

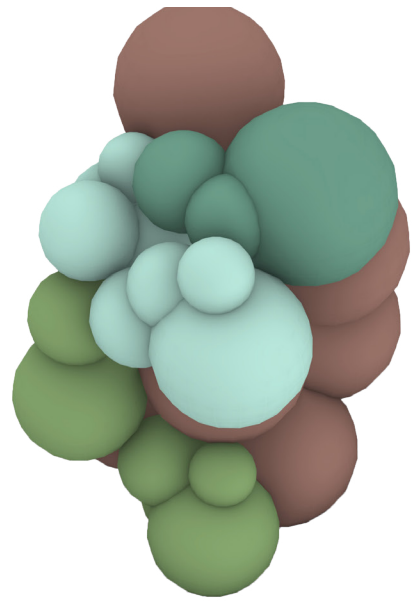
Robotic Building - P5 Presentation Robotic Building - P5 Presentation Robotic Building - P5 Presentation

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Design Tutor: Henriëtte Bier
Research Tutor: Arwin Hidding
Building Technology Tutor: Ferry Adema

The construction industry of tomorrow implemented today

Contents

01



Challenges

- *Housing crisis*
- *Unsustainable construction industry*

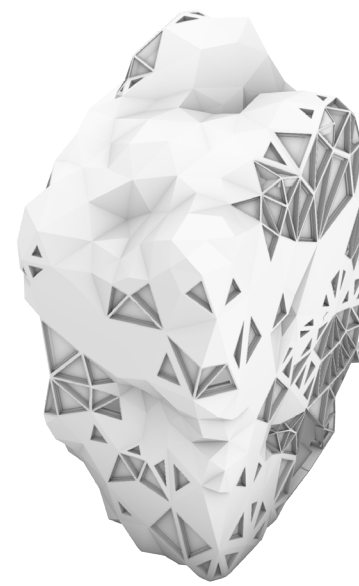
Concept + Questions

- *Innovative circular construction industry*

Target group + Locations

- *Students/Young Professionals*
- *Locations*

02



Interior Design

- *Bubble Script*
- *Platform Script*
- *Human Centric Design Script*
- *Faceted Rationalization*
- *City Adaptation*
- *Building Organization*

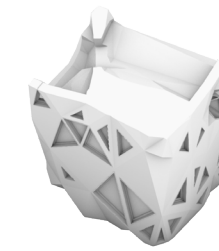
Exterior Design

- *Charge & Wrap*
- *Faceted Architecture*
- *Window Script*
- *Plans & Sections*

Material

- *BFRPLA*

03



Fragment

- *Workshop 01*
- *Structure*
- *Climate Design*
- *Interior*

In-Situ Construction

- *State of the art references*
- *1 Week Construction*

Detail

- *Printing Layers*
- *Wall/Floor Assembly*

Reviewing Locations

- *Script applicable to multiple locations*

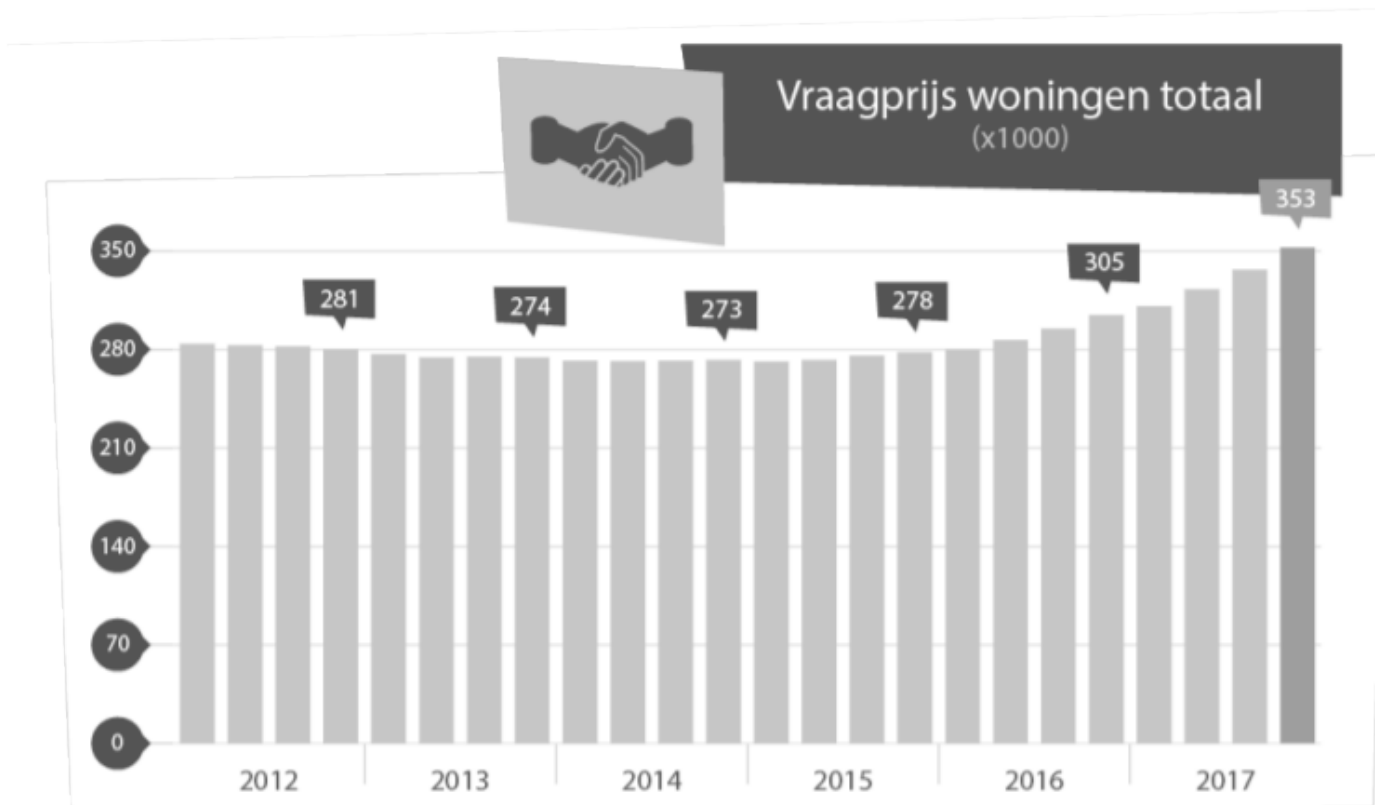
Challenges

Situatie

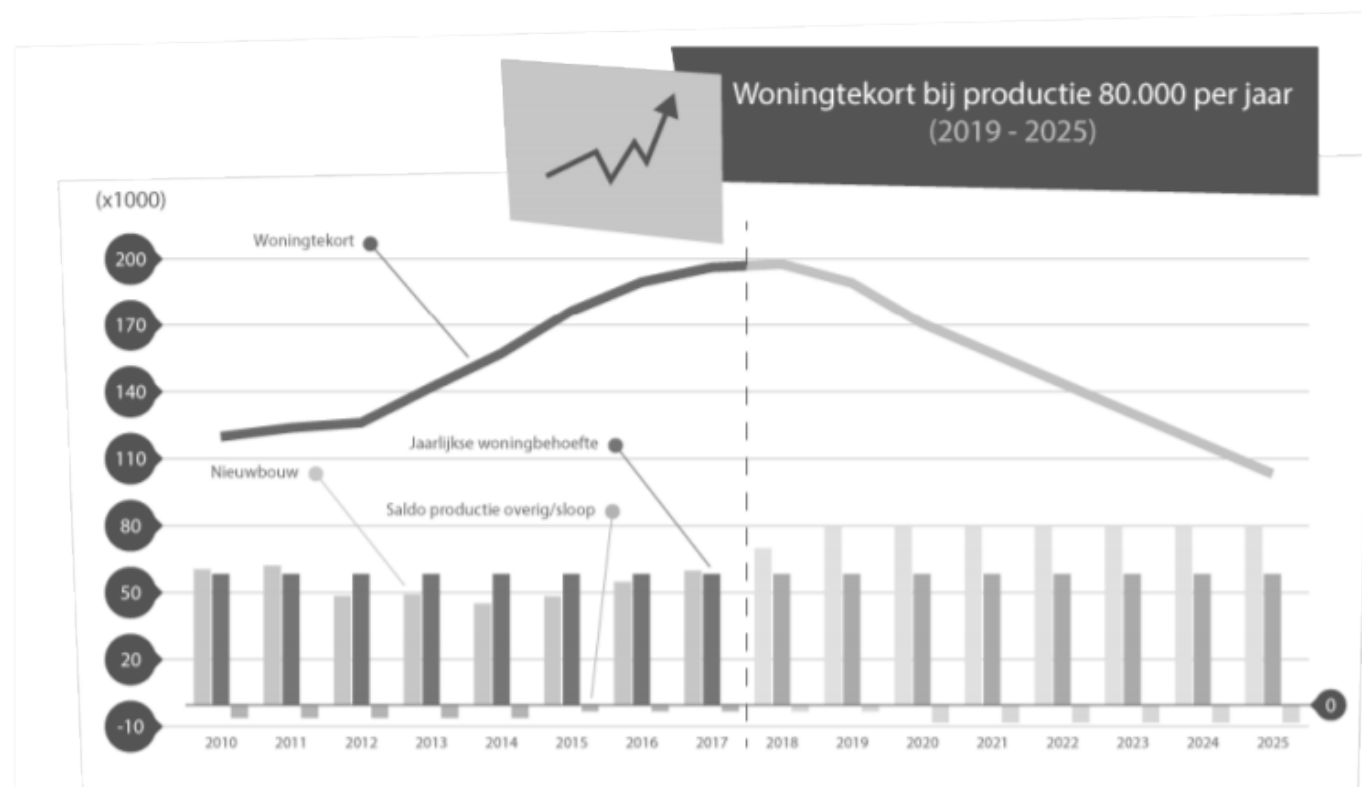
Where am I
going to live after
graduation?

1 Million Homes in 2030

Housing prices



Housing demand/availability



Source: NVM <https://www.nvm.nl/marktinformatie/marktinformatie>

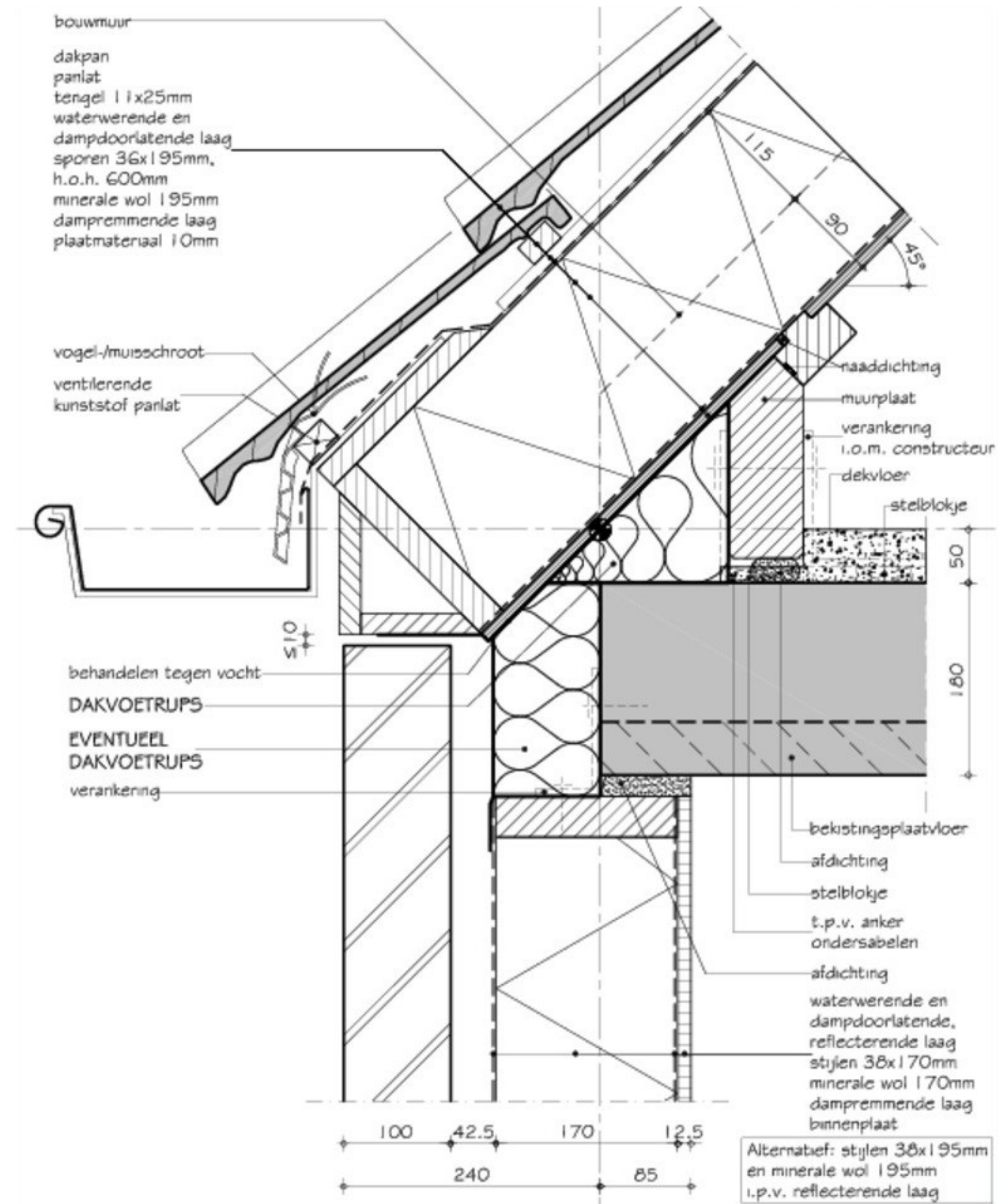
Non Adaptive Construction Industry

This detail consists at least of

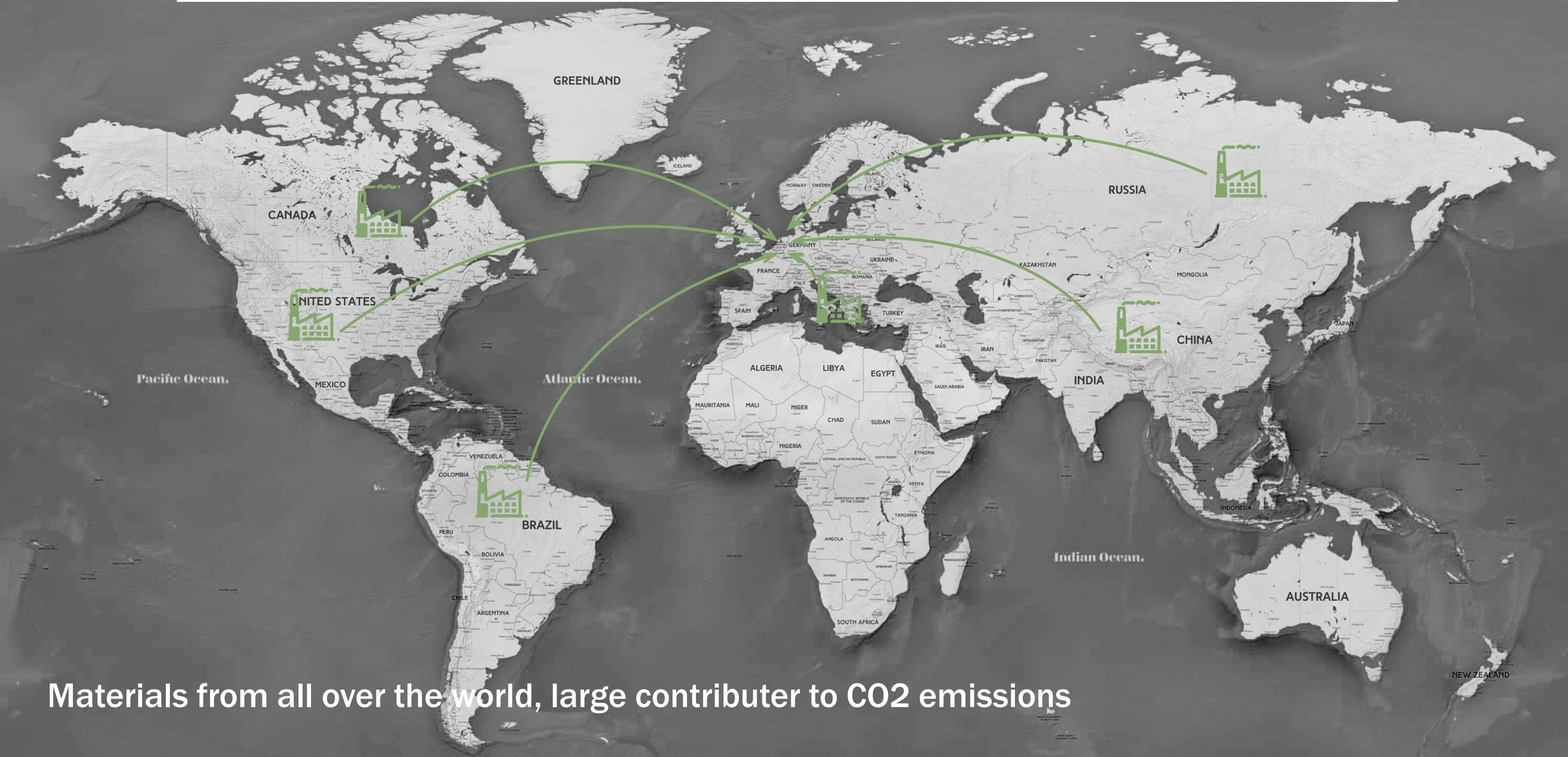
32

different materials/objects

Someone has to put this all together, thats why building takes a long time...



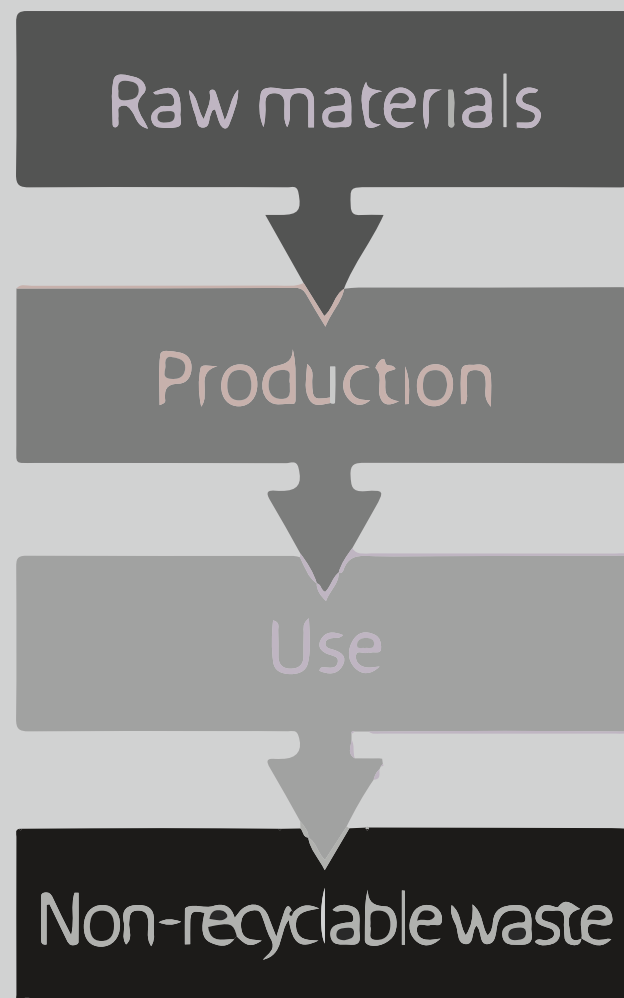
Non Adaptive Construction Industry



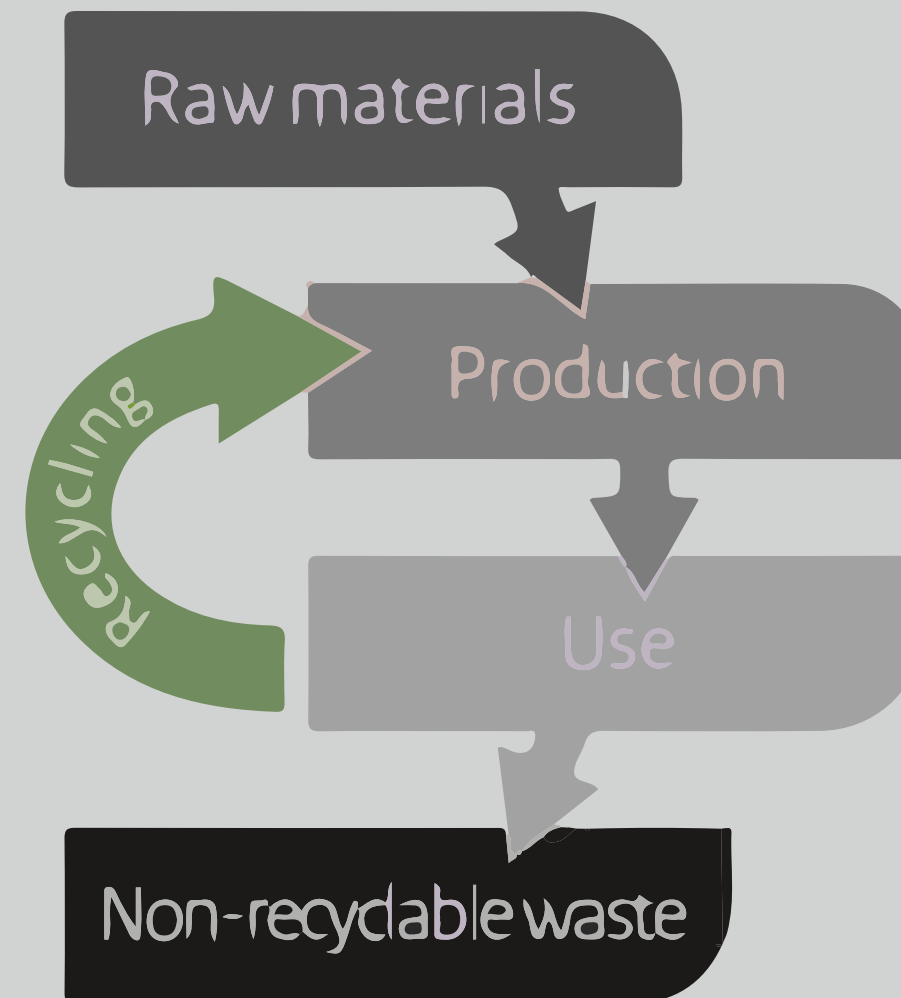
Materials from all over the world, large contributor to CO2 emissions

Linear Economy

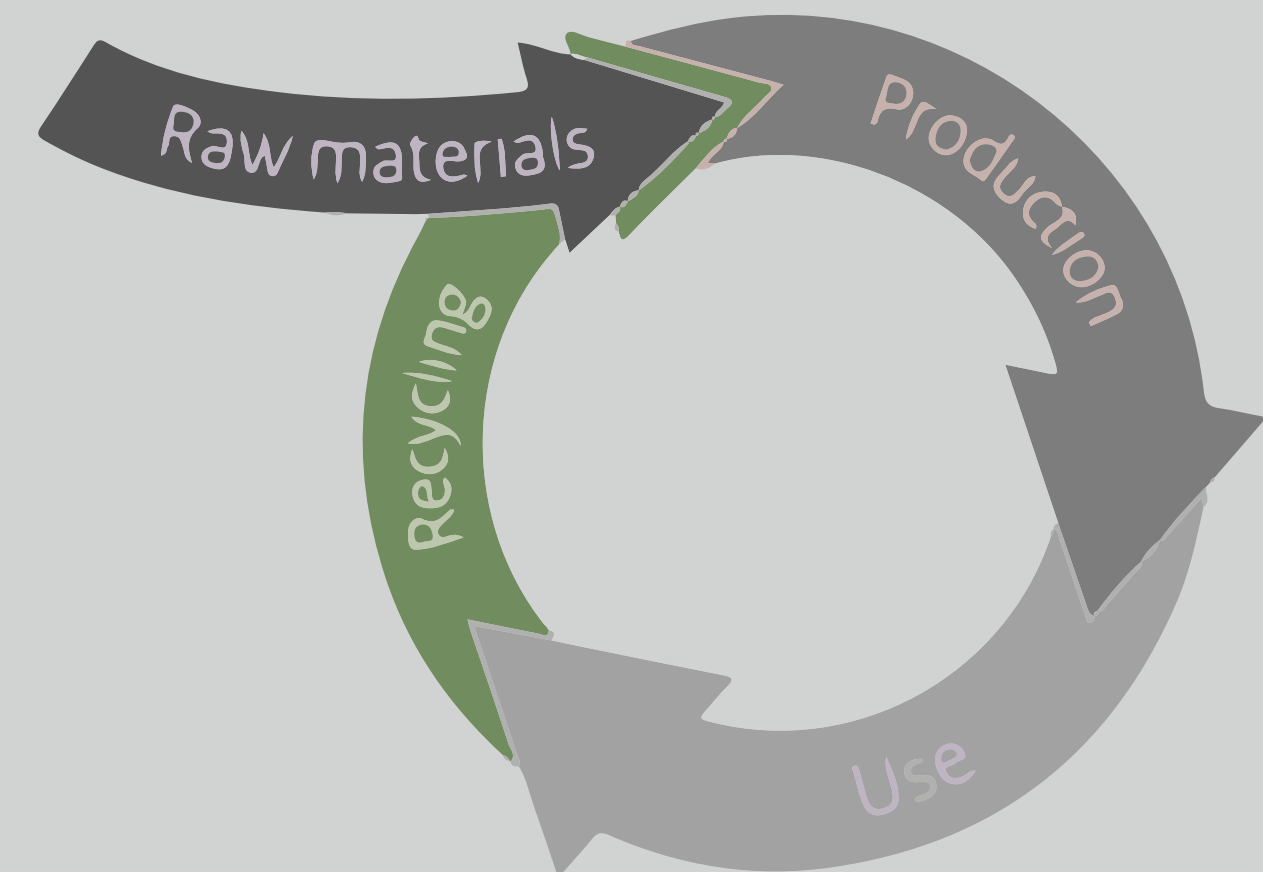
Linear economy



Reuse economy



Circular economy

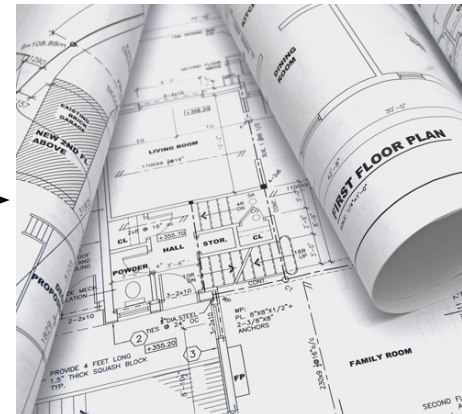


Smarter Workflows

<2000



2D



2D

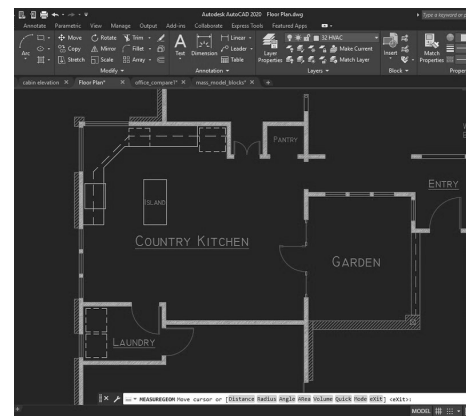


2D

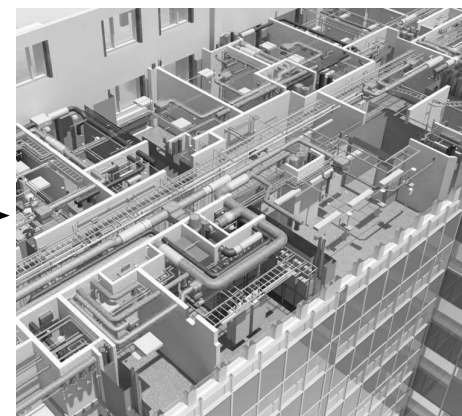


3D

2000 - 2020



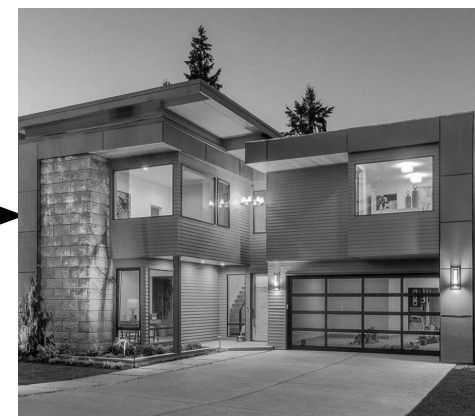
3D



2/3D

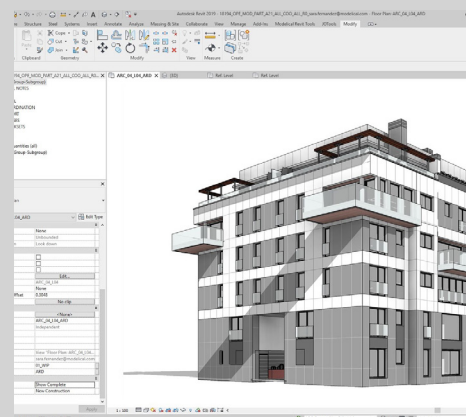


2D

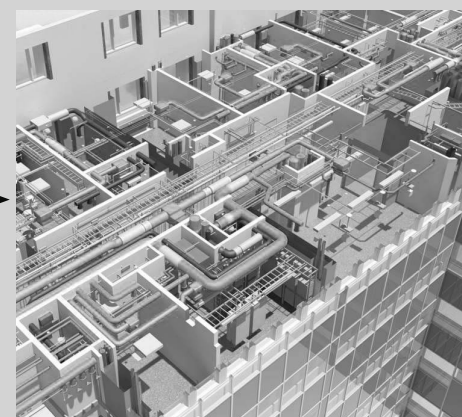


3D

2020<



3D



3D



3D



3D

Concept & Location

Design Question

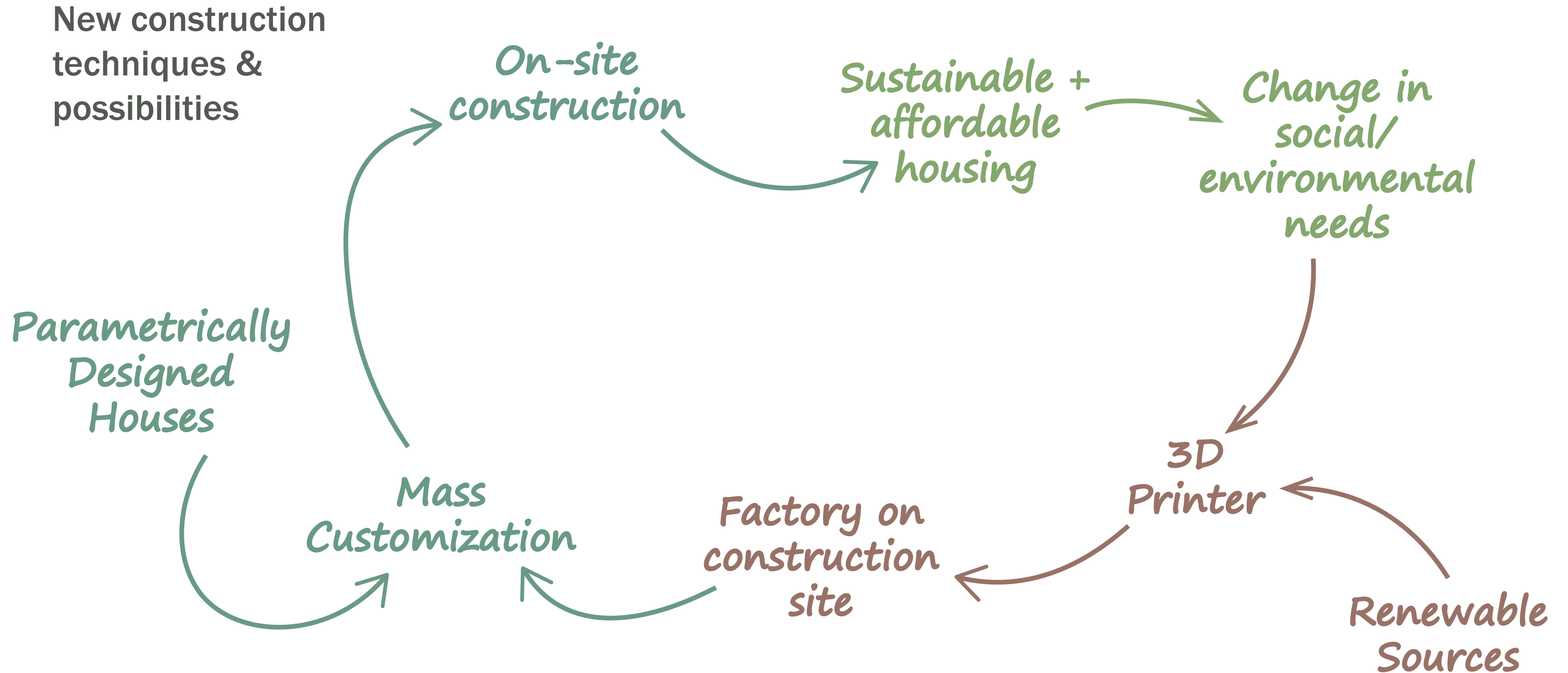
How can the inner city be densified by filling in empty building plots using innovative construction techniques like the 3D printer?

Research Question

*How can this building be 3D printed with renewable/
natural/fewest possible materials & sourced as local
as possible*

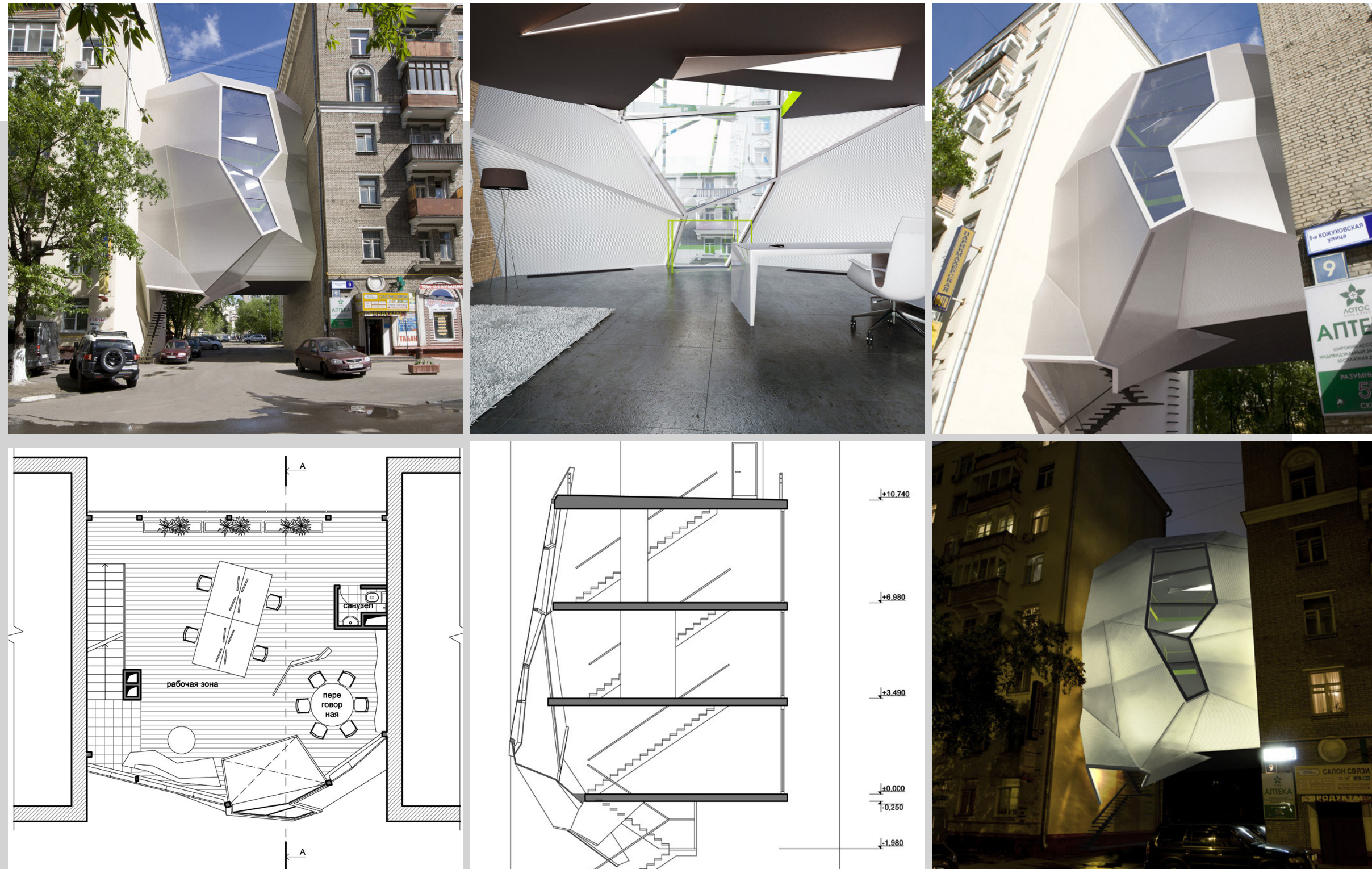
Overall Concept

What kind of housing?



Parasitic Architecture

Unusual spots in the city that are left empty



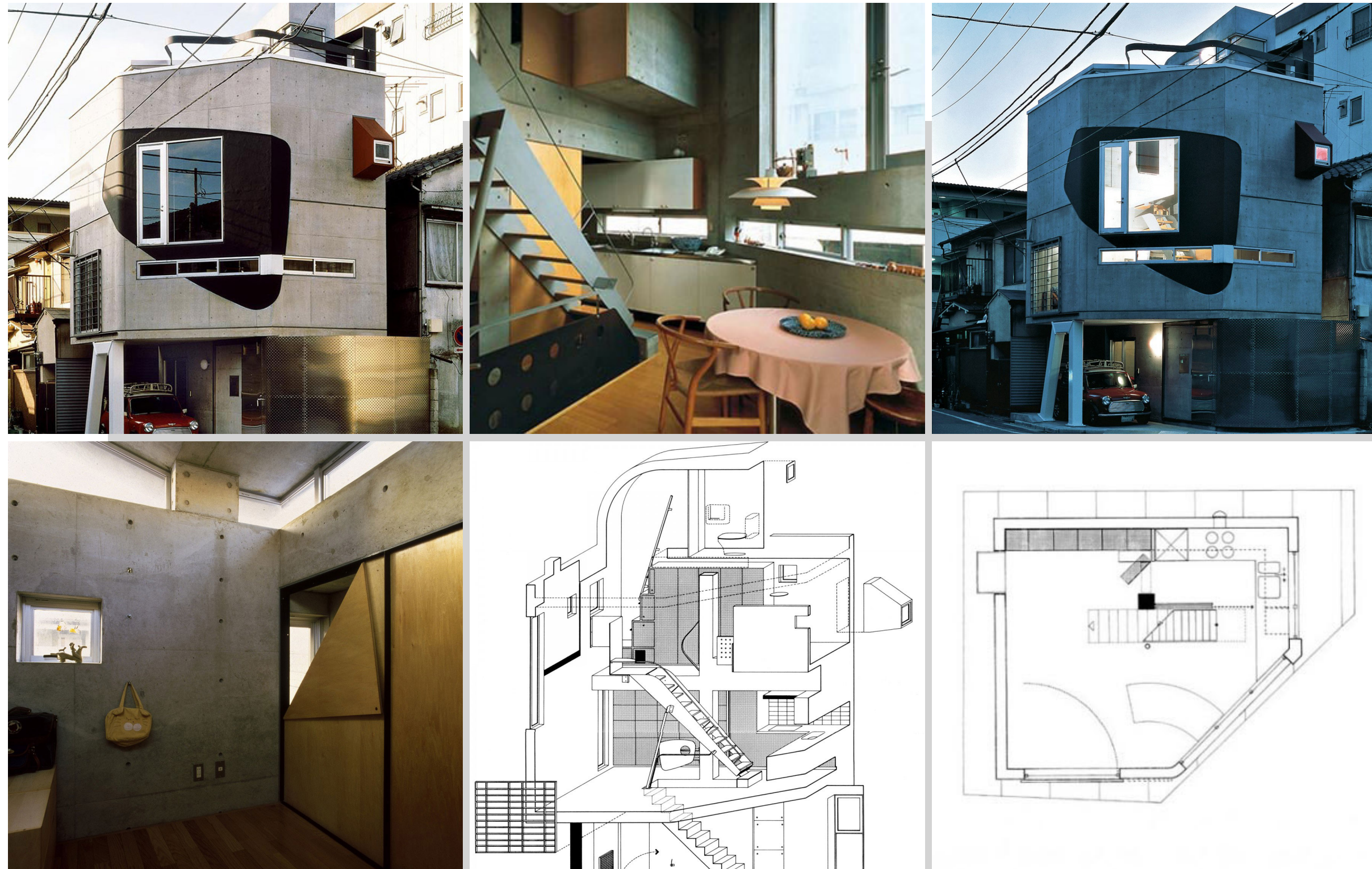
Source: Zaytsev , P., & Za Bor Architects. (2011). Parasite Office / za bor architects [Photograph]. Retrieved from <https://www.archdaily.com/138151/parasite-office-za-bor-architects>

Parasitic Office
Za Bor Architects

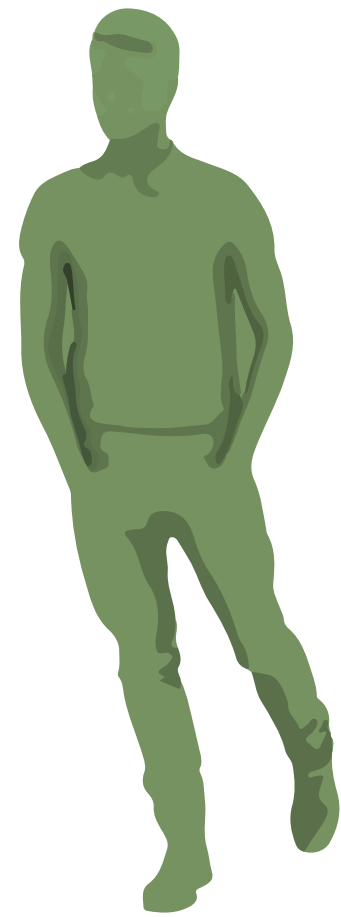
Parasitic Tiny Houses

Achieve high quality and produce large amounts quickly

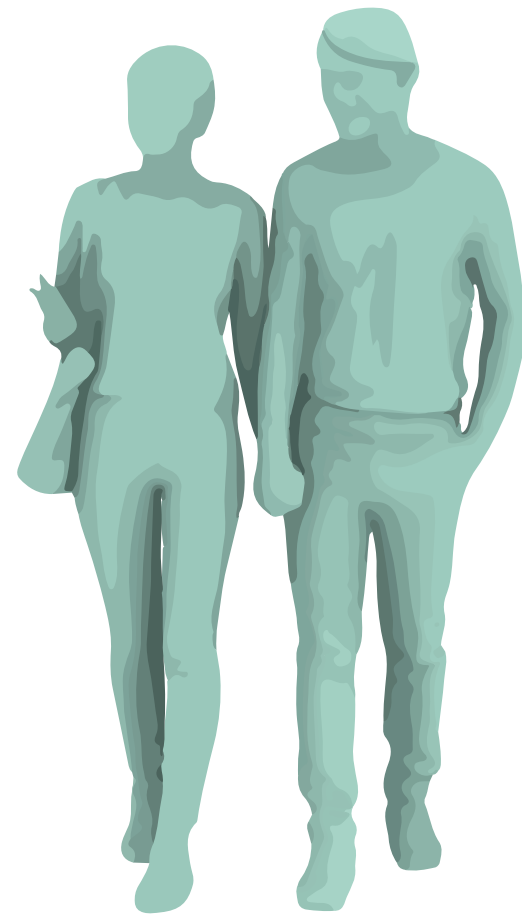
Suzuki House Bolles + Wilson



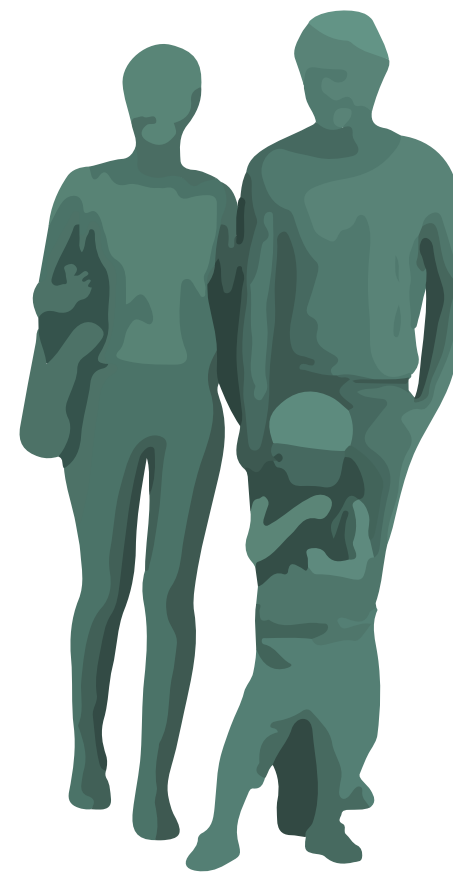
Source: Arch eyses, <http://archeyes.com/suzuki-house-bolles-wil> Source: Miyamoto, R., & Bolles + Wilson. (2019, February 2). Suzuki House / Bolles + Wilson [Illustration]. Retrieved from <https://archeyes.com/suzuki-house-bolles-wilson/> son/



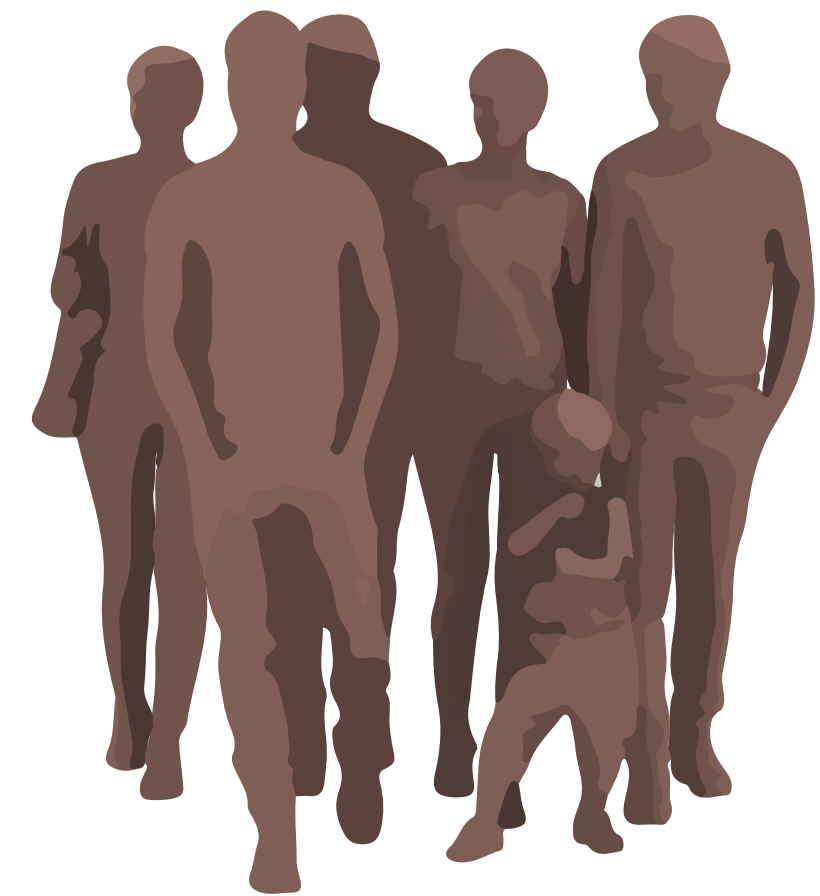
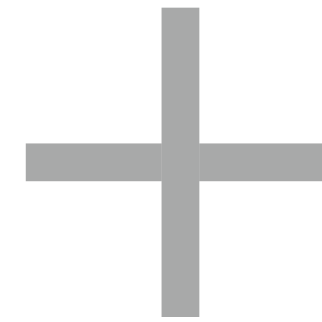
Single



Couple



Couple + Kid



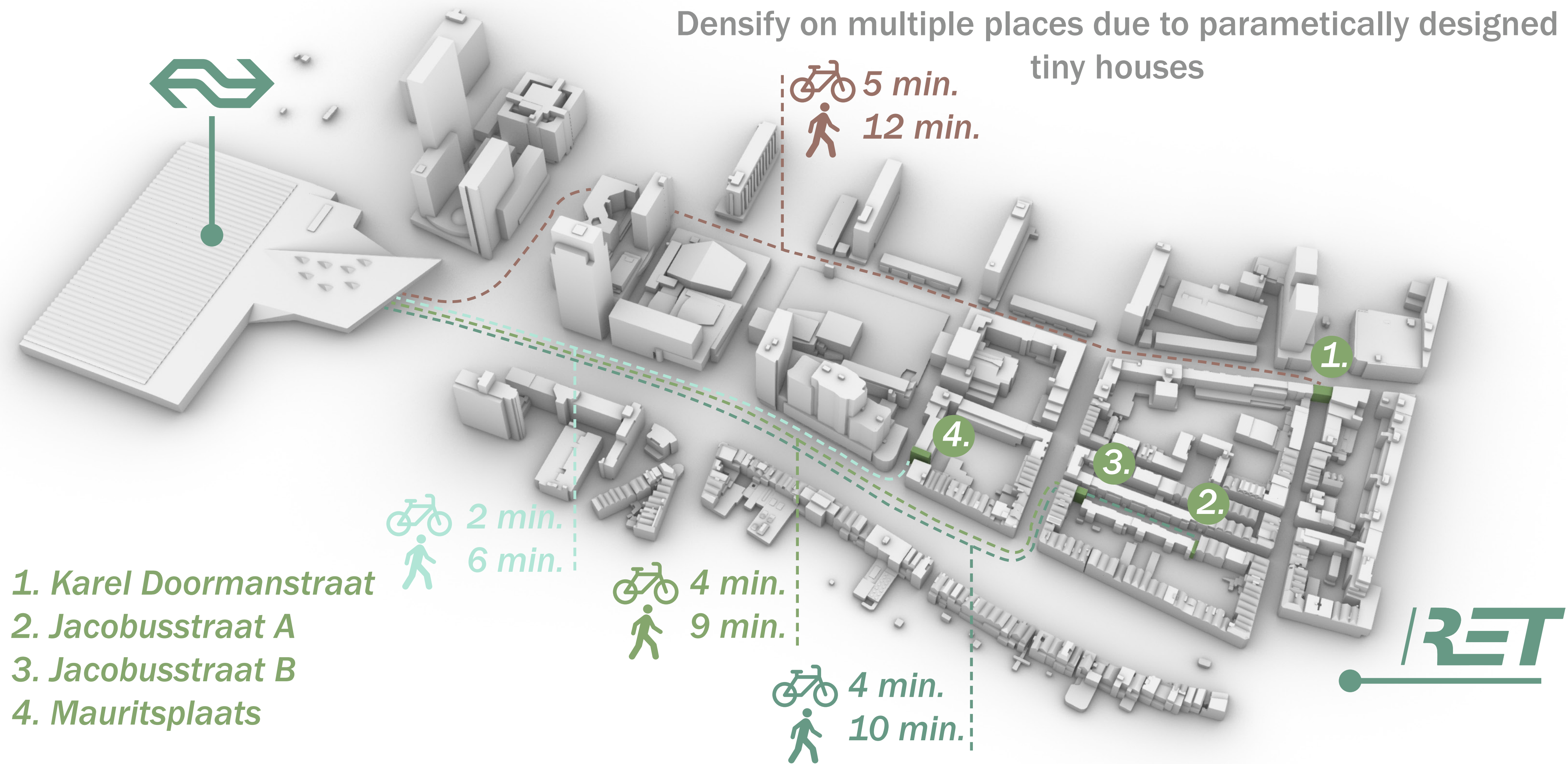
Shared

Students/Young Professionals

Not a lot of money - Like to get out of the house - Not much personal belongings - Public transport to work/university - Want to live in the city - Connection with other people is desired

