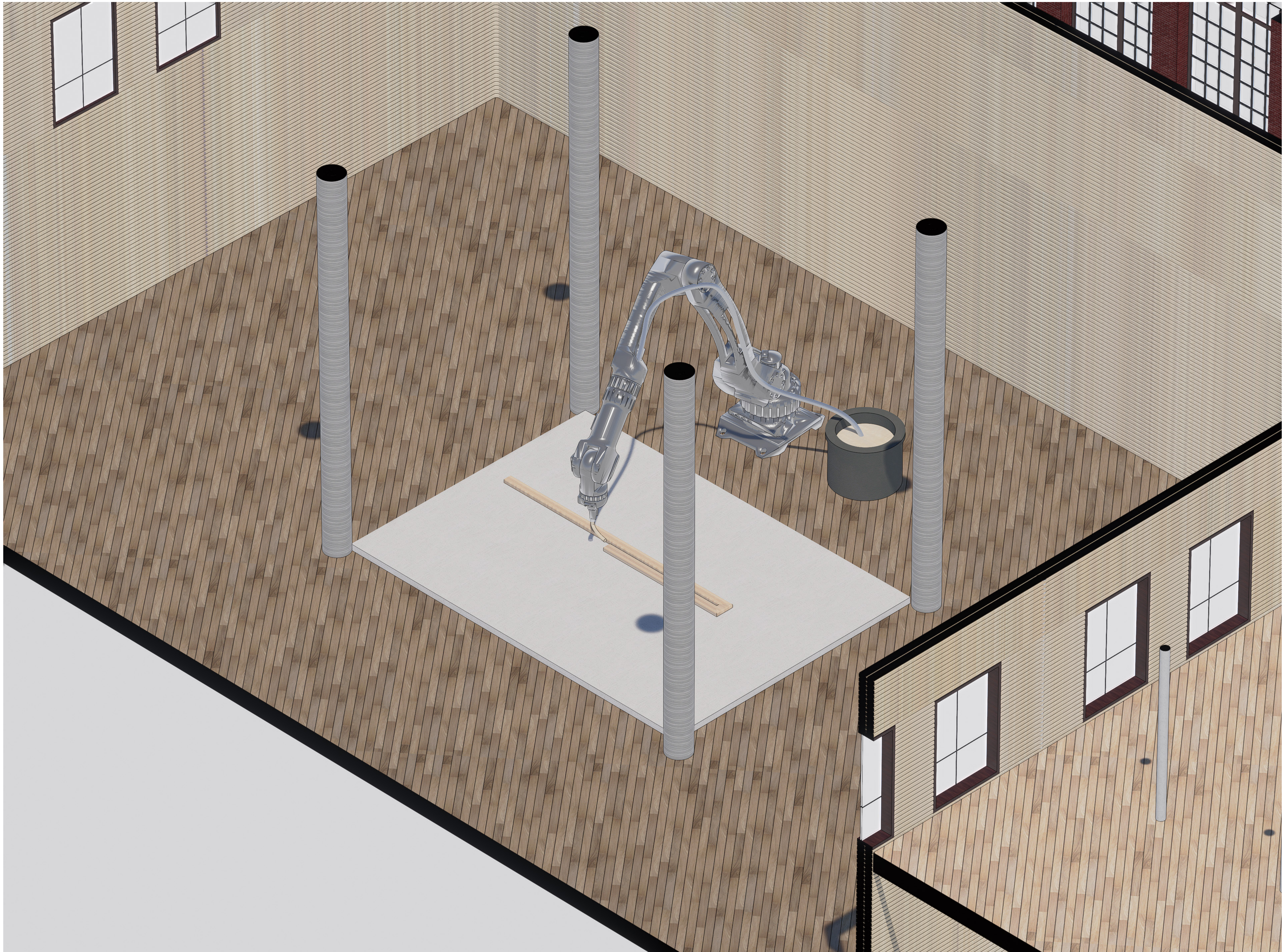


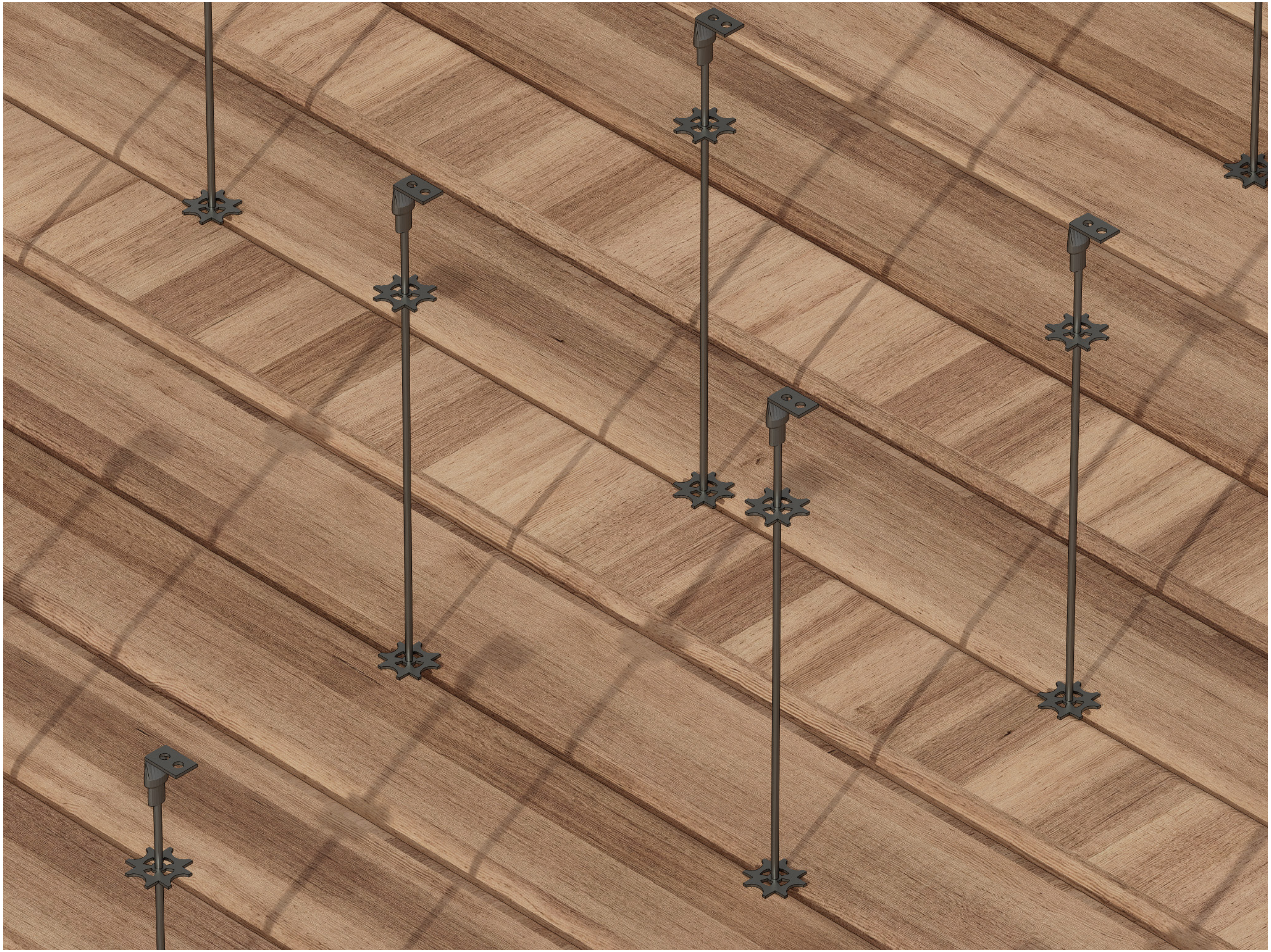


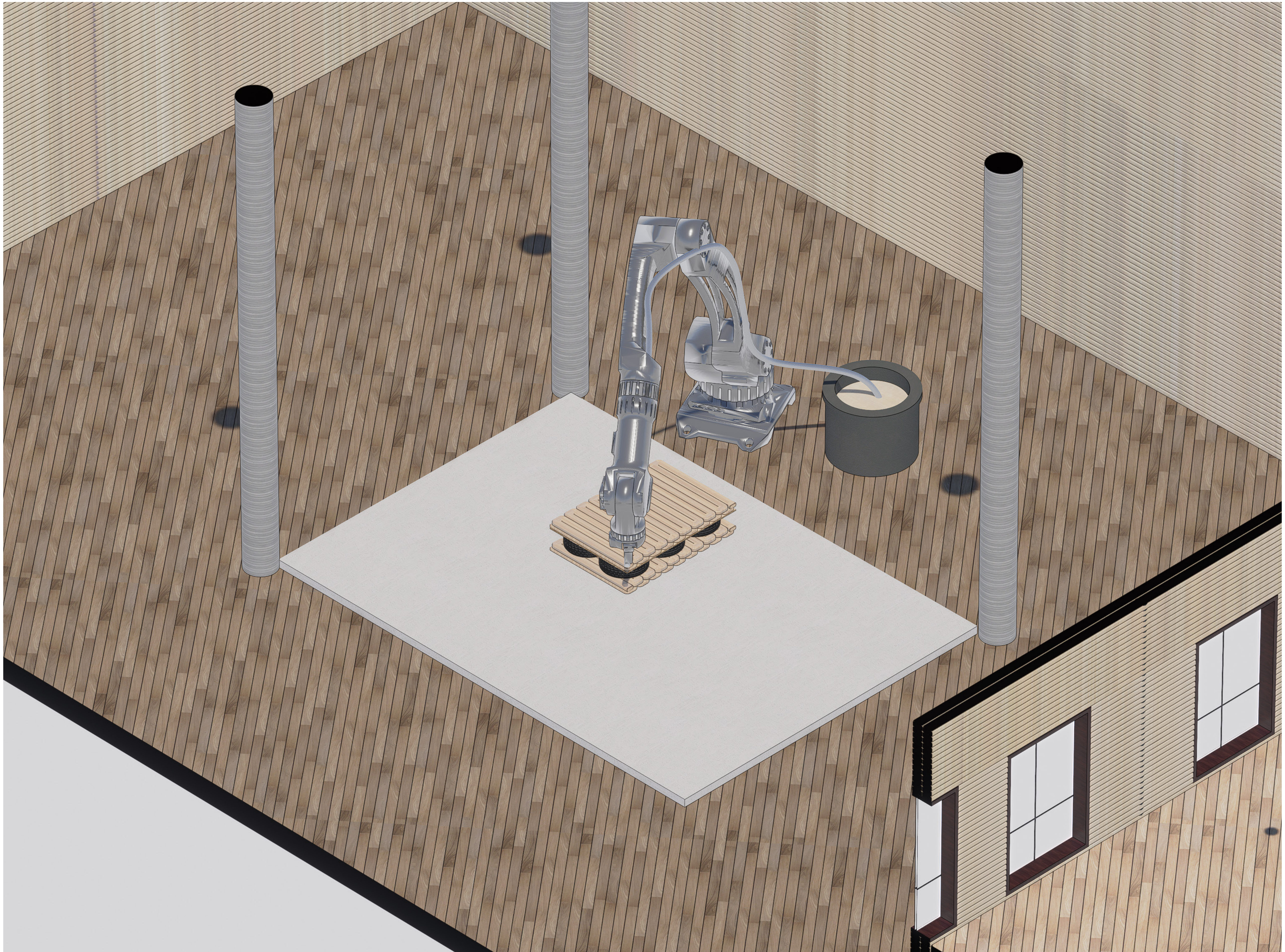


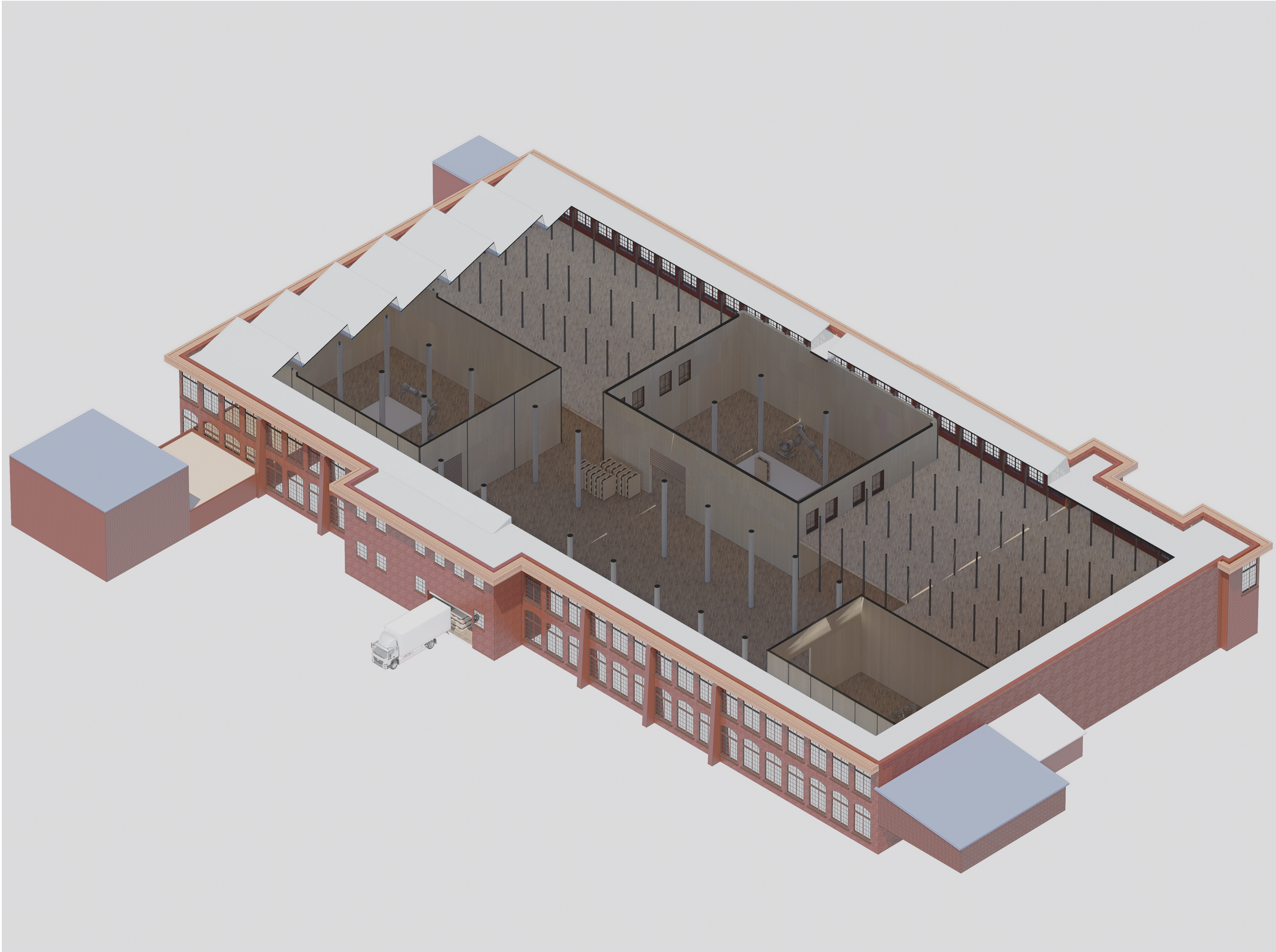