Locations in the city of Rotterdam

Densify on multiple places due to parametrically designed tiny houses



Locations in the City



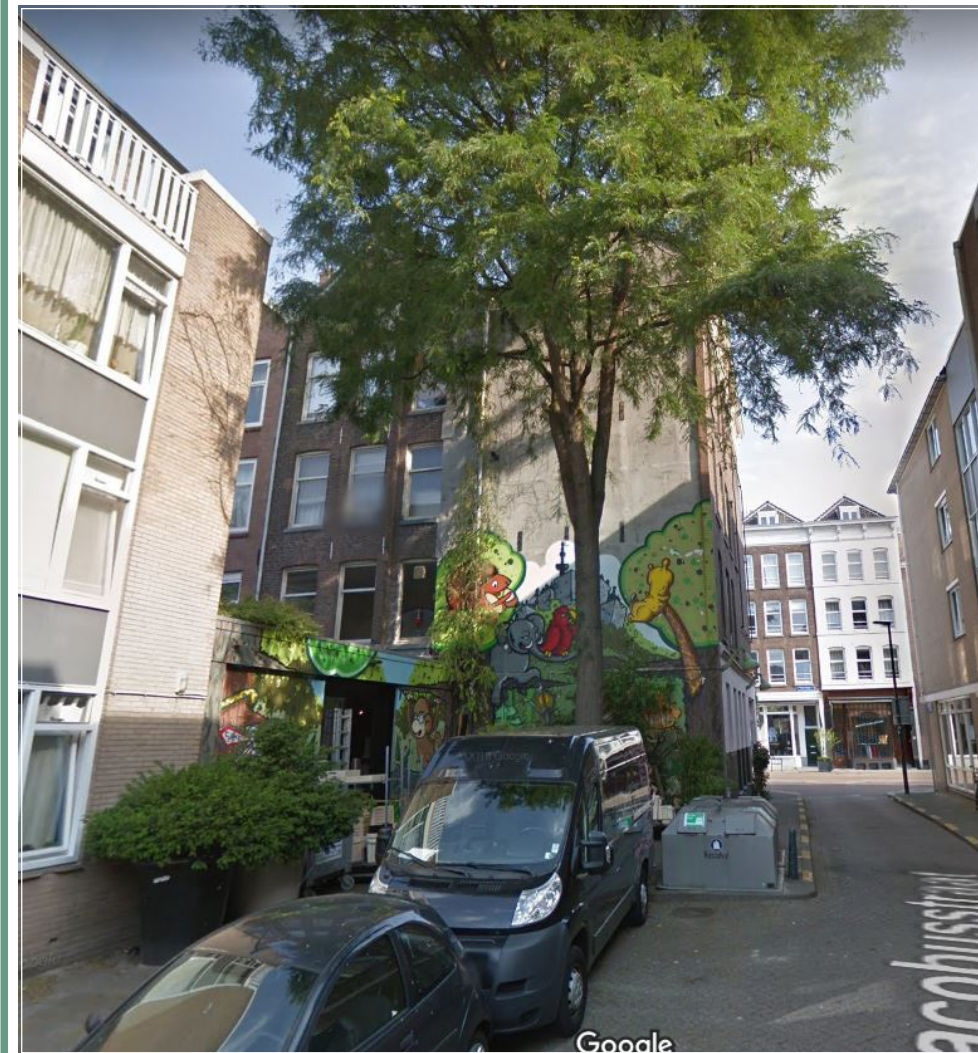
Karel Doormanstraat

Footprint: 136m²
Height: 18m
Floors: 4



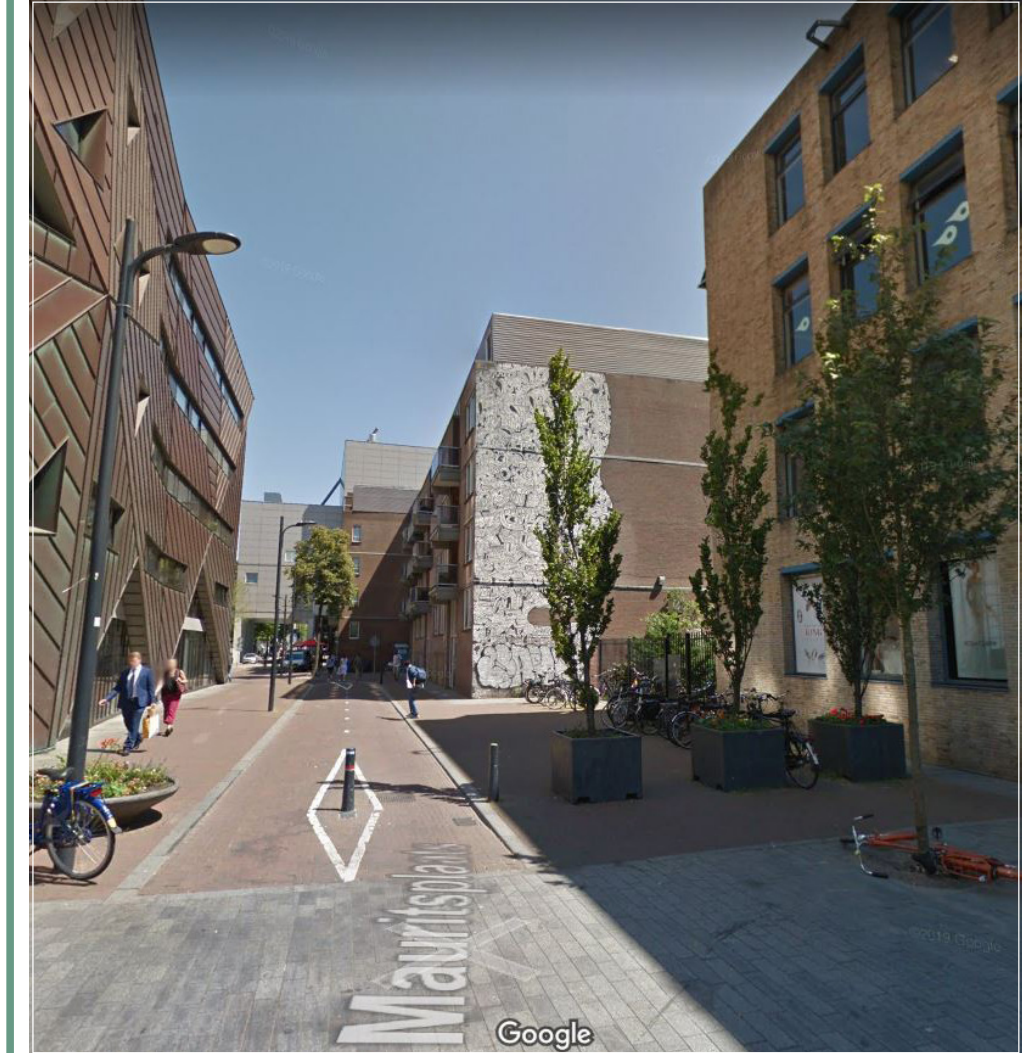
Jacobusstraat A

Footprint: 39m²
Height: 13m
Floors: 3



Jacobusstraat B

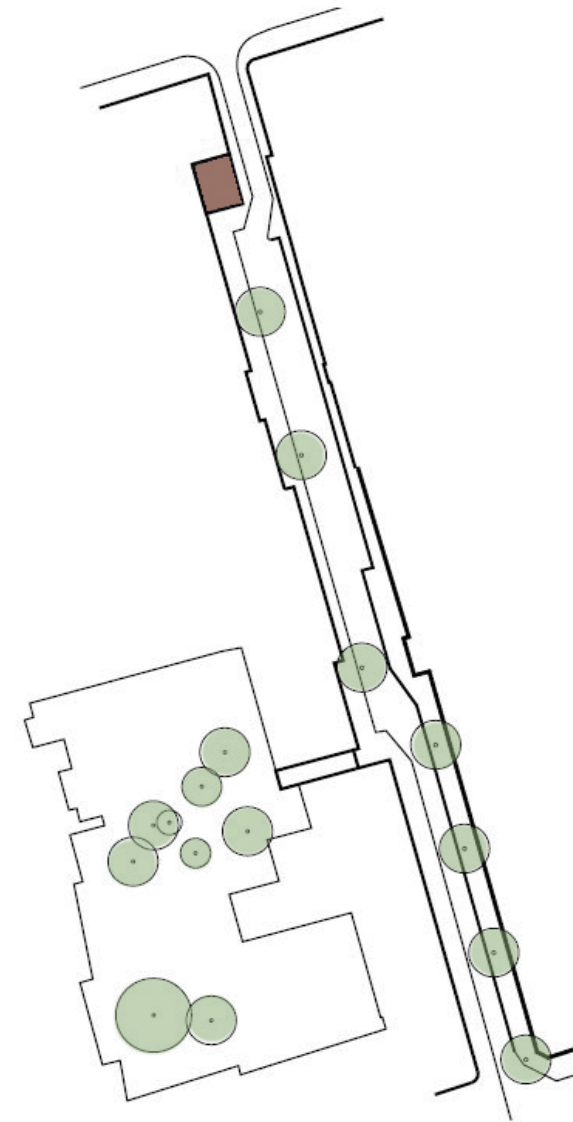
Footprint: 42m²
Height: 13m
Floors: 4



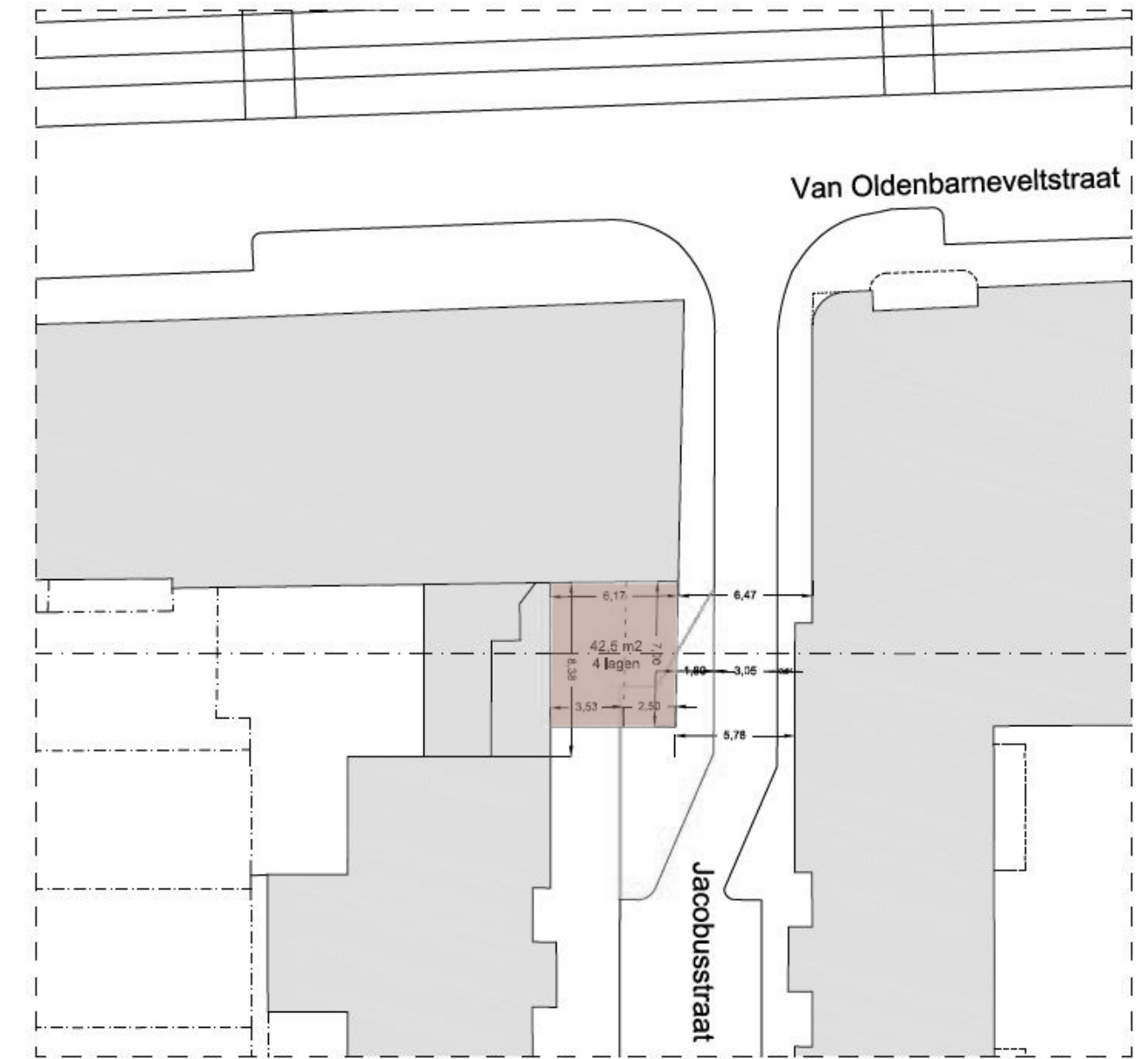
Mauritsplaats

Footprint: 74m²
Height: 15m
Floors: 5

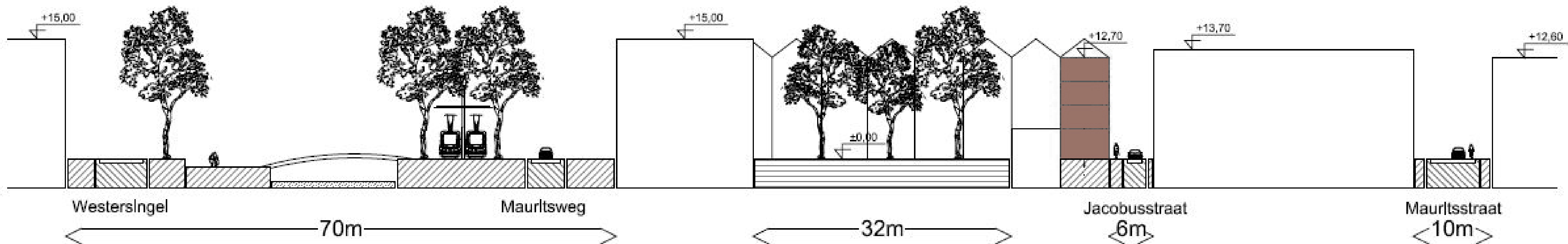
Testing Location Jacobusstraat A



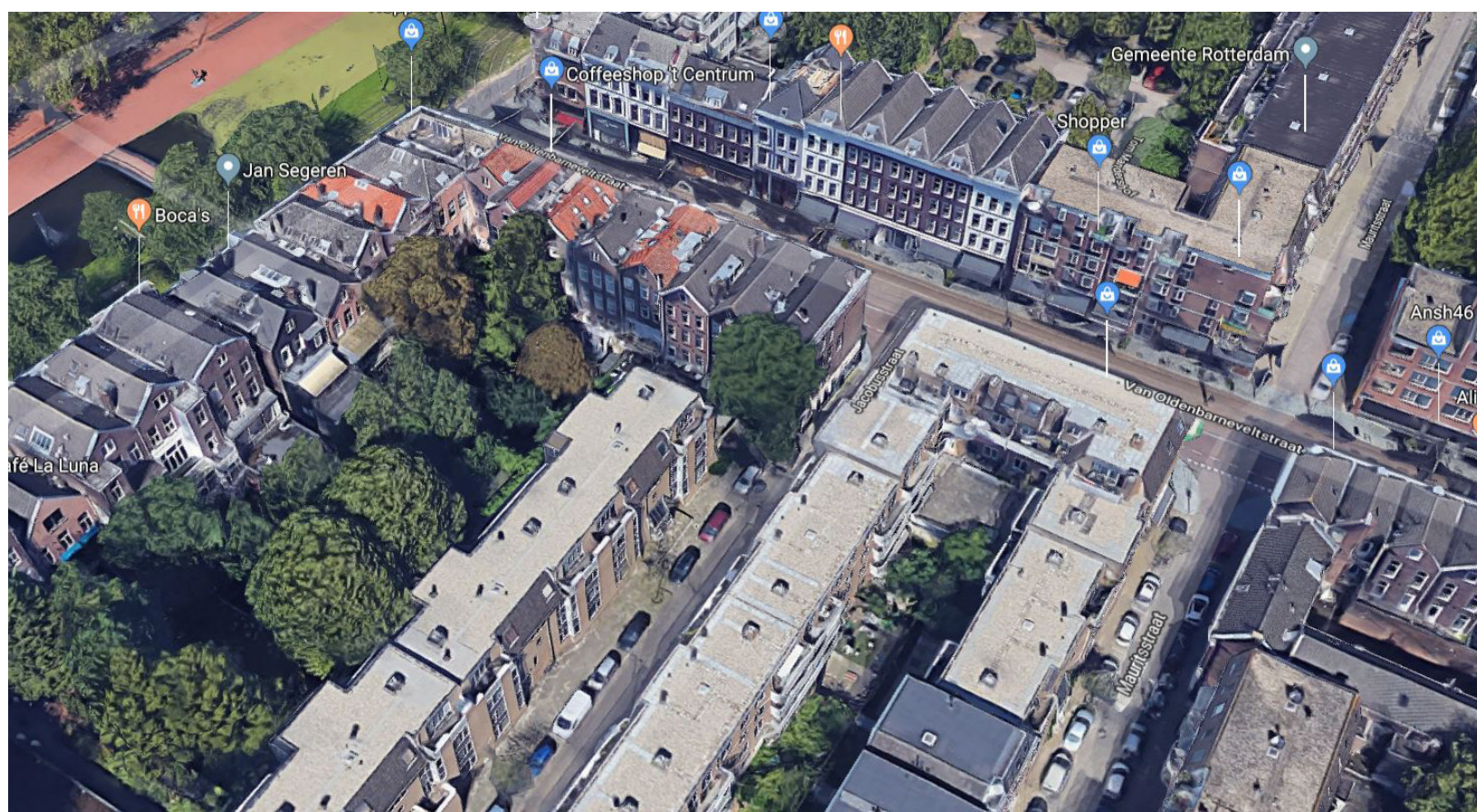
Footprint: 42m²
Height: 12m
Floors: 4



Source: Studio Hartzema BV, & Stadsontwikkeling Rotterdam. (2012). Rotterdam Klein & Fijn - Stedebouw per kavel. Retrieved from <https://www.studiohartzema.com/werken/rotterdam-home-town/>

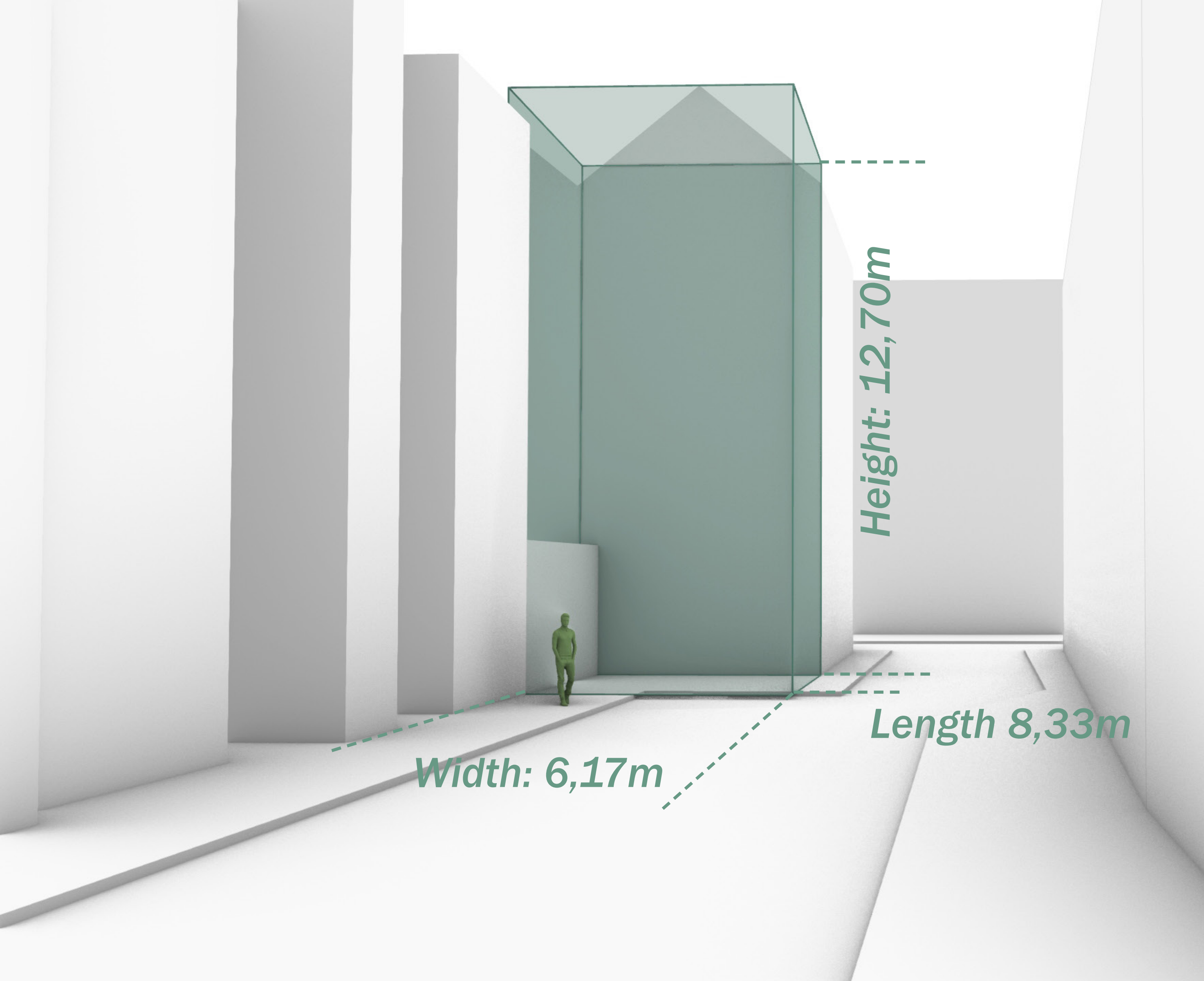


Testing Location Analysis



Bounding Box

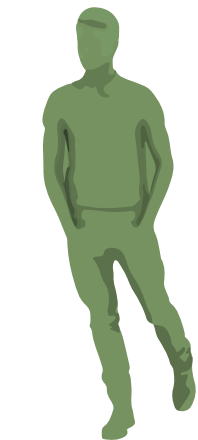
Volume: 652m³



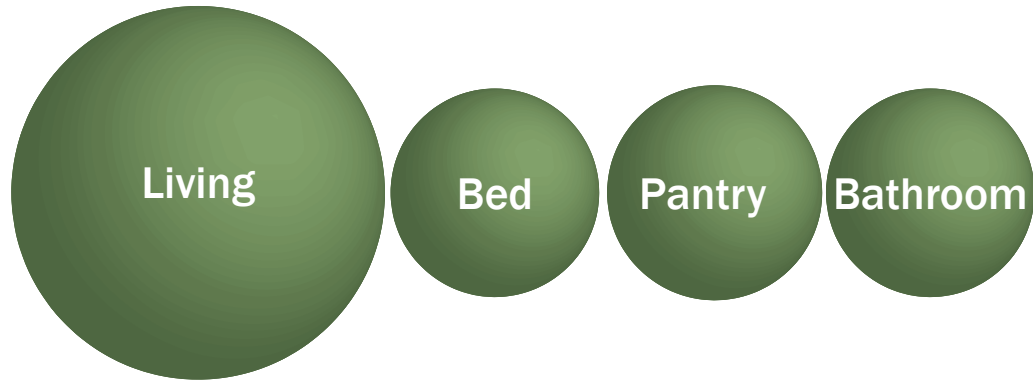
Google

Interior Design

Program of Requirements

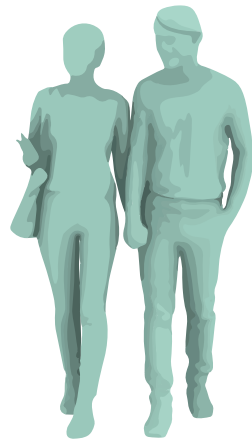


Single

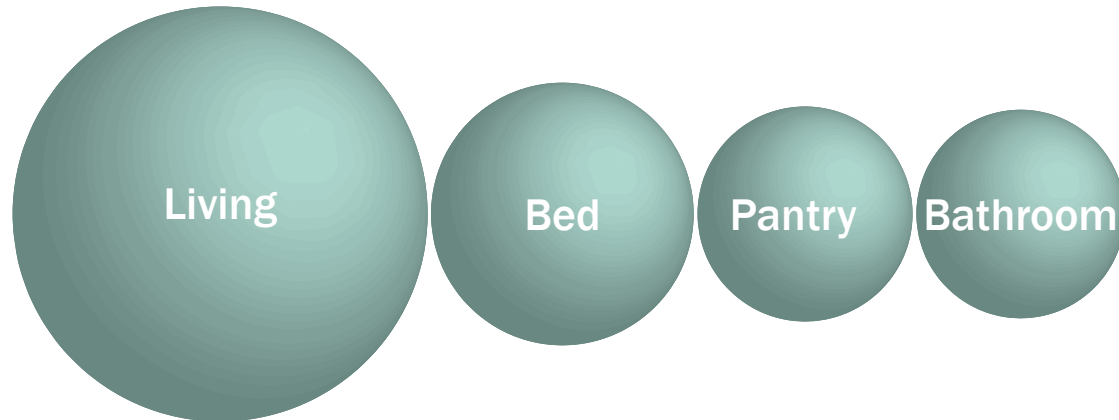


25m2

X2

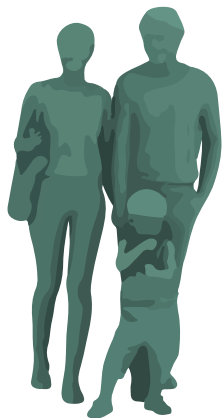


Couple

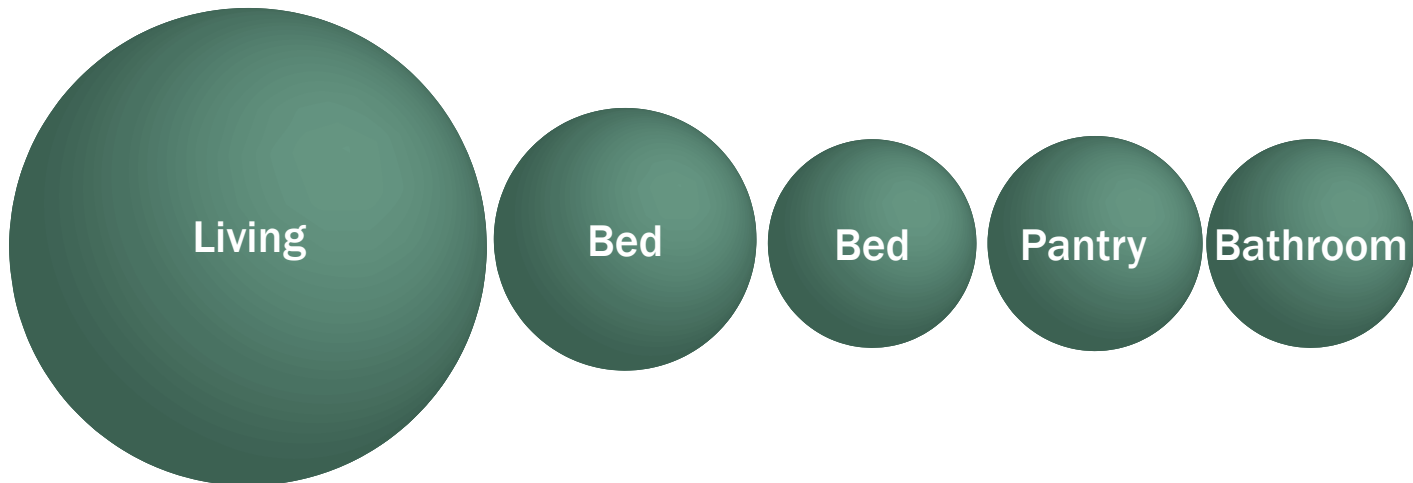


30m2

X2

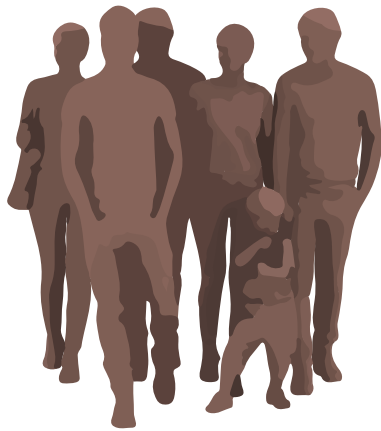


Couple + Kid

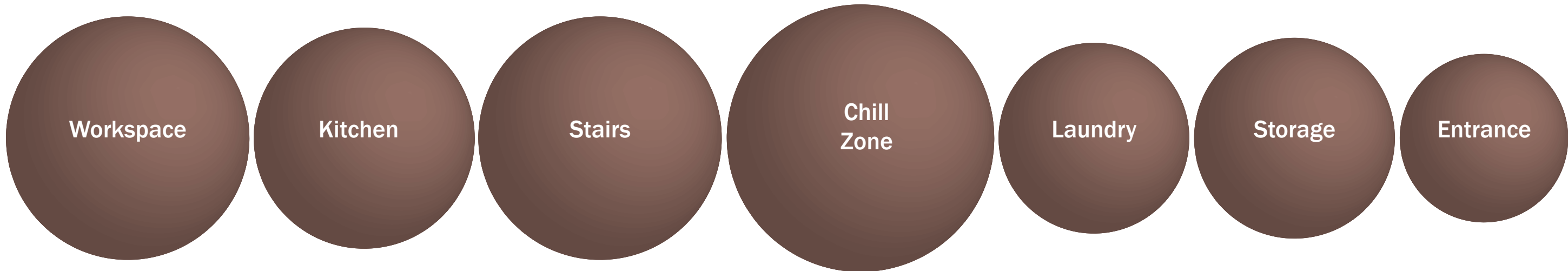


35m2

X2



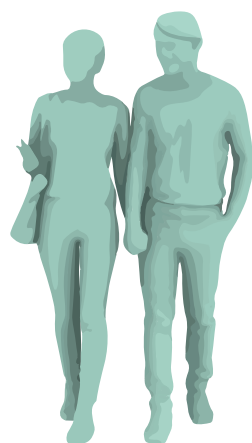
Shared



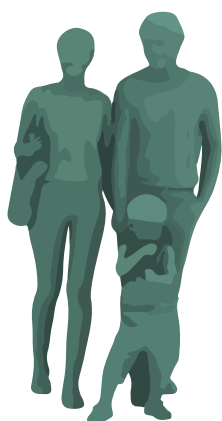
Connection Algorithm



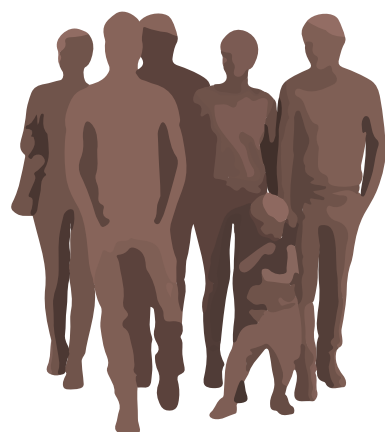
Single



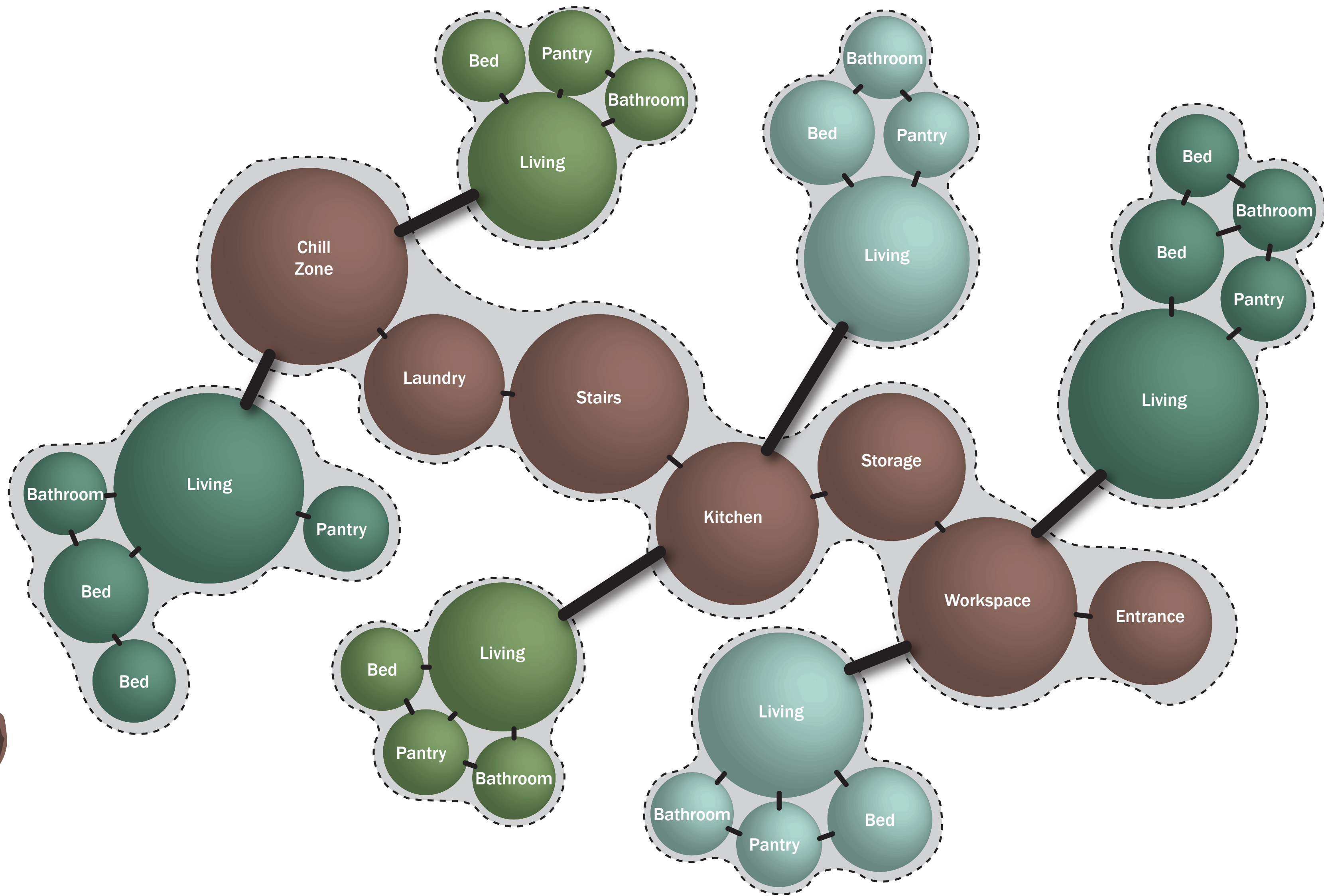
Couple



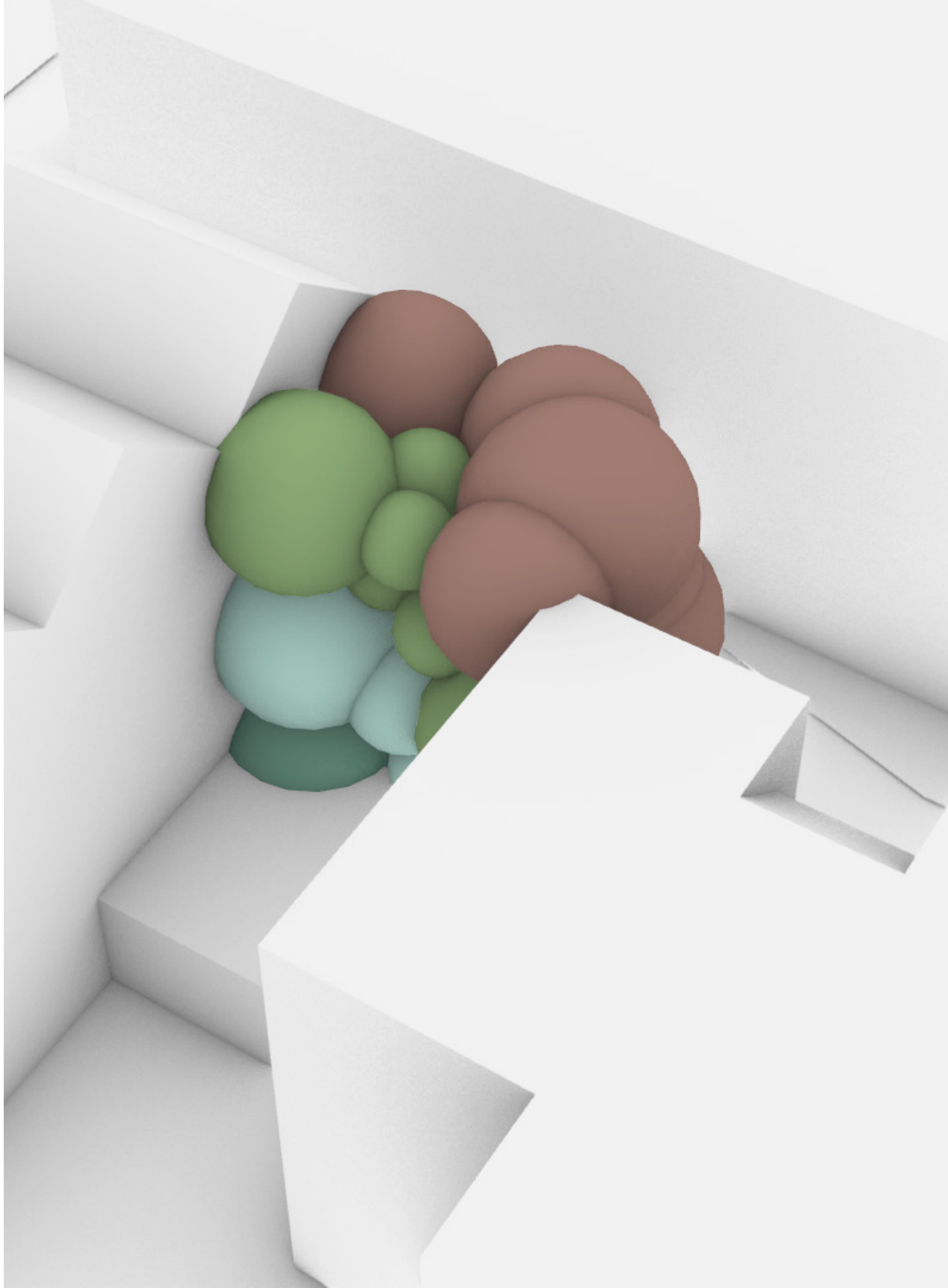
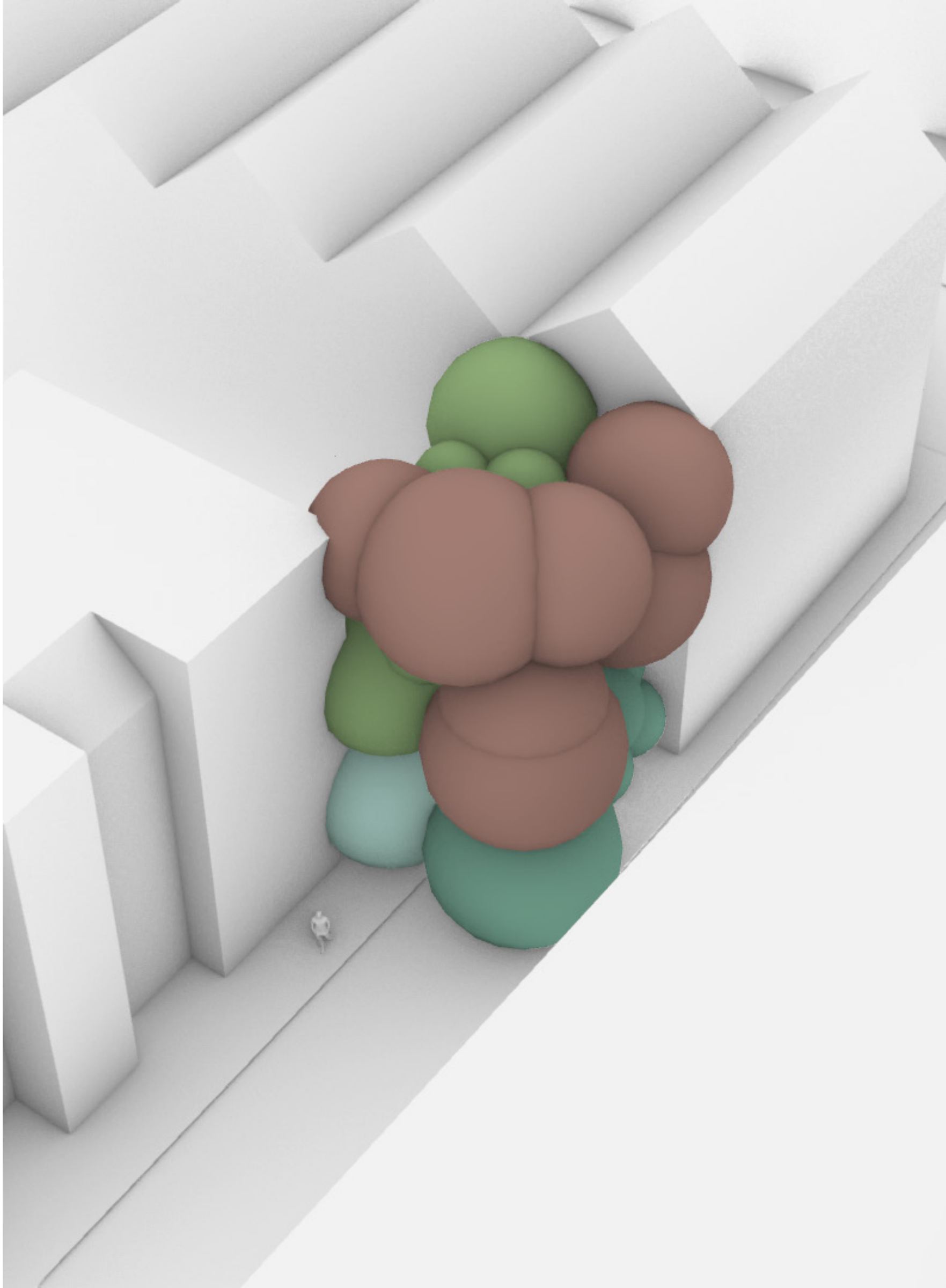
Couple + Kid



Shared



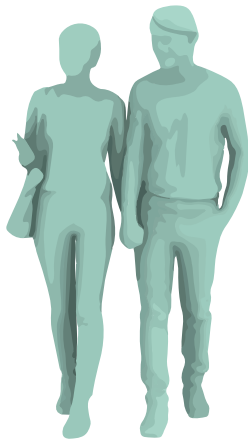
Connection Algorithm



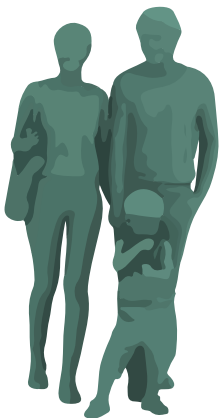
Orientation Algorithm



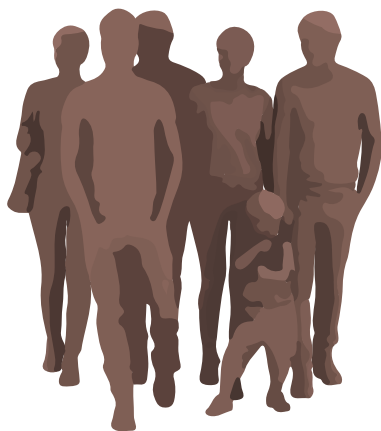
Single



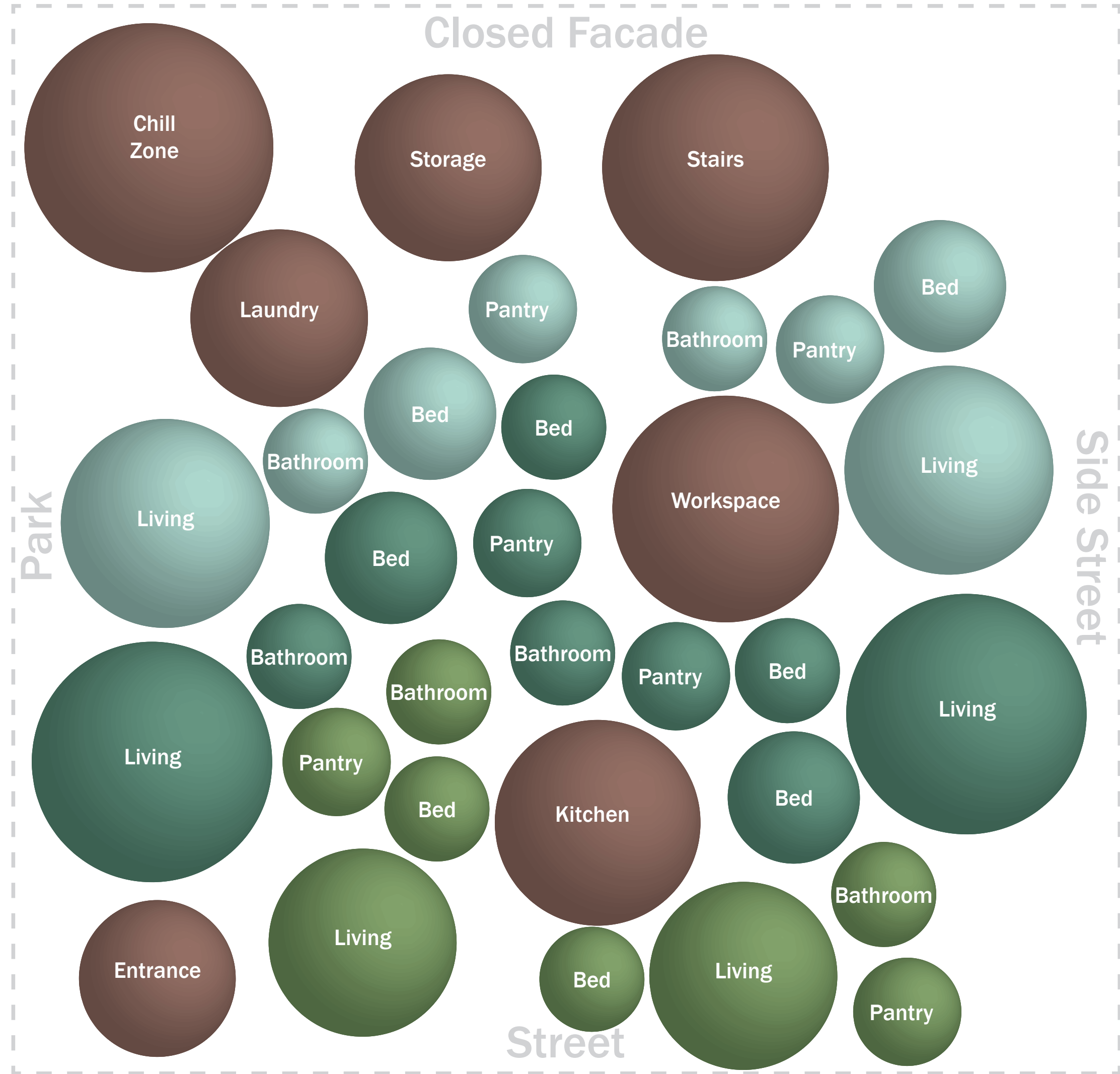
Couple



Couple + Kid

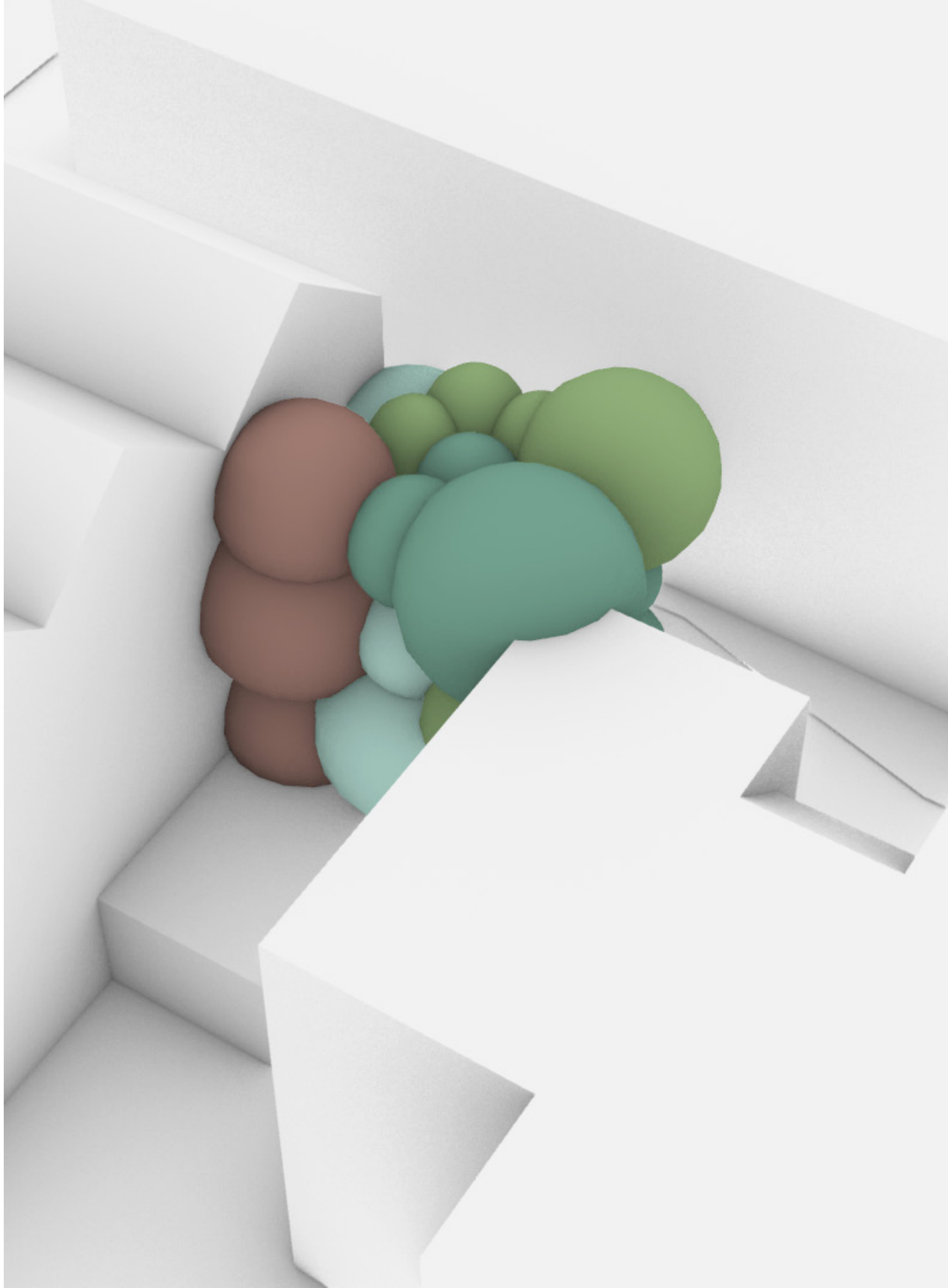
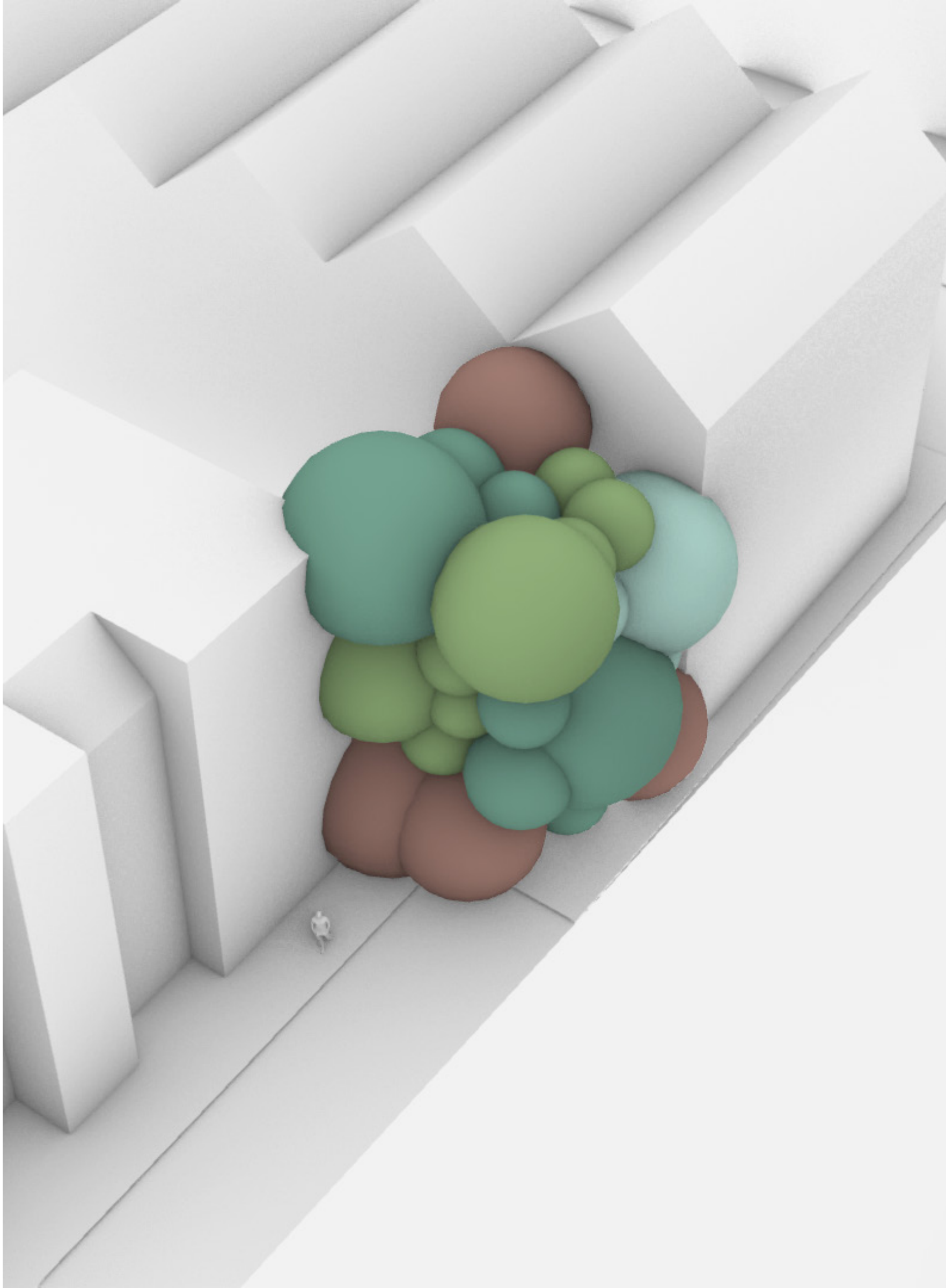


Shared



Bounding
Box

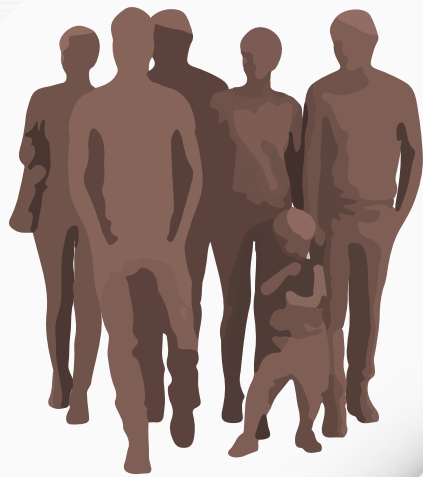
Orientation Algorithm



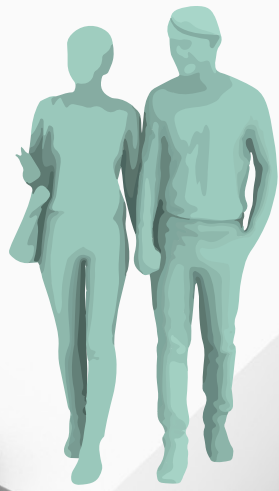
Final Bubble Positions & Parameters



Single



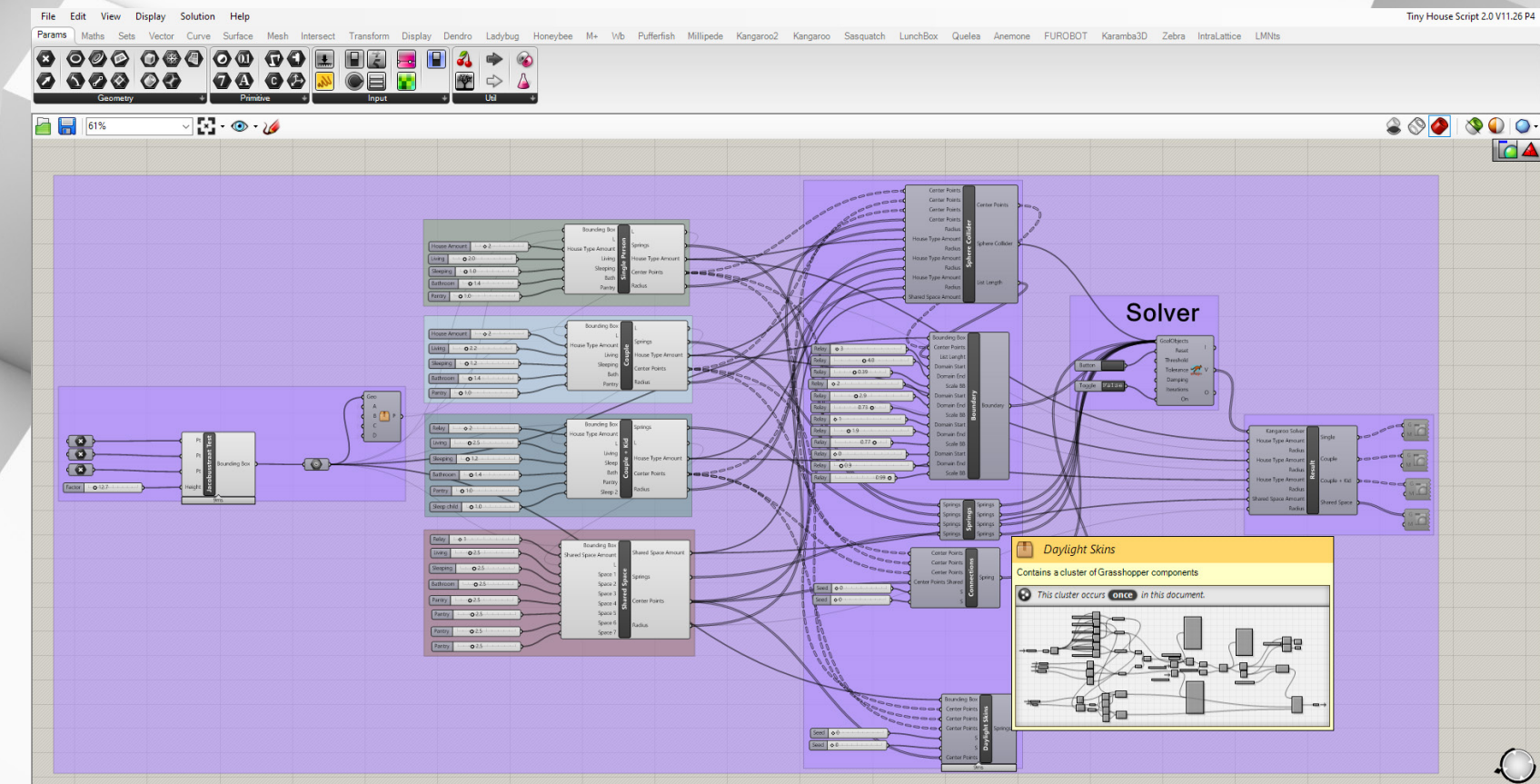
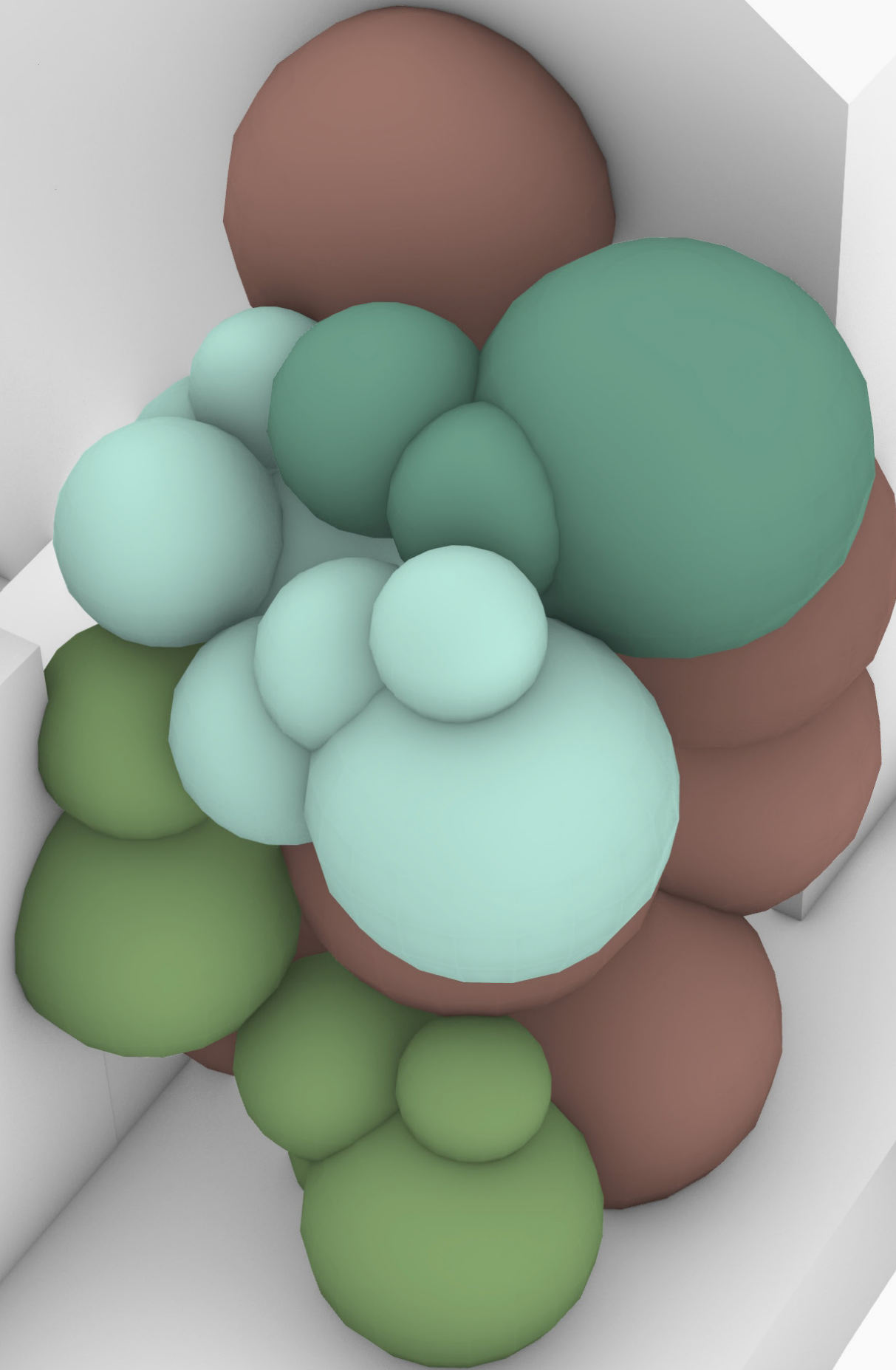
Shared