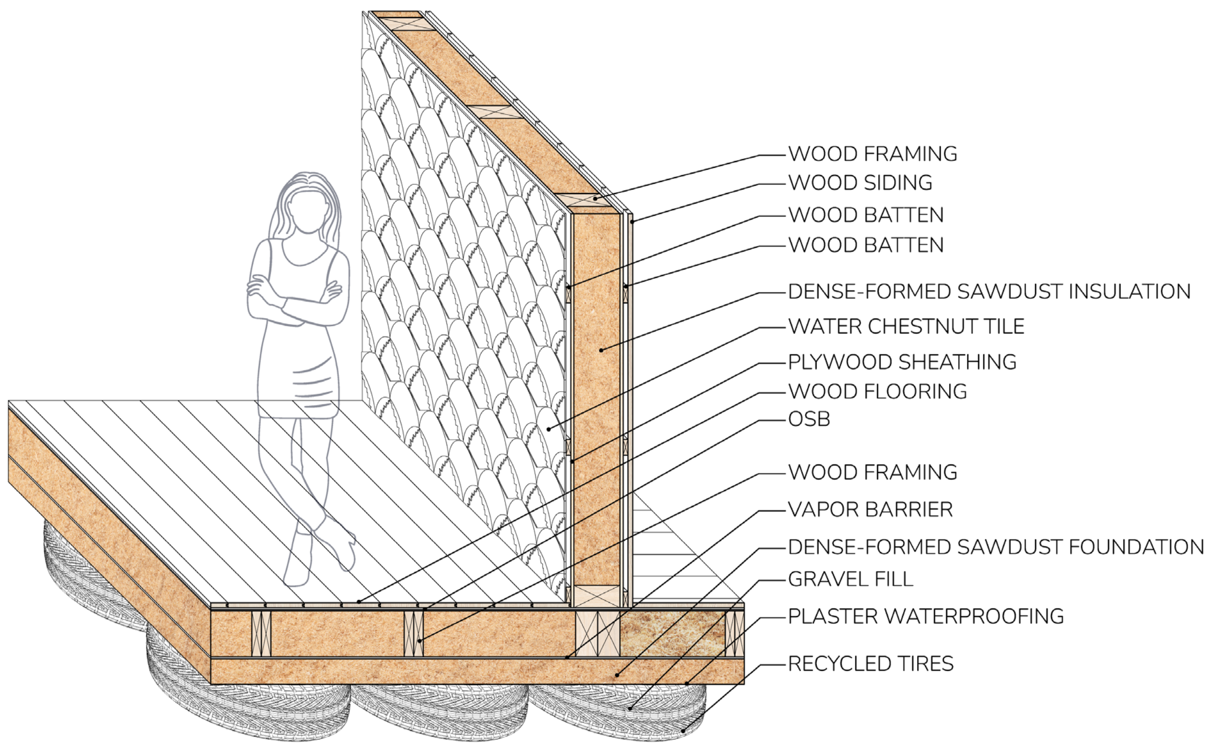


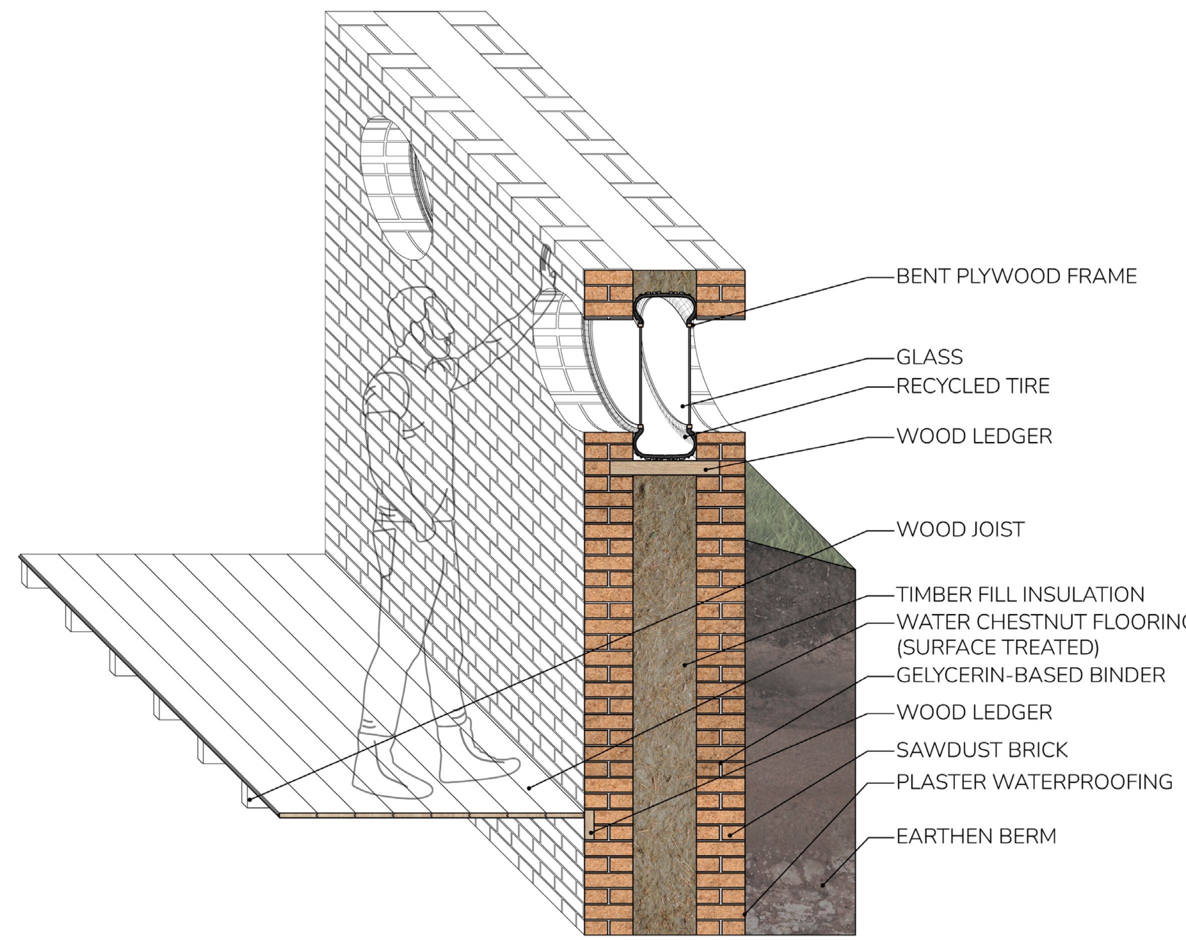


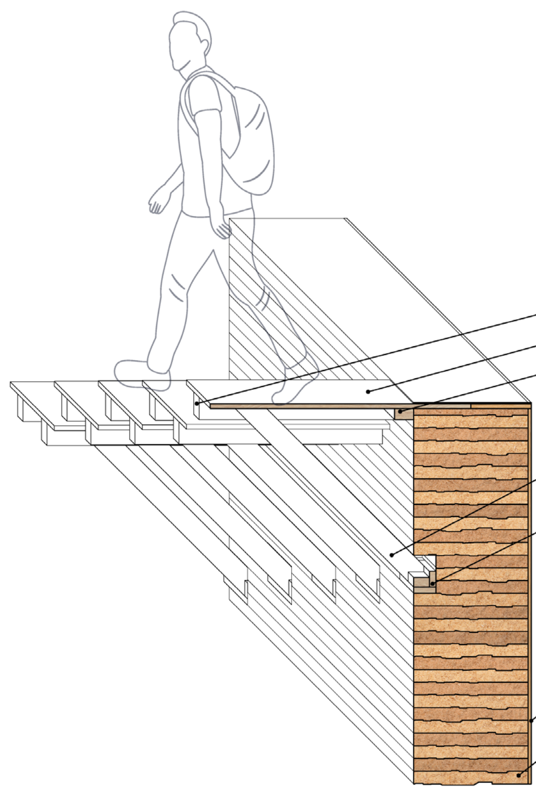