Couple



Couple + Kid



Human Centric Design Principles



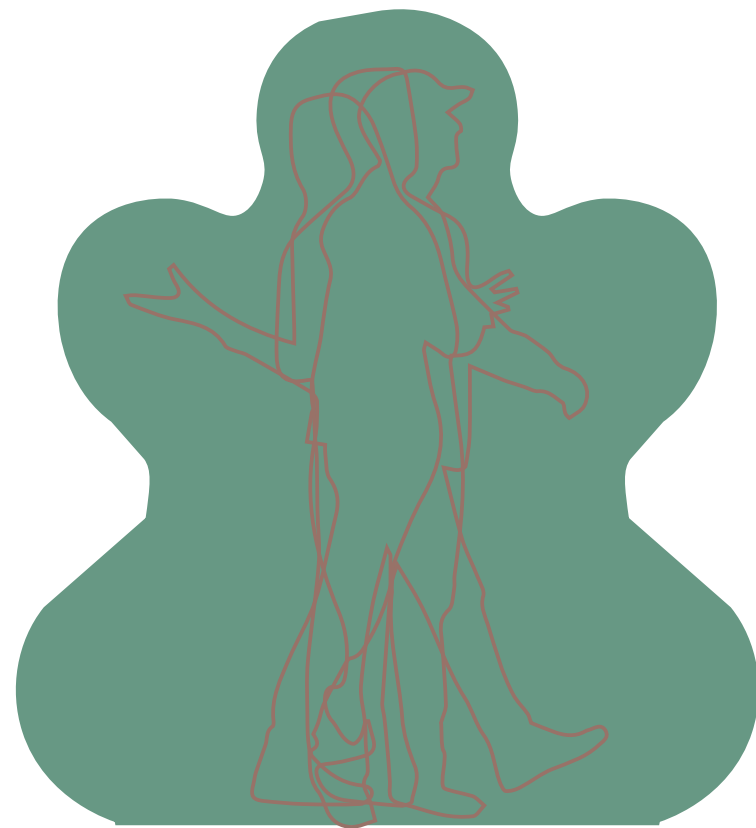
Standing/Walking



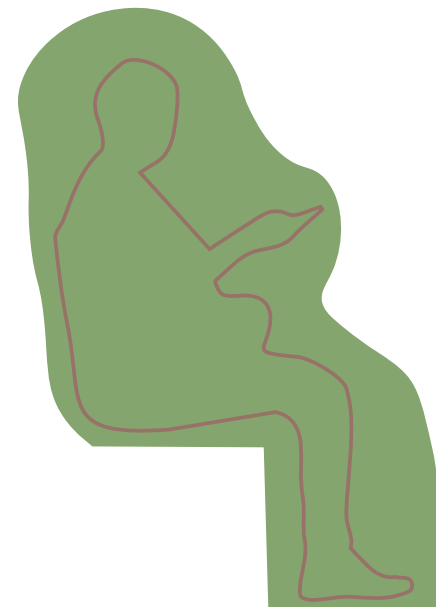
Sitting



Lying down



Standing/Walking Solid Profile

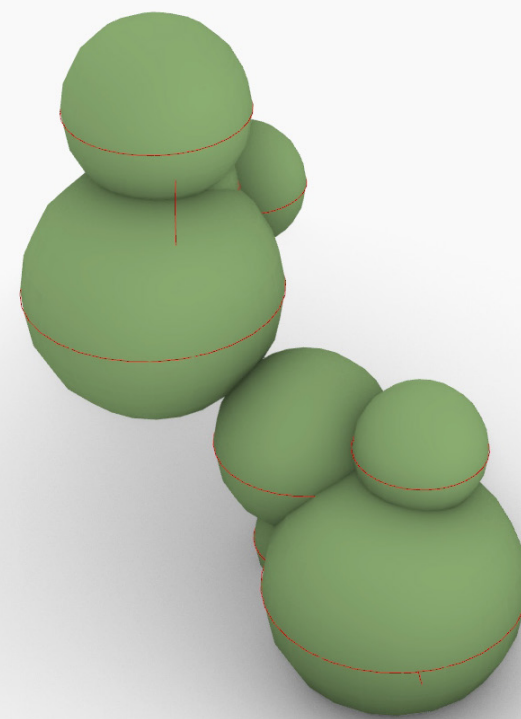
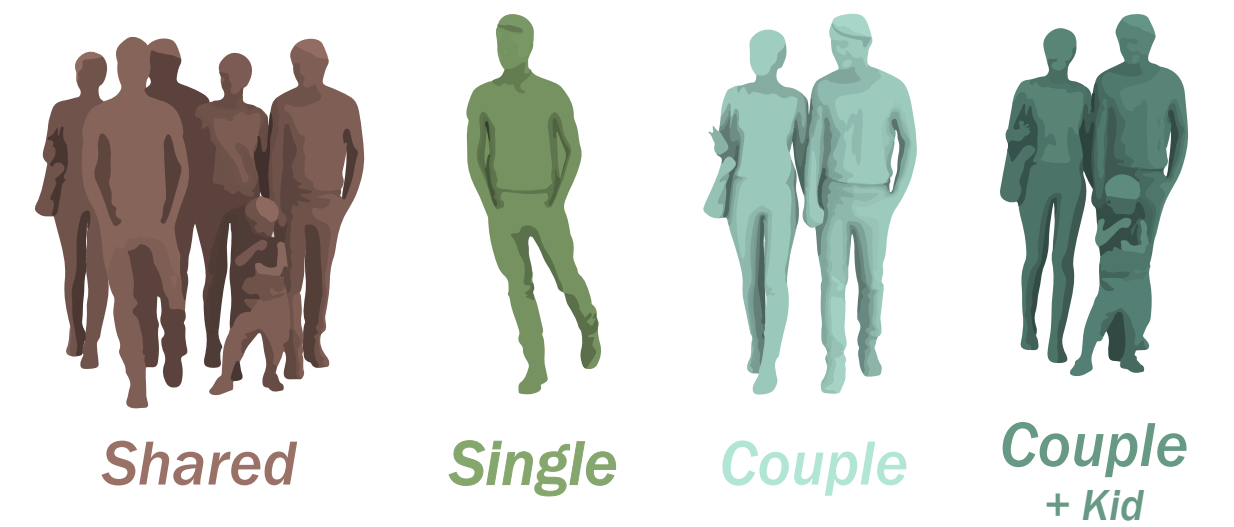


Sitting Solid Profile

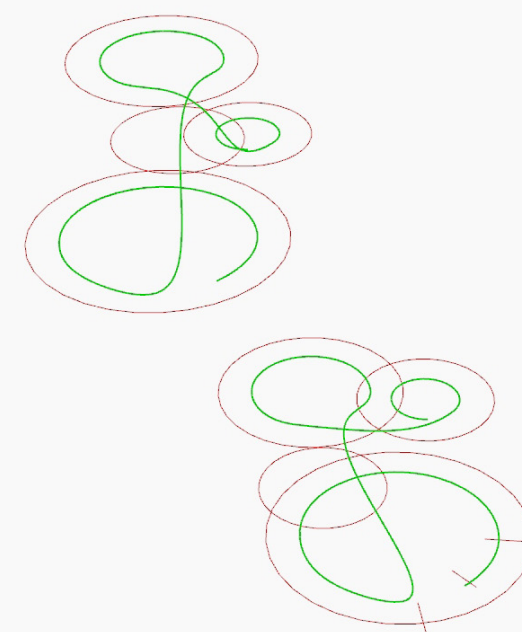


Lying down Solid Profile

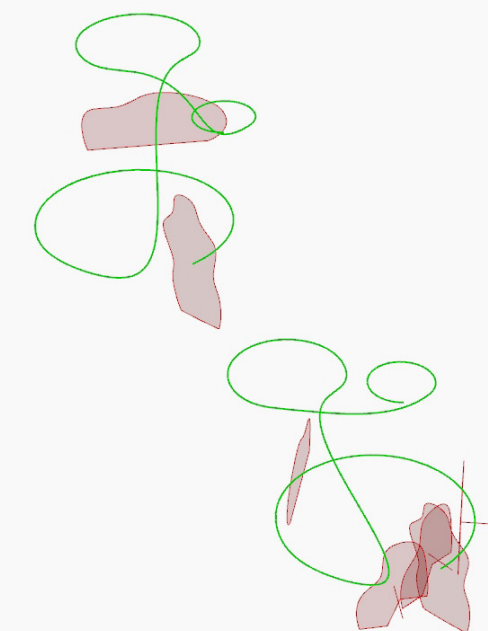
Human Centric Design



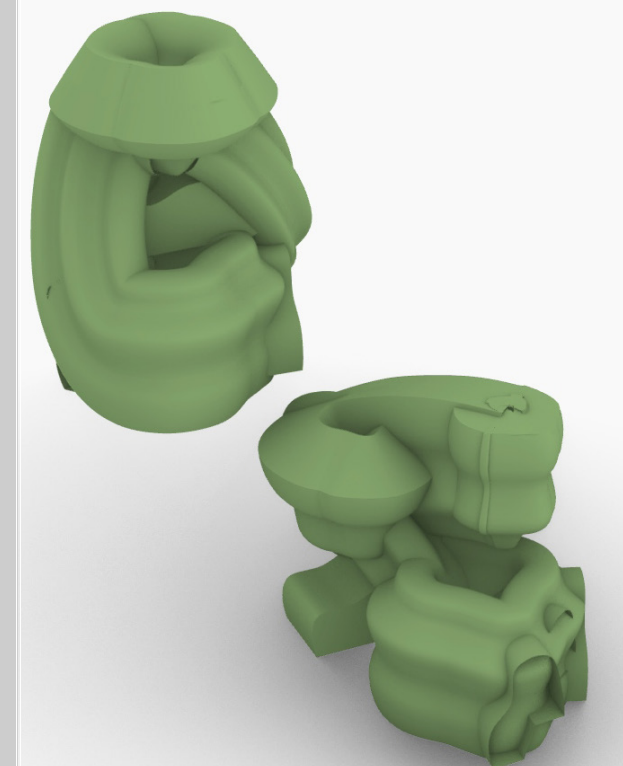
Cut Bubbles



Movement Rail



Sections

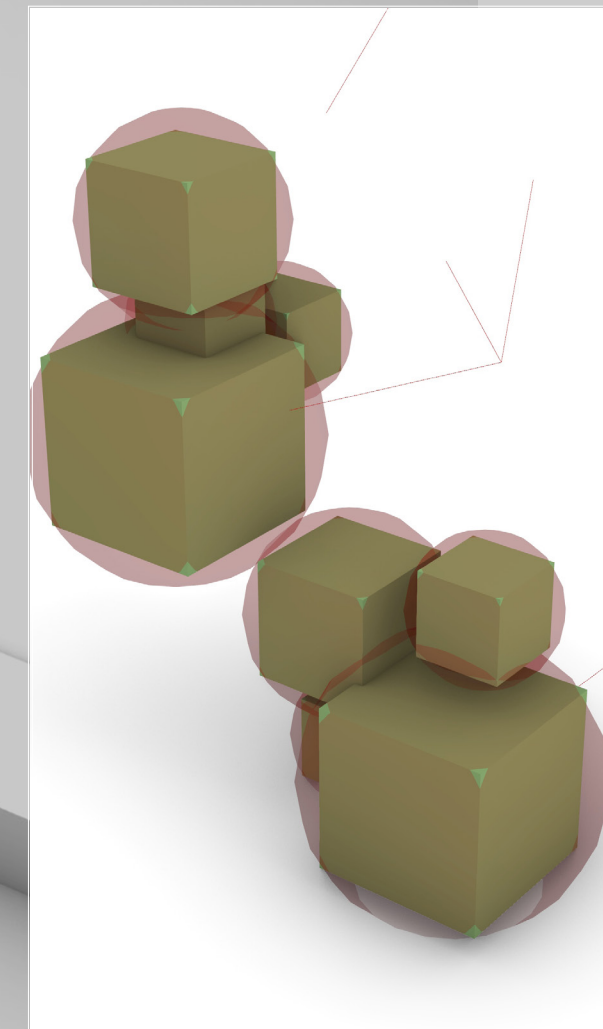
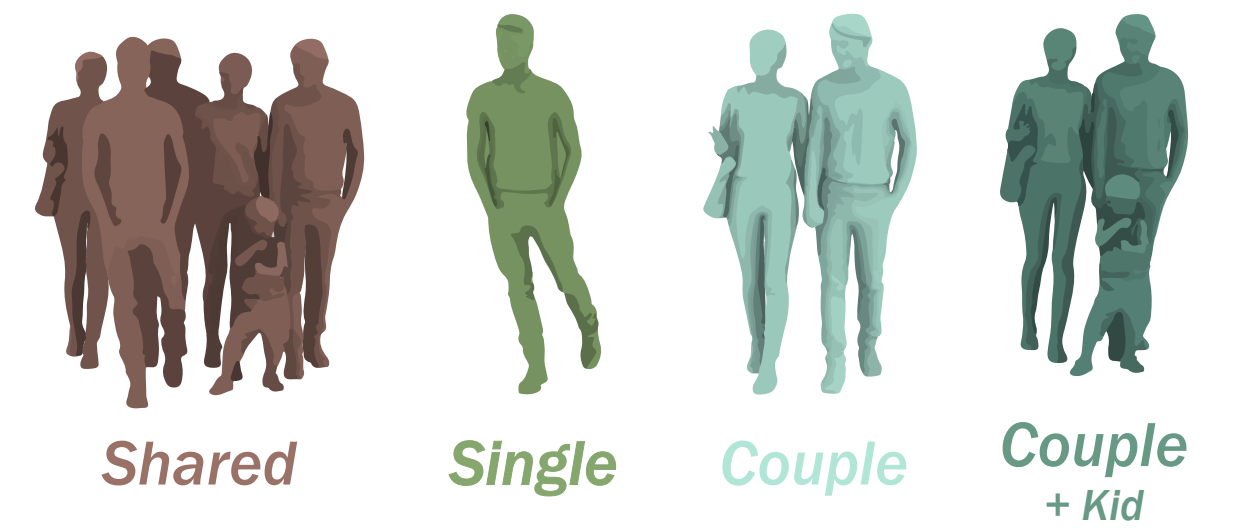


Extrusion

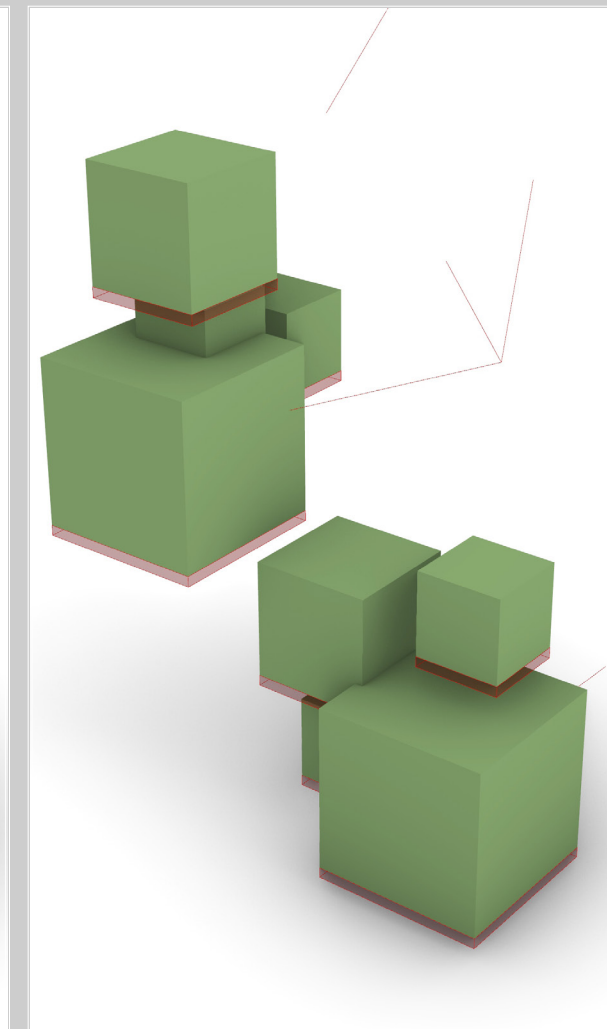
Sou Fujimoto Architects/NA House



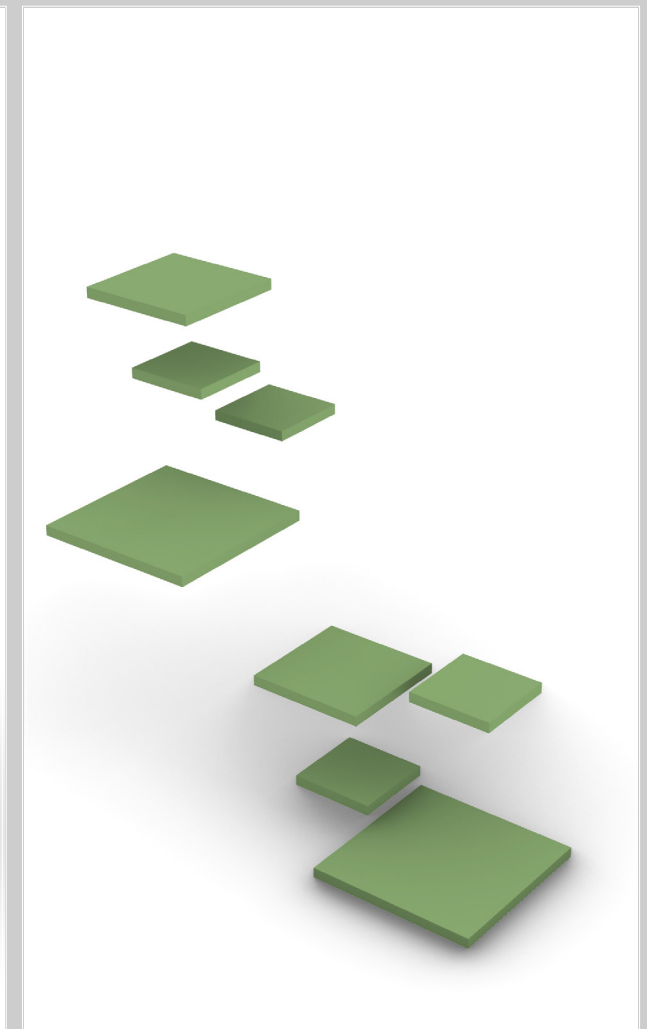
Platform Creation



Cube in bubbles

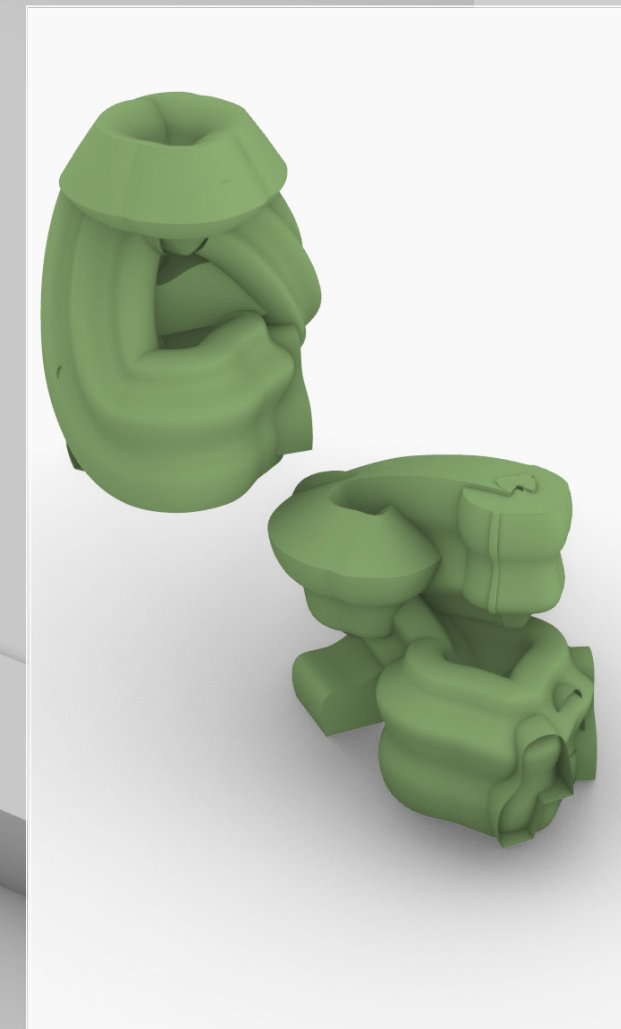
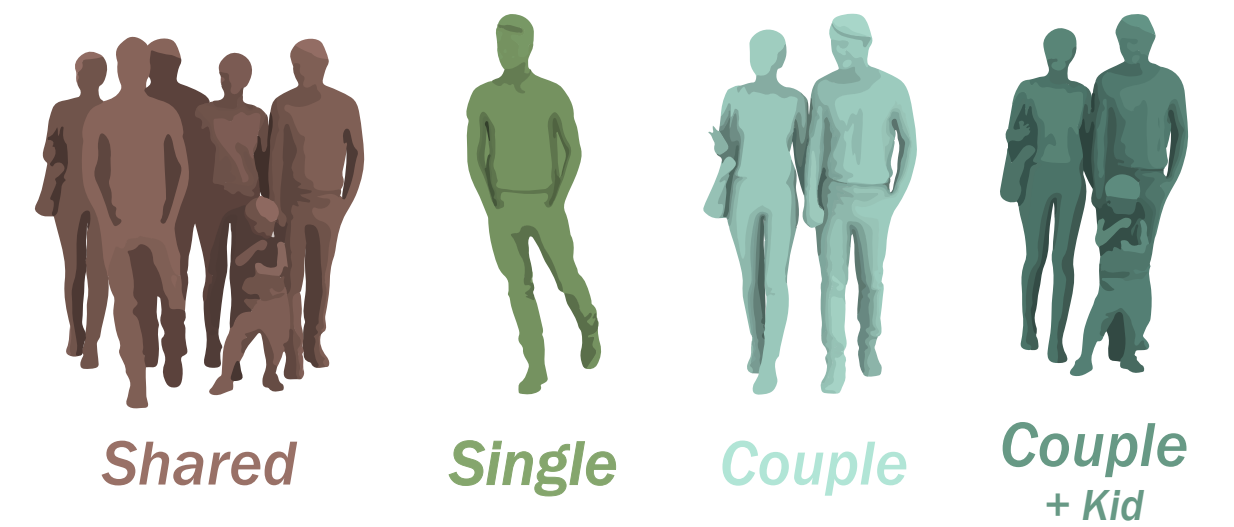
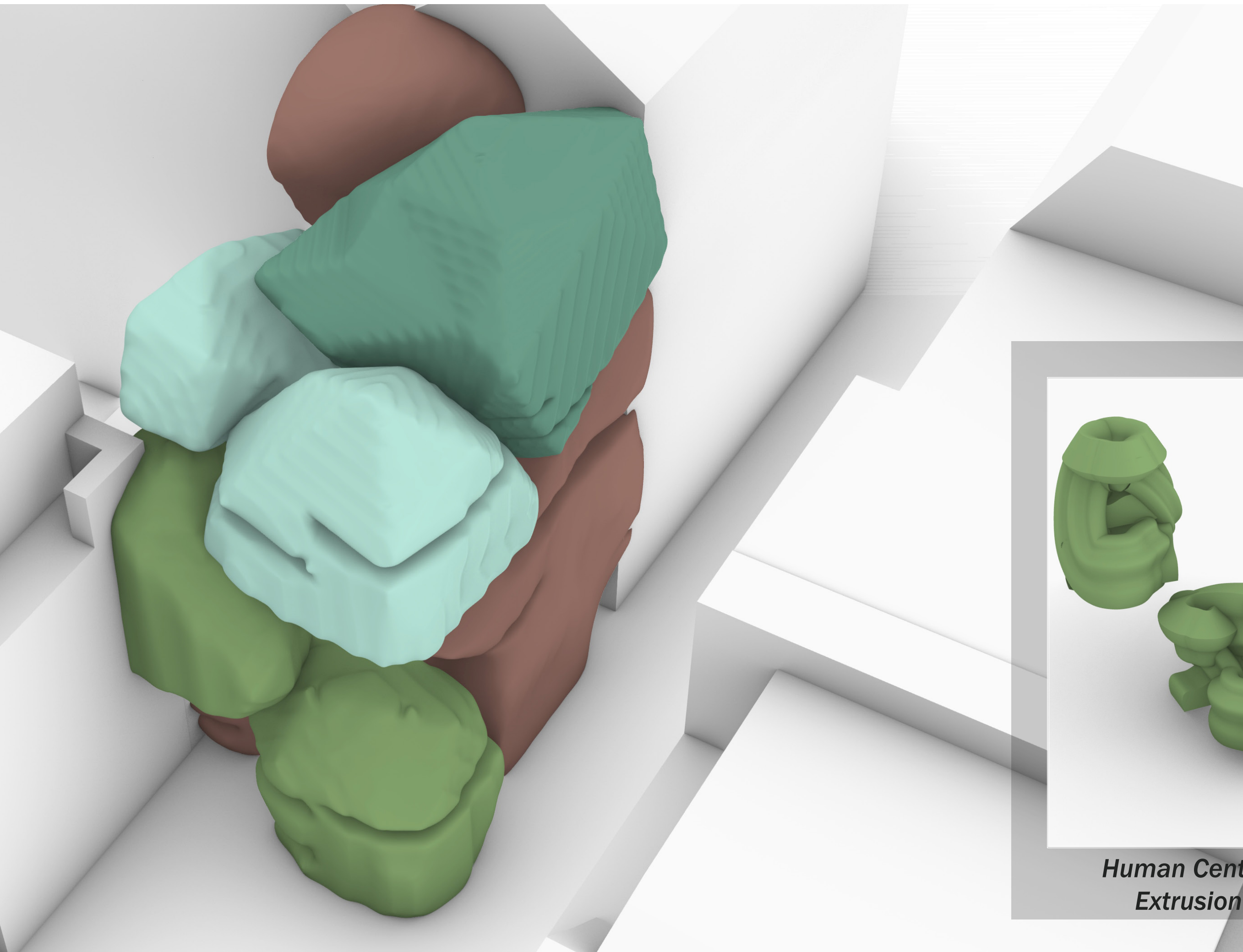


Platform at bottom

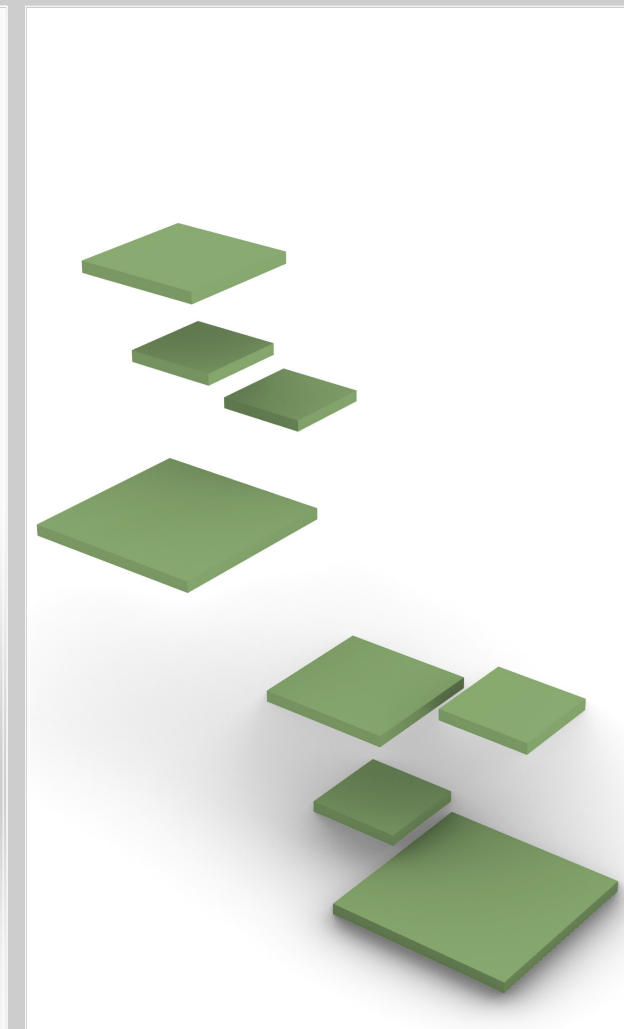


Platform Squares

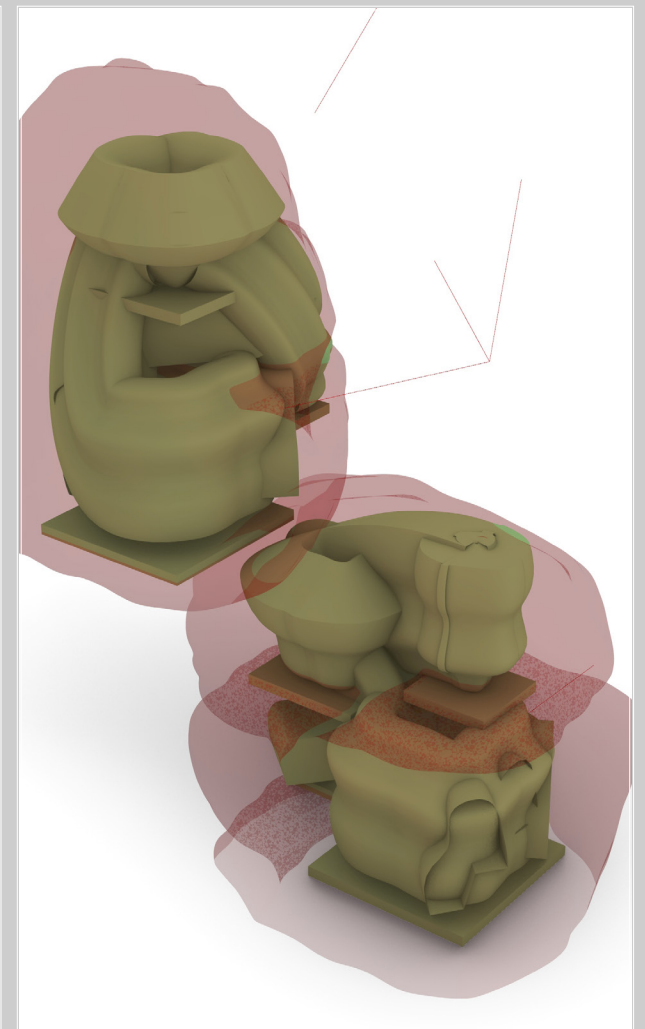
Wrap/Charge Creation



*Human Centric
Extrusion*

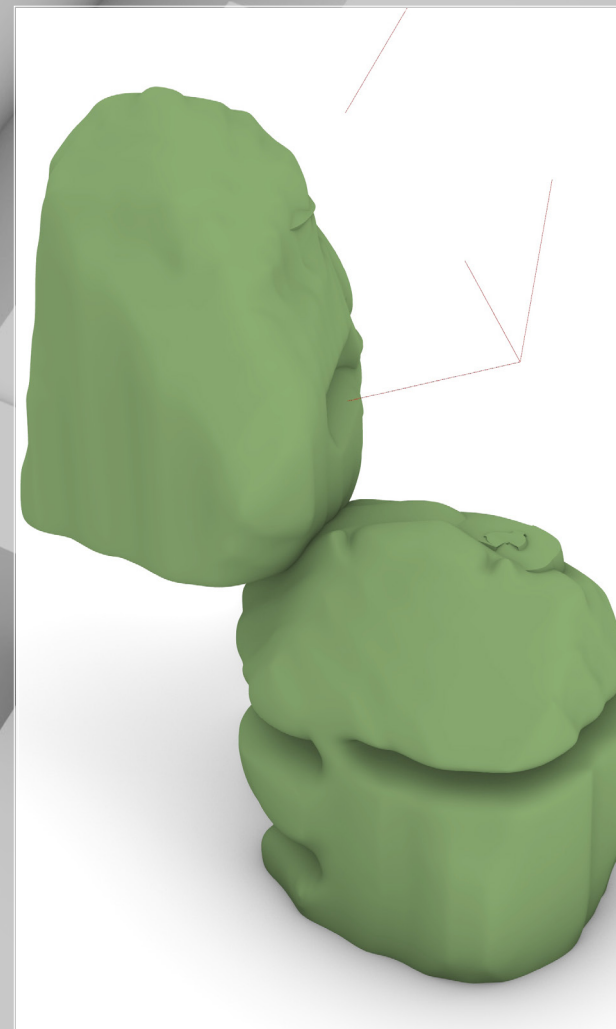
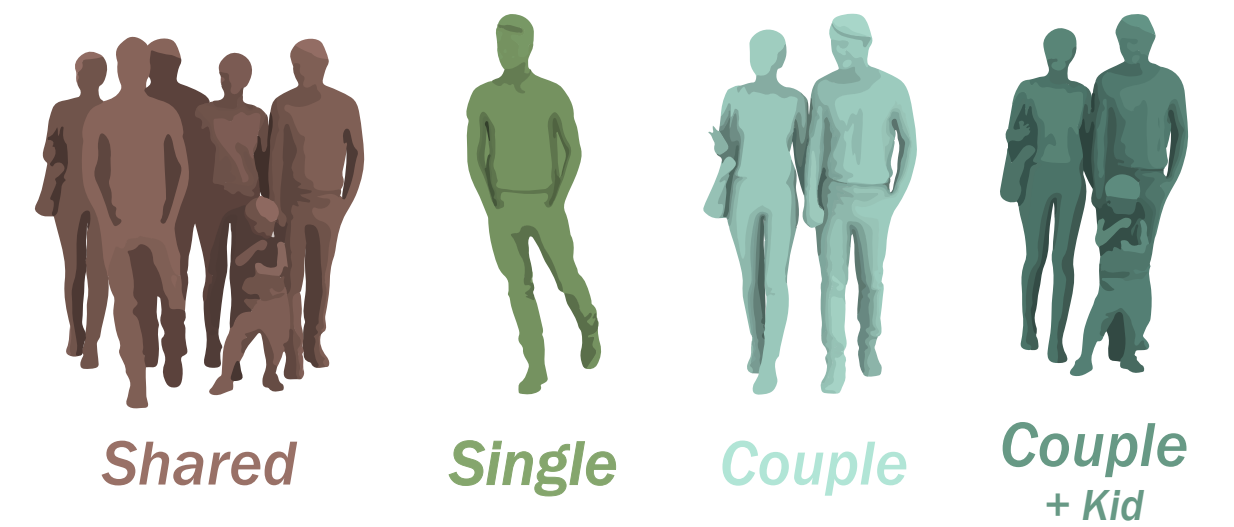
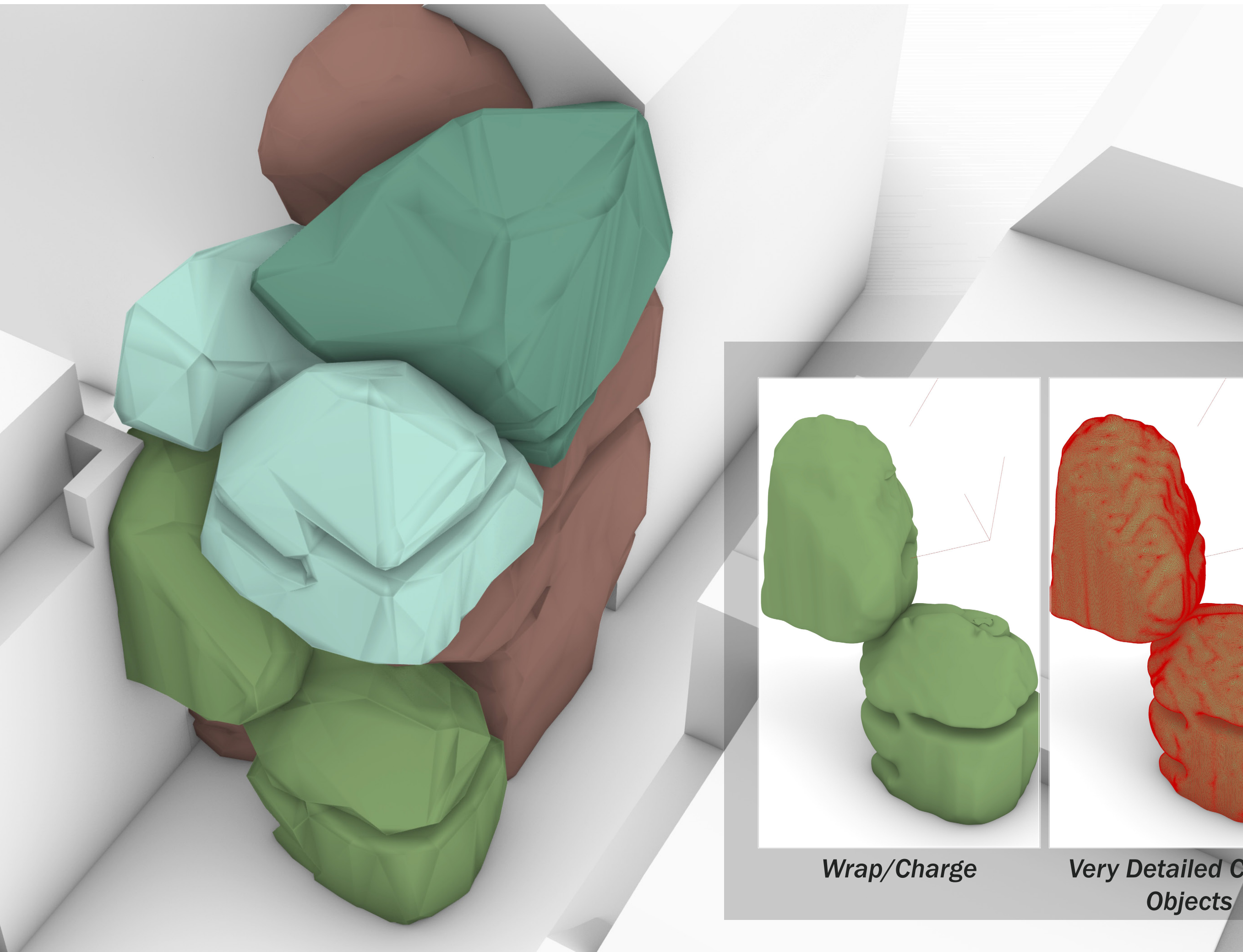


Platforms

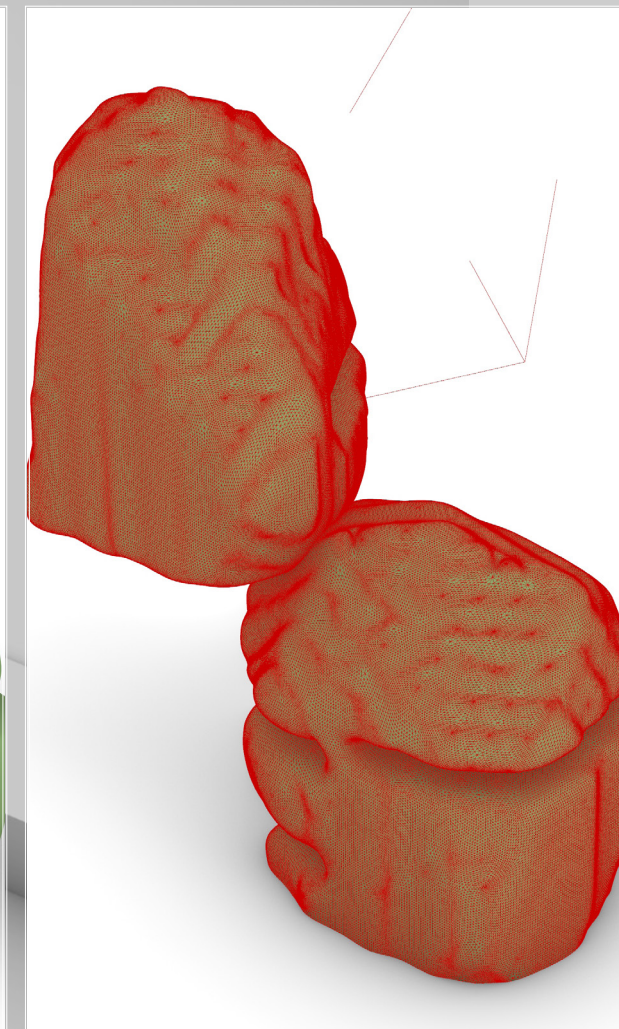


*Wrap around both
spaces combined*

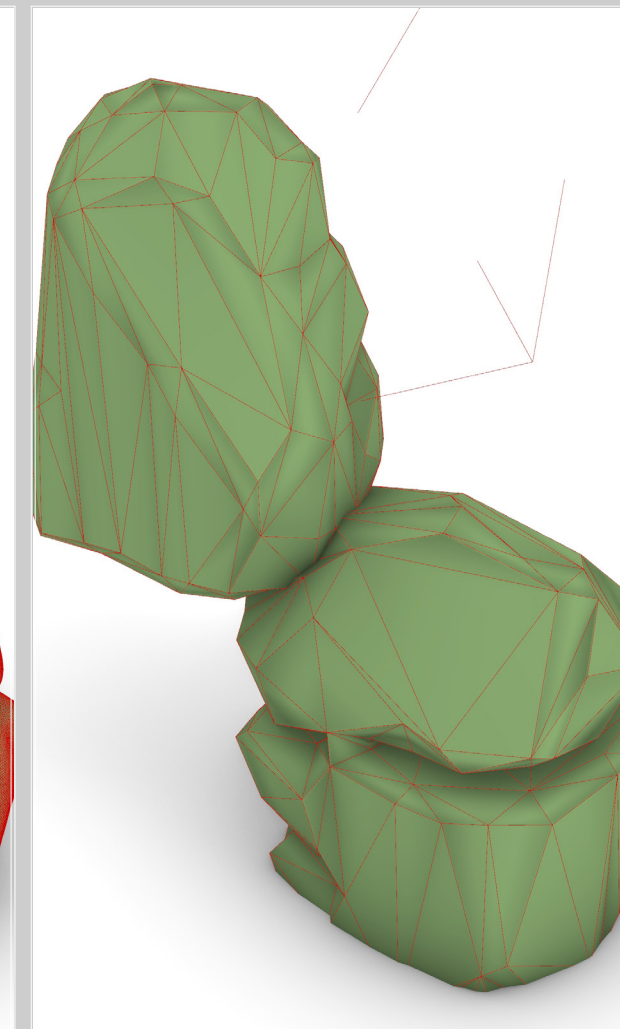
Faceted Rationalization



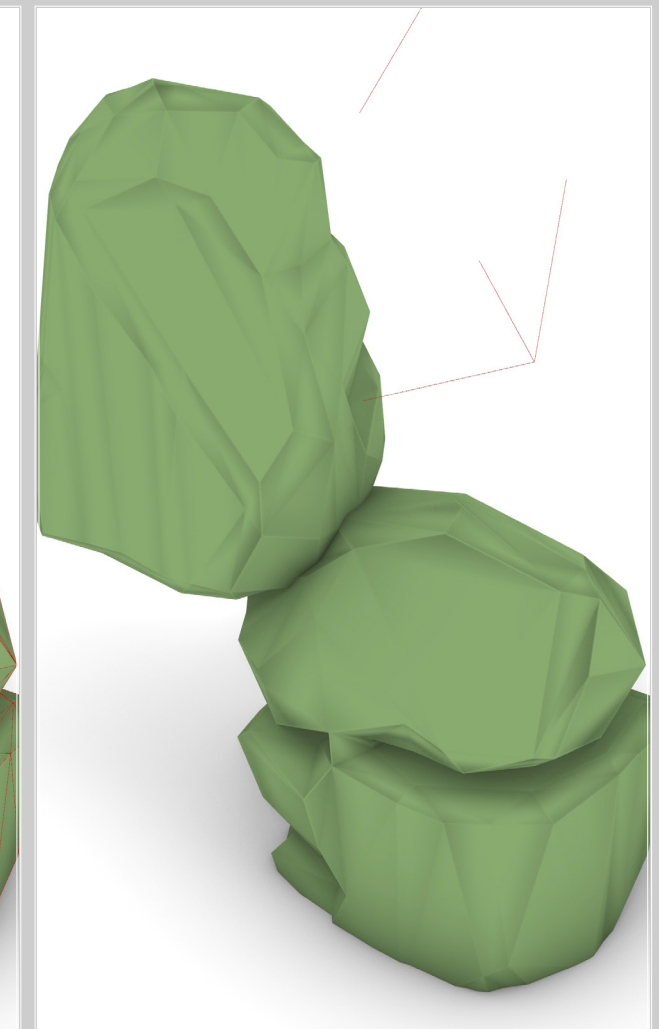
Wrap/Charge



*Very Detailed Curved
Objects*

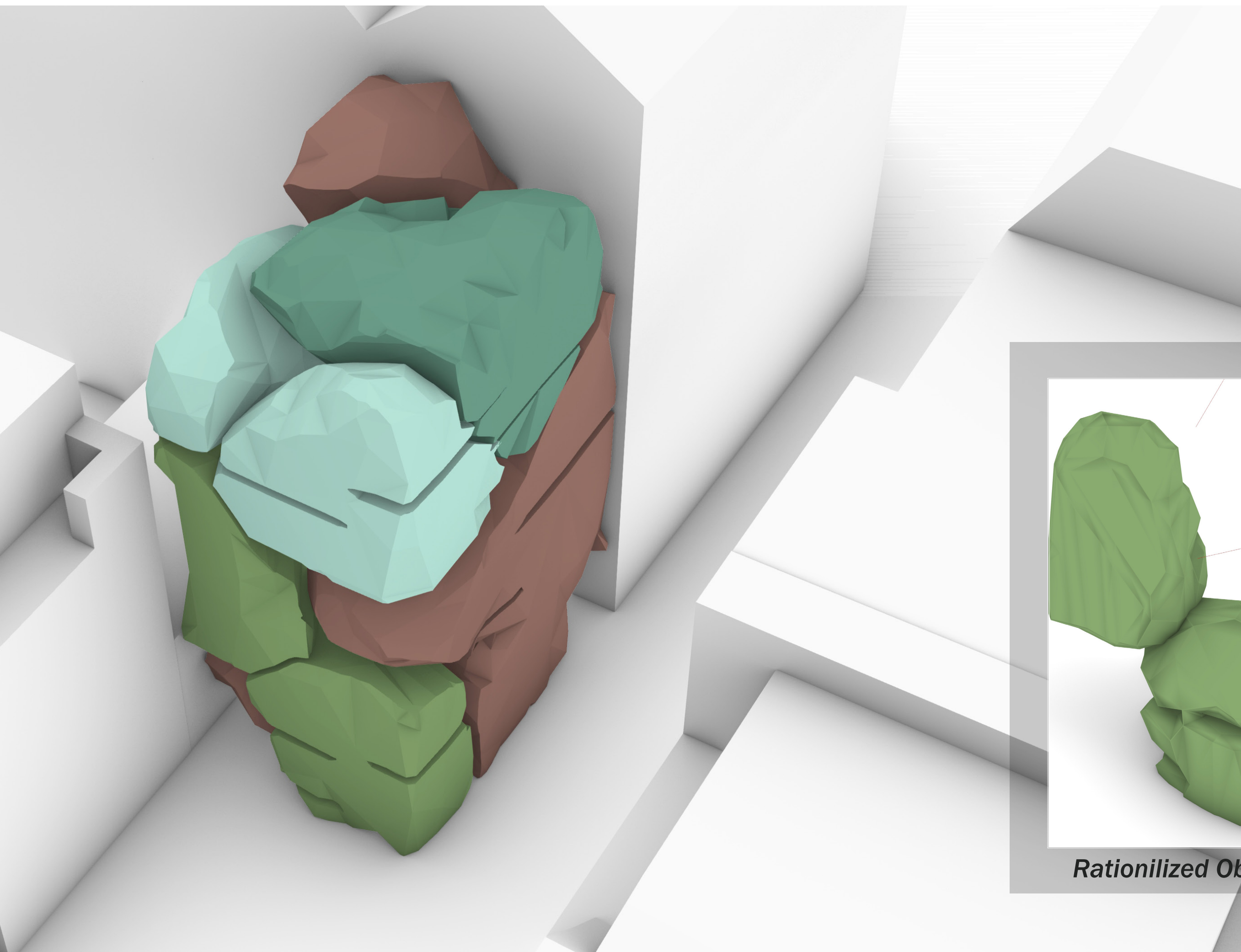


*Rationalize by
triangulation*



*Create more usable
surface area in units*

City Adaptation



Shared



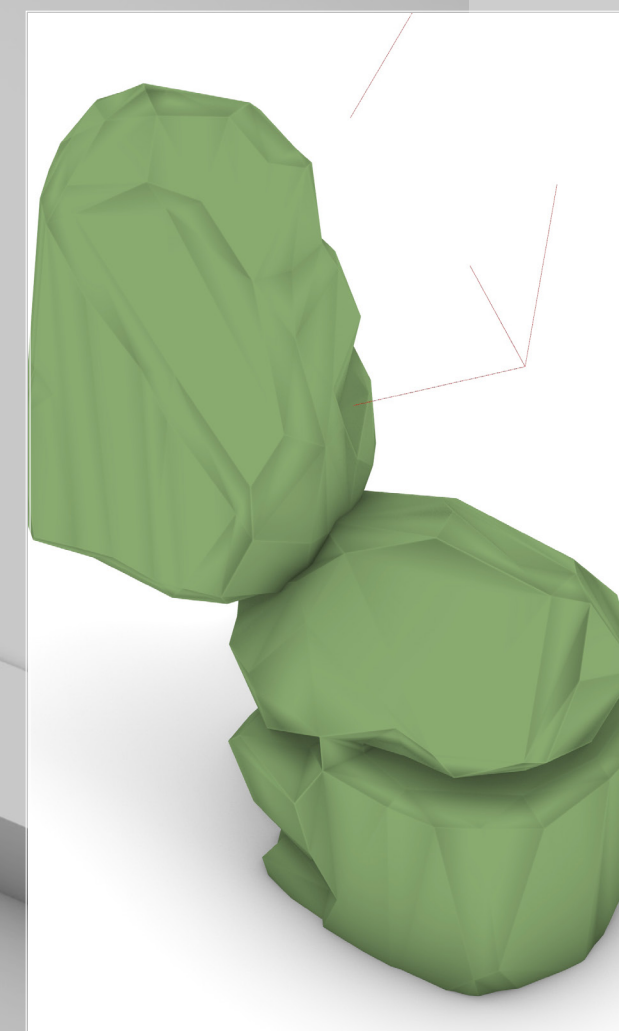
Single



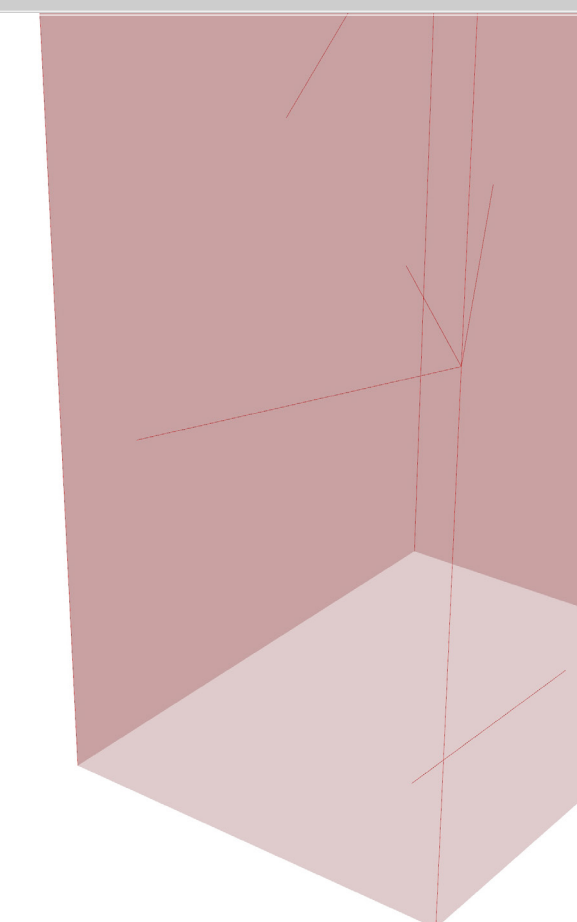
Couple



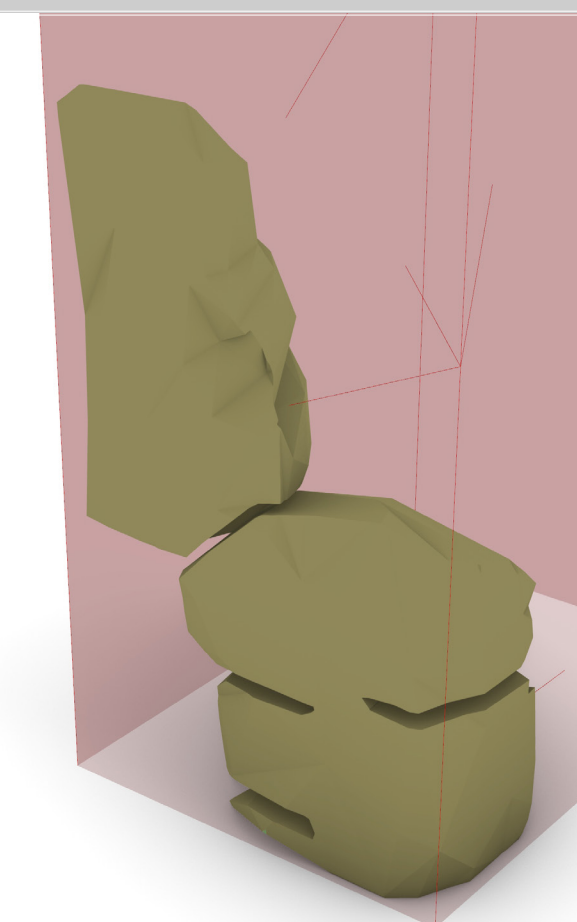
*Couple
+ Kid*



Rationalized Objects



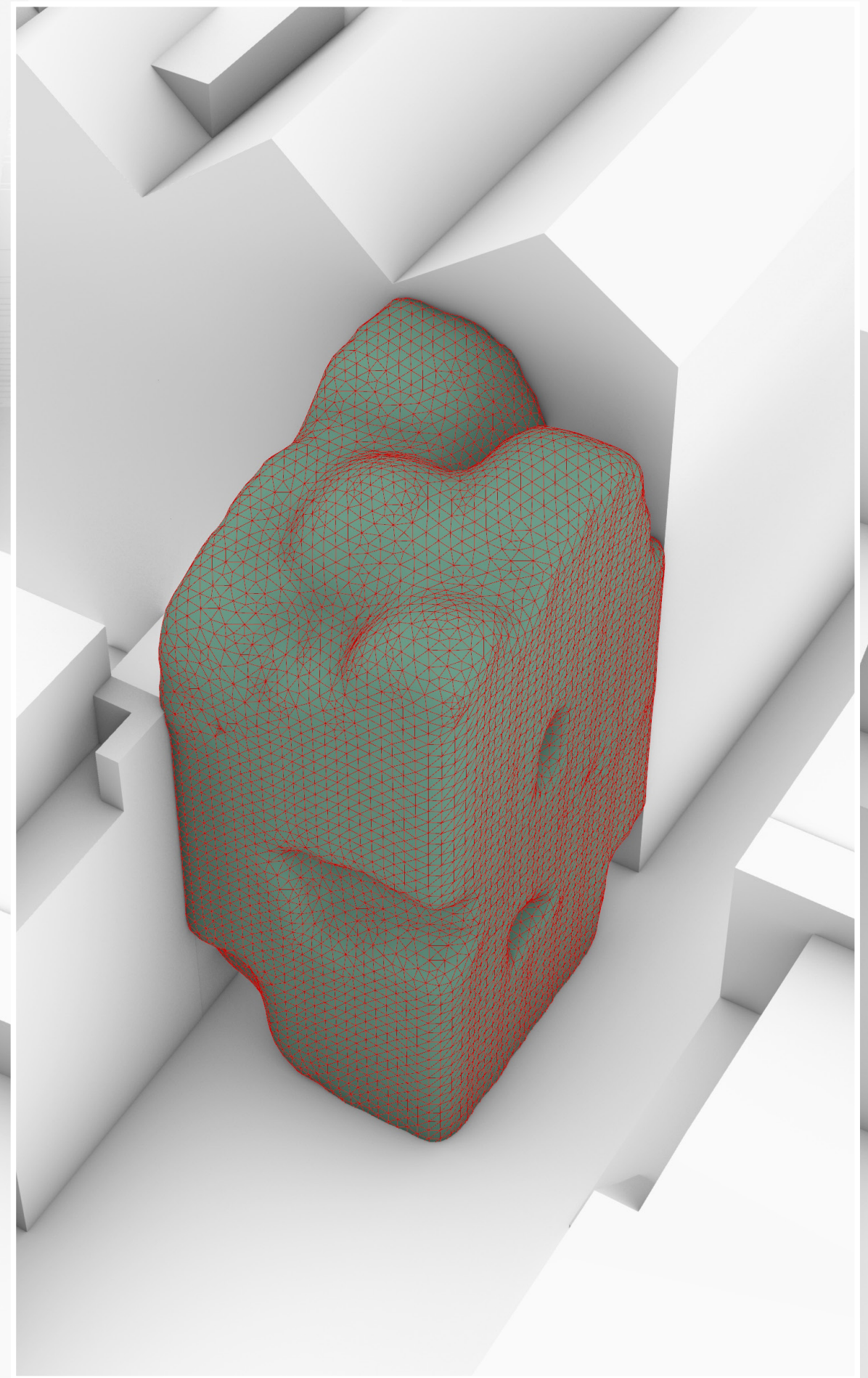
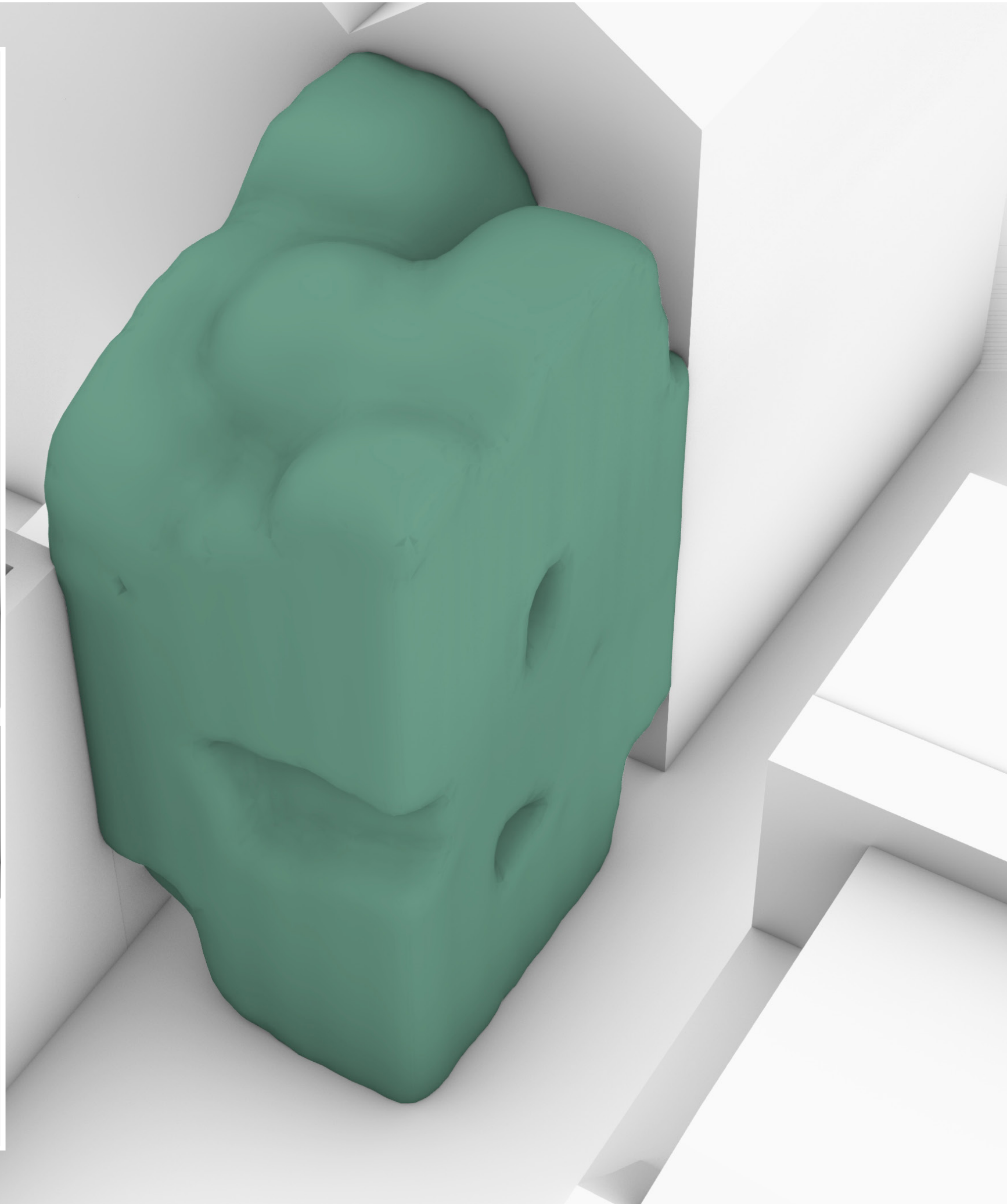
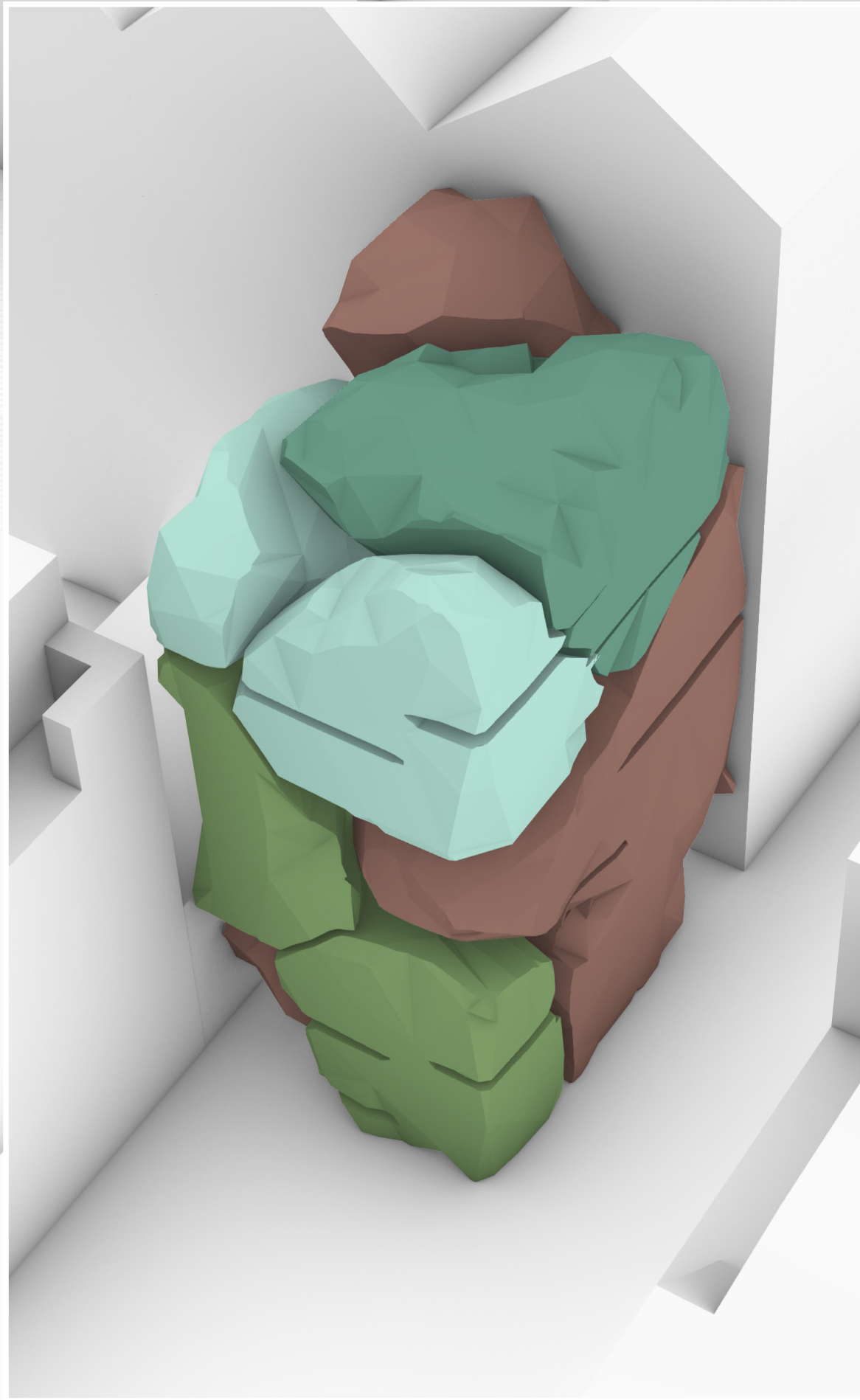
Bounding Box