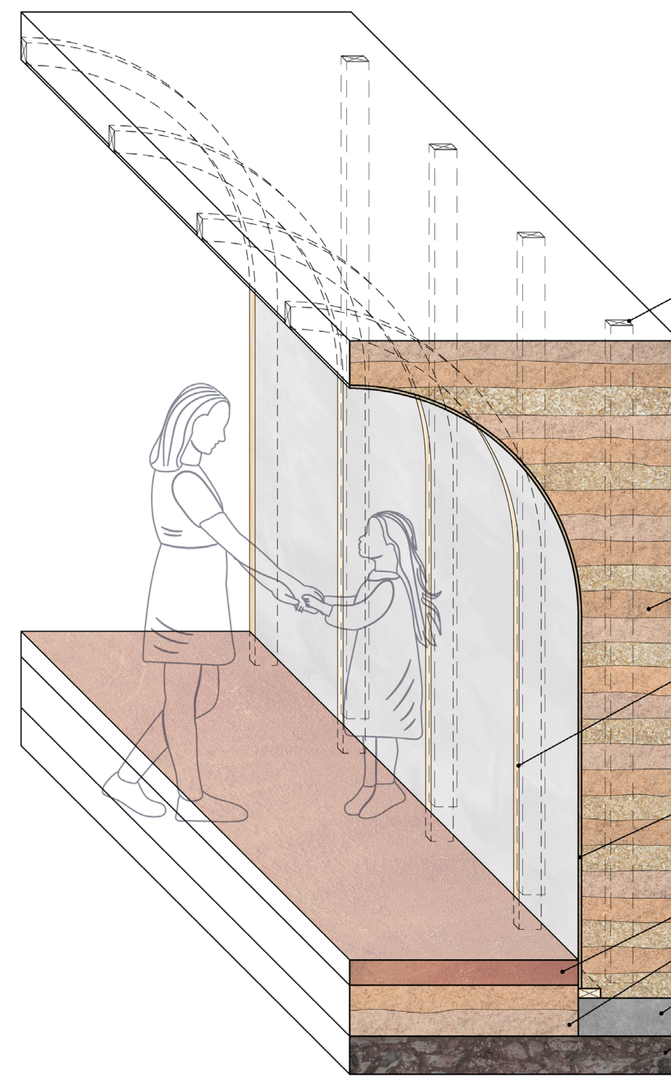





WOOD FRAMING
WOOD SIDING
WOOD BATTEN
WOOD BATTEN
DENSE-FORMED SAWDUST INSULATION
WATER CHESTNUT TILE
PLYWOOD SHEATHING
WOOD FLOORING
OSB
WOOD FRAMING
VAPOR BARRIER
DENSE-FORMED SAWDUST FOUNDATION
GRAVEL FILL
PLASTER WATERPROOFING
RECYCLED TIRES


BENT PLYWOOD FRAME
GLASS
RECYCLED TIRE
WOOD LEDGER
WOOD JOIST
TIMBER FILL INSULATION
WATER CHESTNUT FLOORING
(SURFACE TREATED)
GELYCERIN-BASED BINDER
WOOD LEDGER
SAWDUST BRICK
PLASTER WATERPROOFING
EARTHEN BERM


2"X4" WOOD JOIST
PLYWOOD TREAD
WOOD LEDGER
2"X4" LUMBER TRUSS
CUSTOMIZED WOOD ANCHOR
PLYWOOD SHEATHING
3D PRINTED SAWDUST WALL


WOOD FRAMING
RAMMED SAWDUST WALL
WOOD FRAME
PLASTER FINISH ON BENT
PLYWOOD SHEATHING
COMPRESSED CLAY FLOORING
DENSE-FORMED SAWDUST INSULATION
CONCRETE FOOTING
GRAVEL FILL