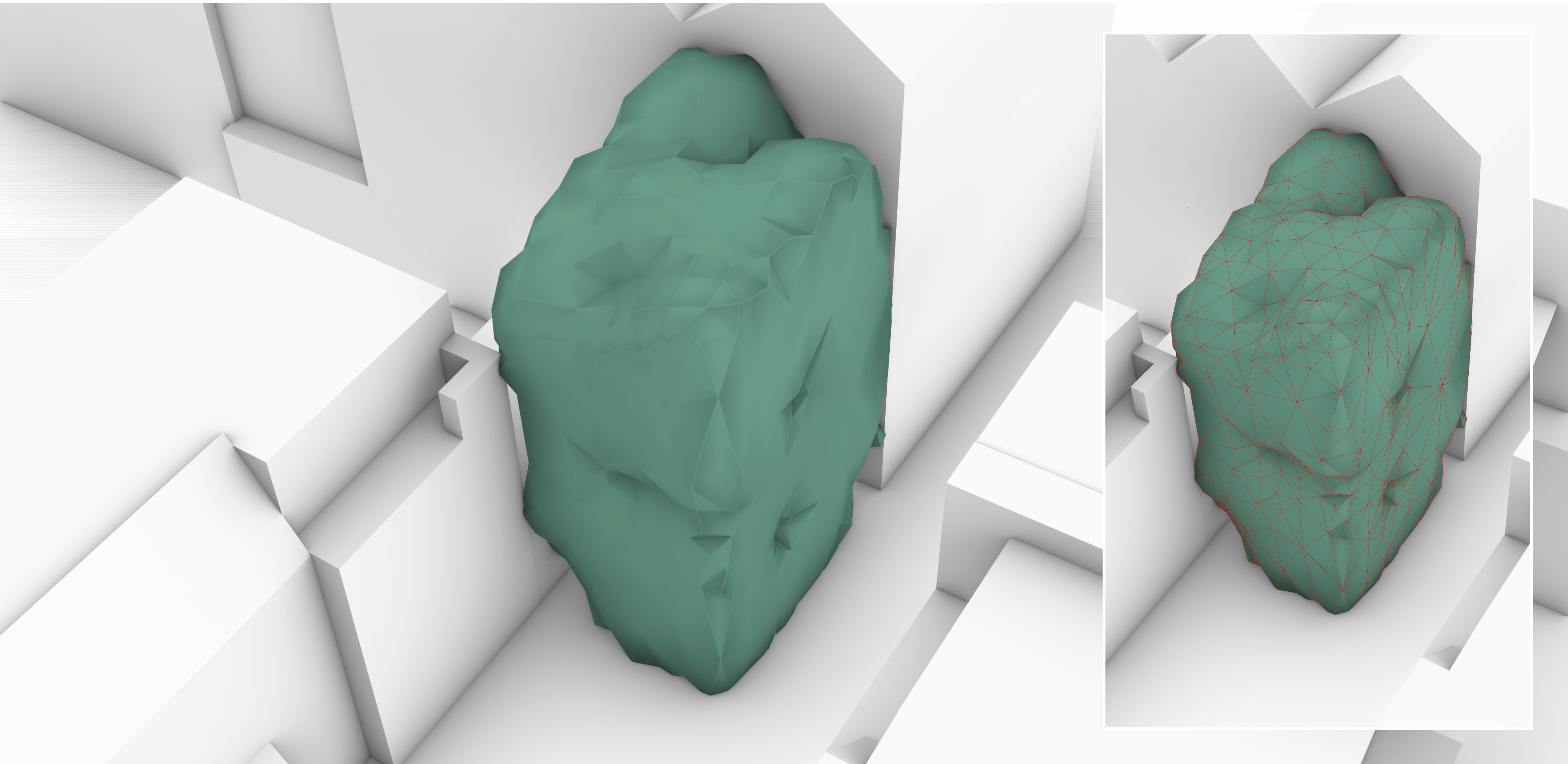
Bounding Box Cut

Exterior Design

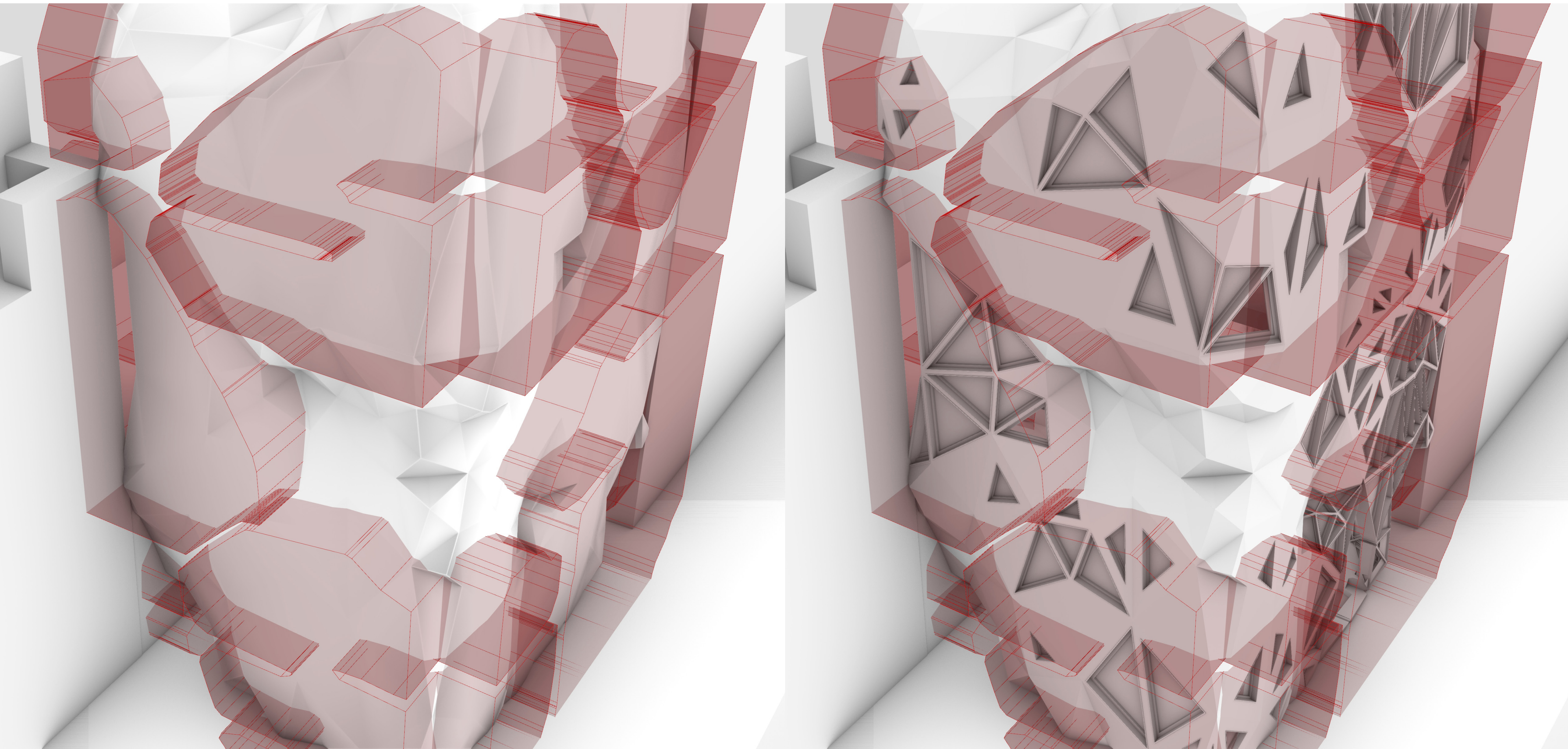
Exterior Wrap Around Interior Units



Faceted Rationalization



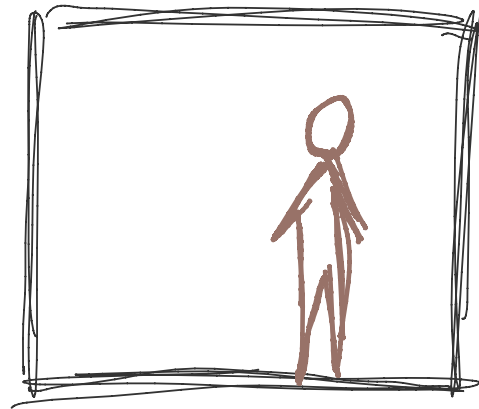
Window Location Script



Window Location Script

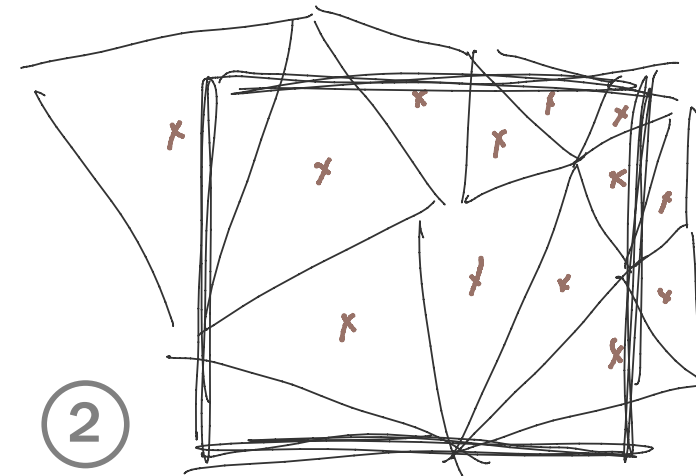
House Section
Living Space

①



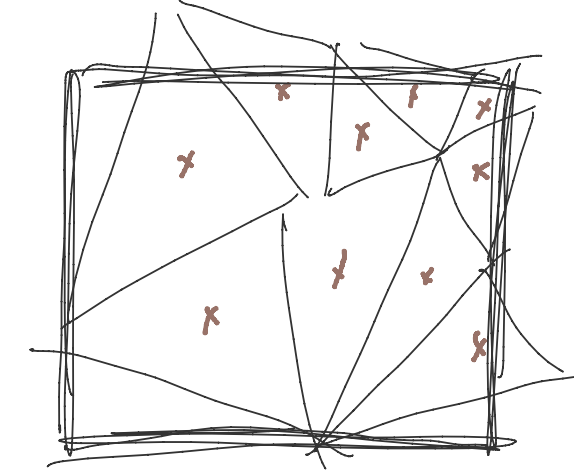
Triangulation
Skin

②



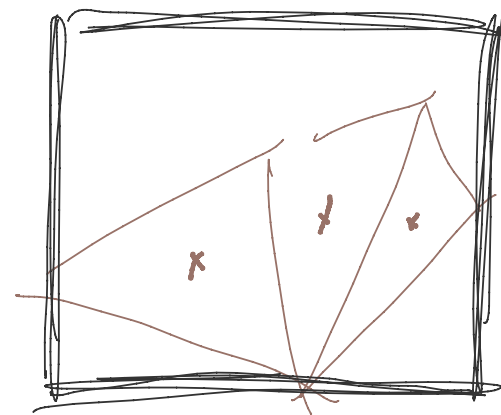
Center Triangle in
Section

③



Entire Triangle Fit
in Section

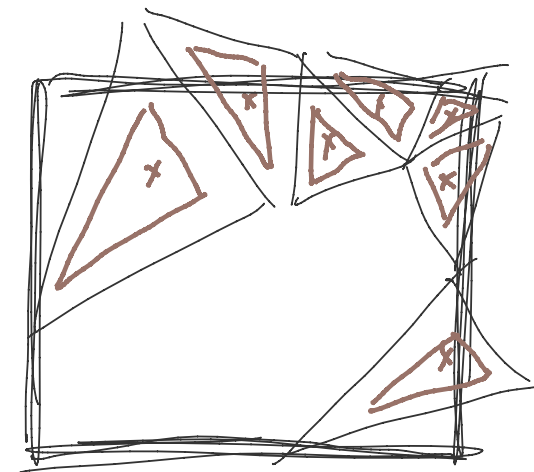
④



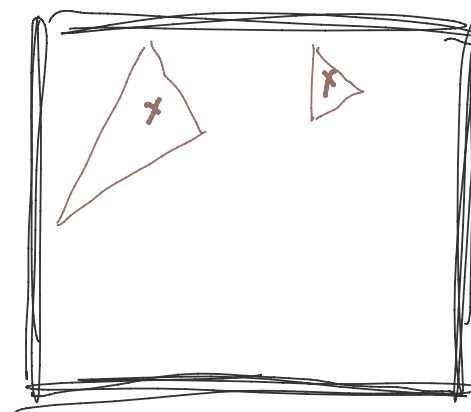
+

Scaled Triangle
Fit in Section

⑤

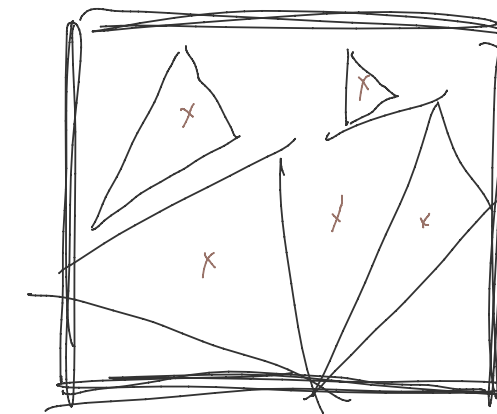


⑥



Gradient
Windows

⑦



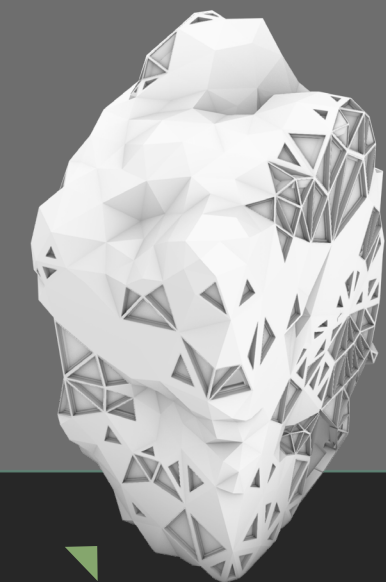
Windows South Skin

1m 5m

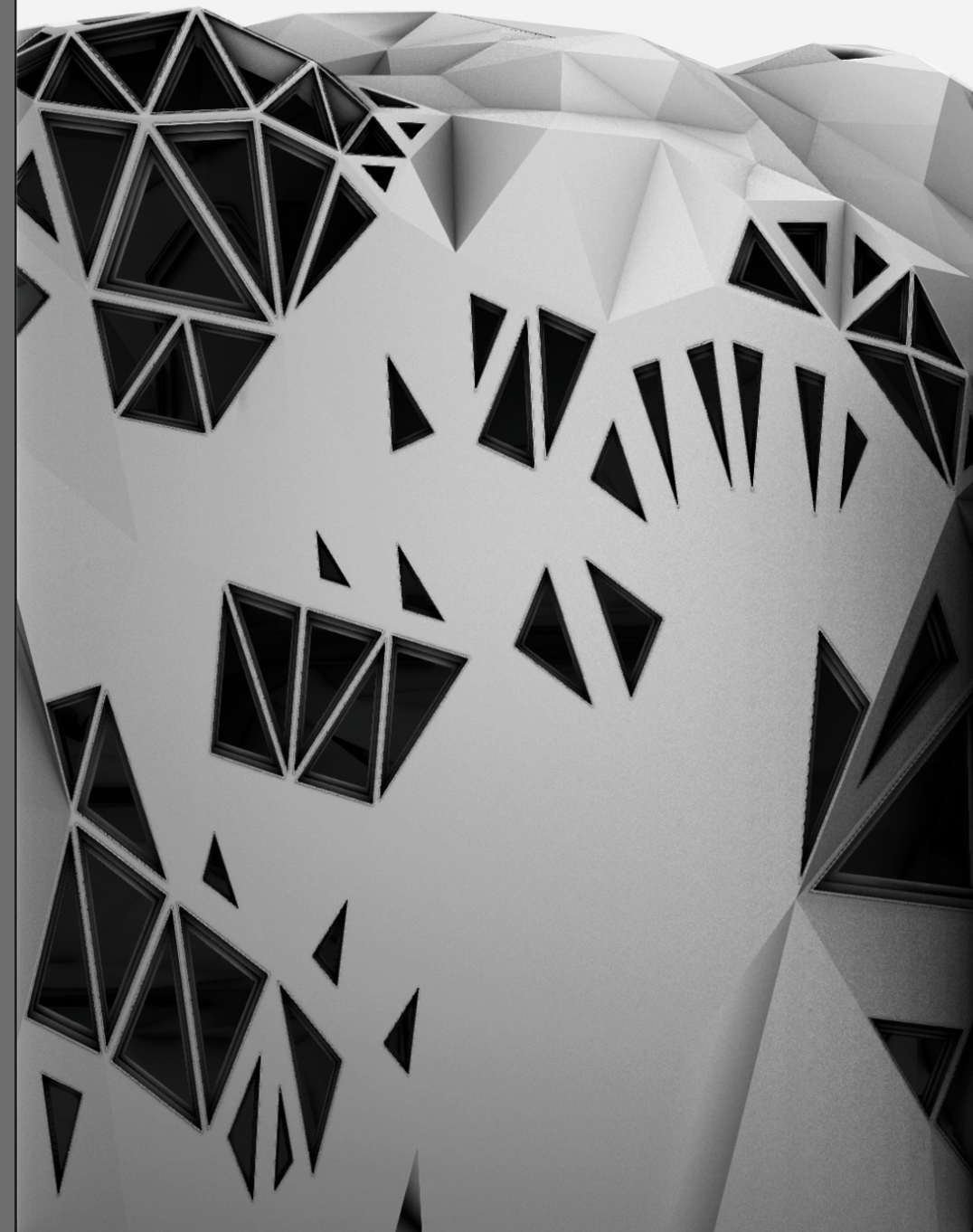
+10500

+5500

+1500



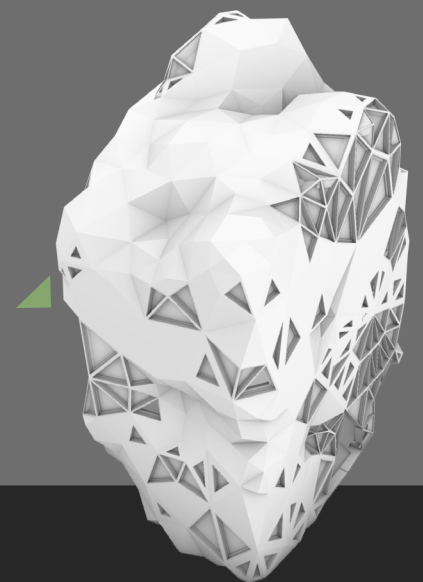
Windows West Skin



+10500

1m

5m



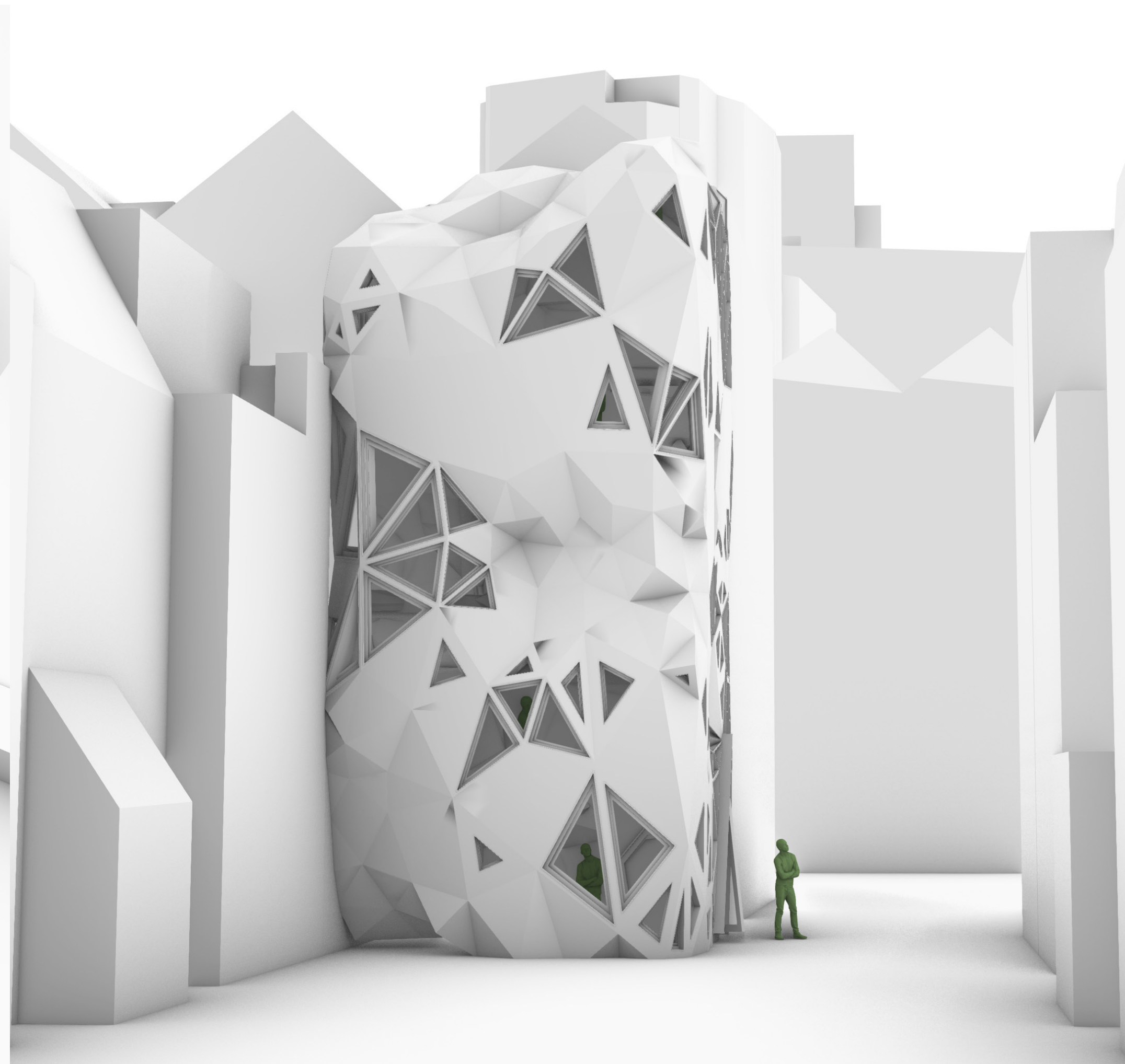
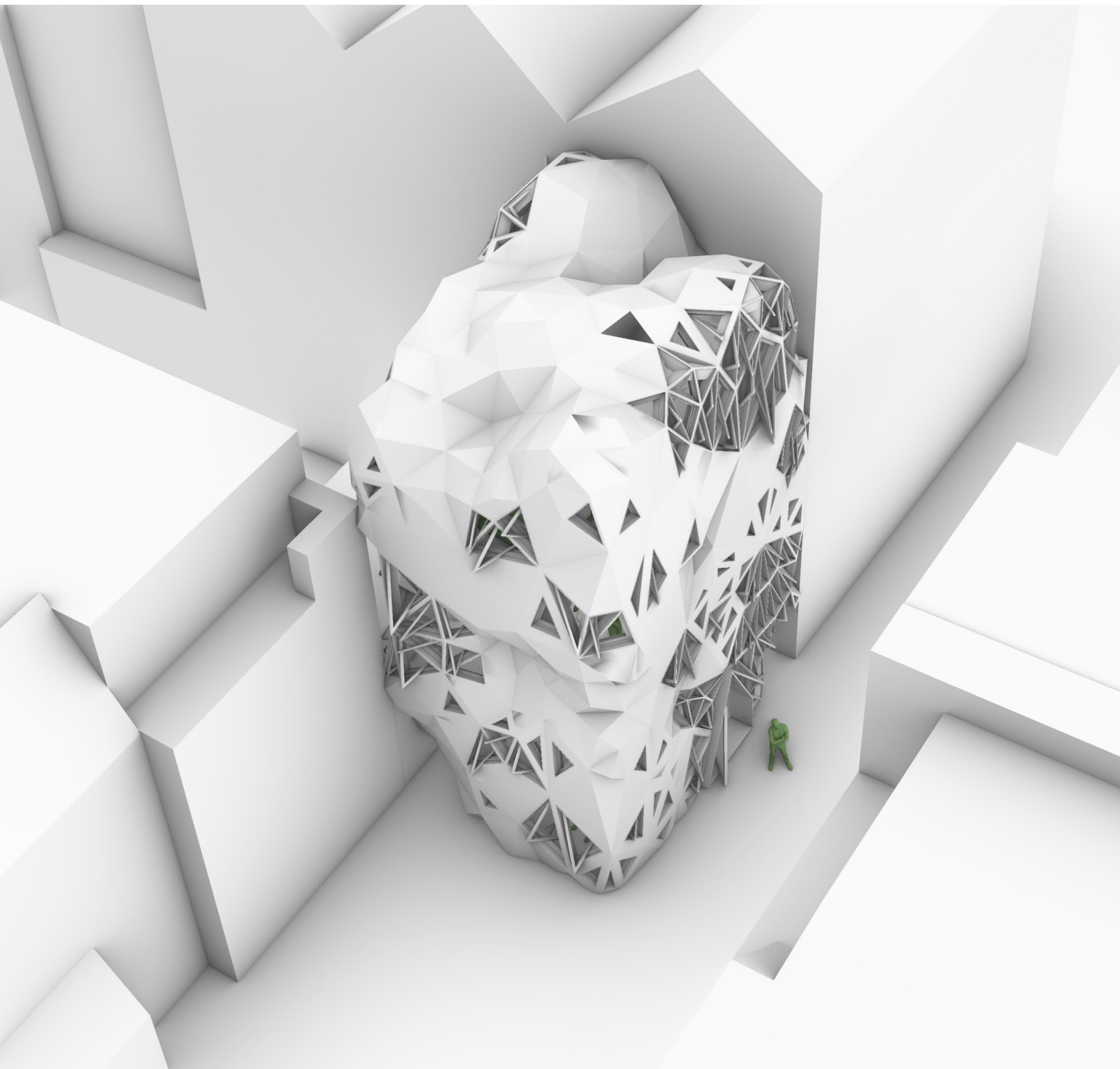
Windows East Skin



1m 5m

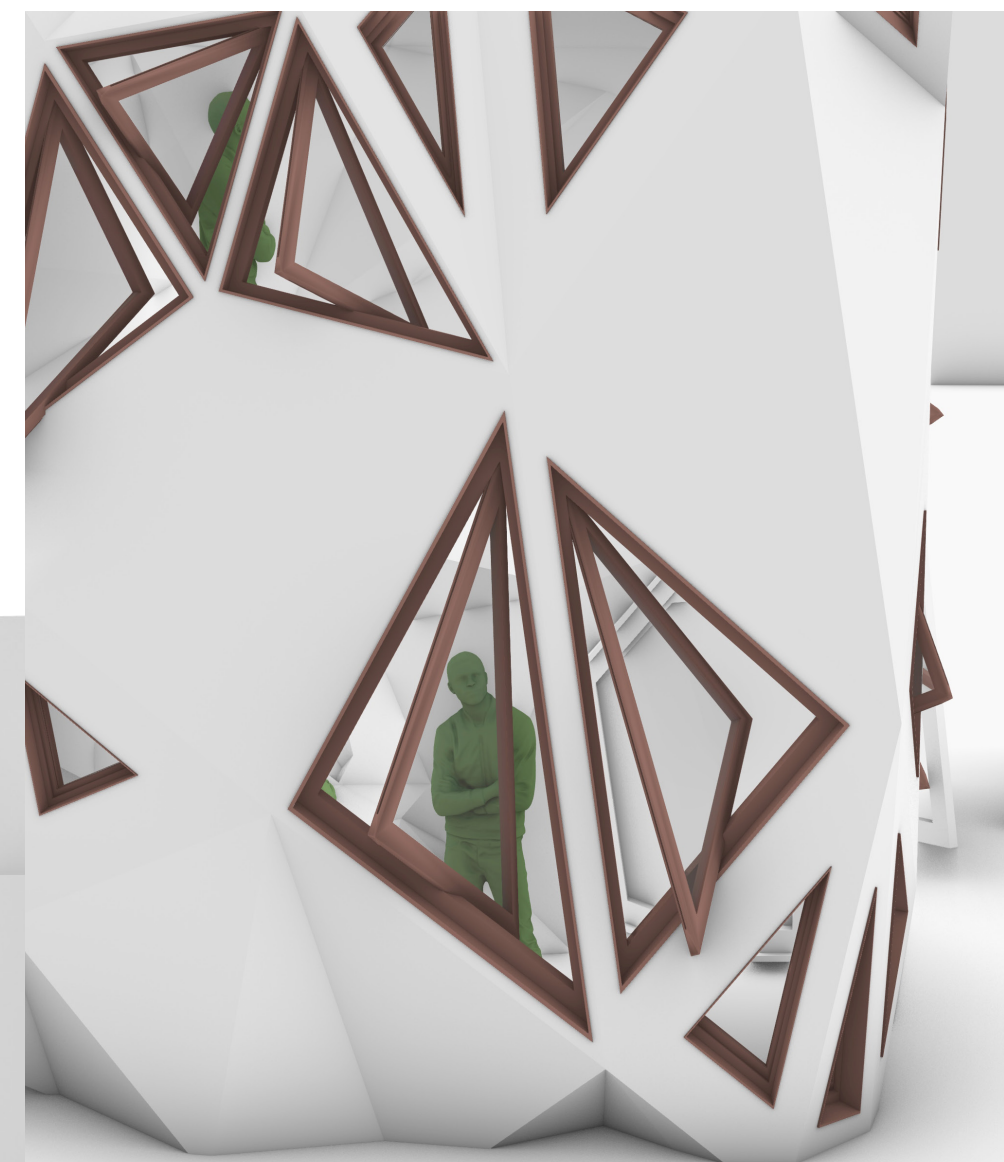
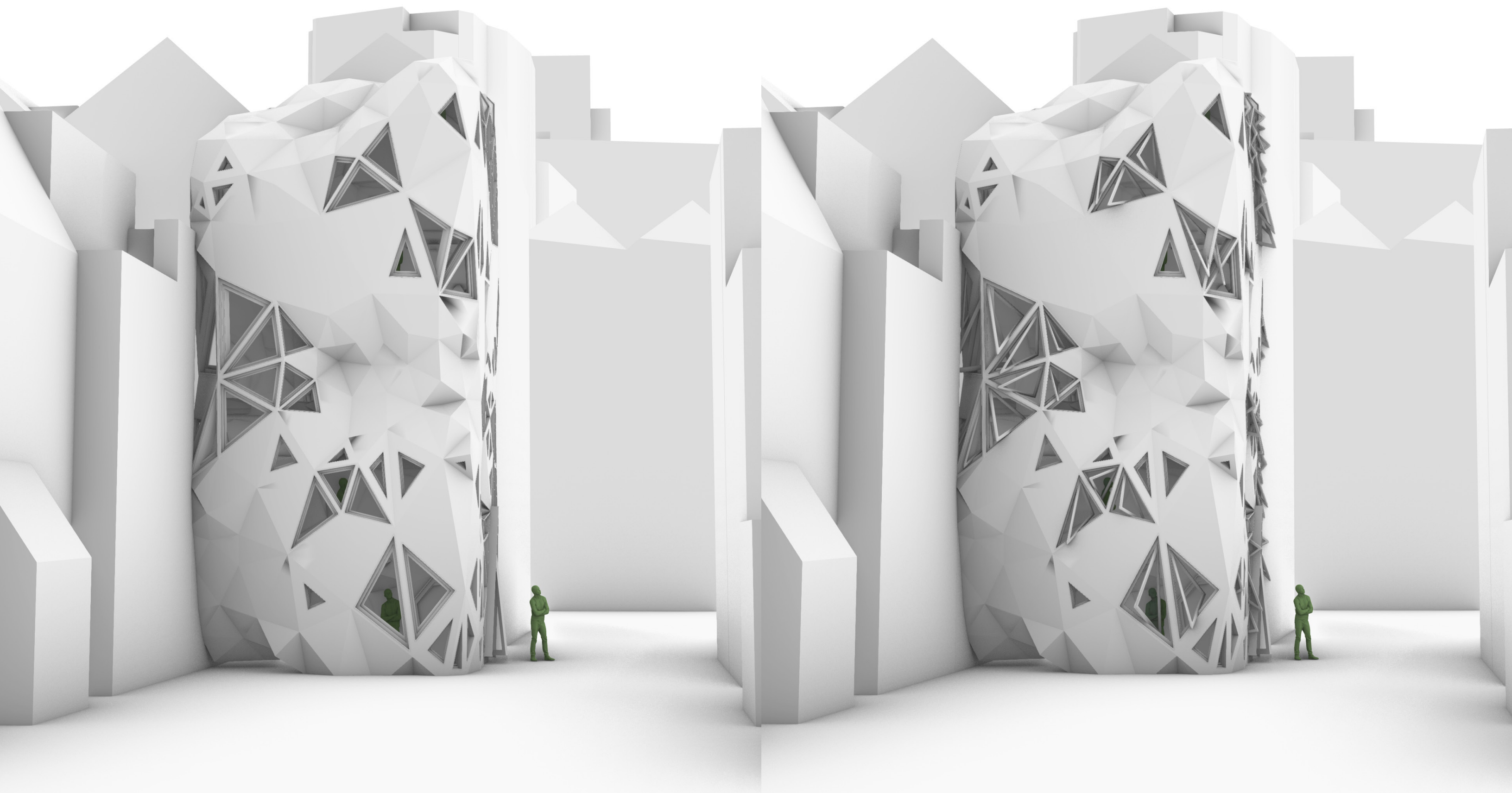


Final Design Isometric & Street View

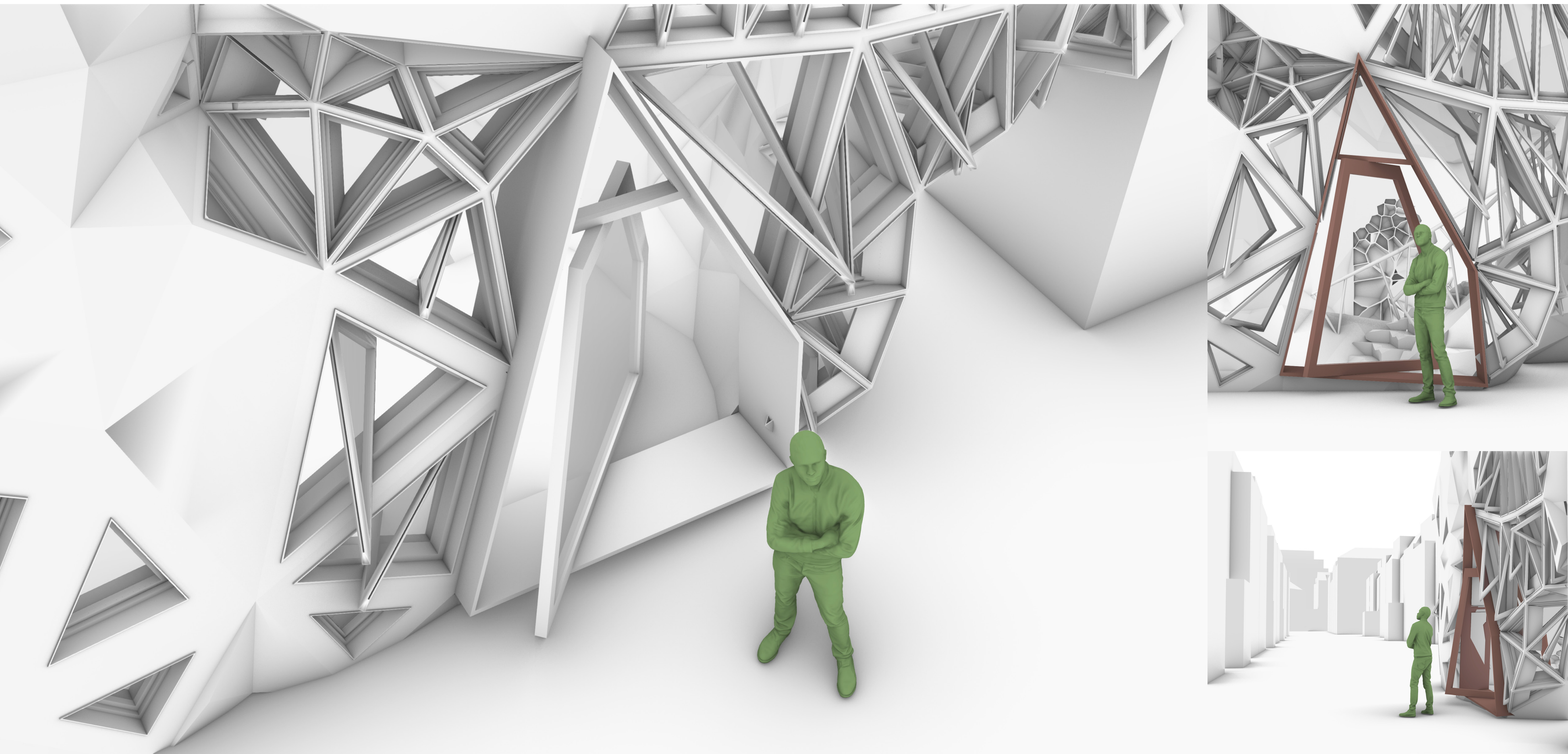


All Large Windows Pivot

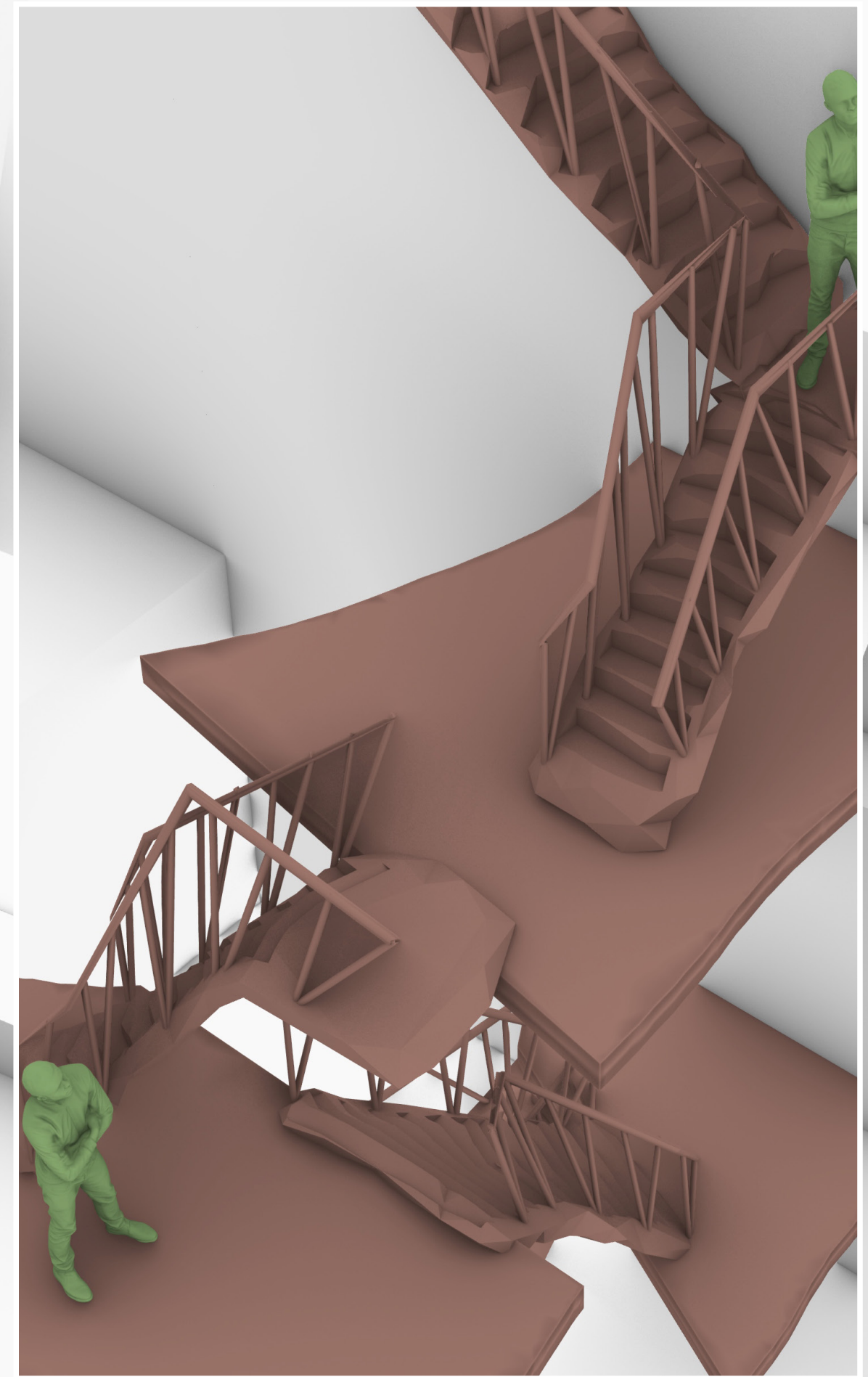
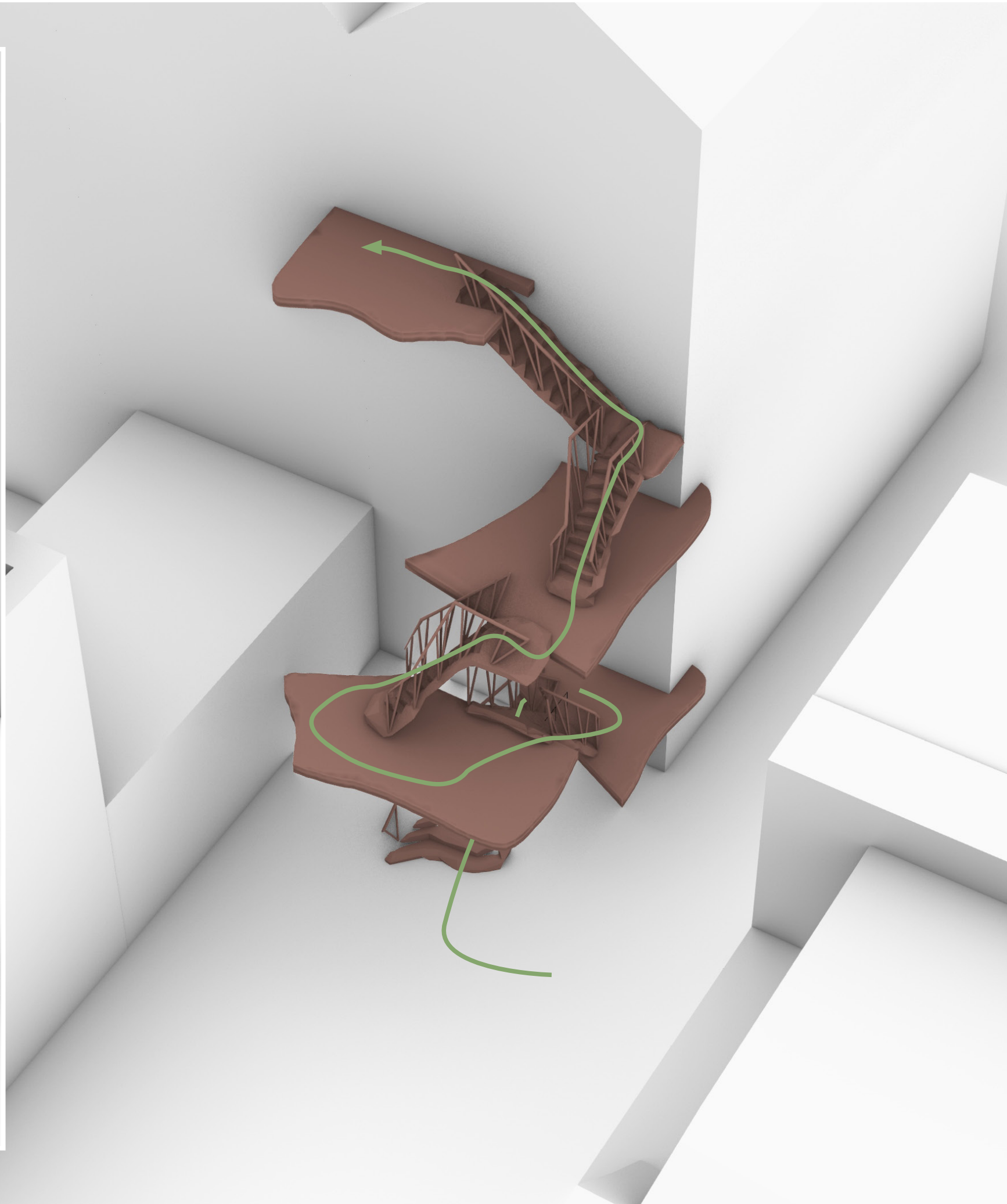
Closed vs Opened



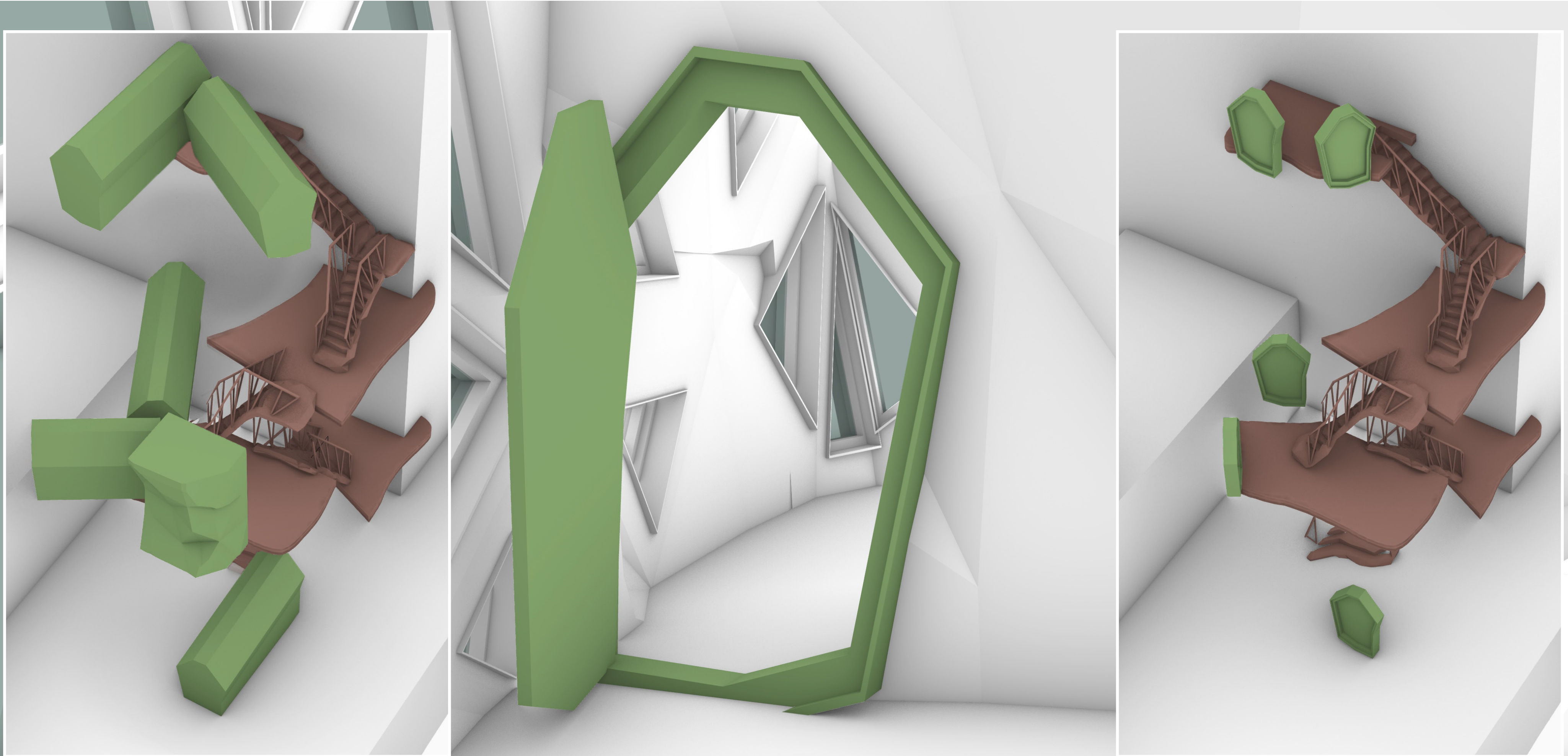
Shared Space: Building Entrance



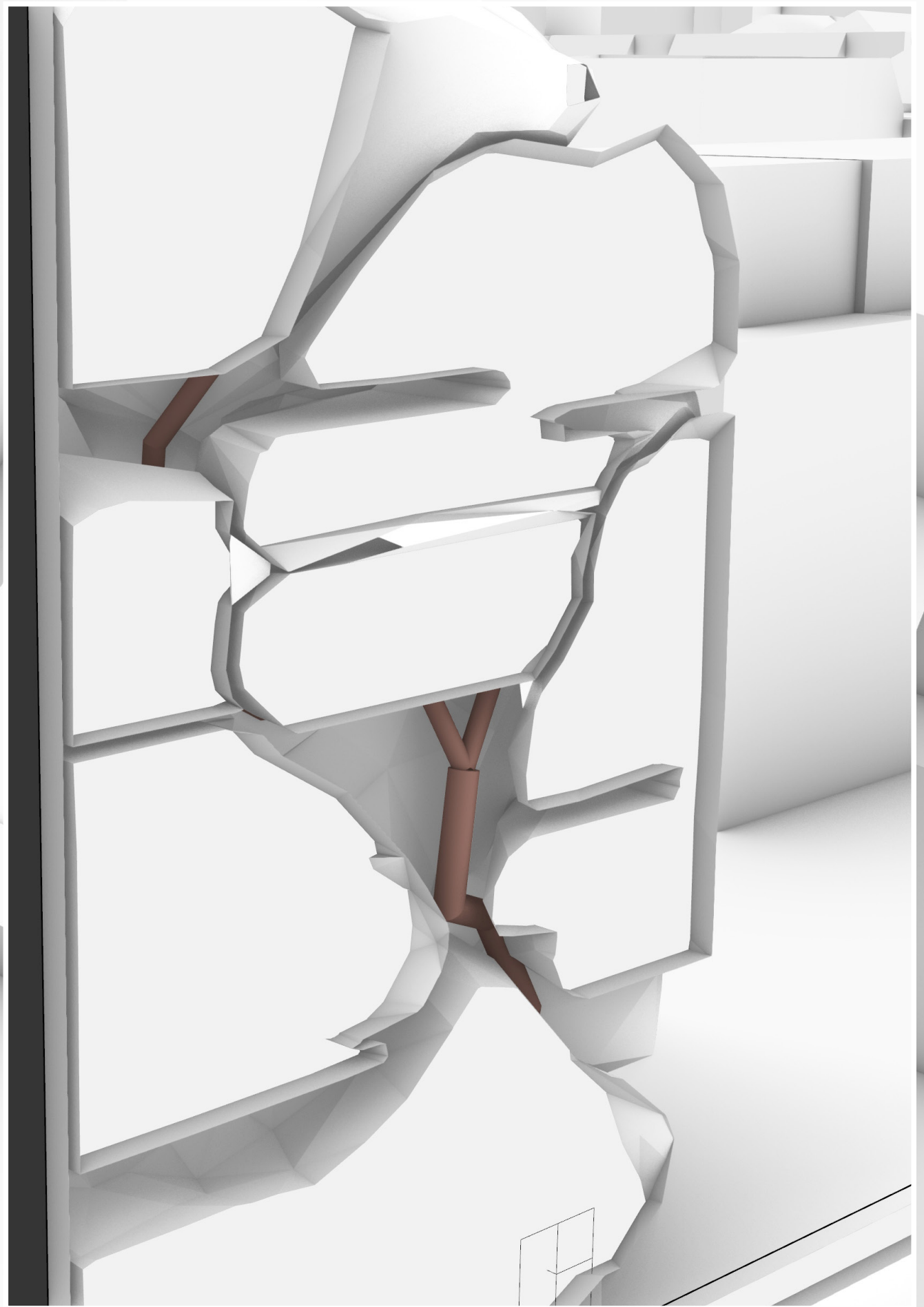
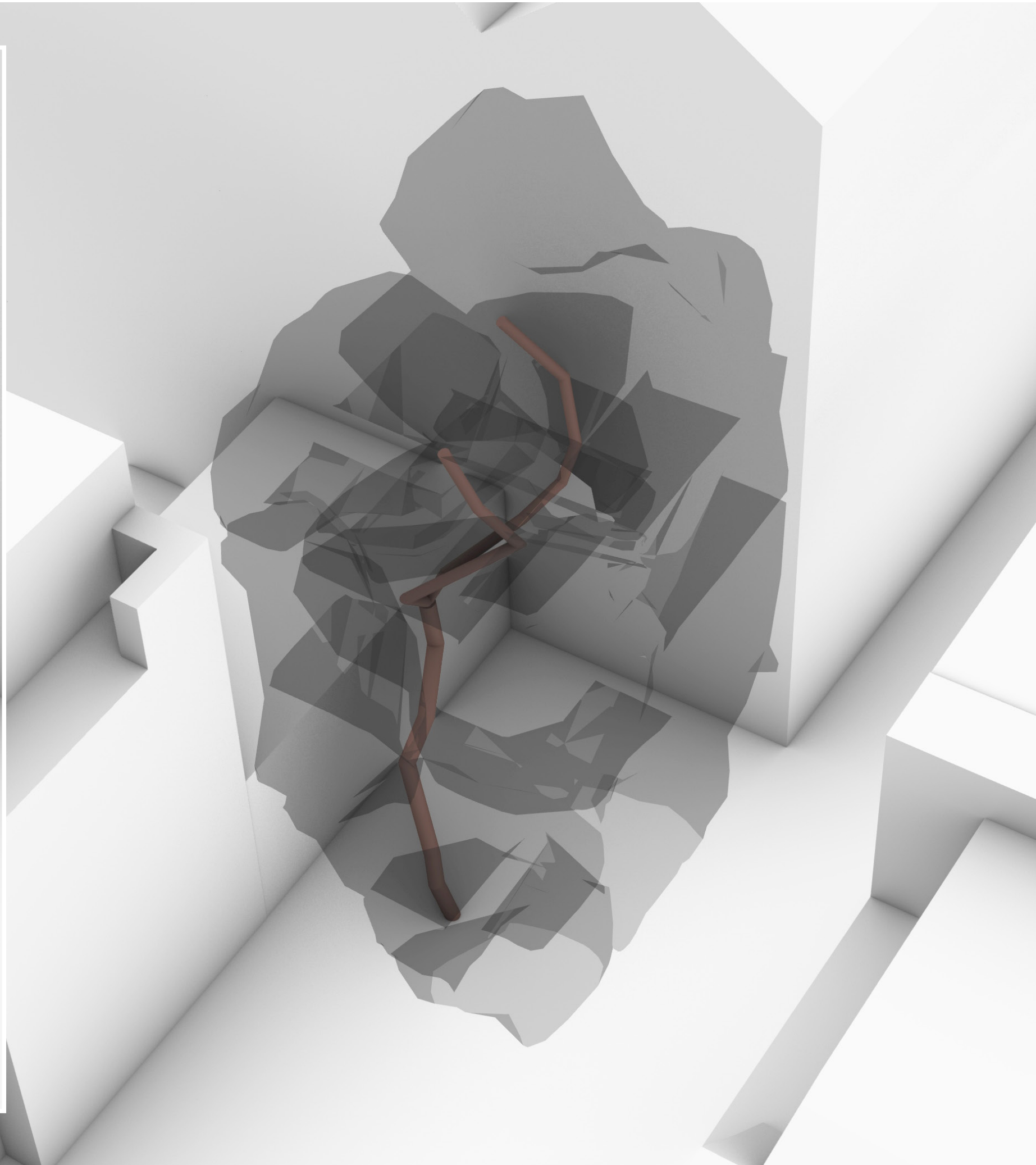
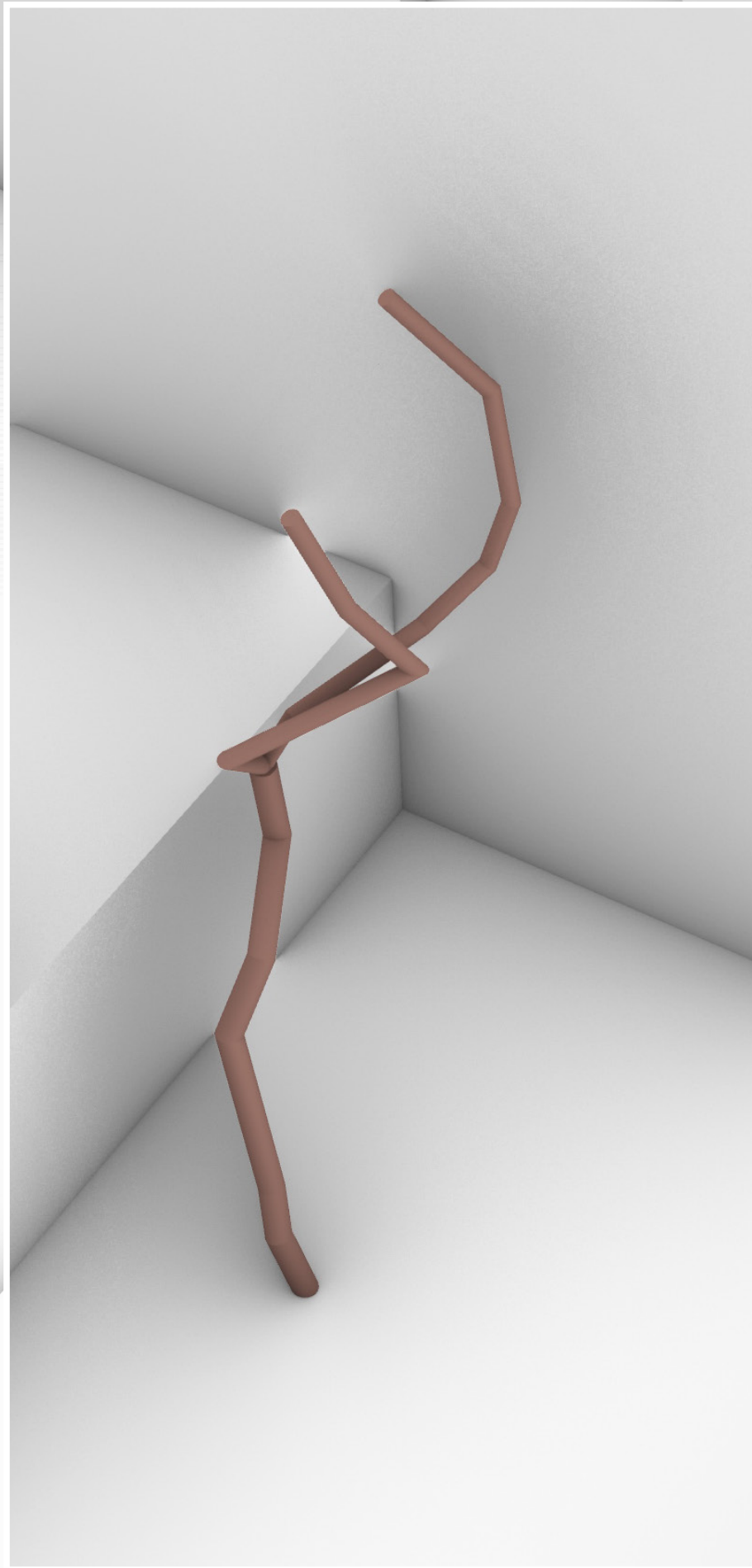
Shared Space: Vertical Circulation



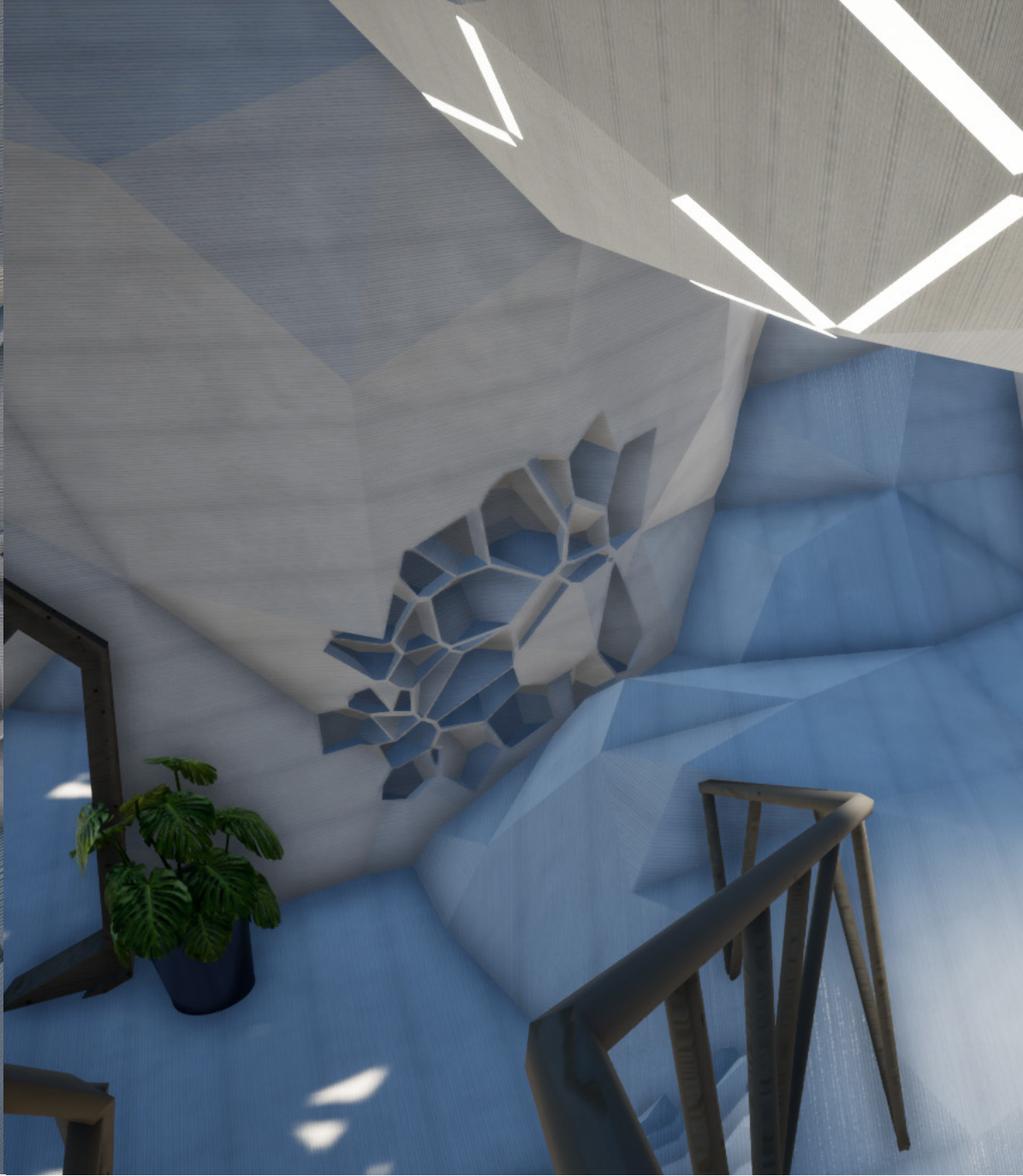
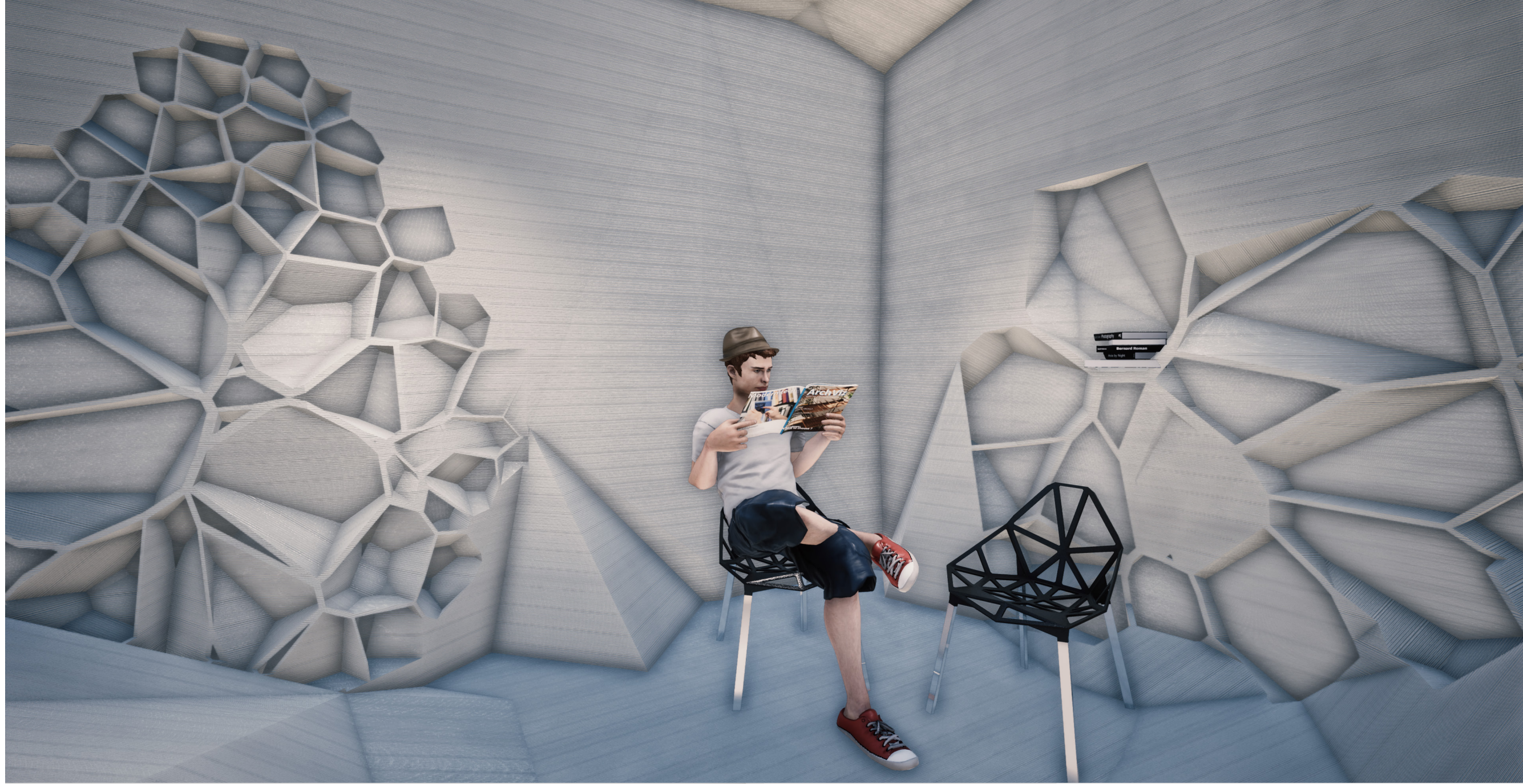
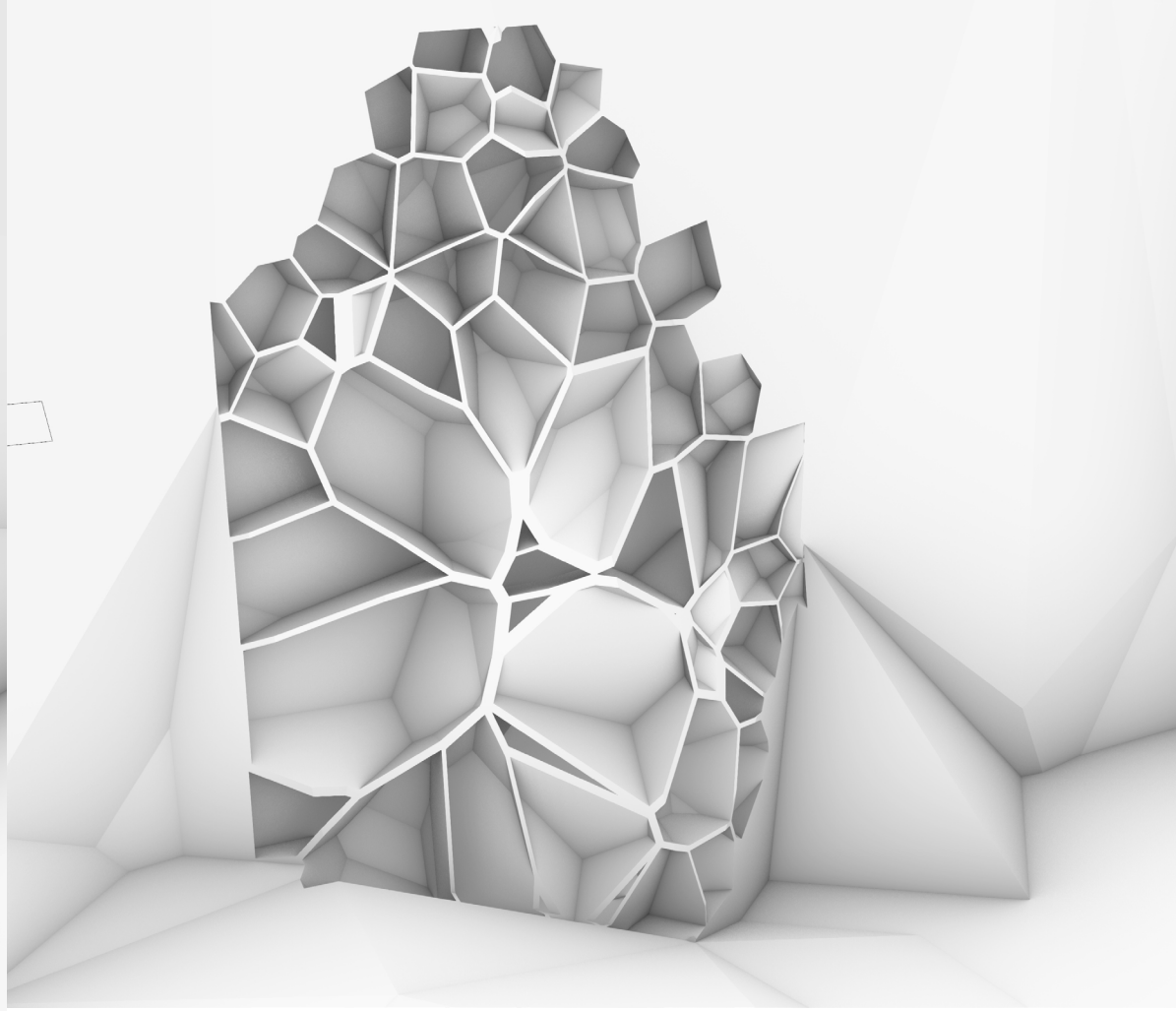
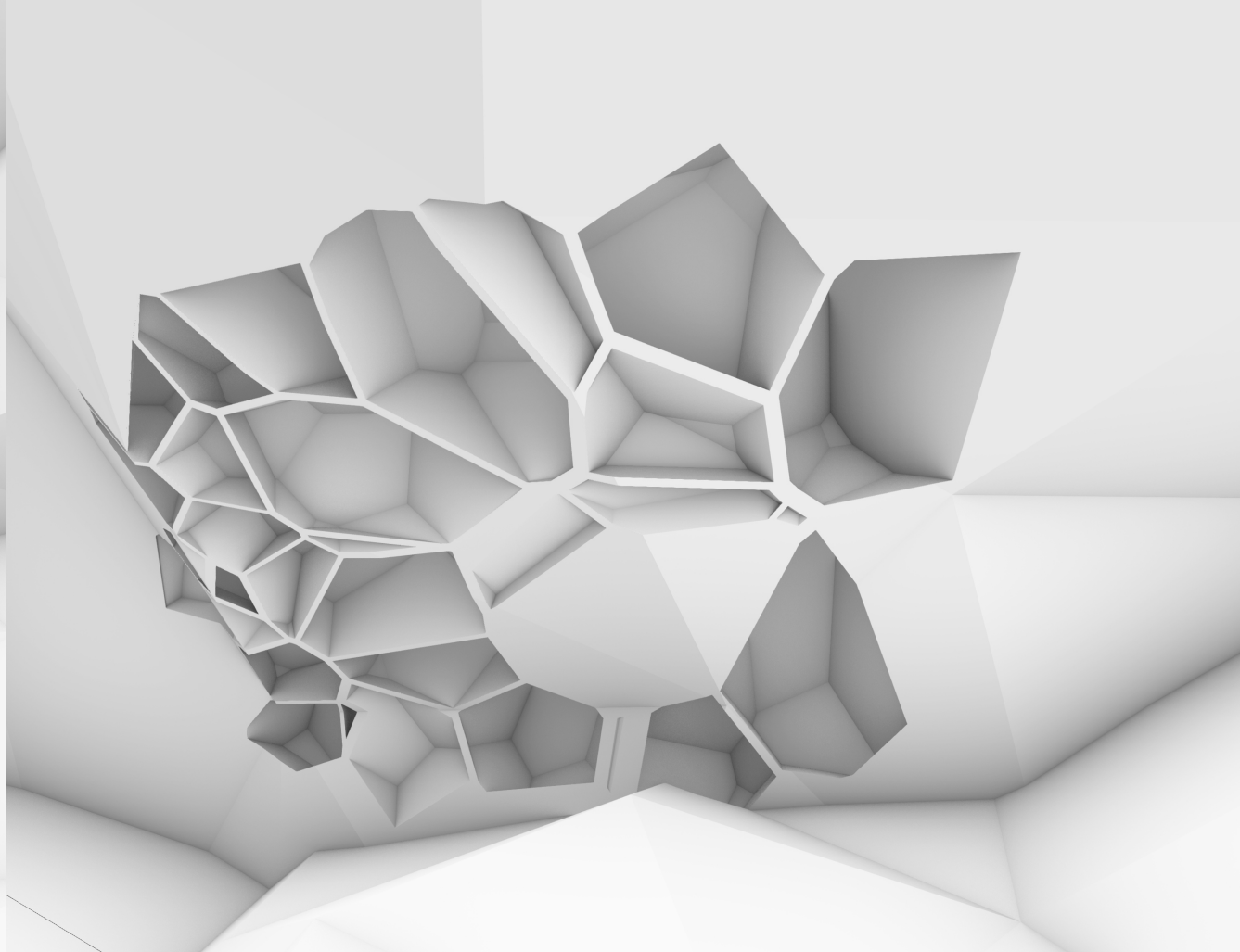
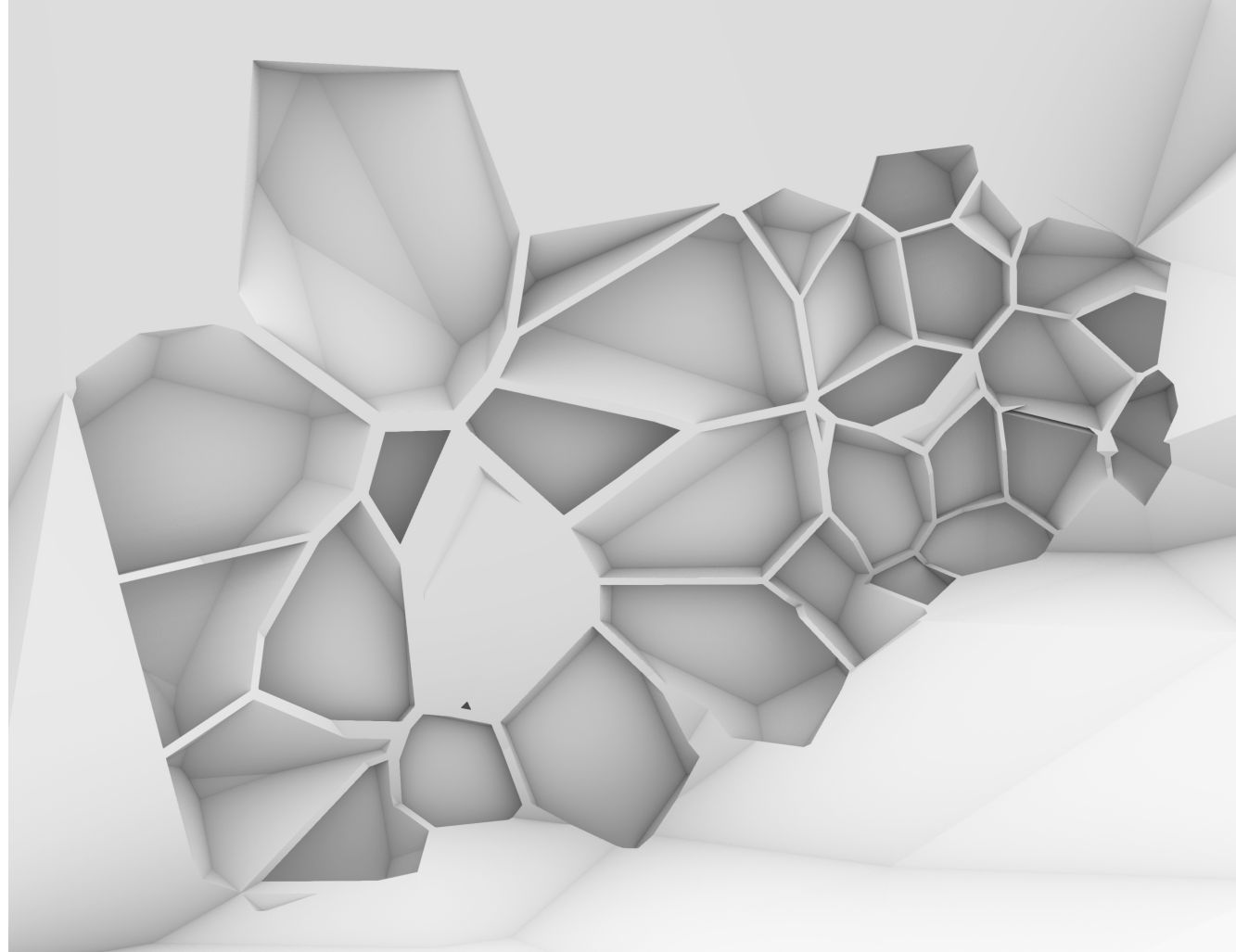
Shared Space: Housing Units Entrances



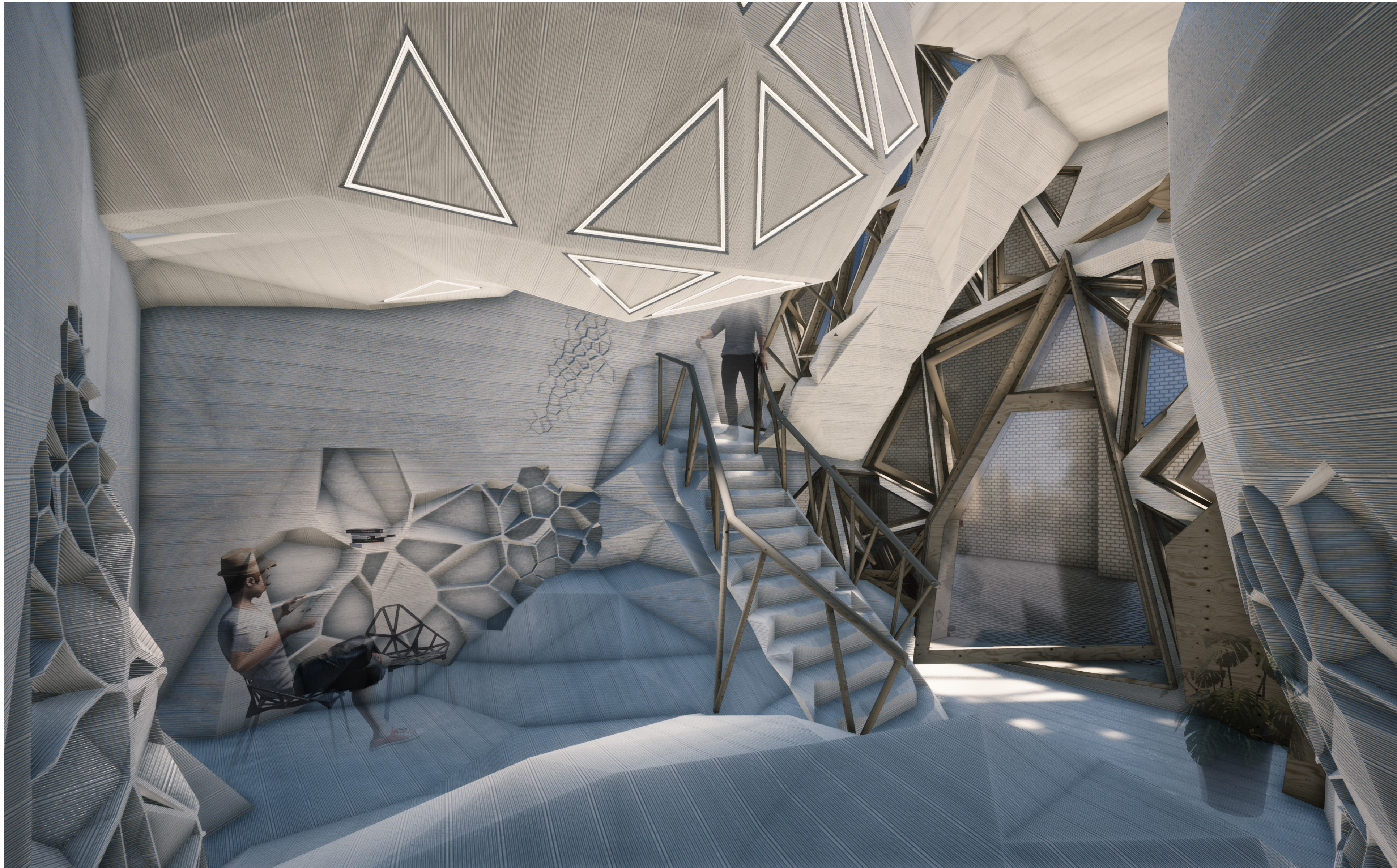
Shared Space: Shafts Between Units



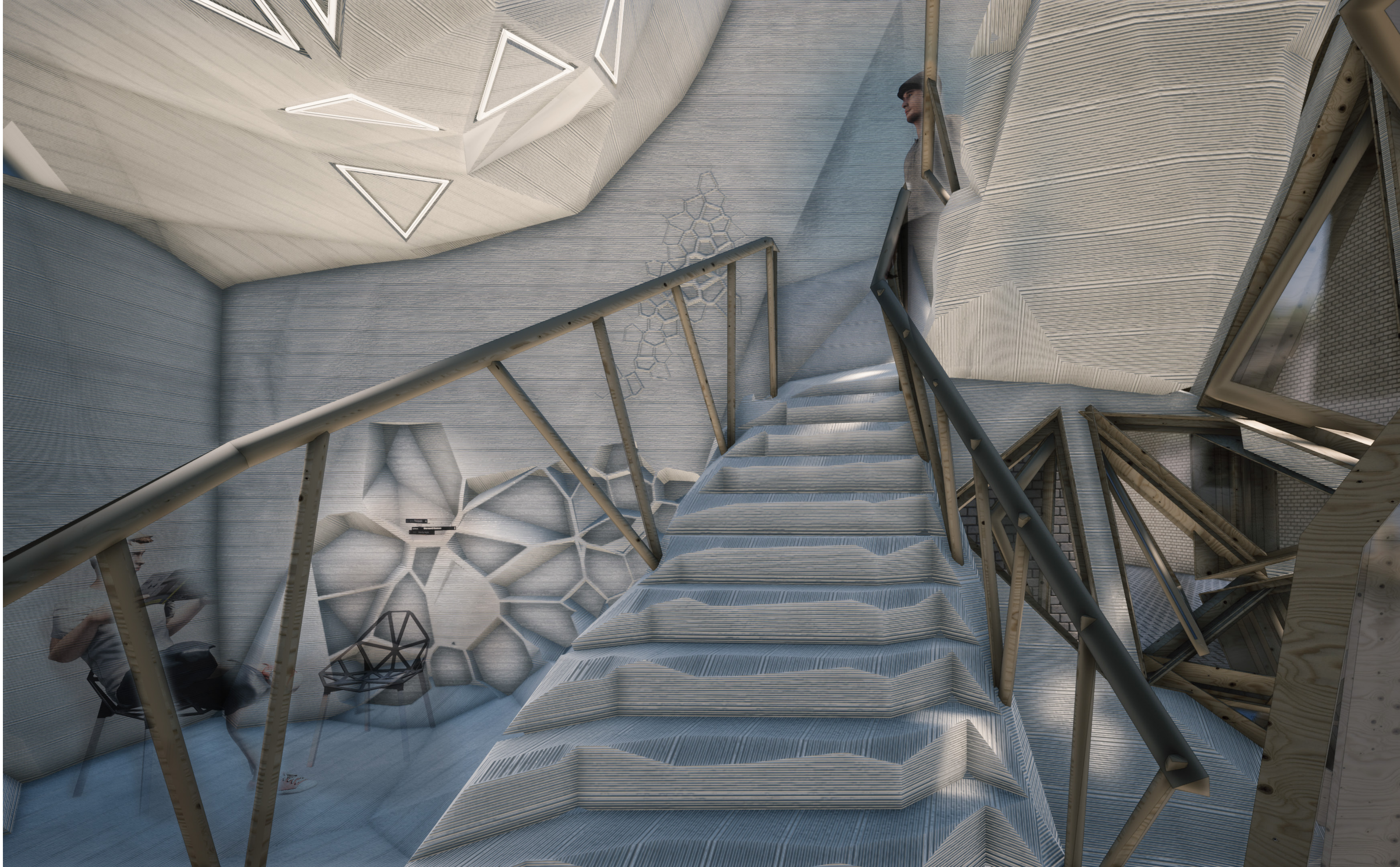
Design Integrated Shelves



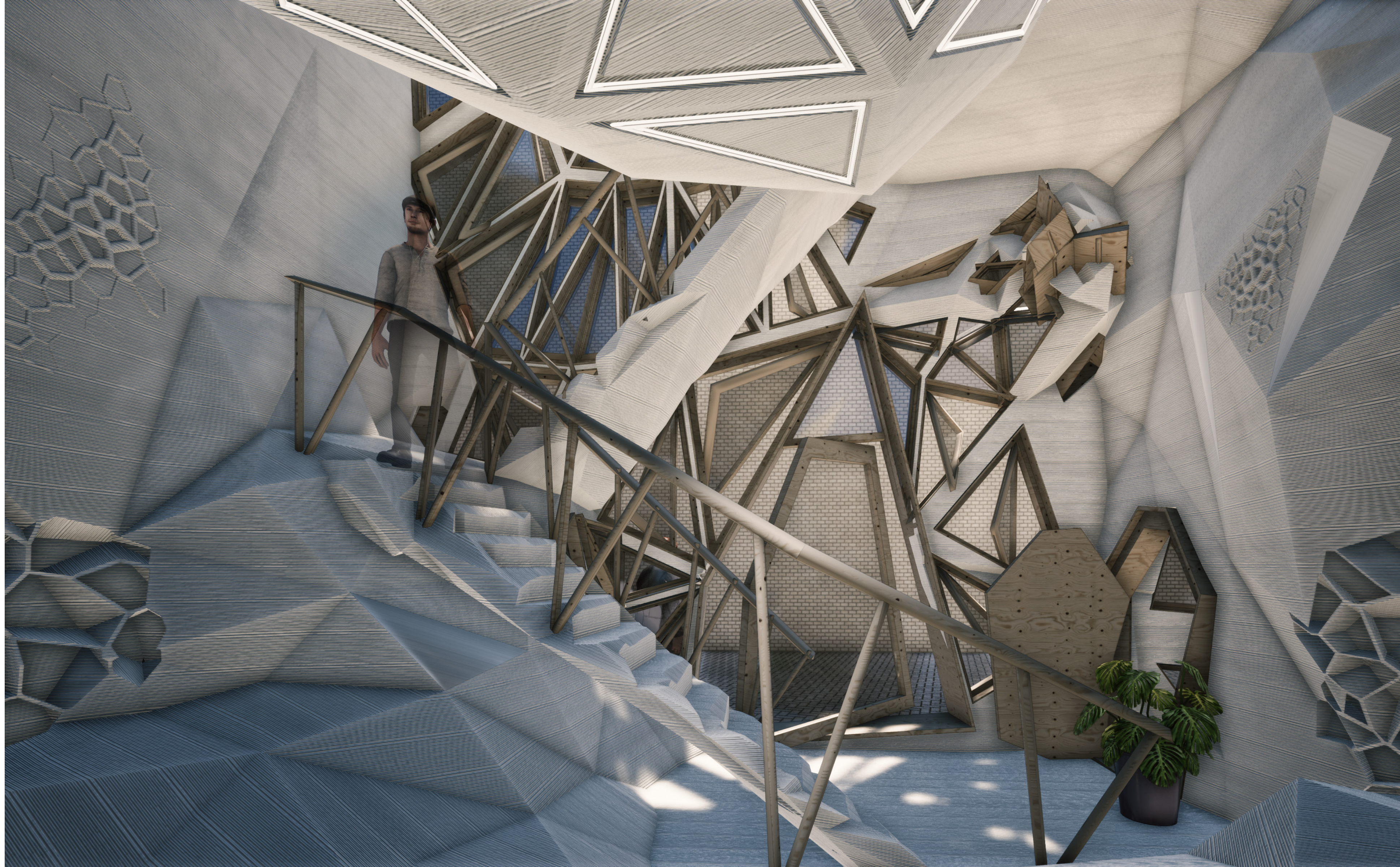
Interior Shared Space



Interior Shared Space



Interior Shared Space

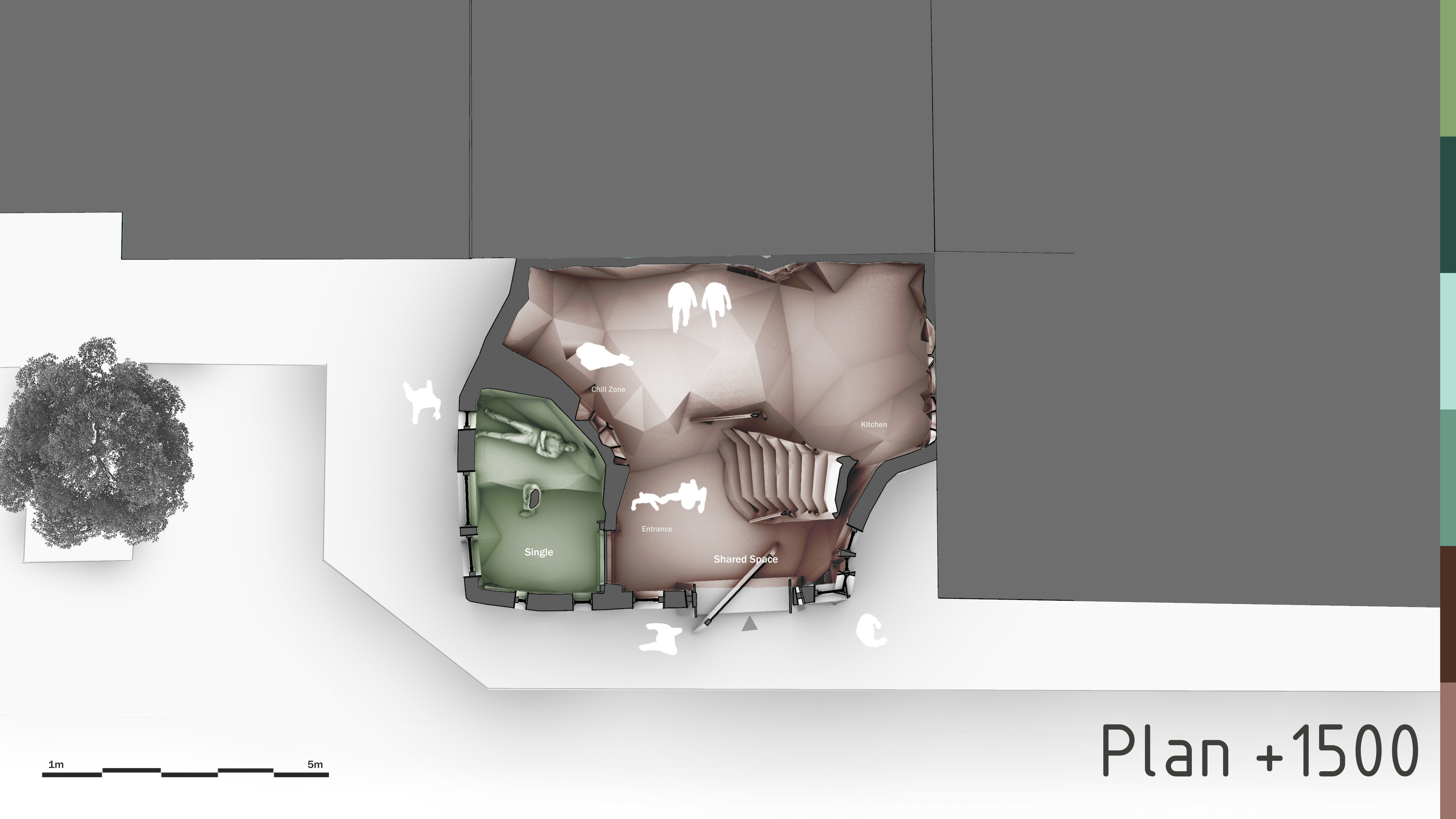


Long Section



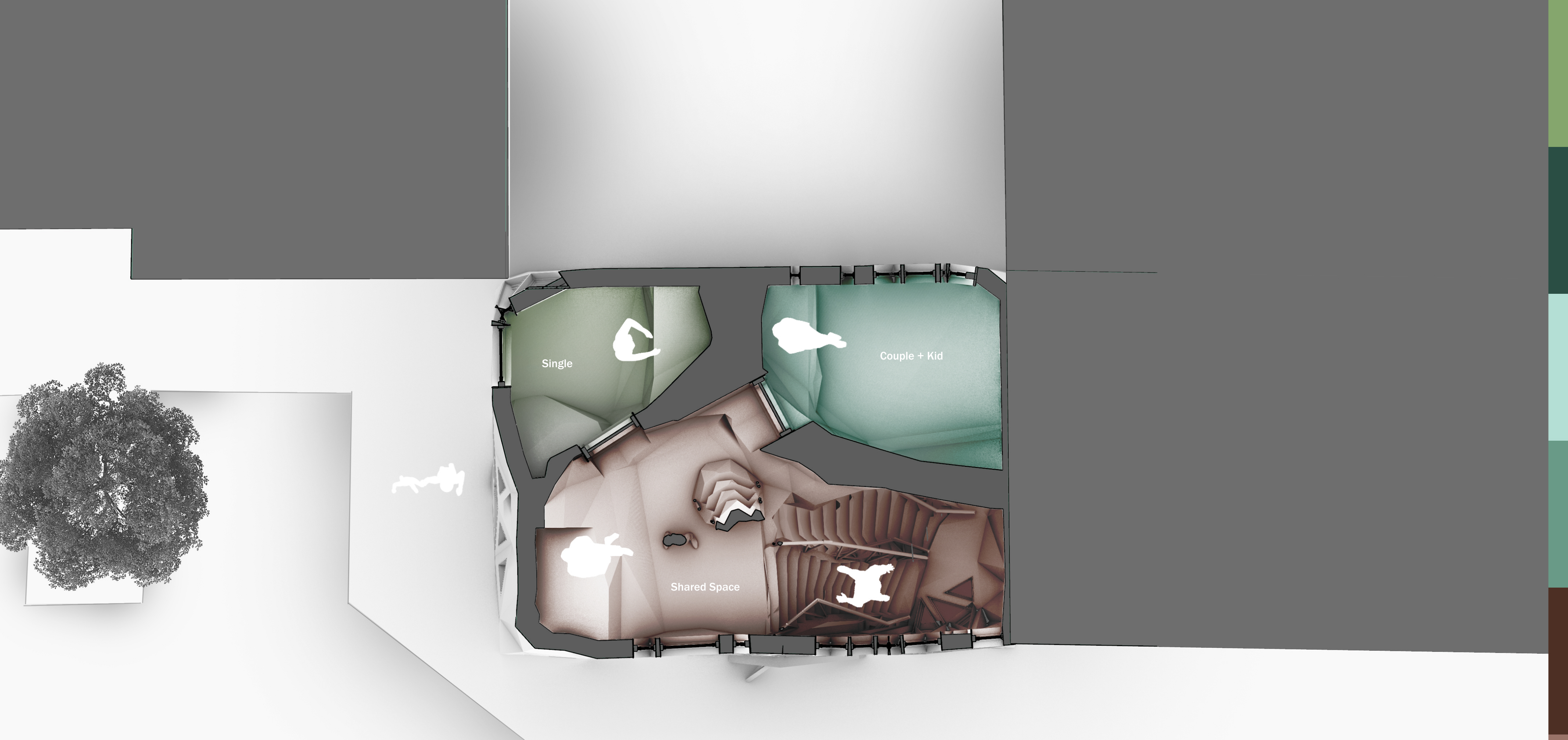
Cross Section





1m 5m

Plan +1500



Plan +5500



1m 5m

Plan +10500

Materialization

Renewable, 3D Printable, Local

Polylactic Acid

- Made from renewable sources
- Is biodegradable in industrial facilities
- Is 3D printable and does not produce smell/harmful smoke
- Can be produced in the Netherlands with crops like sugar beet and potatoe

Renewable



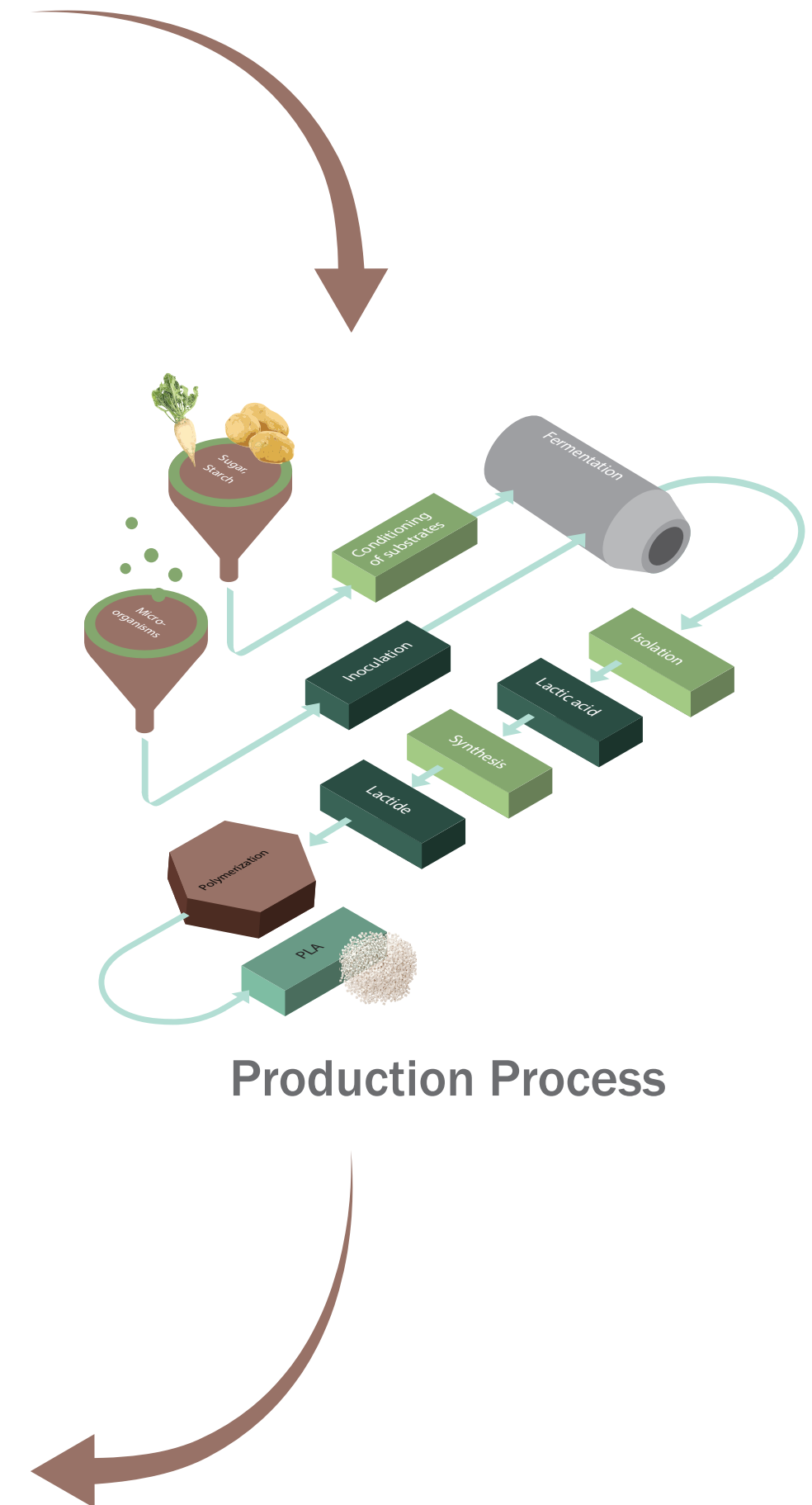
PLA Pellets



Industrial Composting



PLA Pellets/Products



PLA Characteristics

Strengths

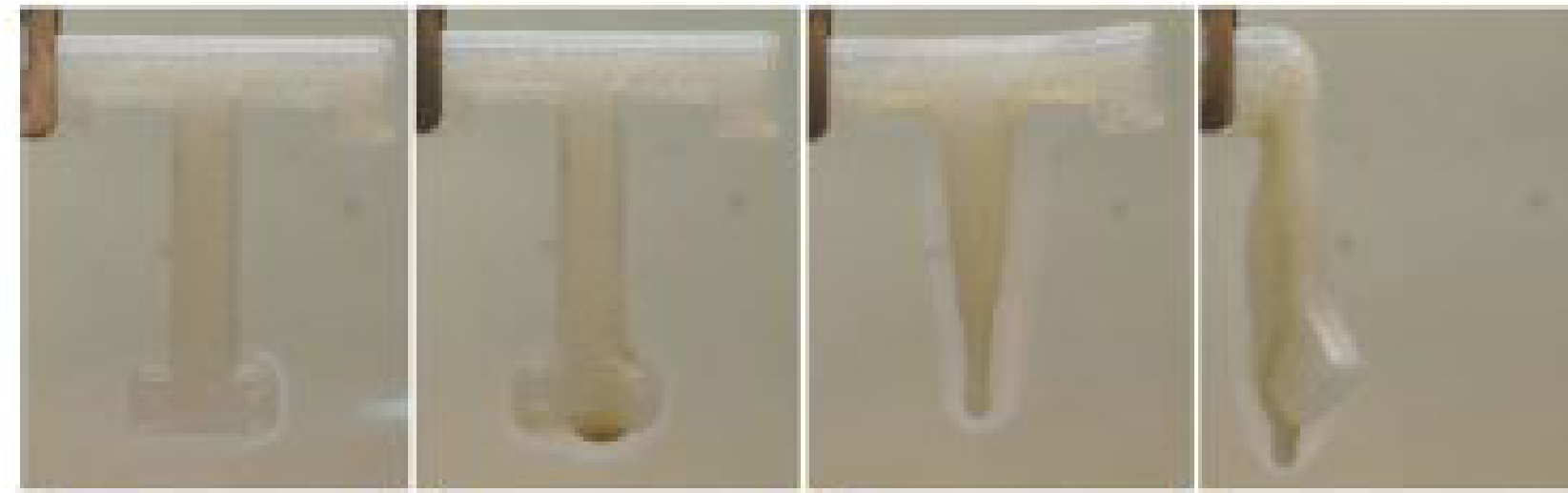
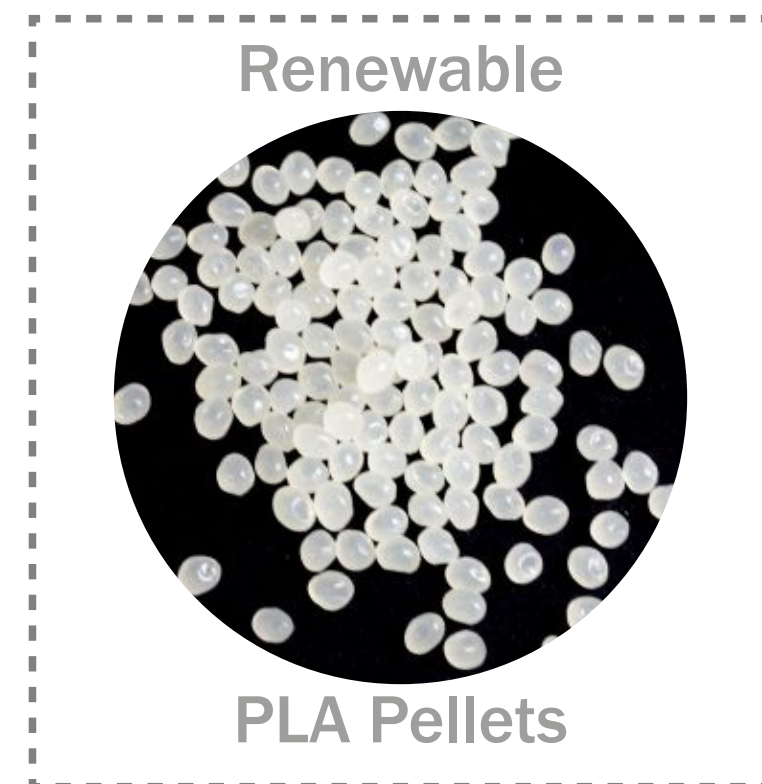
- High strength and stiffness
- Lowest conductivity known among plastics
- Bioplastic

Ultimate construction material?

Unfortunately, no...

Shortcomings

- High Flammability
- Low heat resistance
- Glass transition temperature of only 60 degrees celcius
- Brittle
- Low impact resistance



Behaviour PLA in fire/heat

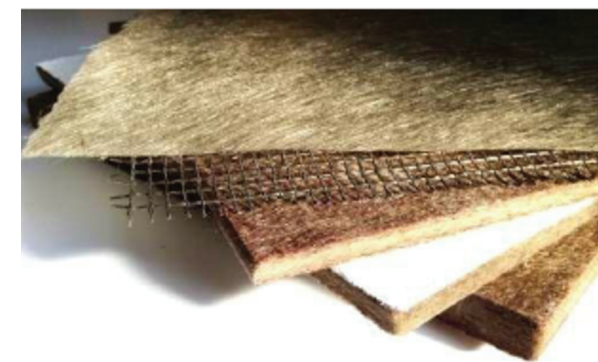


Enhance properties with natural fibers

Natural, Availability, Reusable, Local

Basalt Fiber

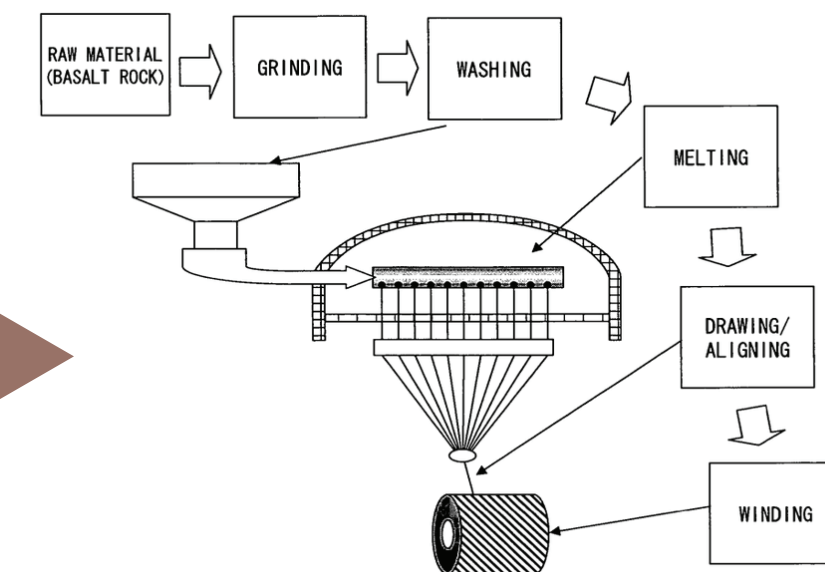
- Natural occurring material
- Production process is straightforward without any additives
- Excellent thermal (0.034 W/mK) and acoustical (High acoustical absorption value) insulation properties
- Chemical and wear proof
- High tensile strength
- Fire resistant material with very high melting temperature (1500 degrees celsius)
- Low water absorption
- UV resistant
- Local availability



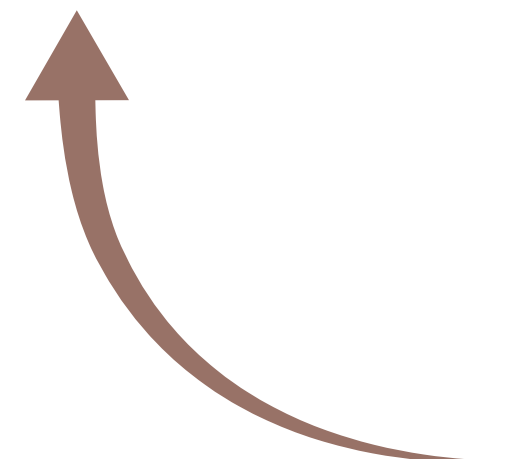
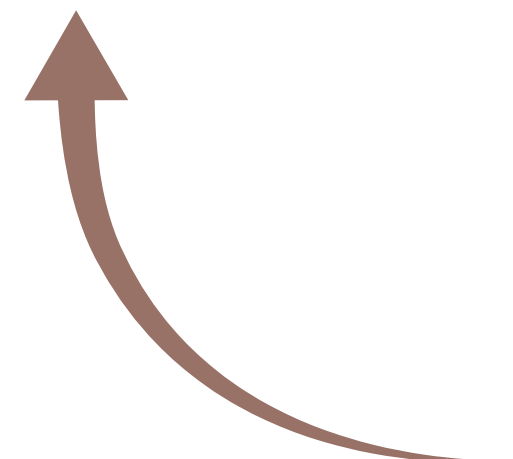
BF Products



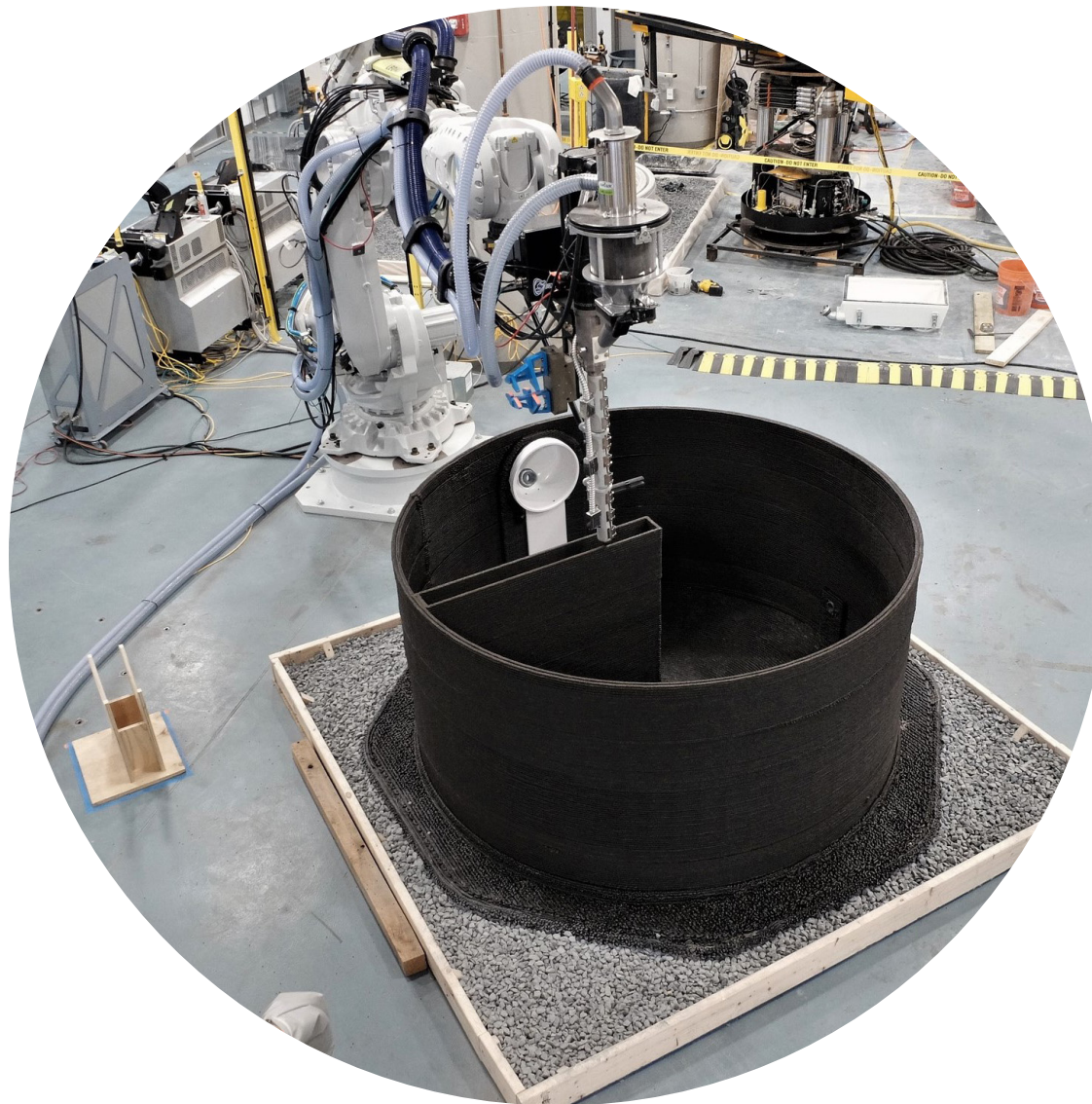
BF Composites



Production Process



BFRPLA Composite Aesthetic



Source: AI SpaceFactory. (n.d.). AI SpaceFactory (@AISpaceFactory) | Twitter. Retrieved January 20, 2020, from <https://twitter.com/AISpaceFactory>

Basalt Fiber Reinforced Polylactic Acid

Characteristics

- 50% Stronger than concrete
- 50% Lighter than concrete
- Basalt as fire resistant protection layer
- Is still reusable and recyclable & can be separated
- High thermal and acoustical insulation value
- Increased glass temperature of PLA to 120 degrees celsius

Renewable



PLA Pellets

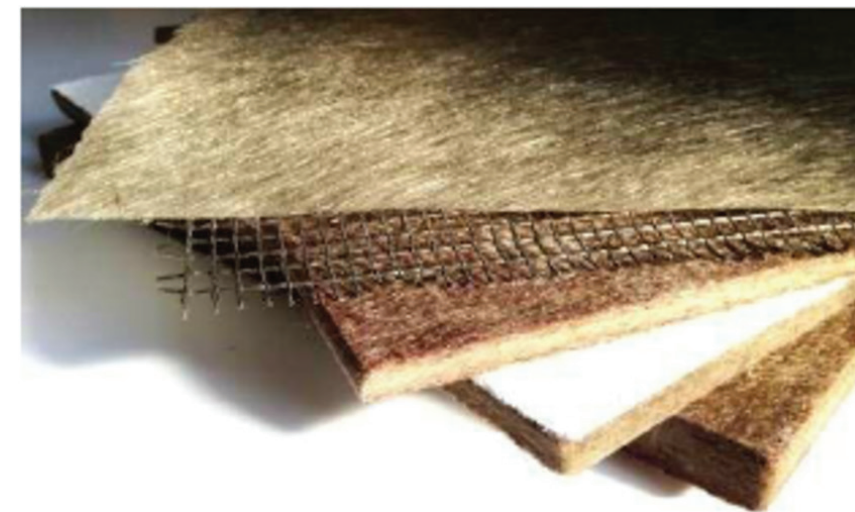
Natural



Basalt Fiber



Textured surface 3D printed BFRPLA: good sound absorption



Thermal insulation value BFRPLA is very good, structure of building is also insulation

Insulation (thermal/acoustic)

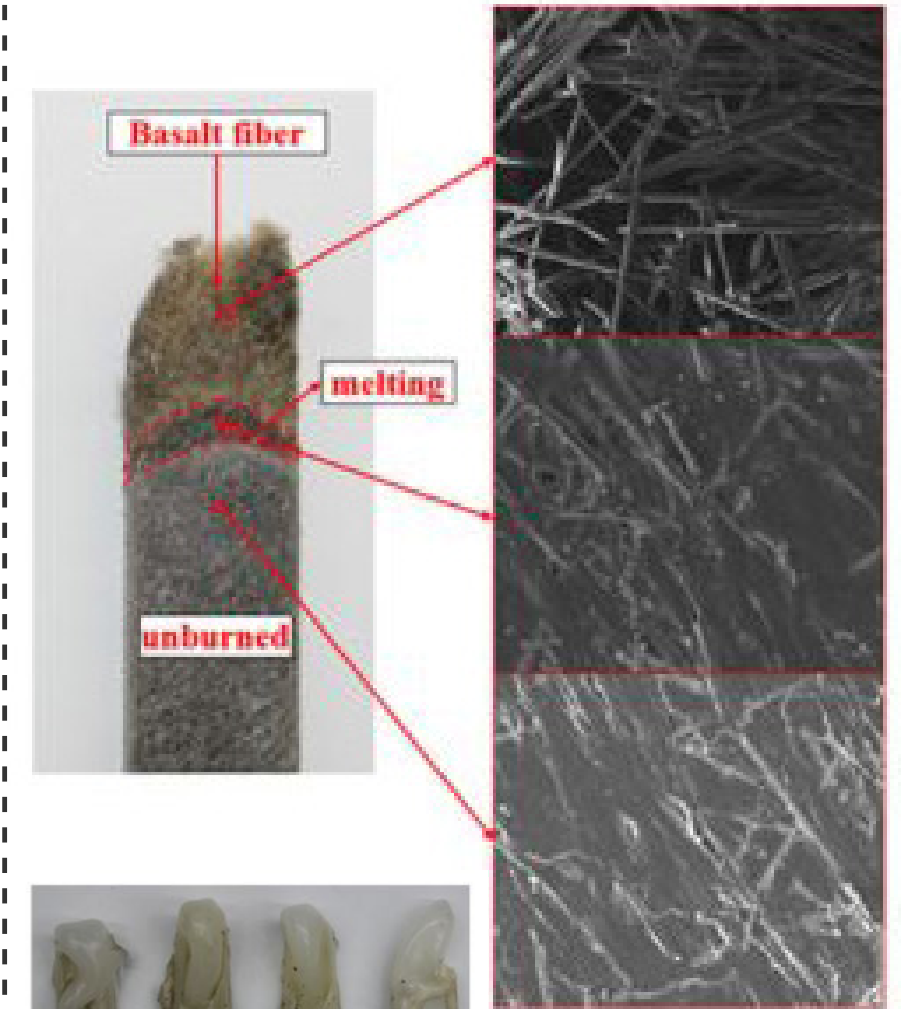


3D Printed BFRPLA: structure stays intact under load, does not collapse



3D Concrete: Collapses under less pressure than BFRPLA

Structural Strength vs. Concrete



(a)

Raw PLA would drip (a), BFRPLA not (b).



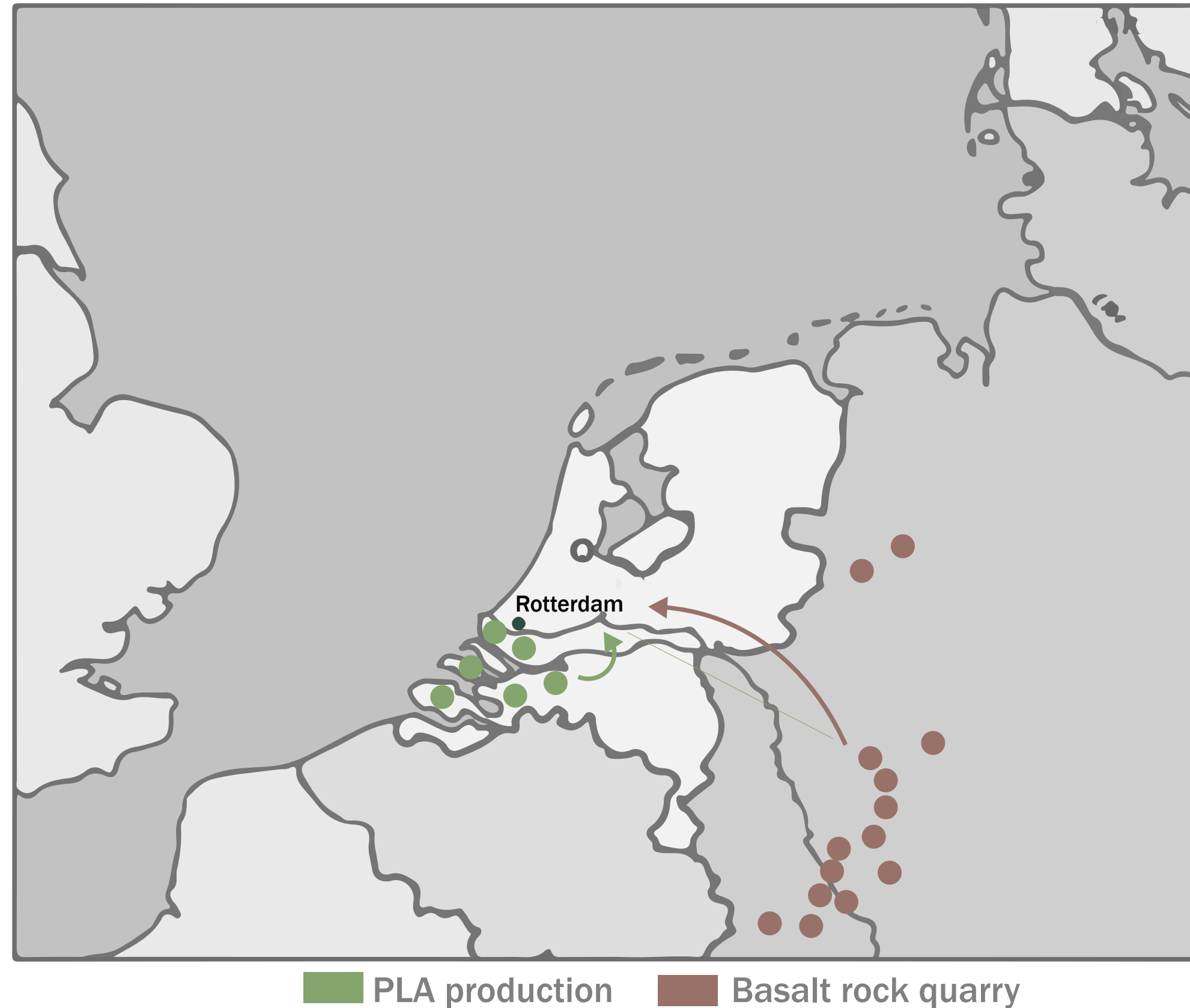
(b)

BF as fire resistant layer

BFRPLA Locally Produced

PLA

Basalt Fiber



Renewable



PLA Pellets

Natural



Basalt Fiber

Produced in:
The Netherlands

BFRPLA Circularity

Renewable



PLA Pellets

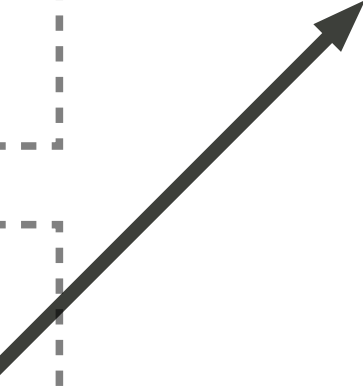
Natural



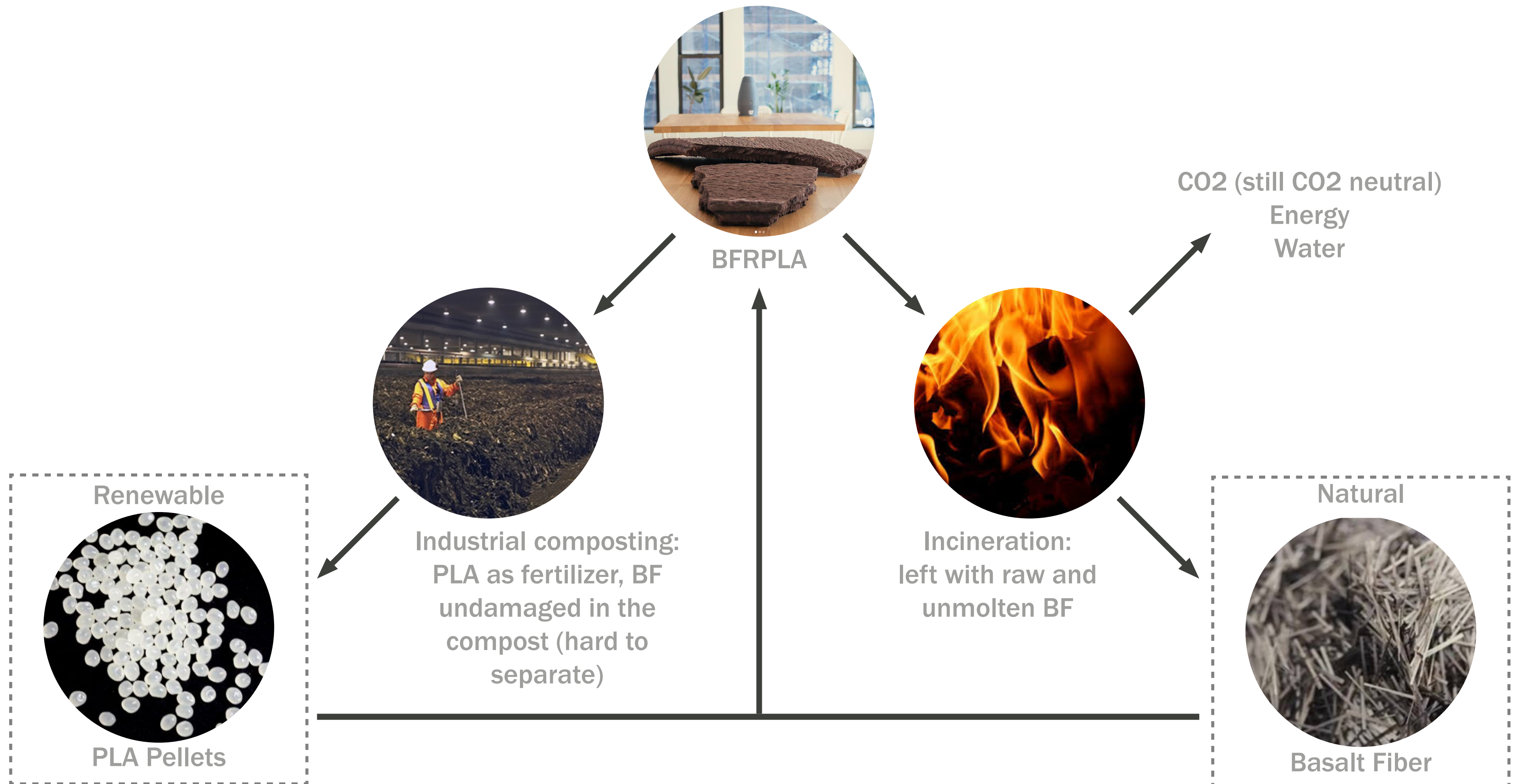
Basalt Fiber

Produced in:
Germany

(Color change only caused by addition colors added in the composite, natural color is stone grey)

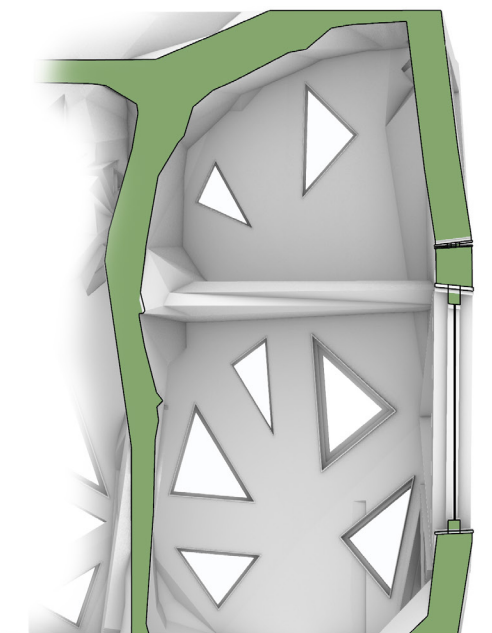
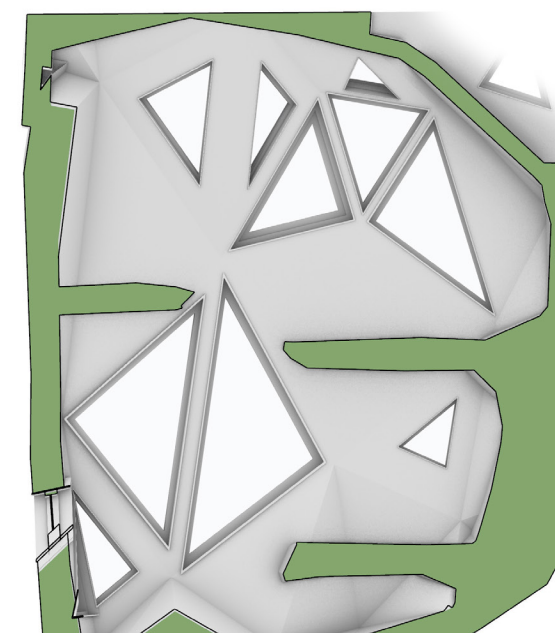
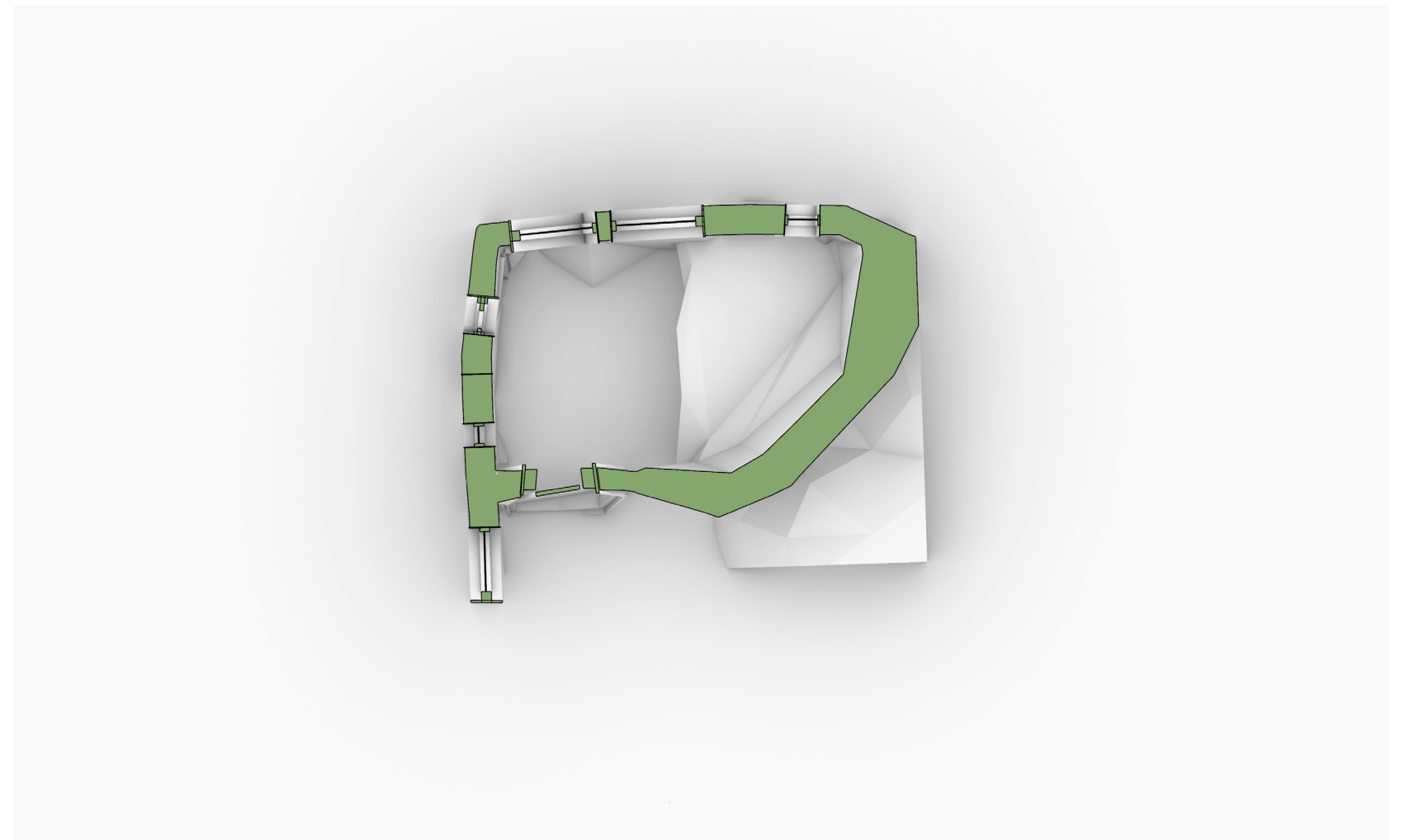
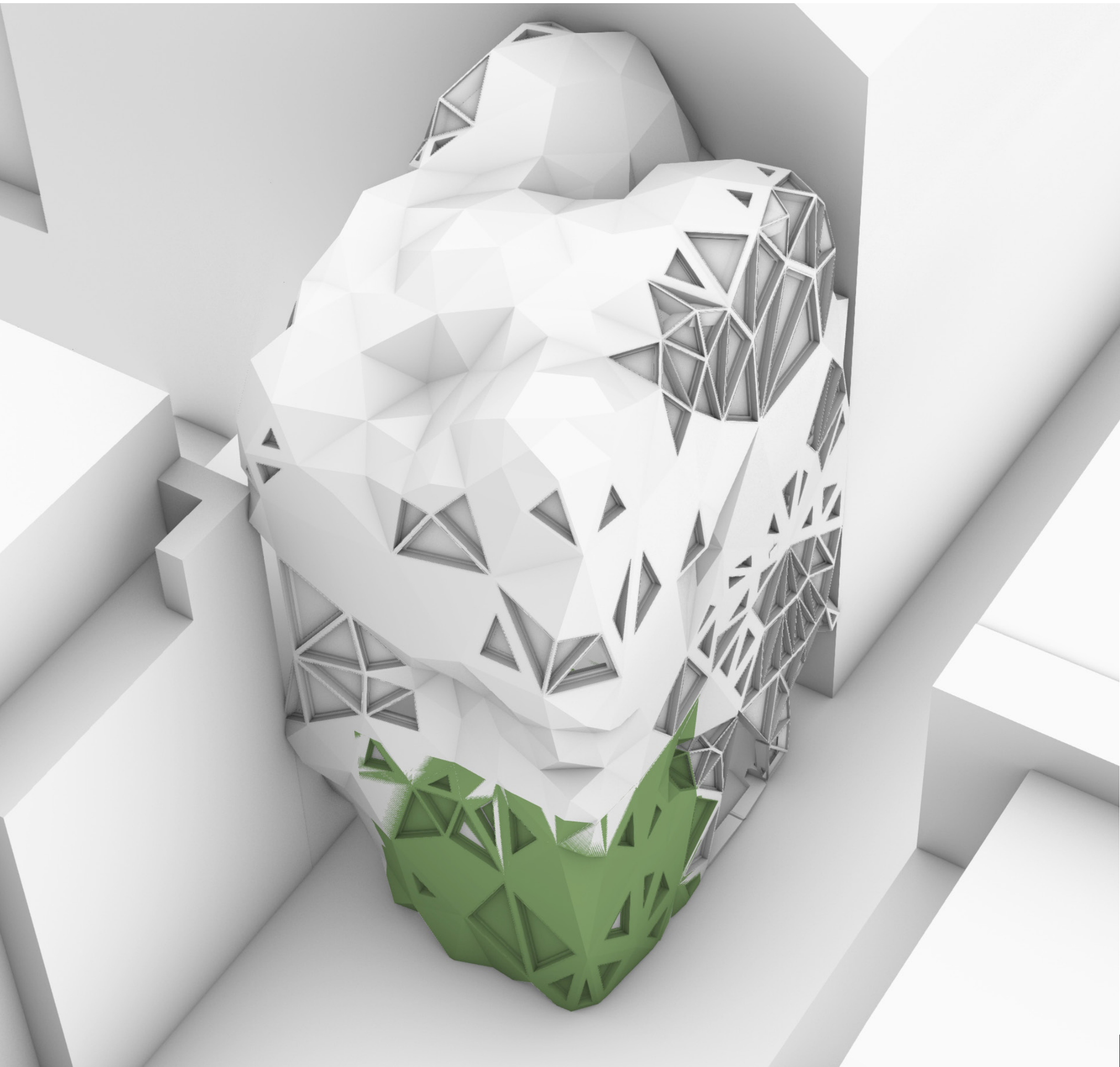


BFRPLA Separation After Life



Fragment

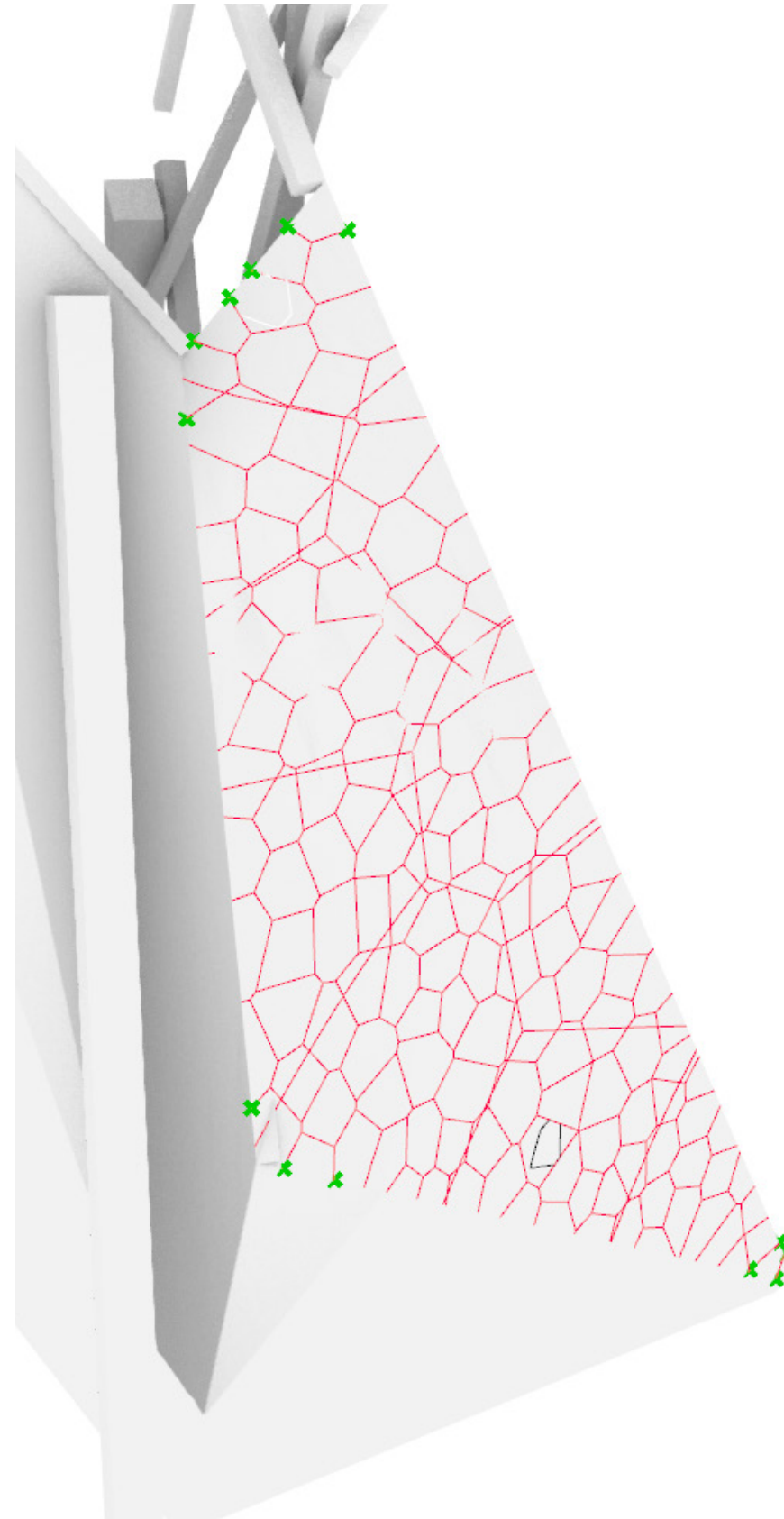
Fragment Location



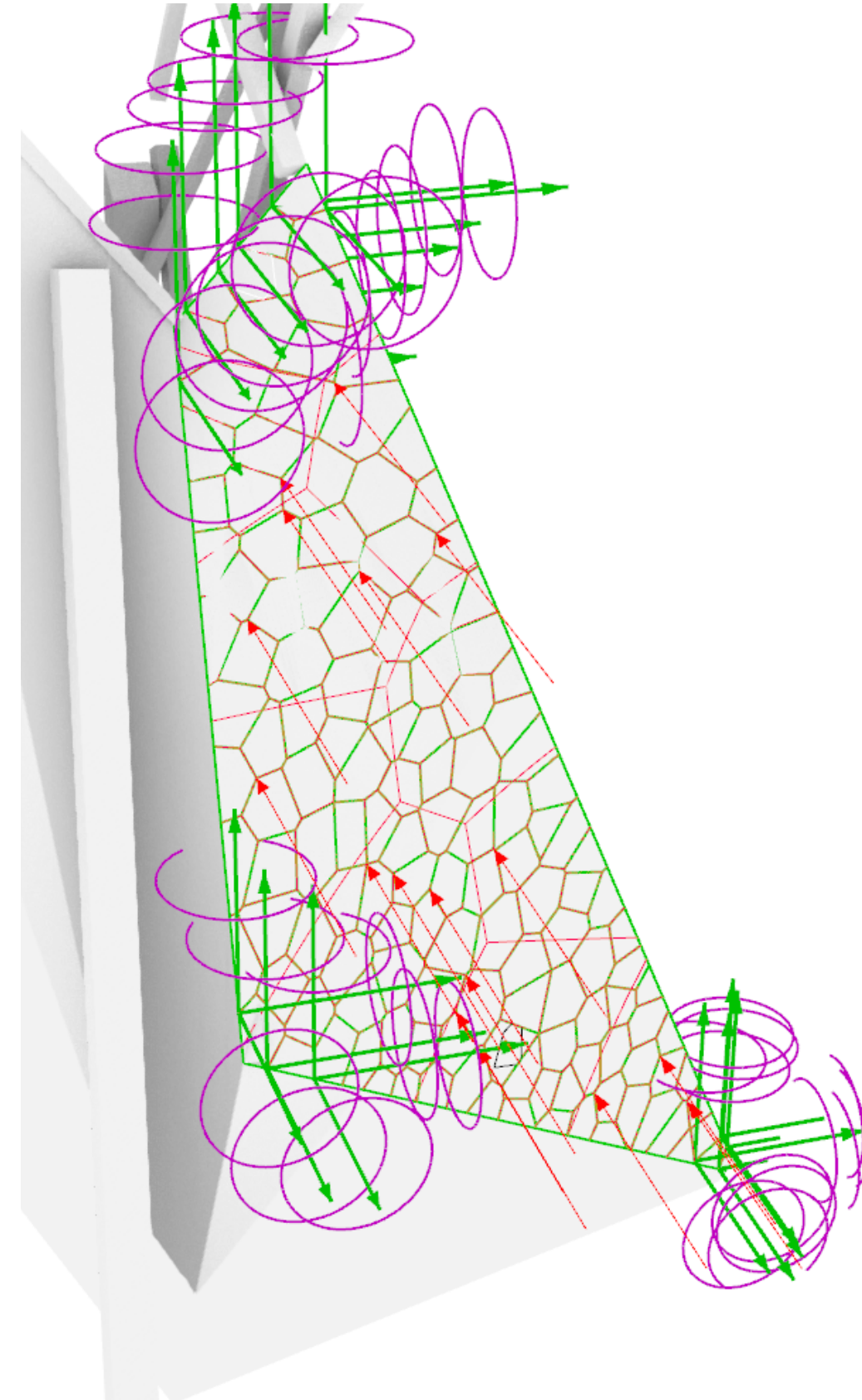
Structure & Acoustics – Workshop 01



Double curved skin panel



Support points & structure lines



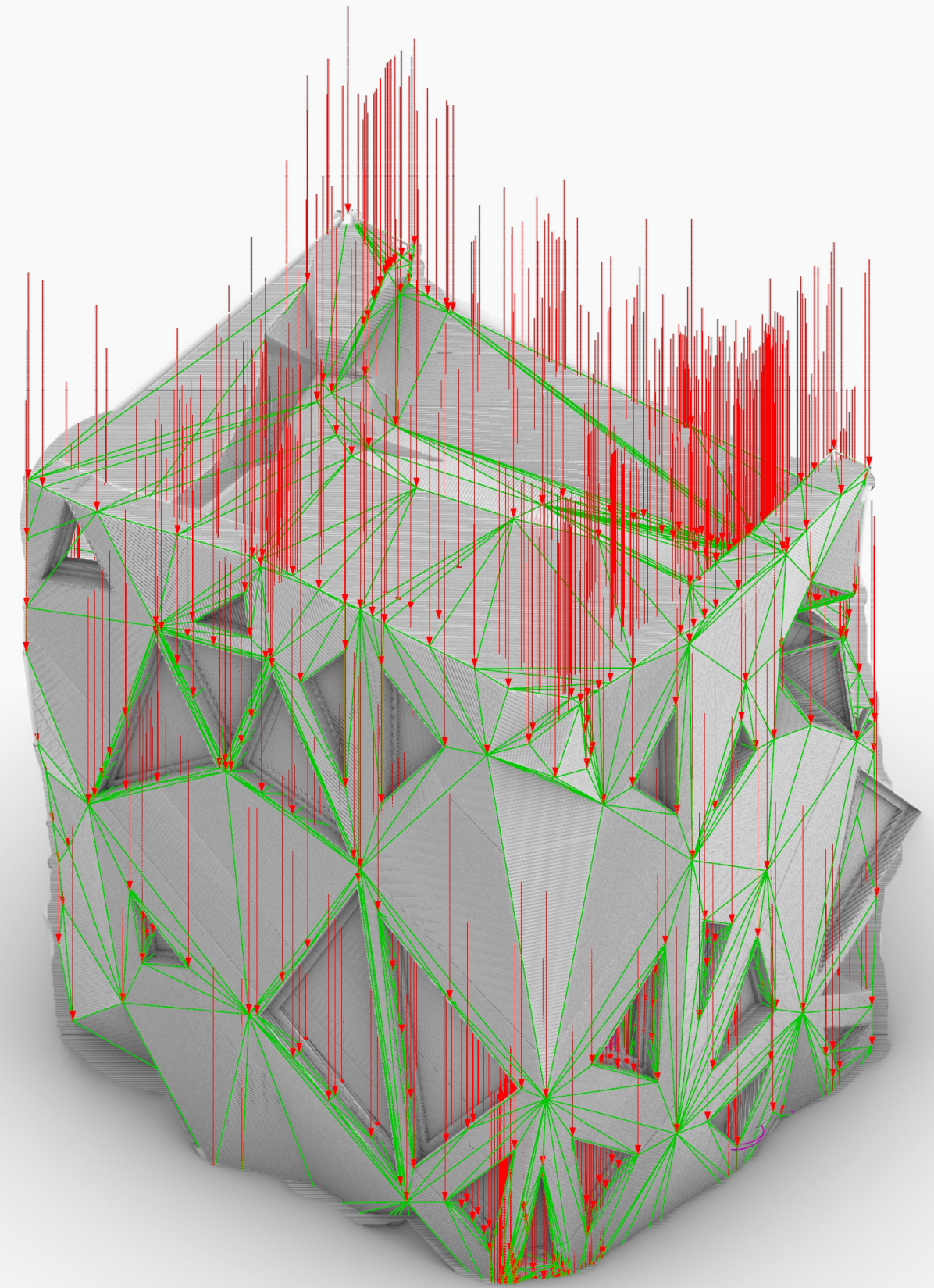
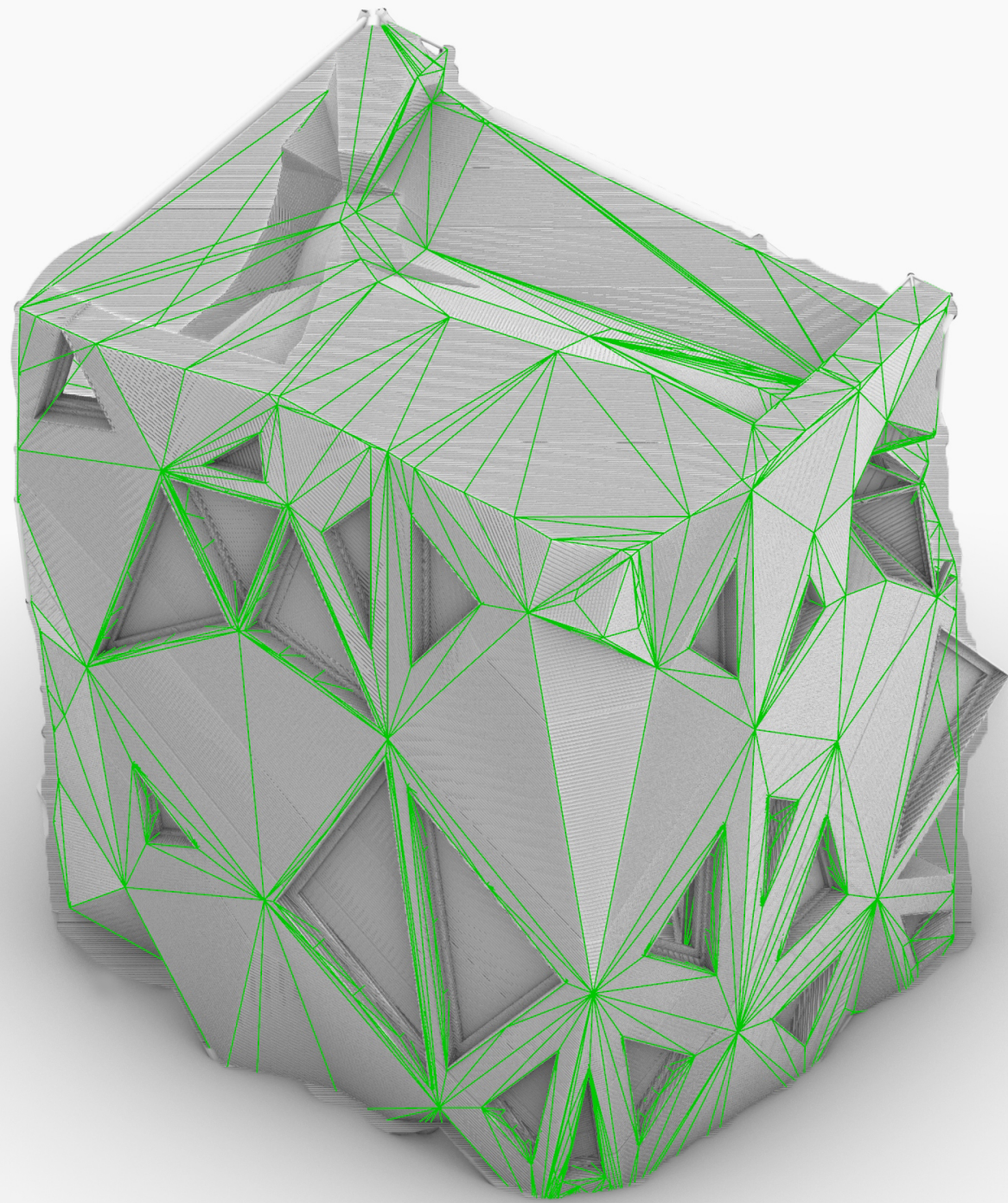
Forces on panel (wind & gravity)

Structure & Acoustics – Workshop 01

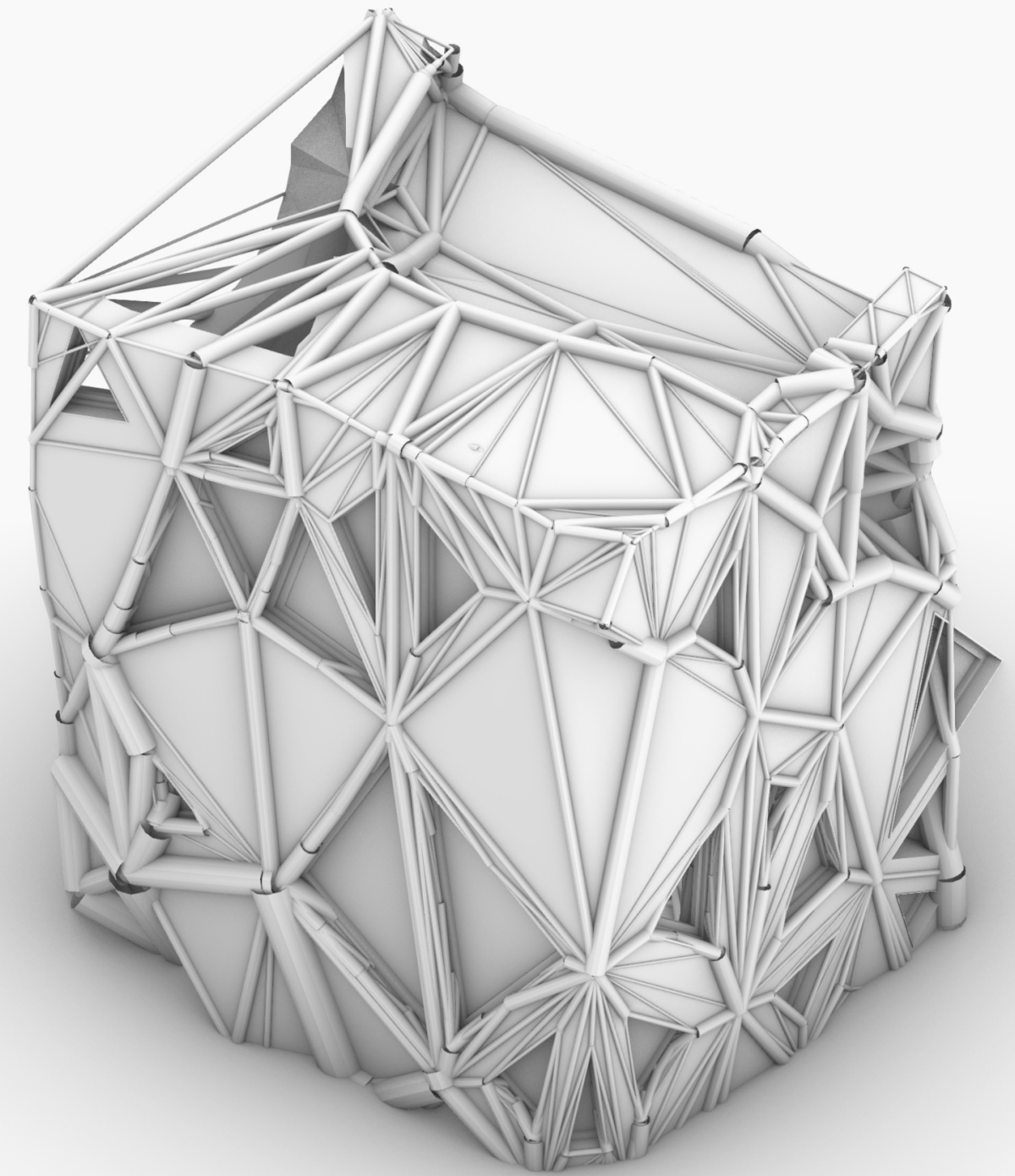
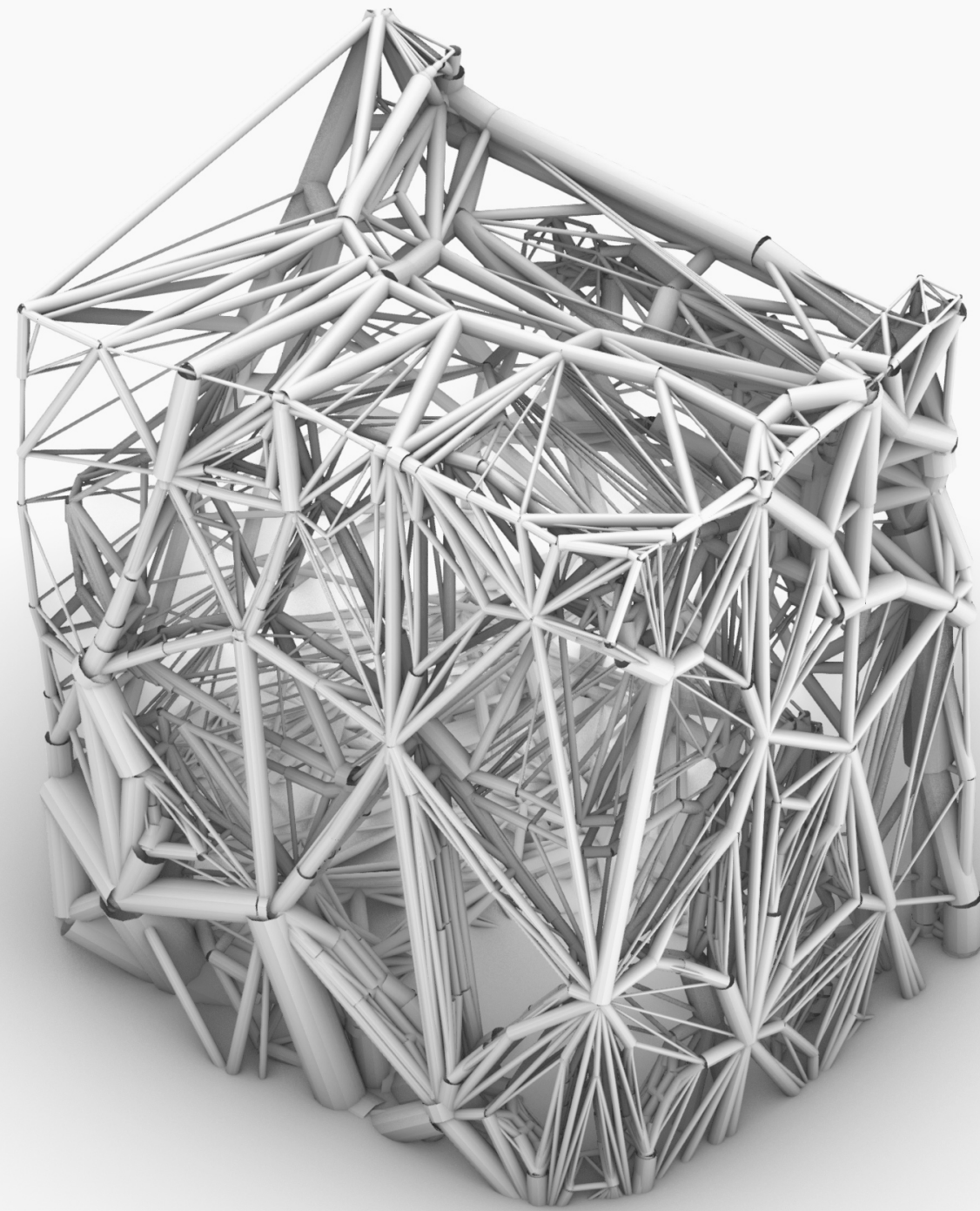
Structure & Acoustics – Workshop 01



Fragment Structure



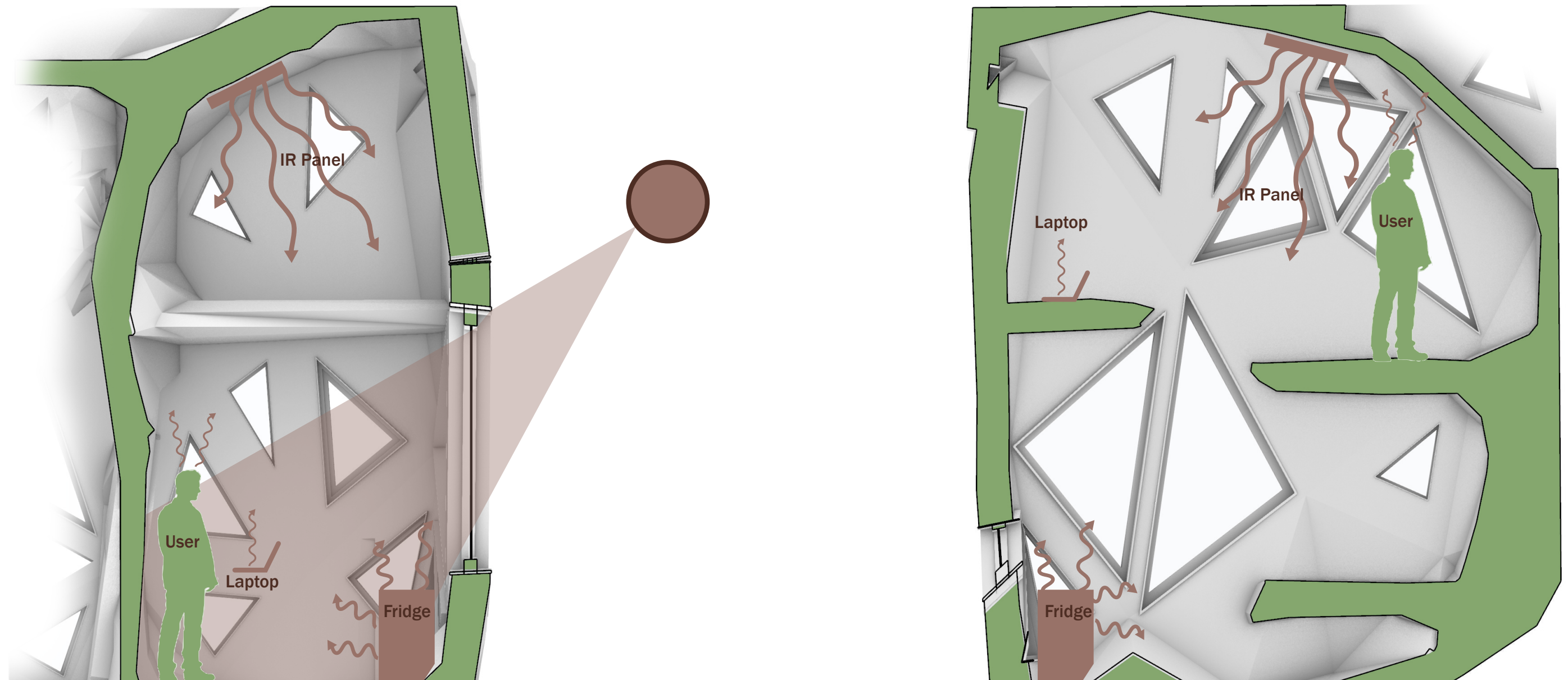
Fragment Structure



Climate Design: Heating

Heating Concept

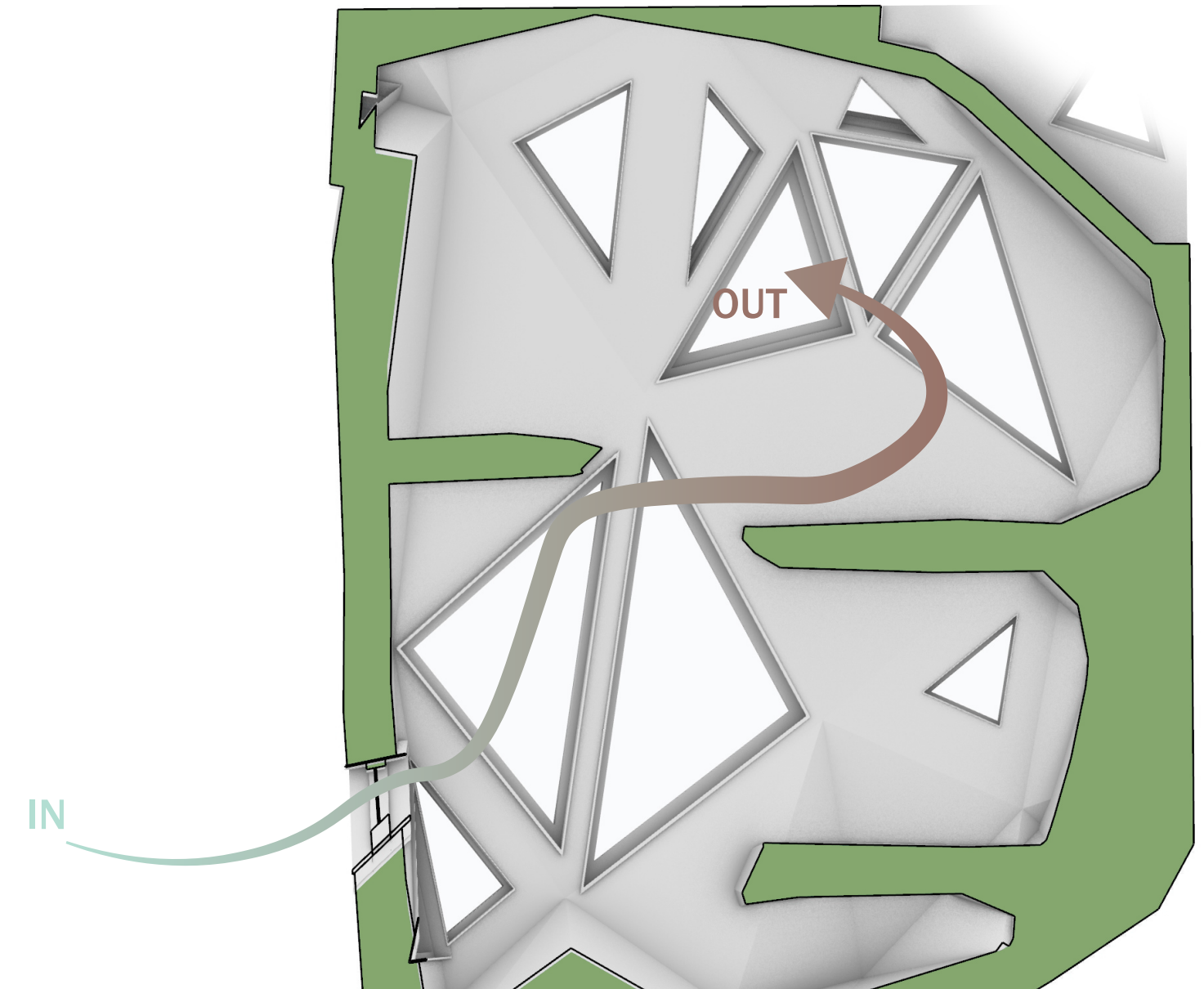
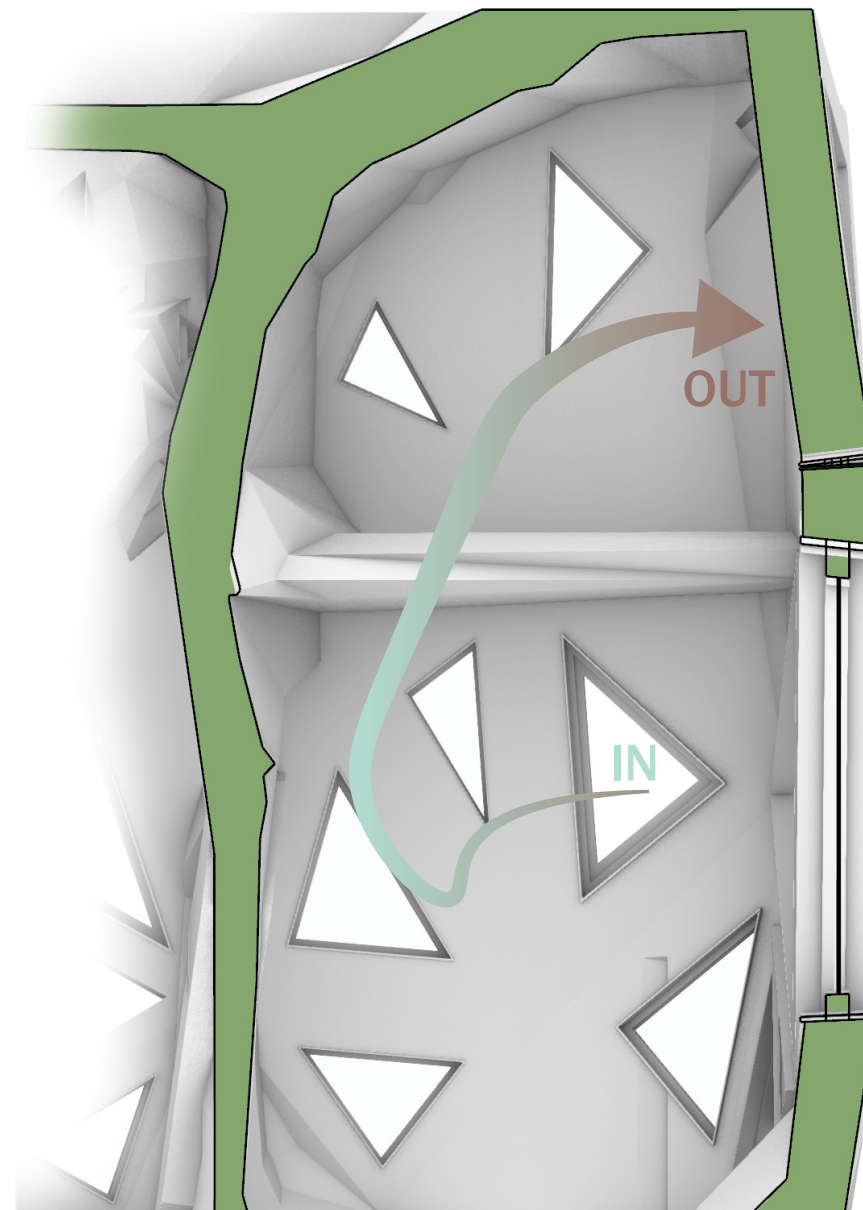
- Small housing units, meaning small volume to heat
- Heating by occupant, electronic devices, and the sun shining through the windows.
- Overheating is reduced due to surrounding buildings in the dense inner city
- For immediate heat needs there is a single far infrared panel per housing unit.
- Shared space is also heated with far infrared panels, so this space only gets efficiently heated when its used.



Climate Design: Ventilation

Ventilation Concept

- Due to the high ceilings of these housing ventilation is done naturally by means of the stacking effect
- Ventilation air gets preheated so there is no draught
- Windows can be opened
- Natural (preheated) in and natural out

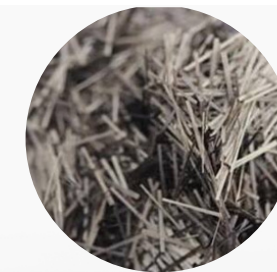


Interior Design Plan

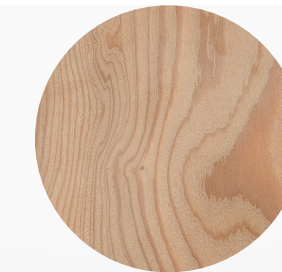
Persons in sections represent different parts of the human centric design principle, this is a single person unit



PLA Pellets



Basalt Fiber

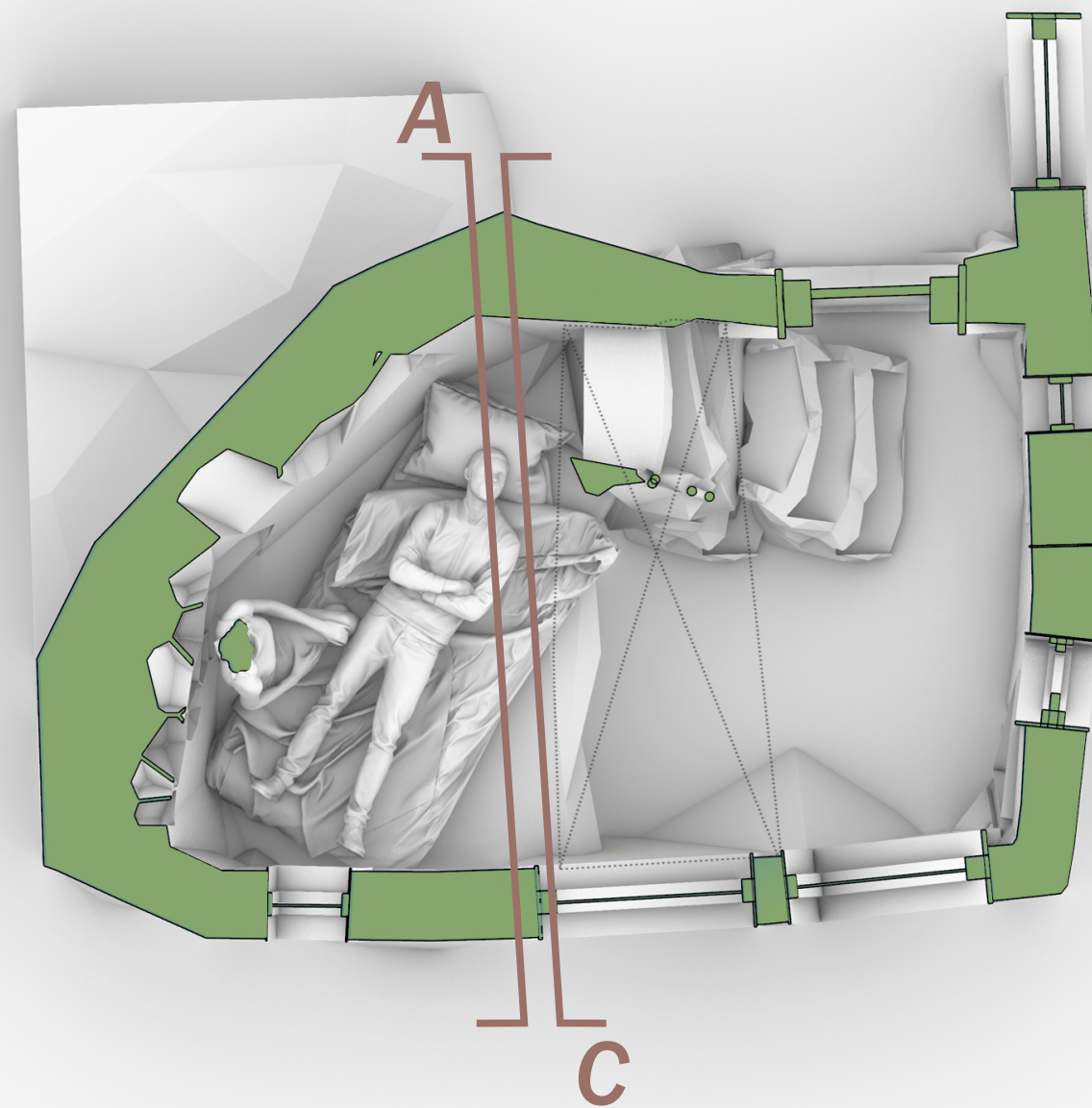


Larch Wood



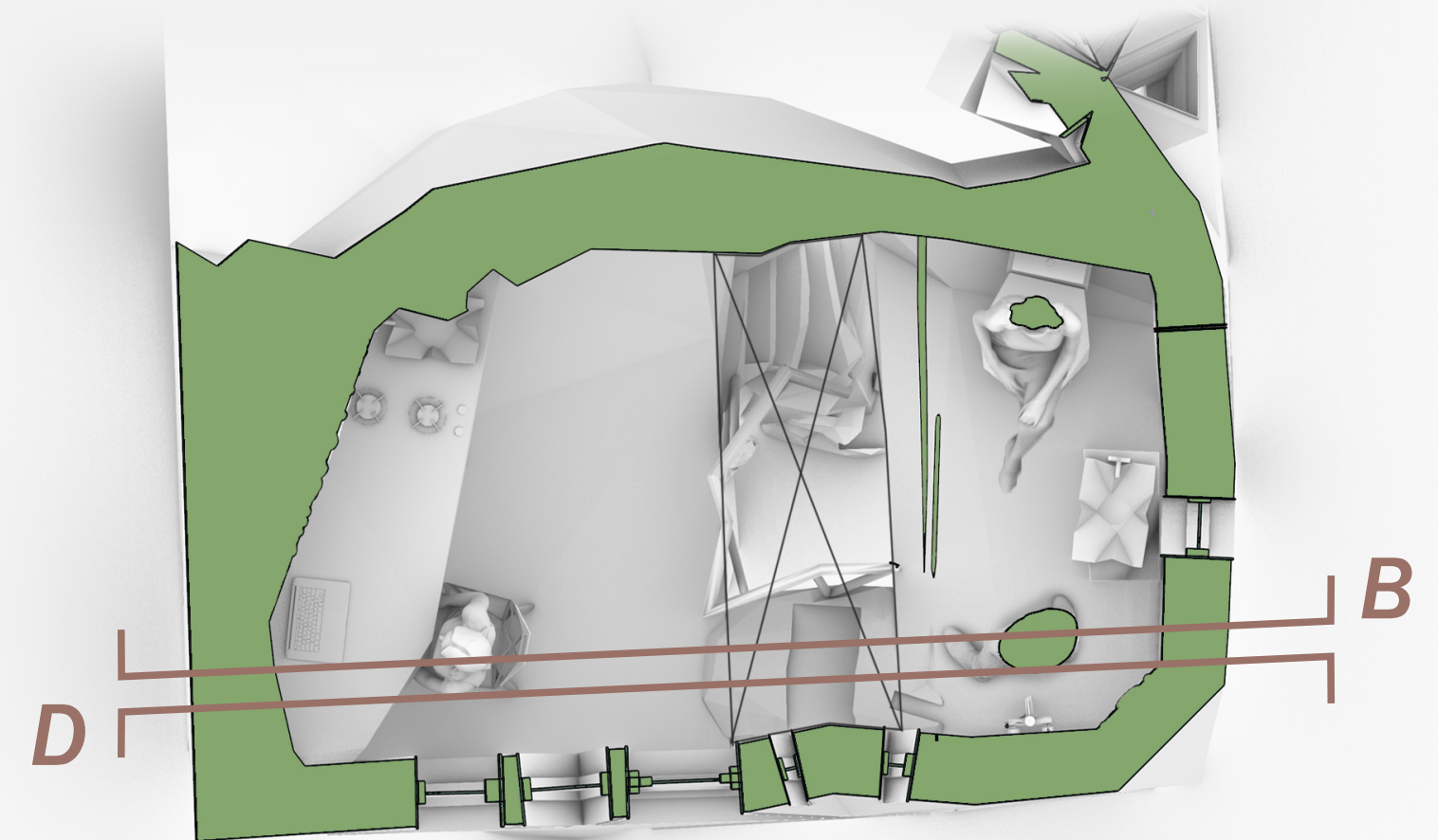
Double Glass

Interior furniture is made from local produced wood that can be found in the Netherlands & can be used interior and exterior



1m

5m



Interior Design Section A + B

Persons in sections represent different parts of the human centric design principle, this is a single person unit



PLA Pellets



Basalt Fiber

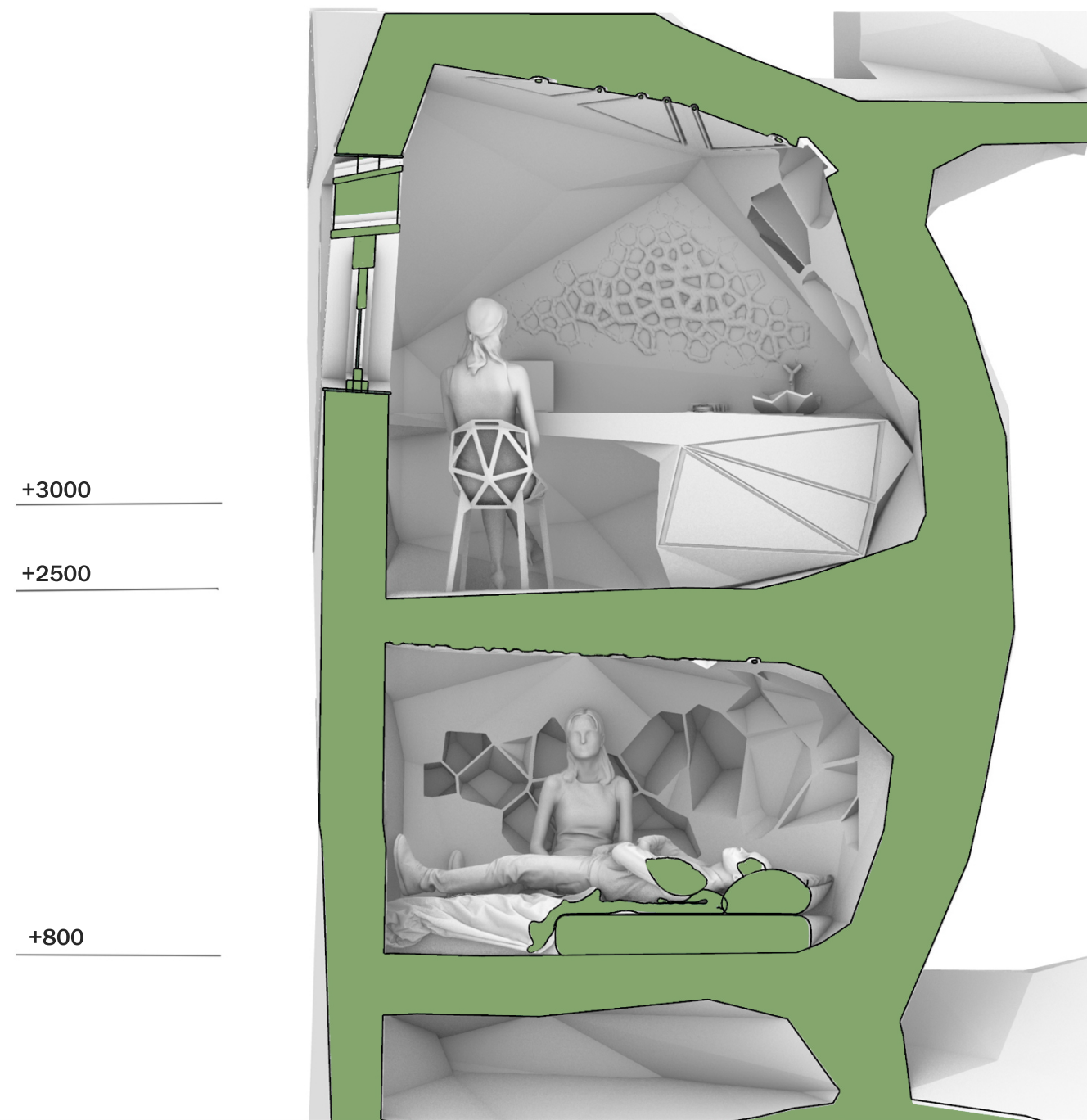


Larch Wood

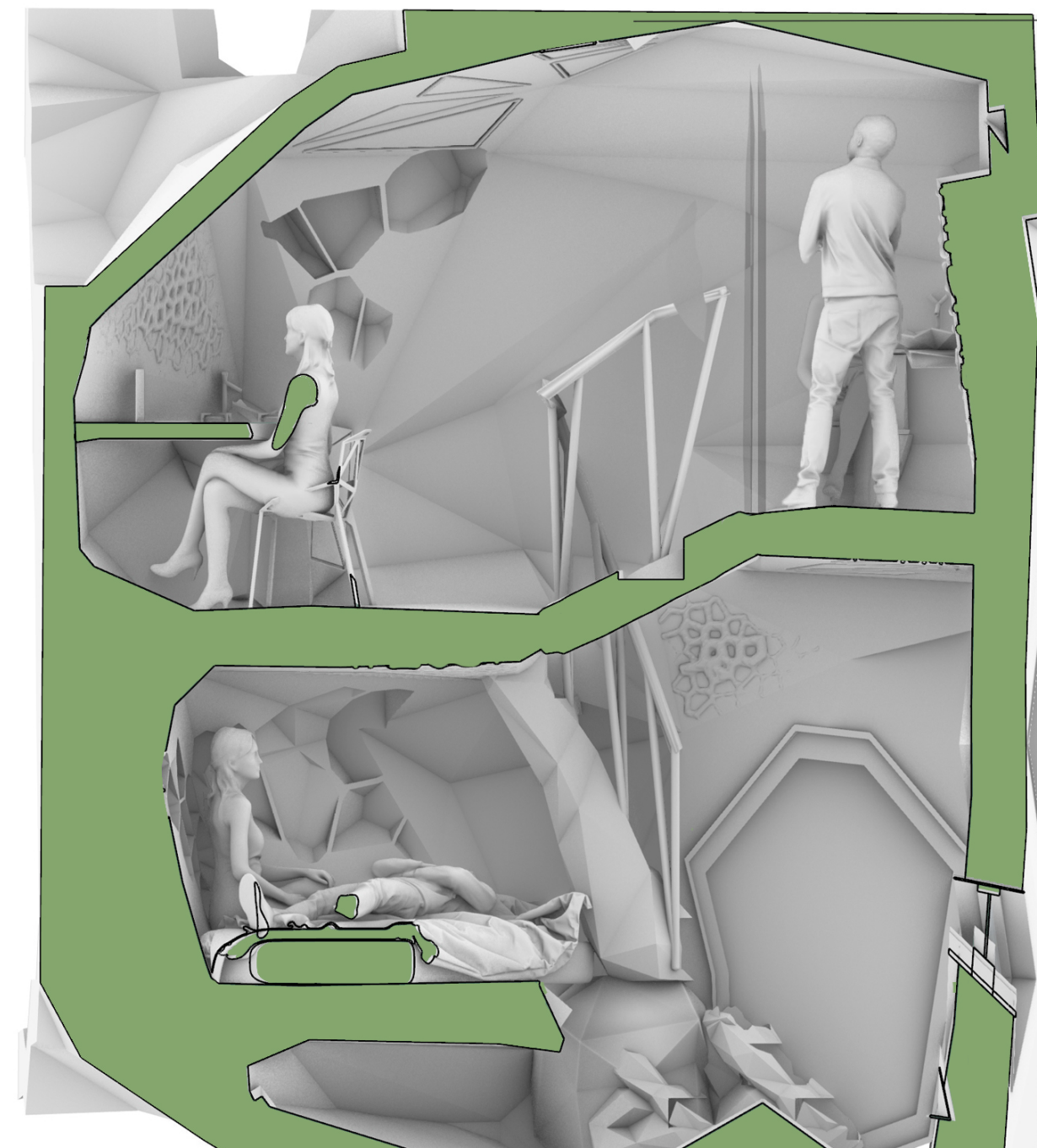


Double Glass

Interior furniture is made from local produced wood that can be found in the Netherlands & can be used interior and exterior



1m 5m



h = 5000

Interior Design Section C + D

Persons in sections represent different parts of the human centric design principle, this is a single person unit



PLA Pellets



Basalt Fiber

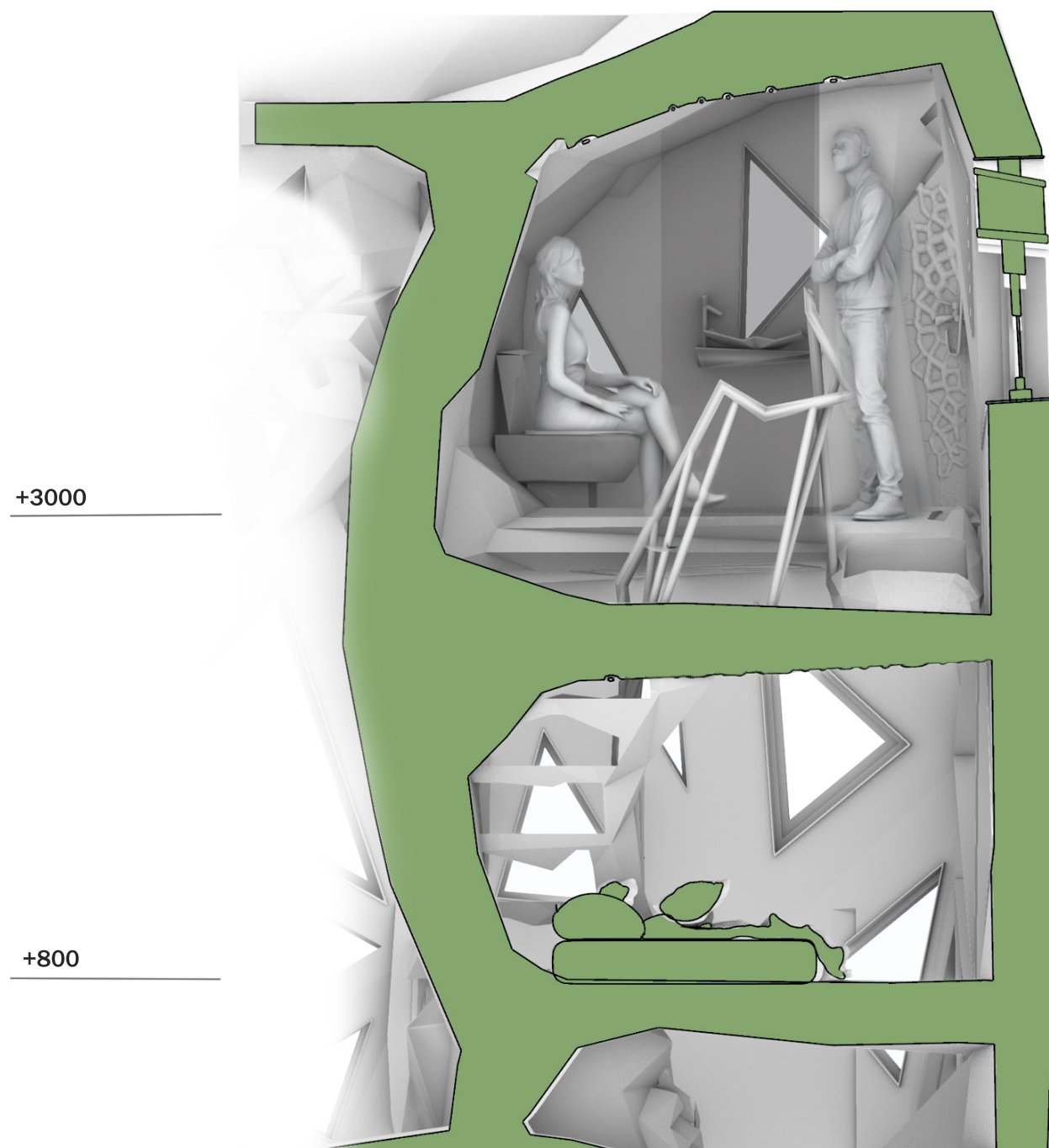


Larch Wood



Double Glass

Interior furniture is made from local produced wood that can be found in the Netherlands & can be used interior and exterior

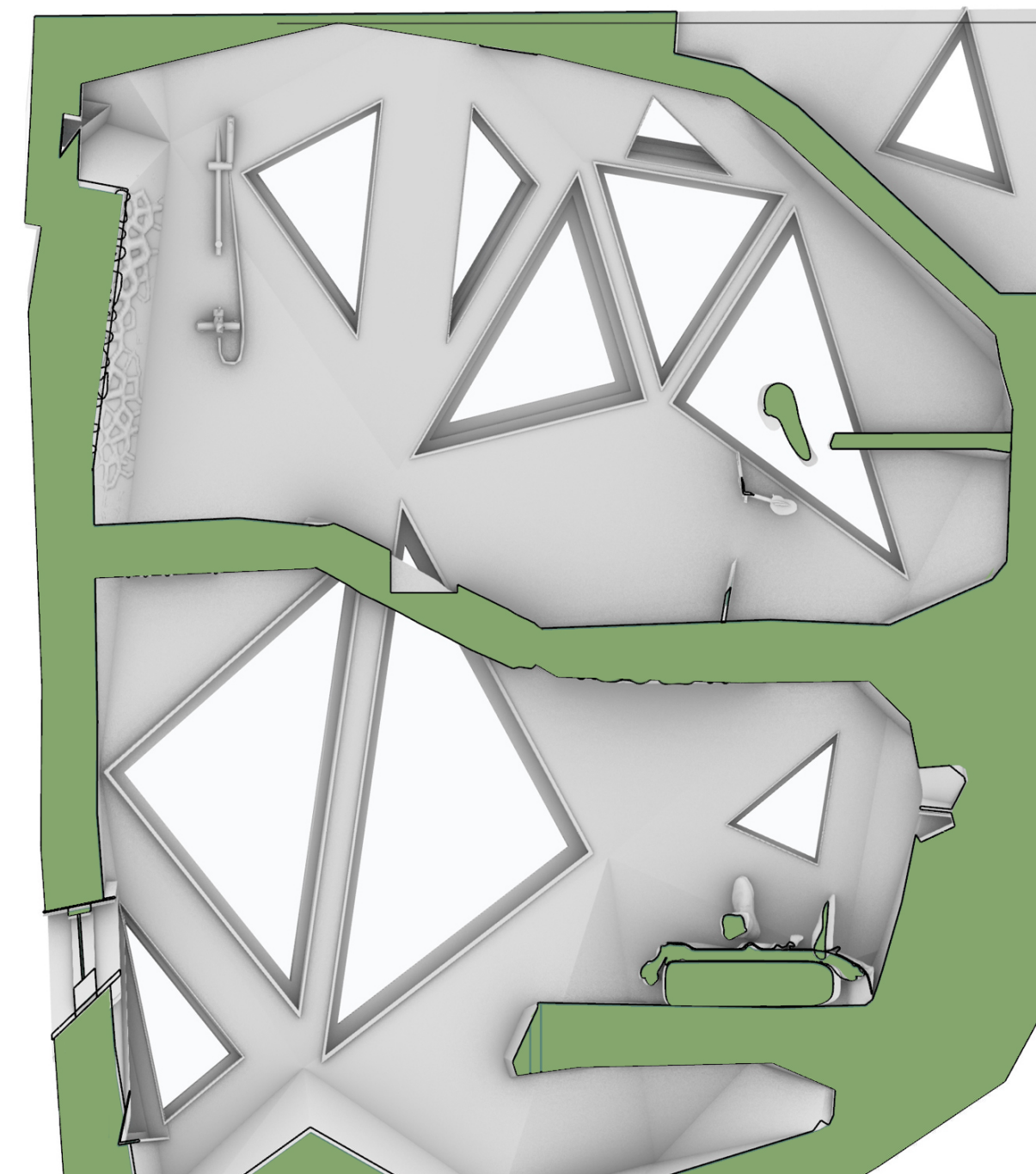


+3000

+800

1m

5m



h = 5000

360 Image Interior

360 Image Interior

In-Situ Construction

References 3D Printing: ICON

3DP Characteristics

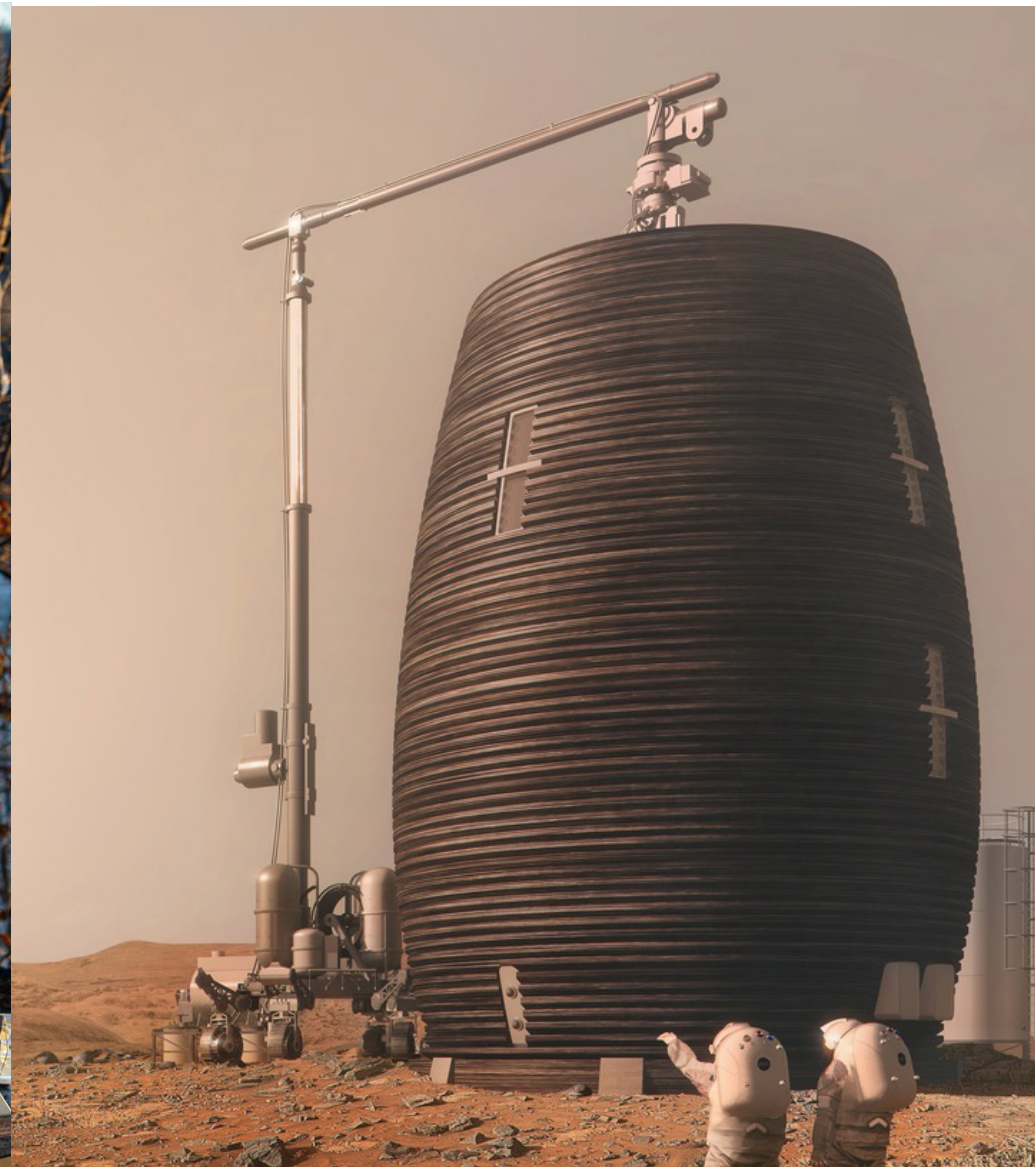
- Printing an entire house in 24 hours
- Large gantry style 3D printer
- Printer is transported in lorry
- Material: Concrete
- Reach of 3D printer is in one direction infinite, in other directions it is limited by the size of the printer
- Printing speed of 150mm/s



References 3D Printing: AI Spacefactory

3DP Characteristics

- Designs for houses on mars as well as on earth
- Printing a house with renewable materials (BFRPLA)
- Very mobile printer consists of a 6 axis robotic arm placed on a forklift
- 3D Printing outdoors without any protection
- Can print on irregular surfaces
- Printing speed of 65mm/s

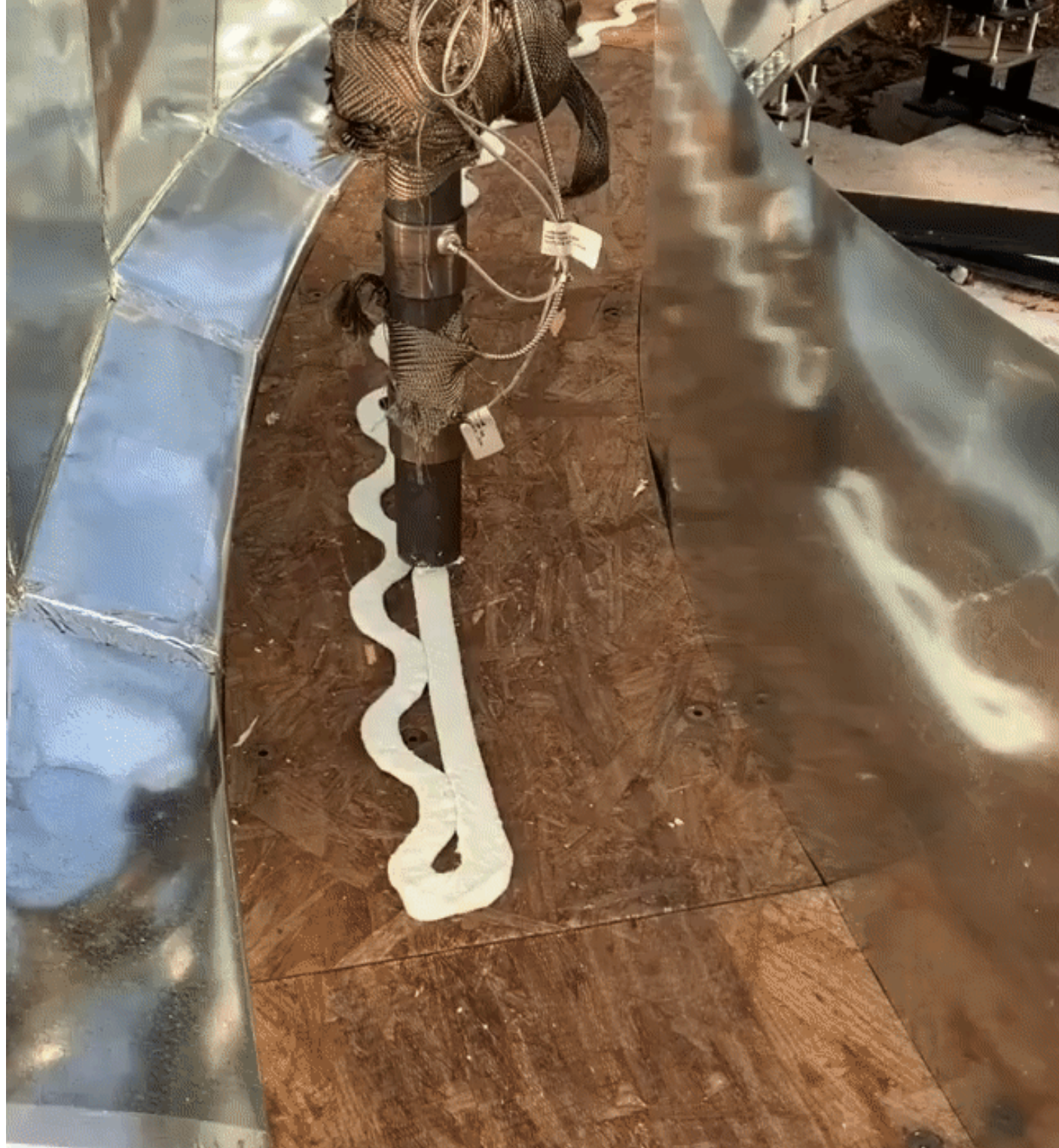


3D Printing Unit



- Upgrade existing hardware + 6 axis robotic arm
- very mobile for hard to reach locations in the inner city
- Easy installation and calibration
- Small footprint





3D Printing Time Calculation

AI Spacefactory printing speed:
65mm/s

Print length fragment: 5577m
Print layer height: 25 mm

Printing time fragment:
150mm/s = 10 hours
65mm/s = 22 hours

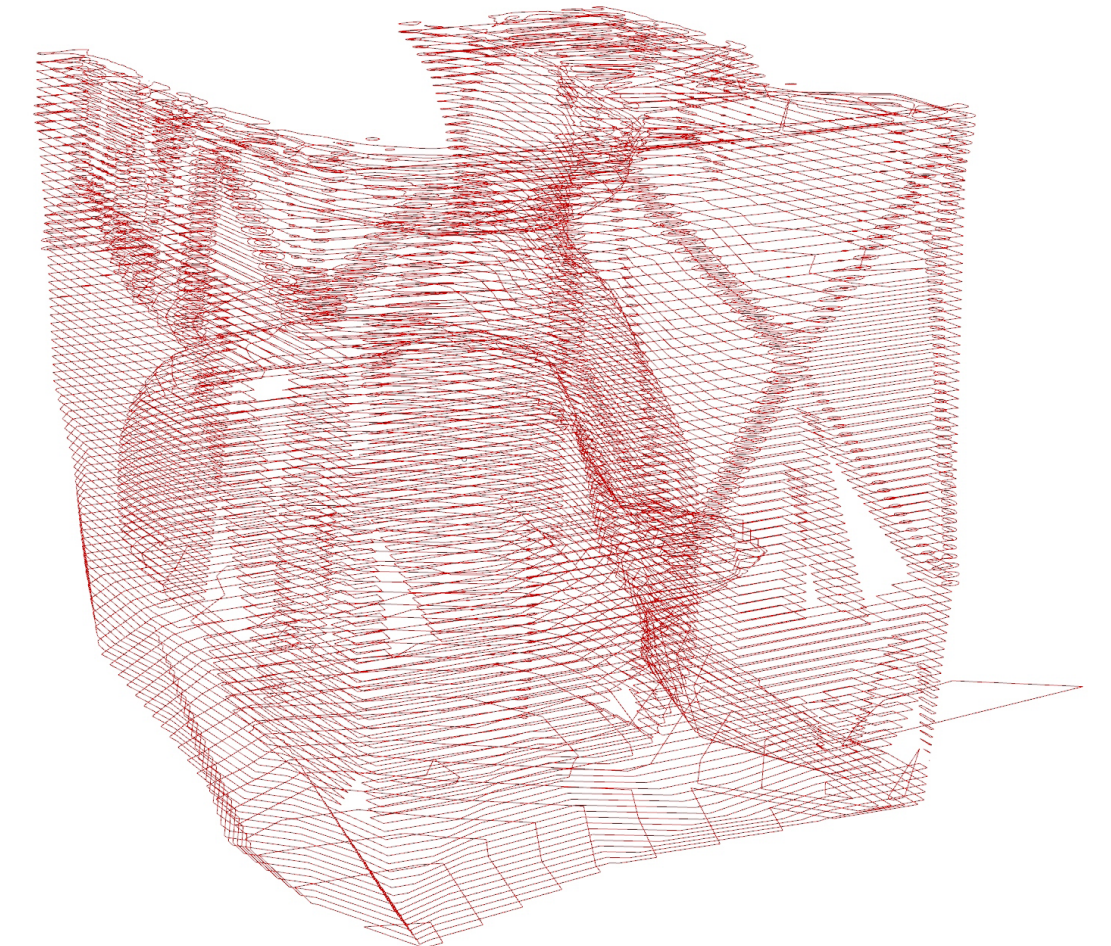
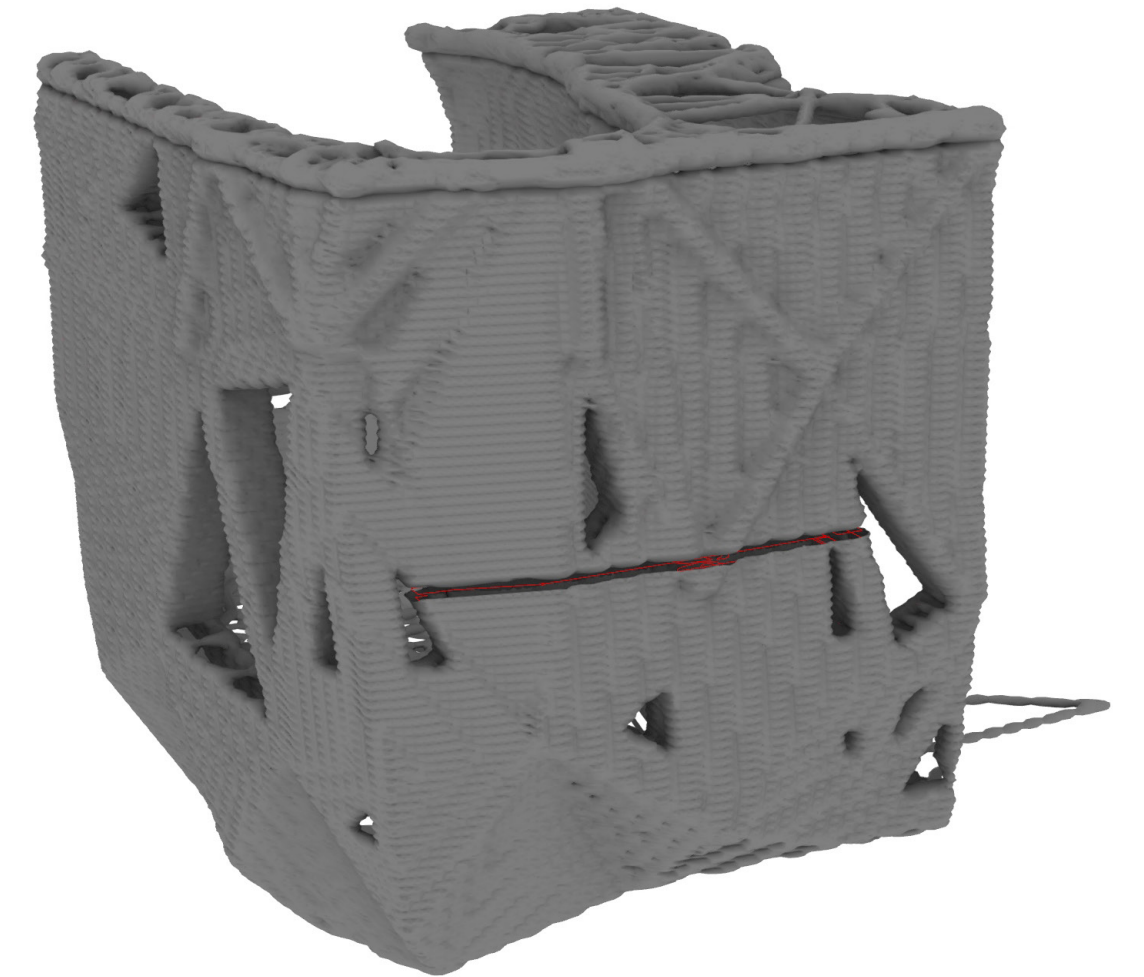
Total building printing time:
80-176 hours

Print length fragment: 2790m
Print layer height: 50 mm

Printing time fragment:
150mm/s = 5 hours
65mm/s = 11 hours

Total building printing time:
40-88 hours

ICON printing speed: 150mm/s



3D Printing Construction Planning



BFRPLA



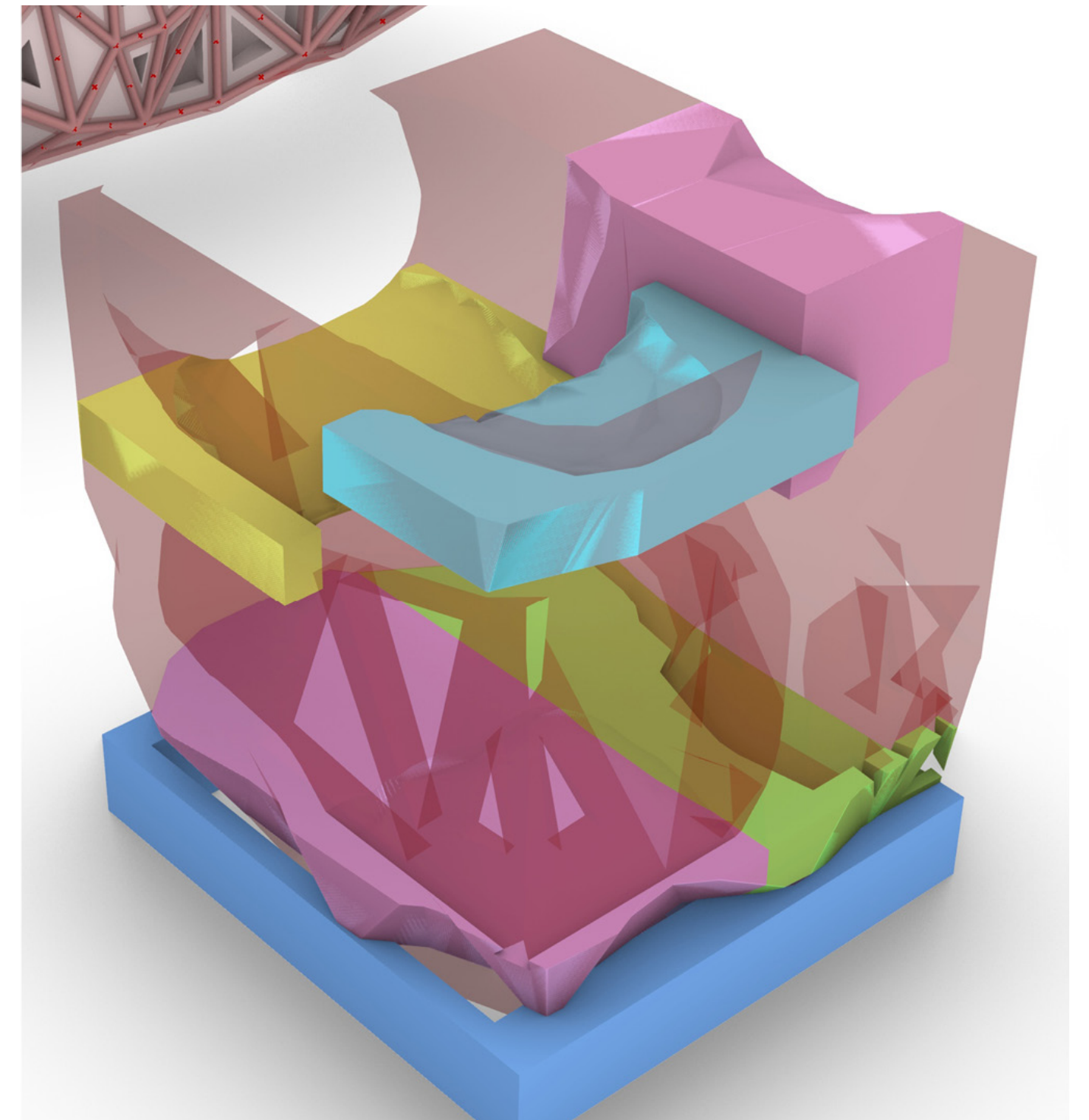
Larch Wood



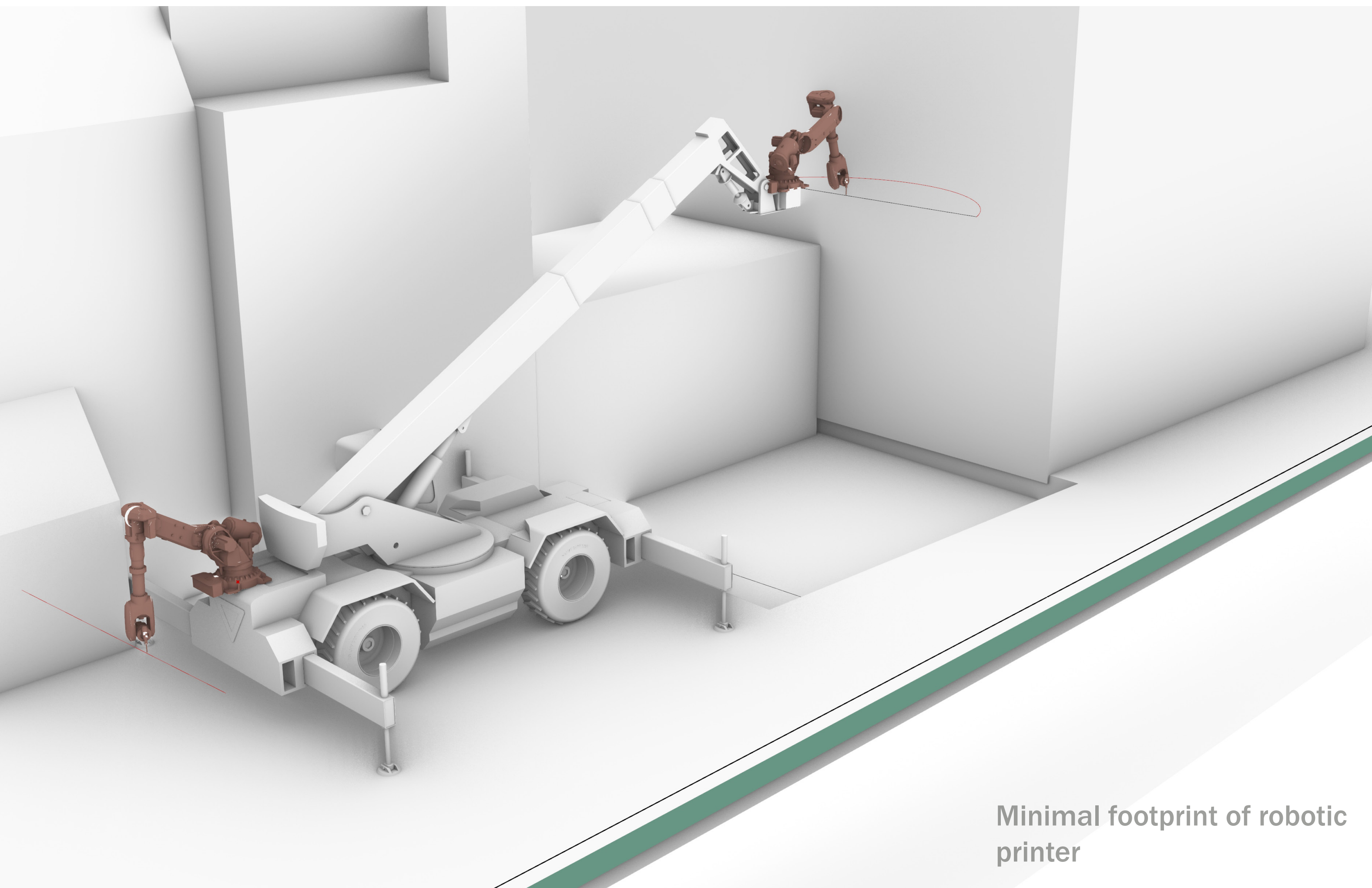
Double Glass

Building elements, their material and construction order:

- 1. Premade Foundation Piles (BFRPLA)*
- 2. In-Situ 3DP Foundation Beams (BFRPLA)*
- 3. Premade In-Situ Floors (BFRPLA)*
- 4. Secure with bolts*
- 5. In-Situ 3D printed walls (BFRPLA)*
- 6. Premade Window Panels (Wood, Glass)*

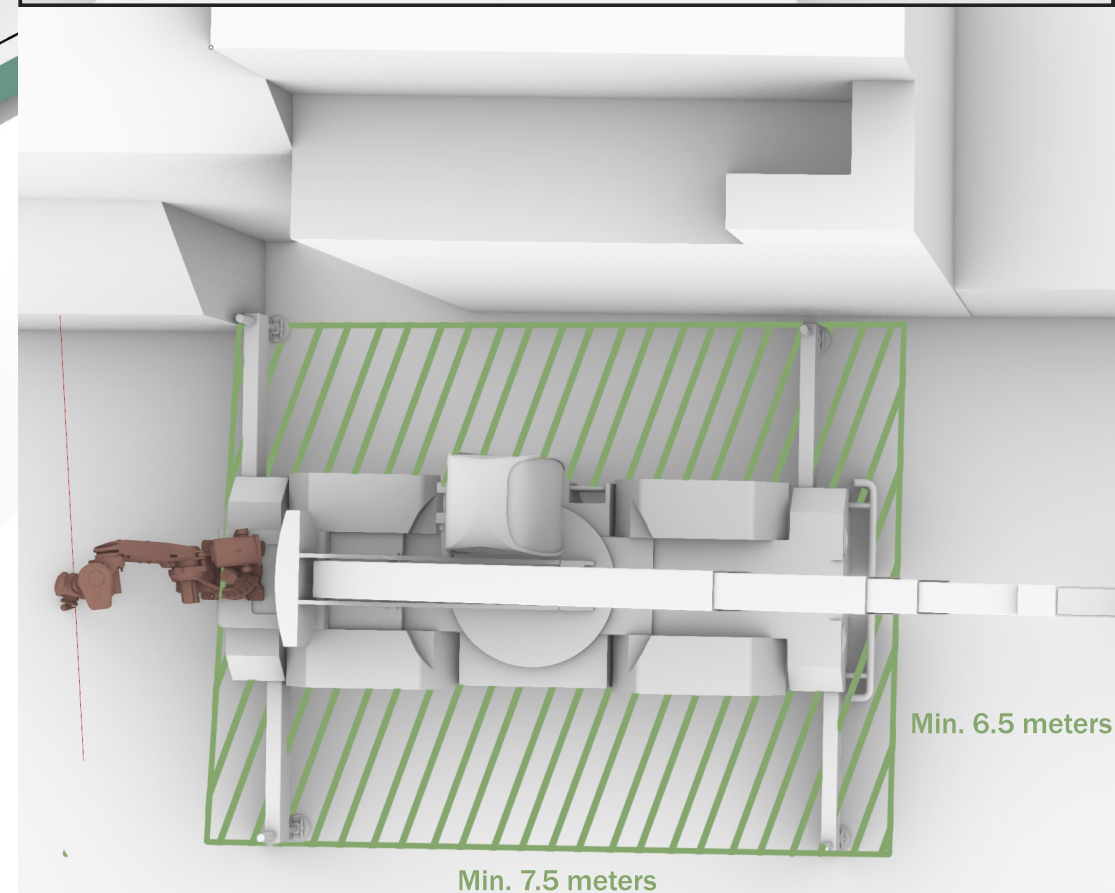
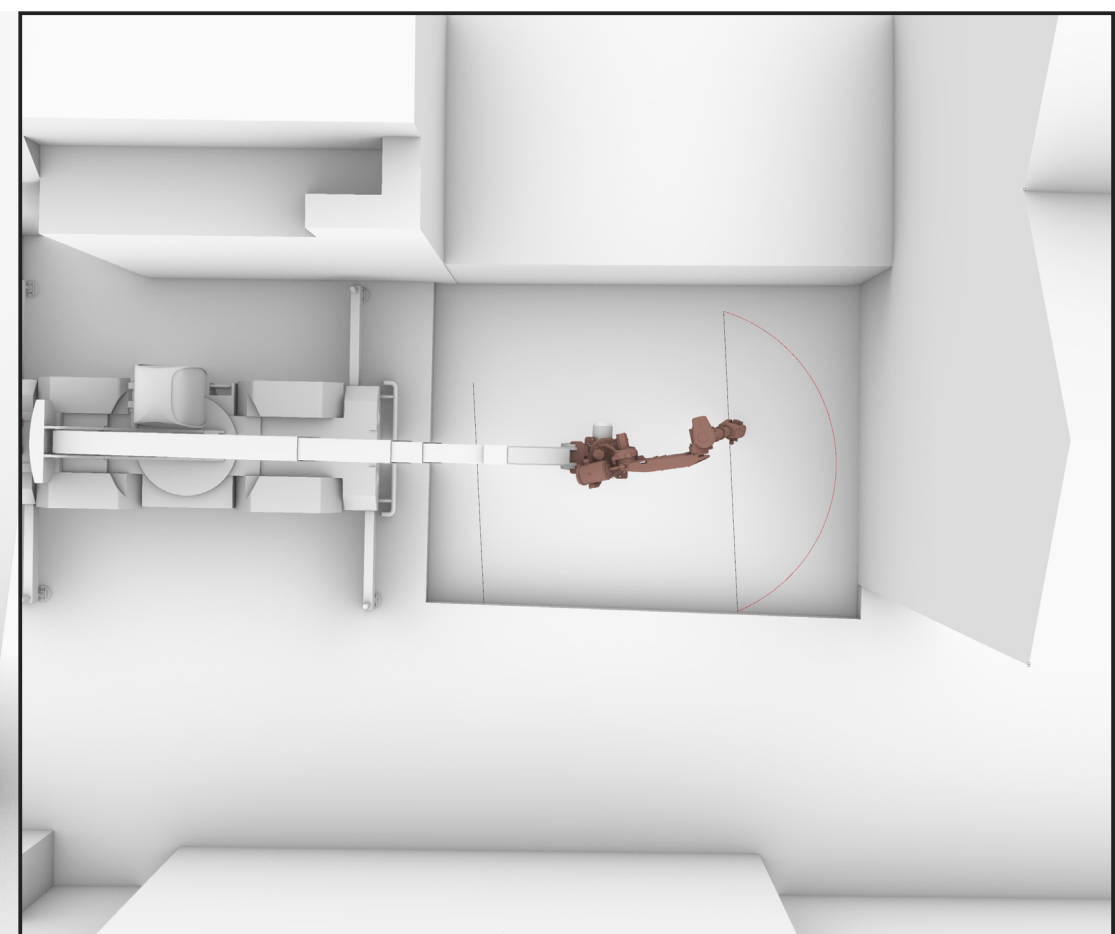


Construction 1/8



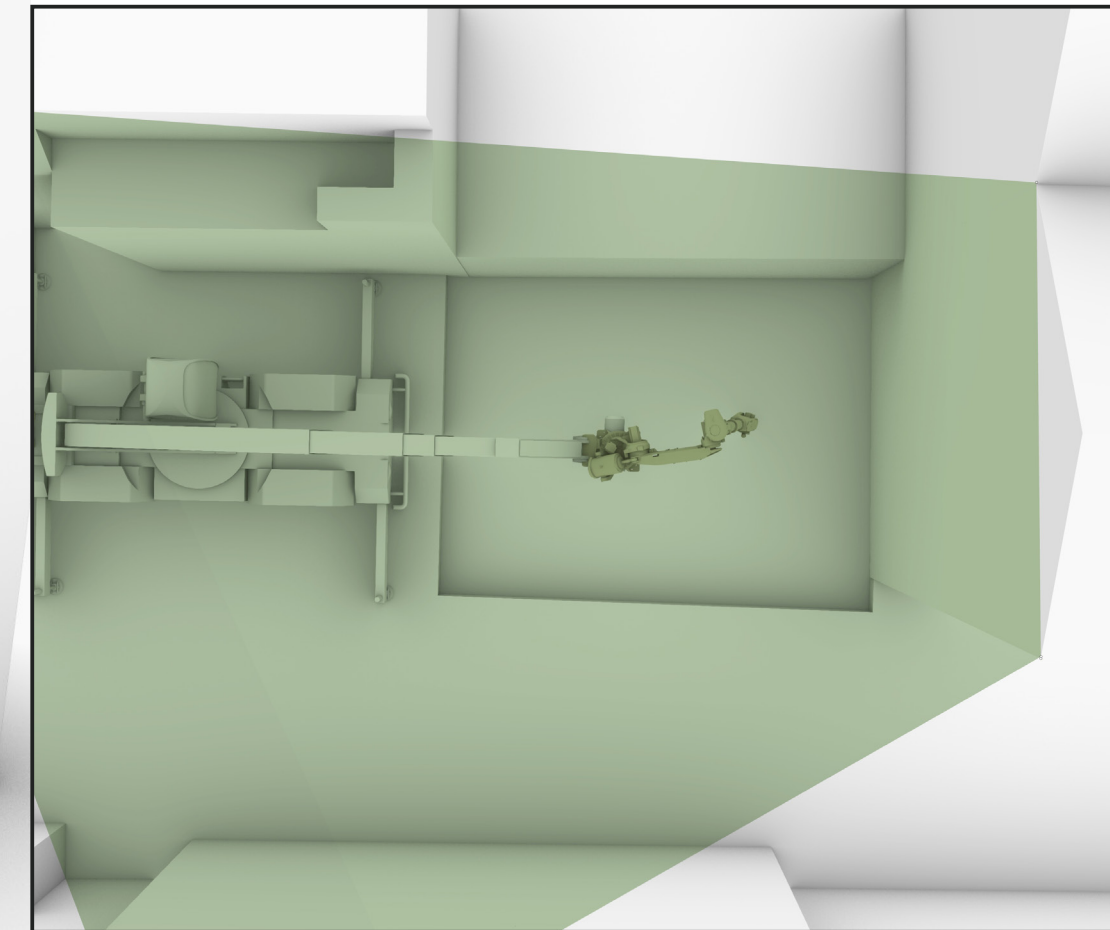
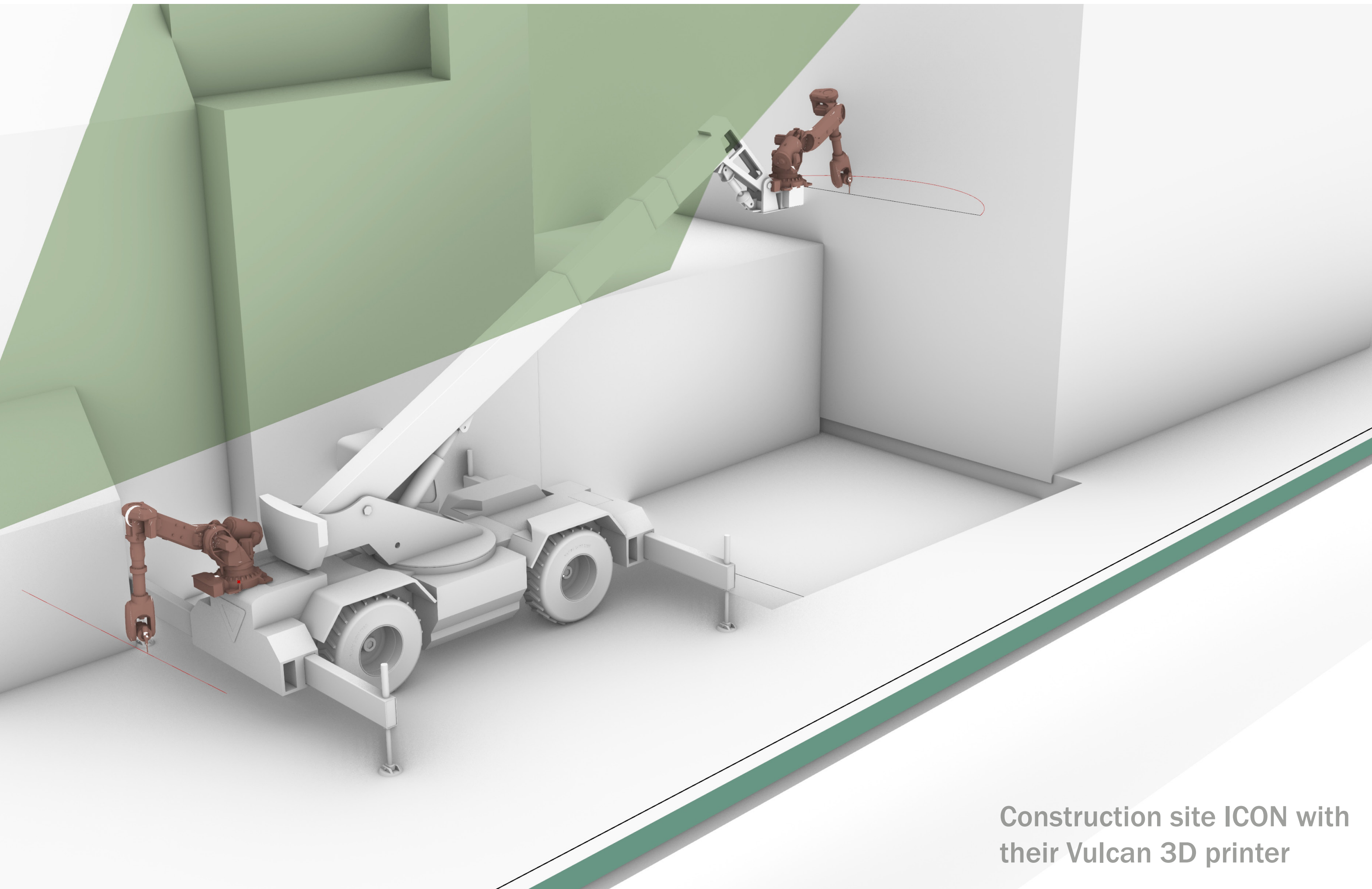
Minimal footprint of robotic printer

Top View



Construction 2/8

Top View

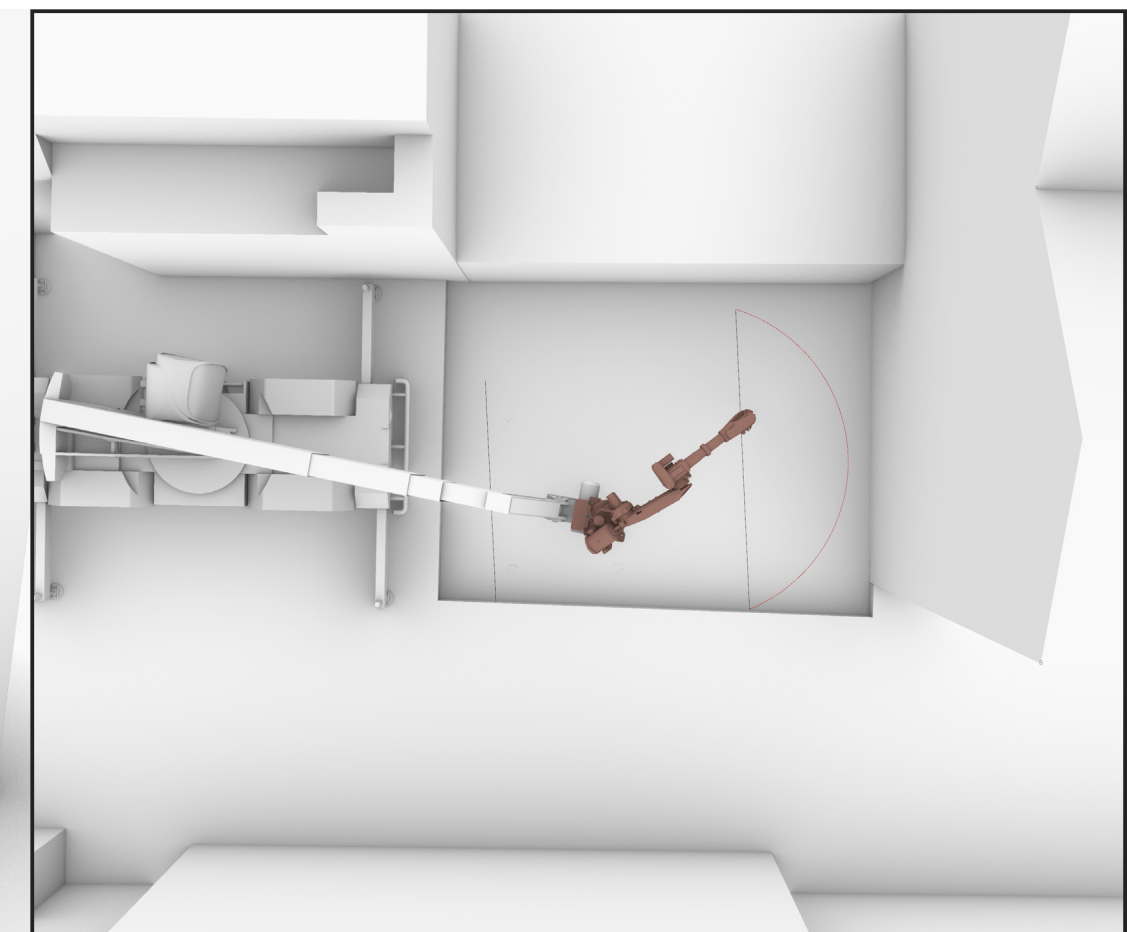
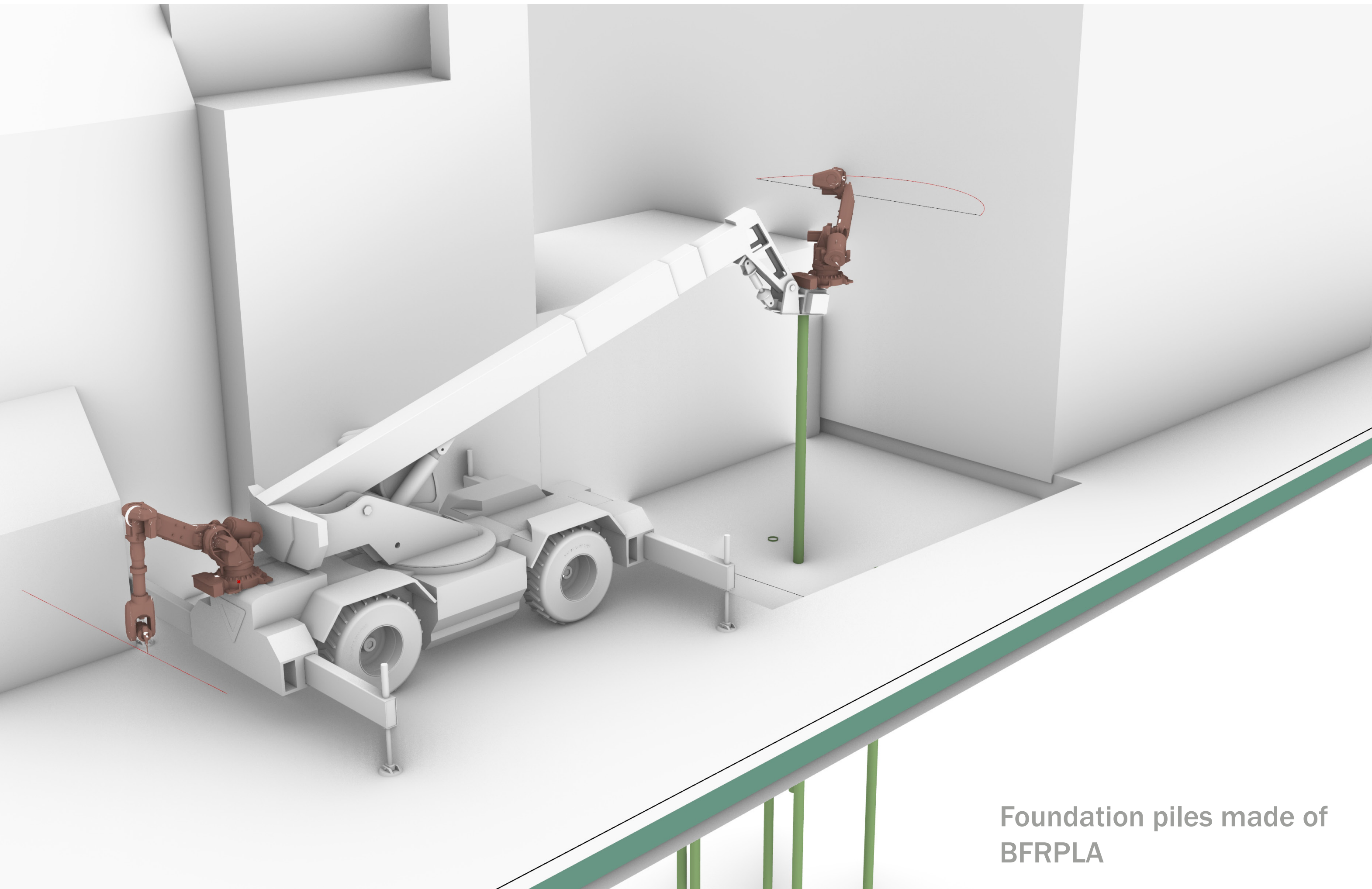


Construction site ICON with their Vulcan 3D printer



Construction 3/8

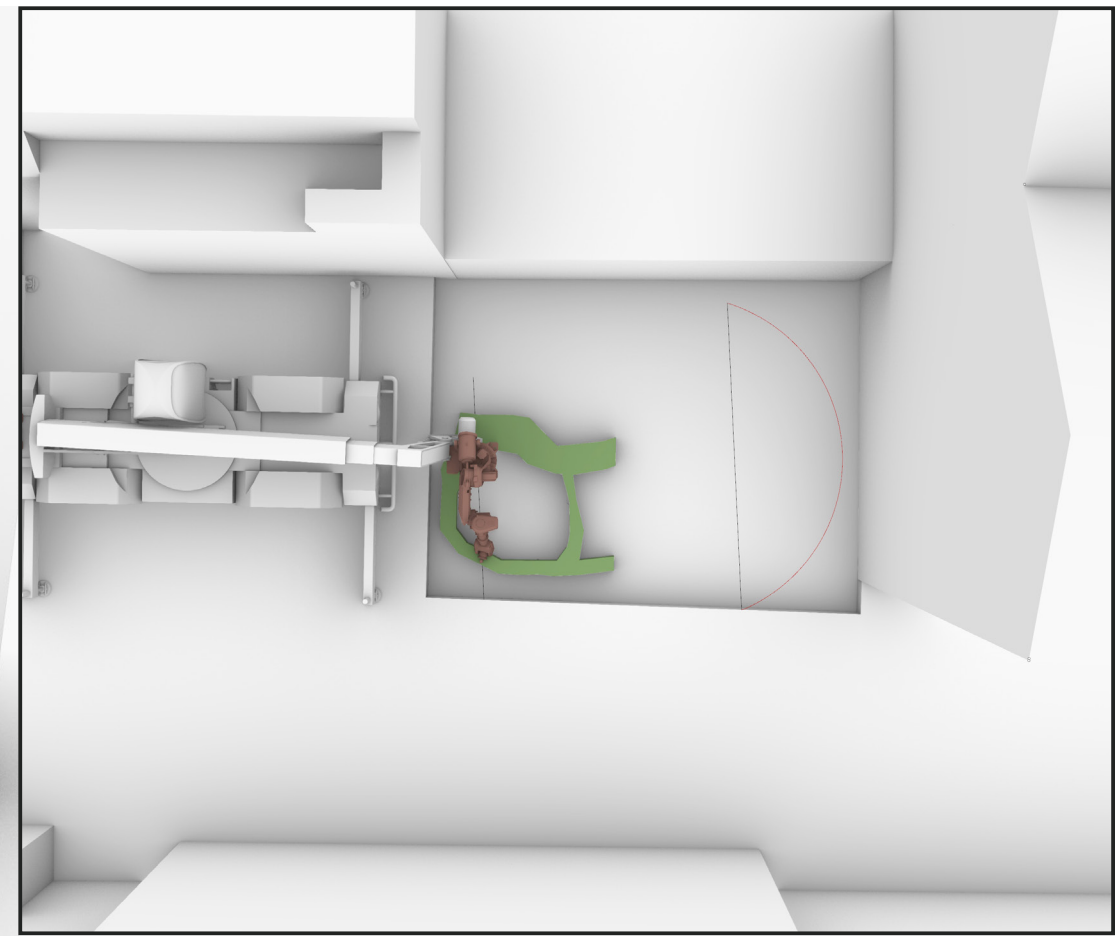
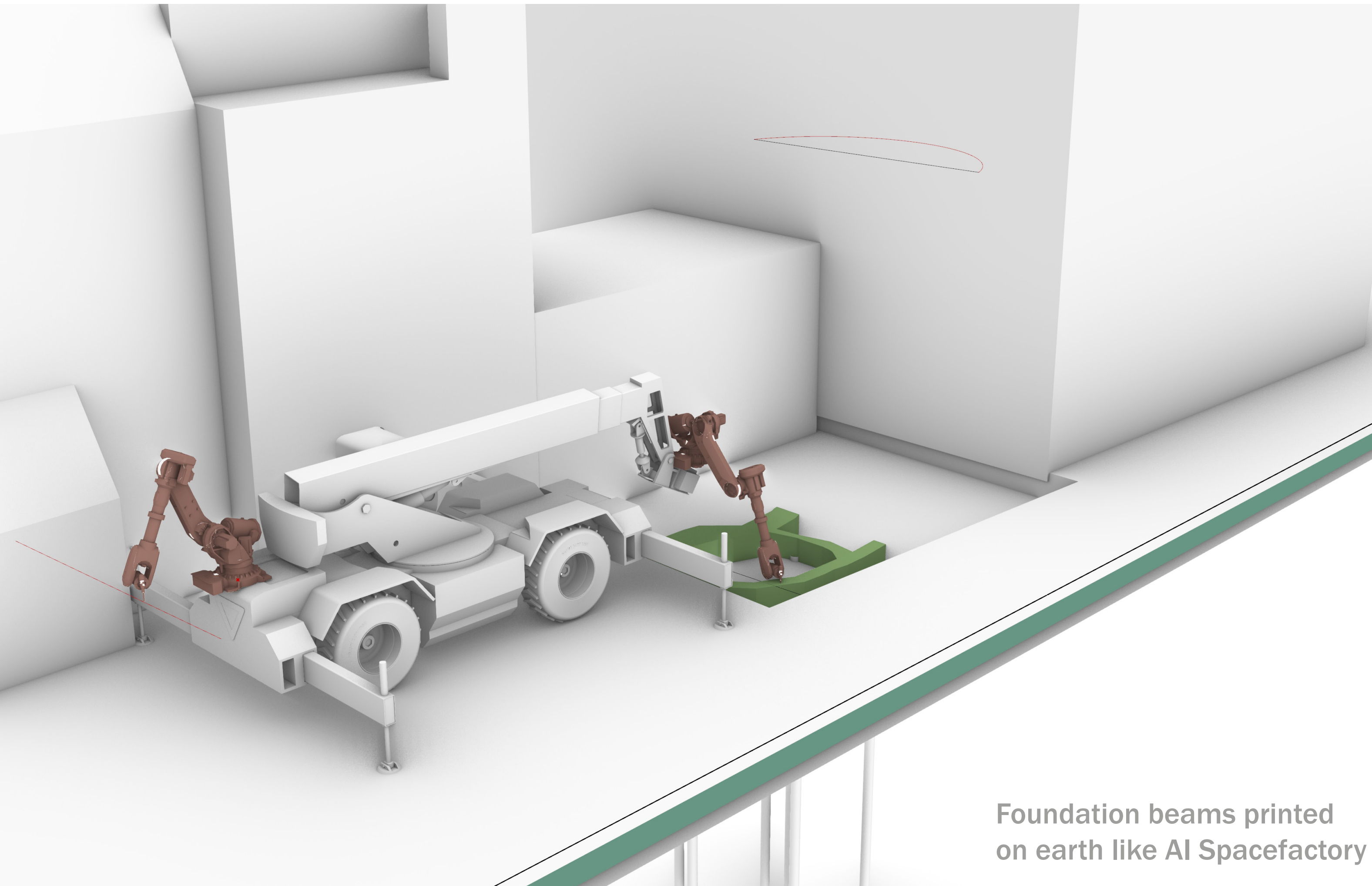
Top View



Foundation piles made of BFRPLA

Construction 4/8

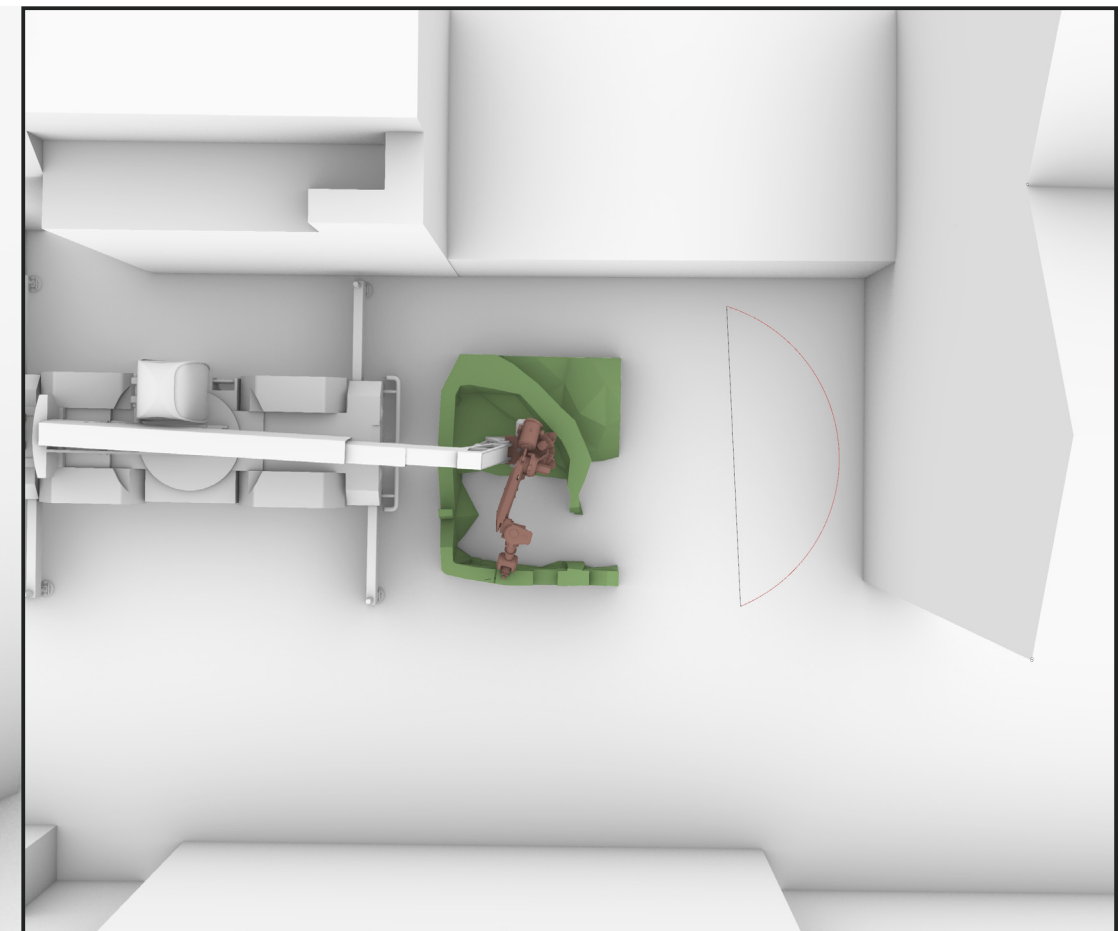
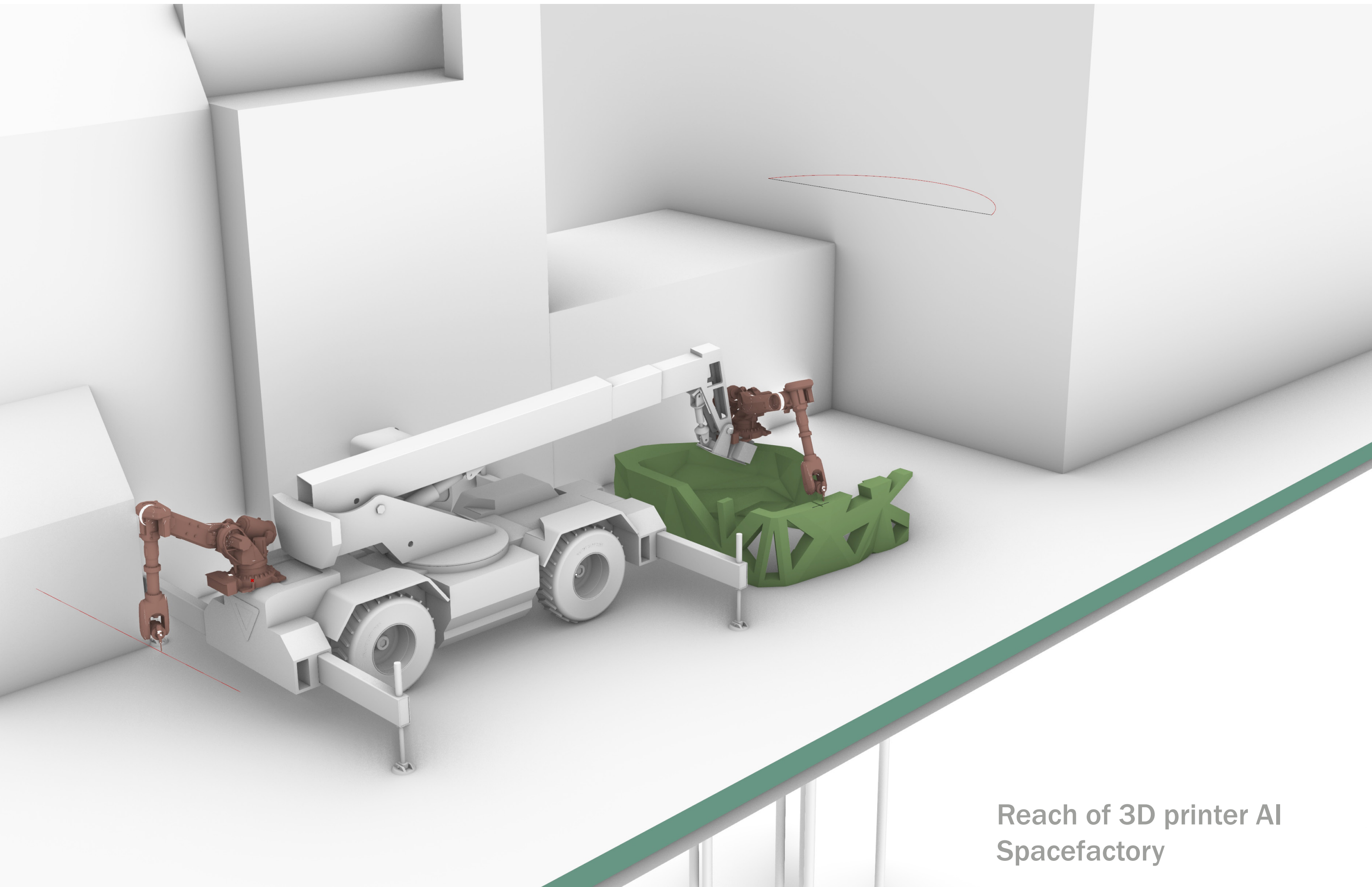
Top View



Foundation beams printed
on earth like AI Spacefactory

Construction 5/8

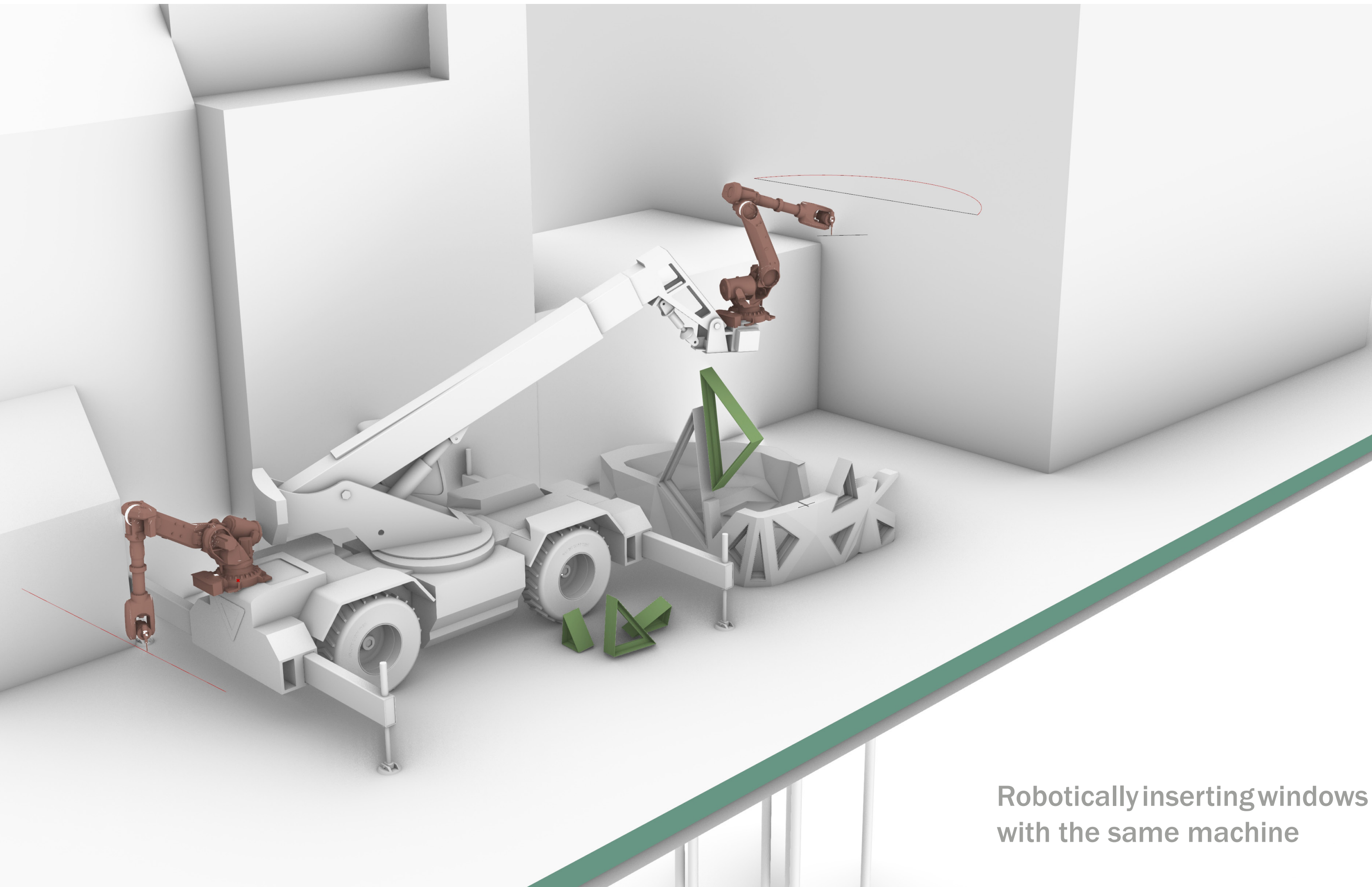
Top View



Reach of 3D printer AI
Spacefactory

Construction 6/8

Top View

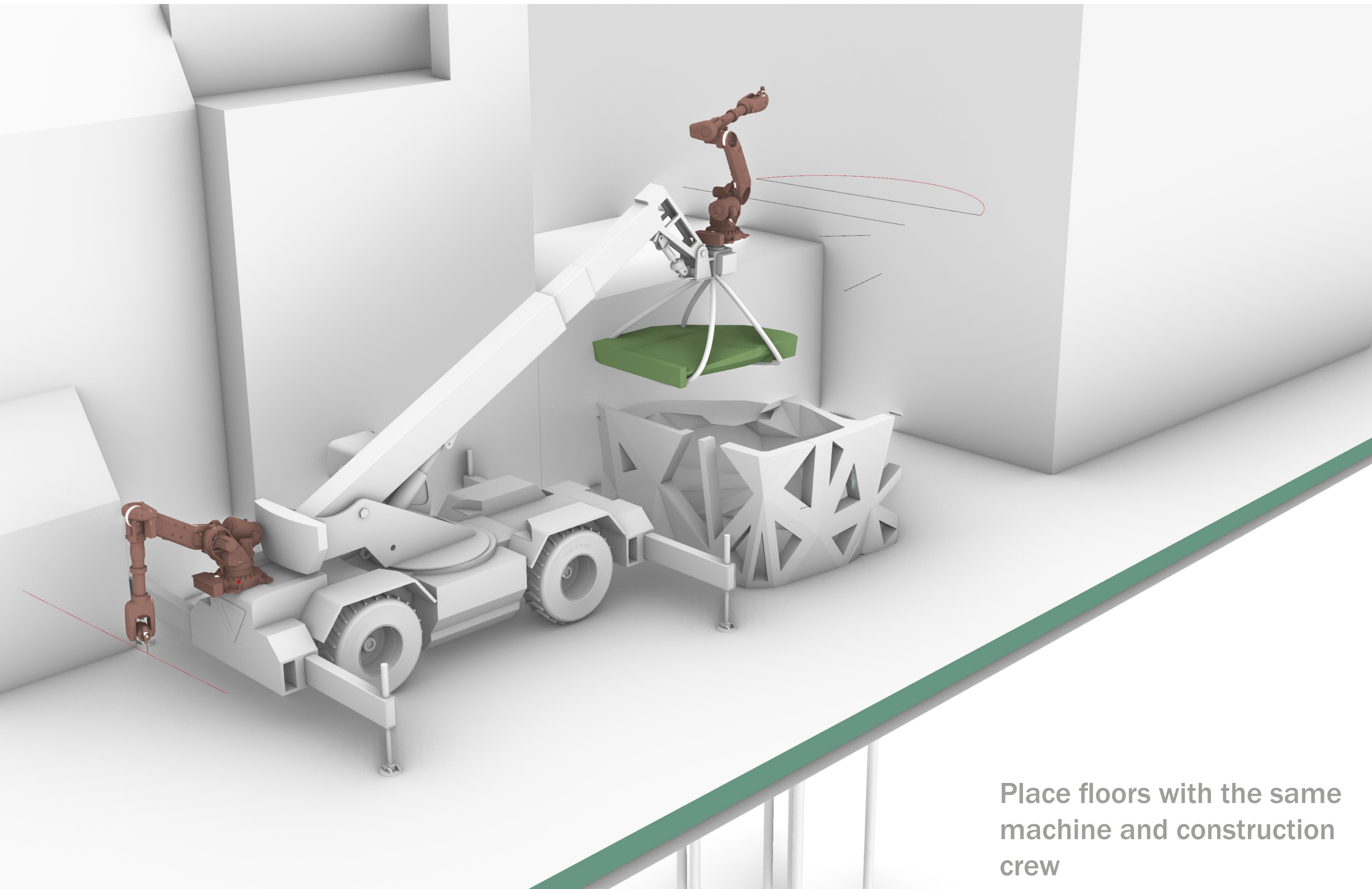


Robotically inserting windows
with the same machine



Construction 7/8

Top View

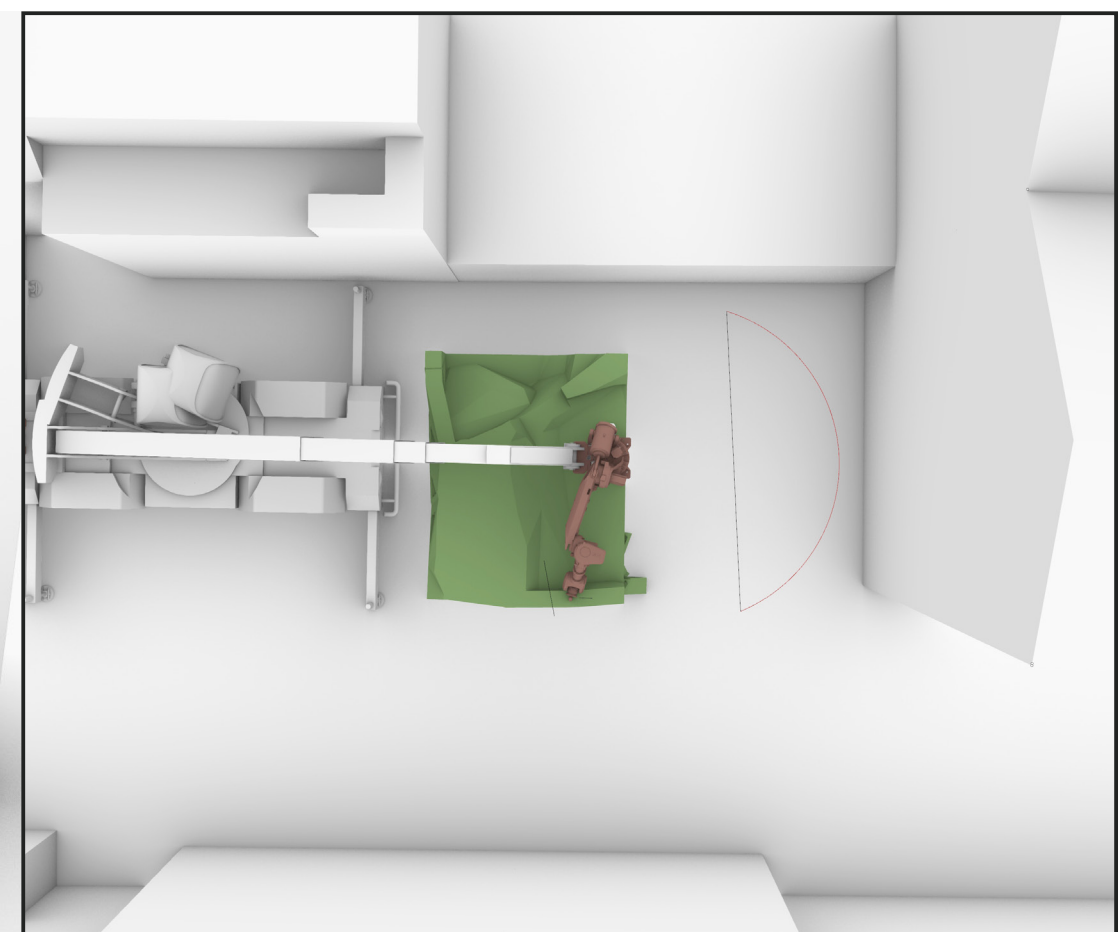
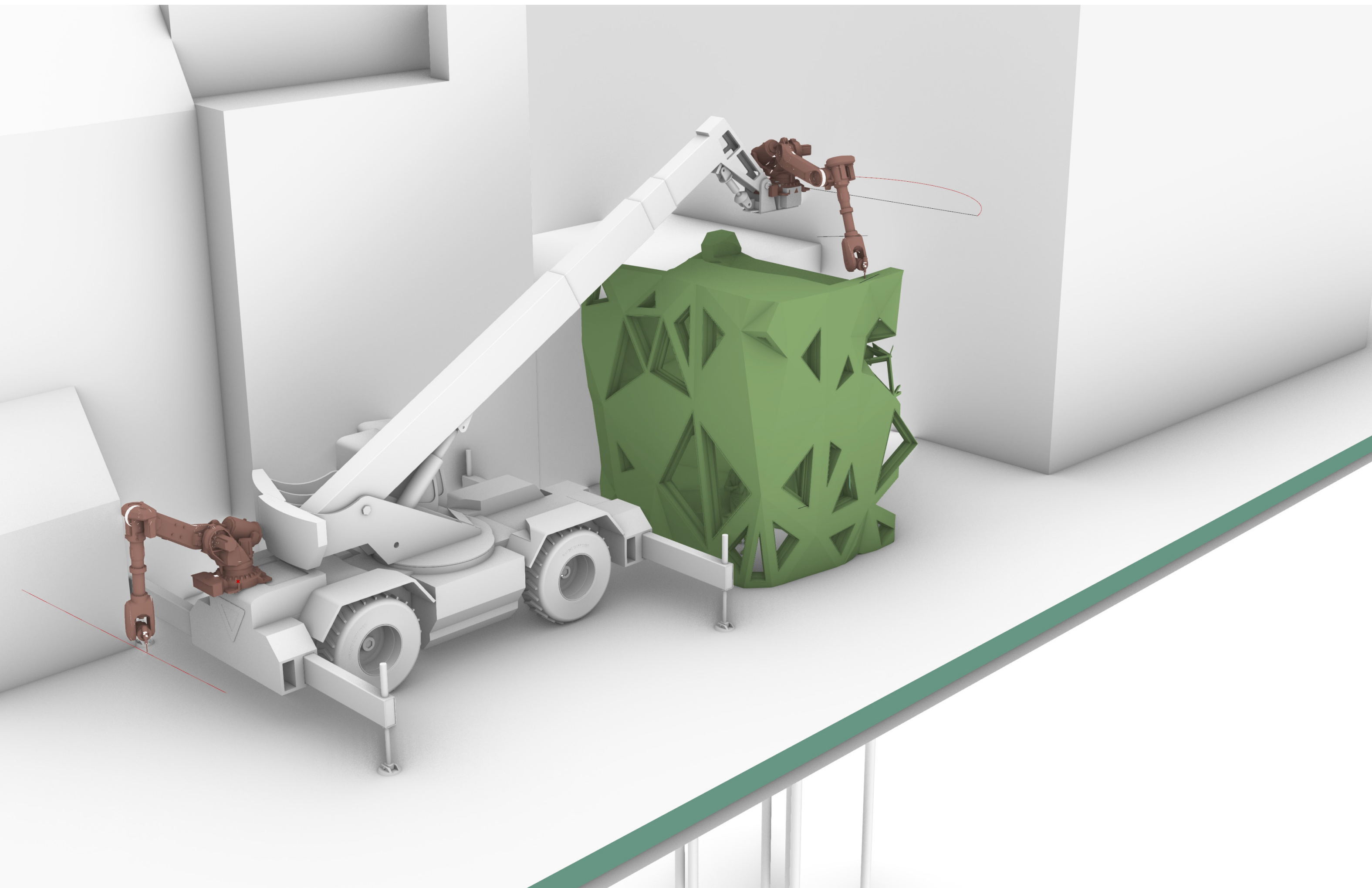


Place floors with the same machine and construction crew



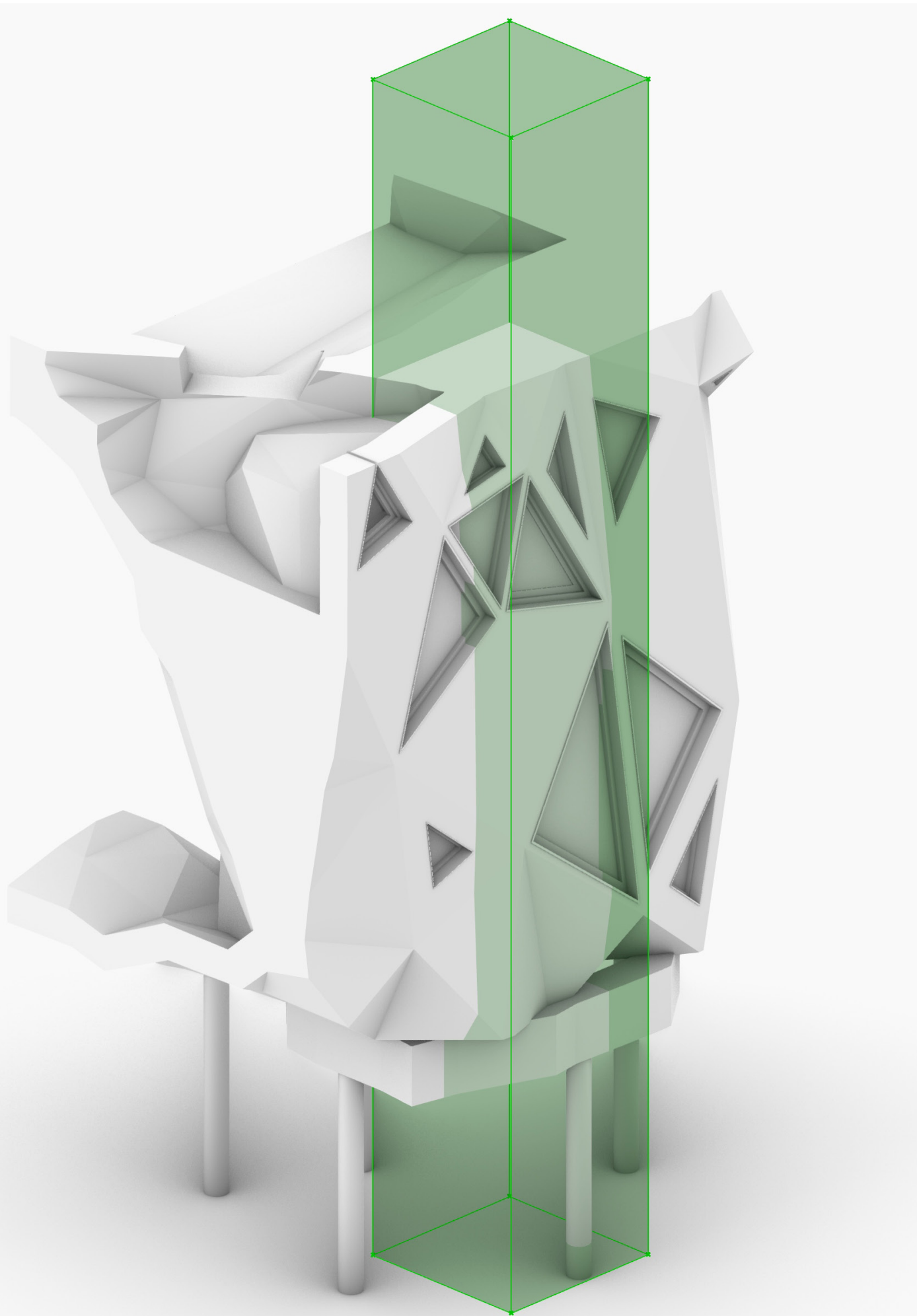
Construction 8/8

Top View

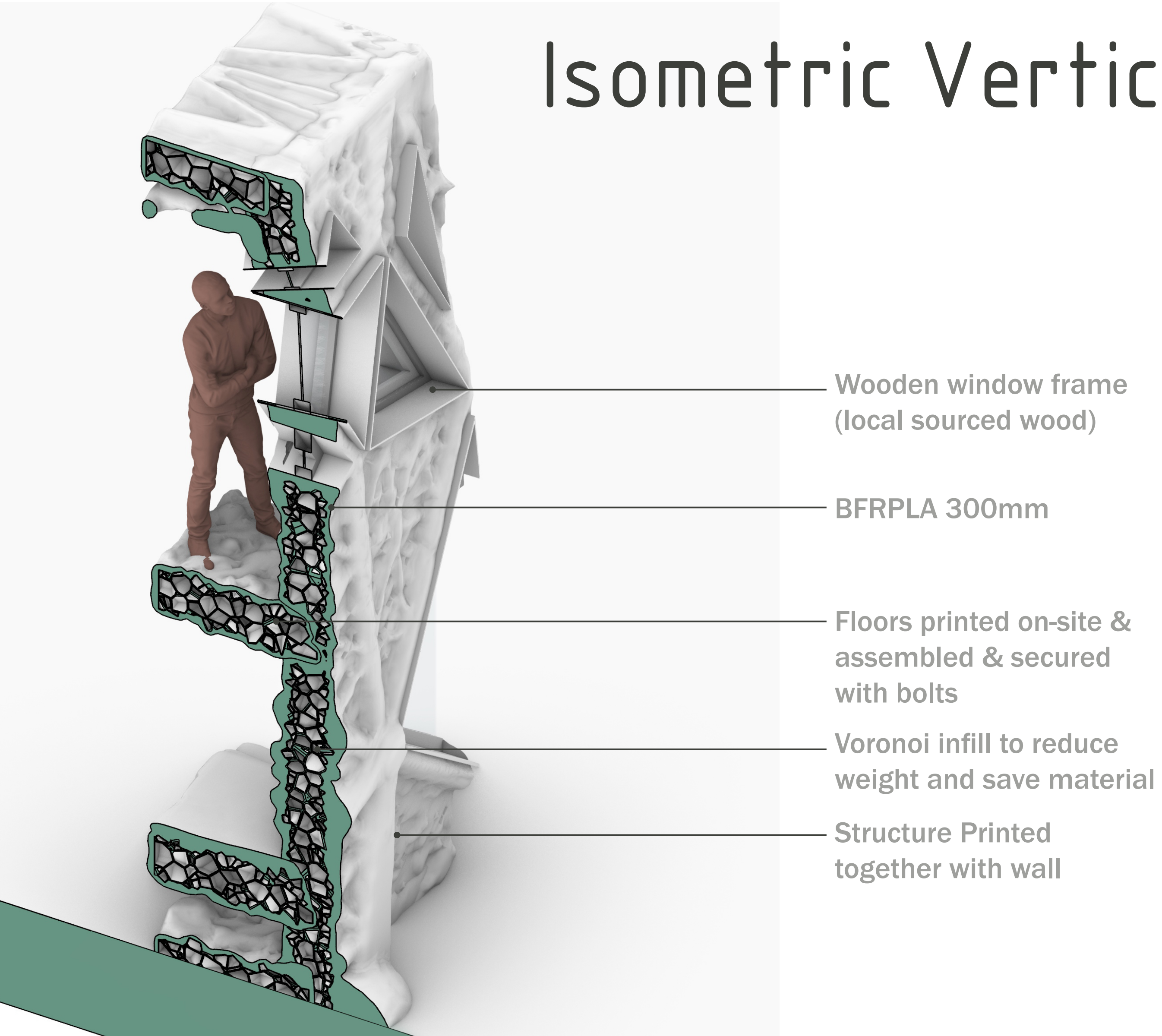


Detail

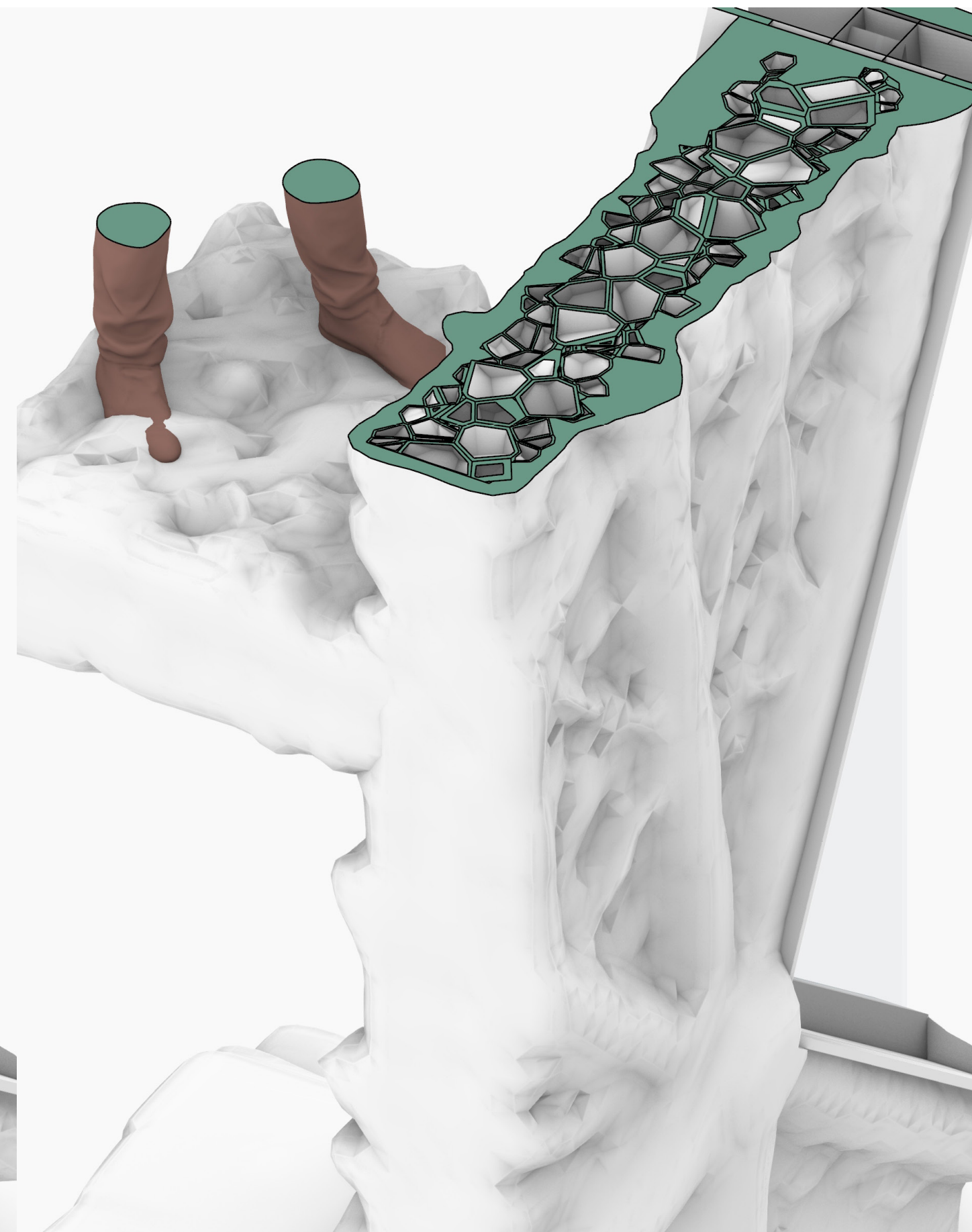
Detail Location



Isometric Vertical Detail Section



Wall/Floor Securing

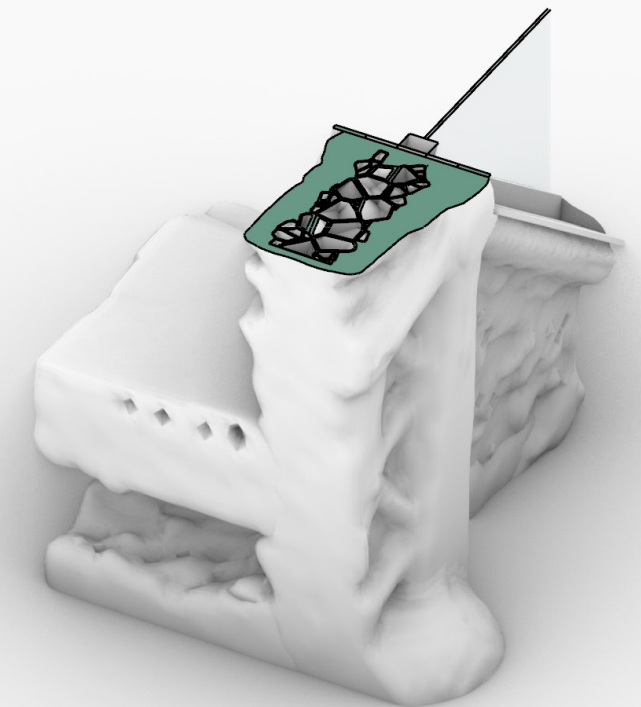
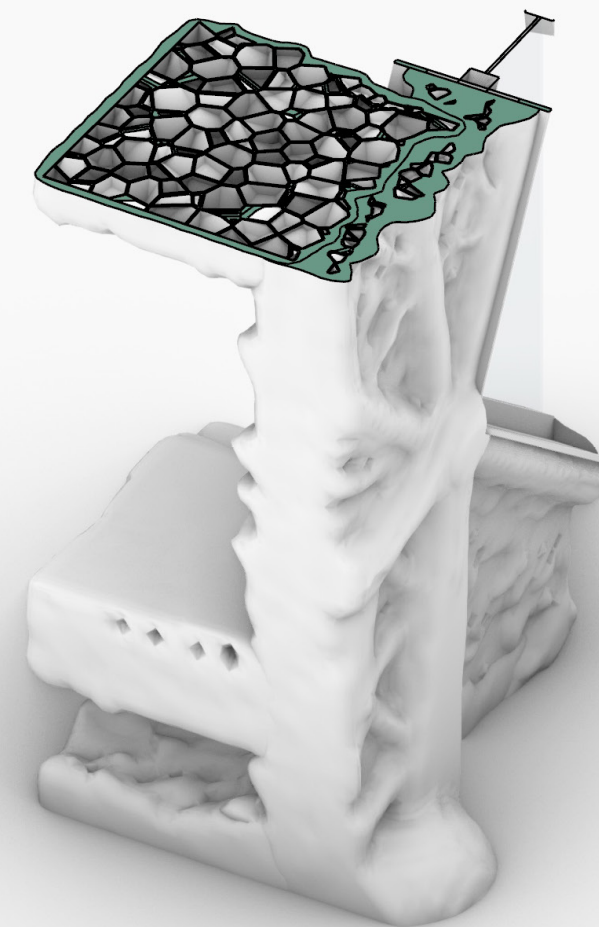


3D print wall until support floor + incorporate a thread insert in the 3D print

Place floor and secure with threaded bolts

Continue 3D print on top of floor/wall

Isometric Horizontal Section



2D Details Vertical/Horizontal

BF: 0.034 W/mK
PLA: 0.110 W/mK

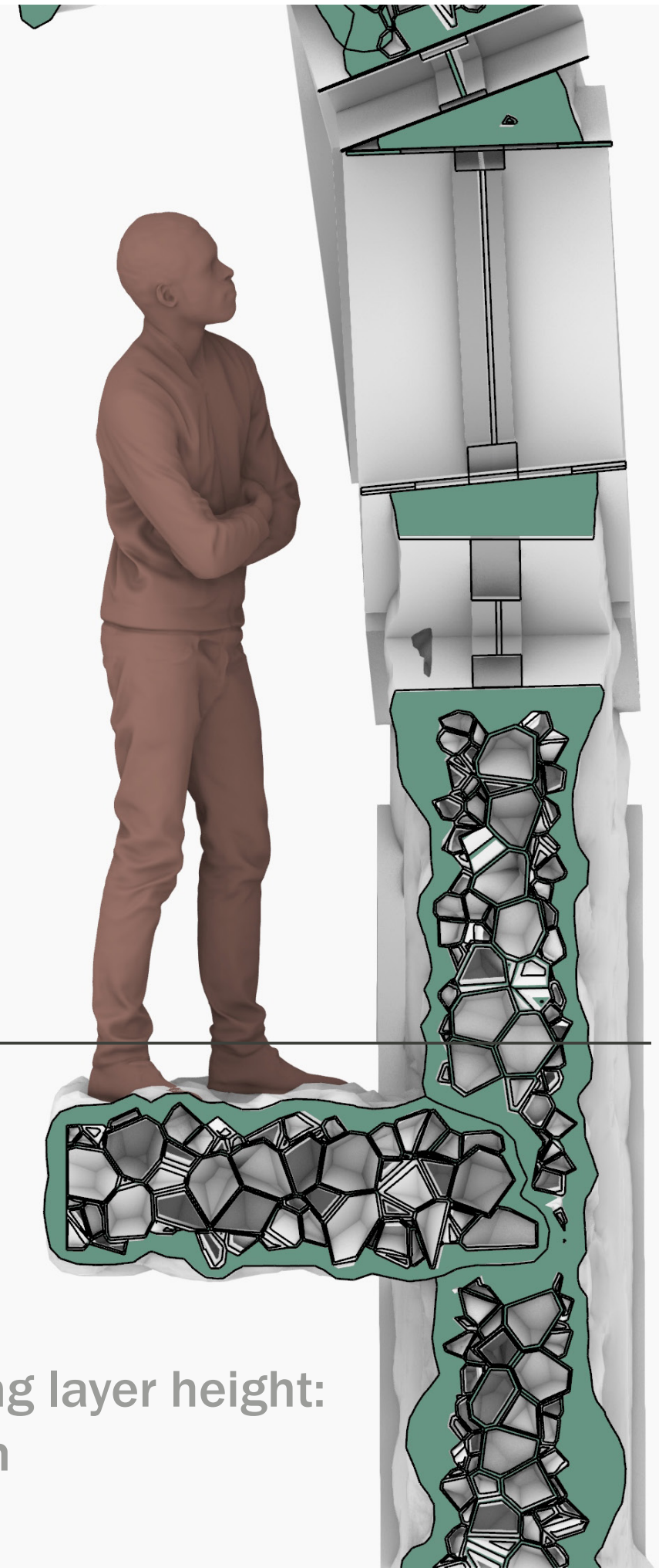
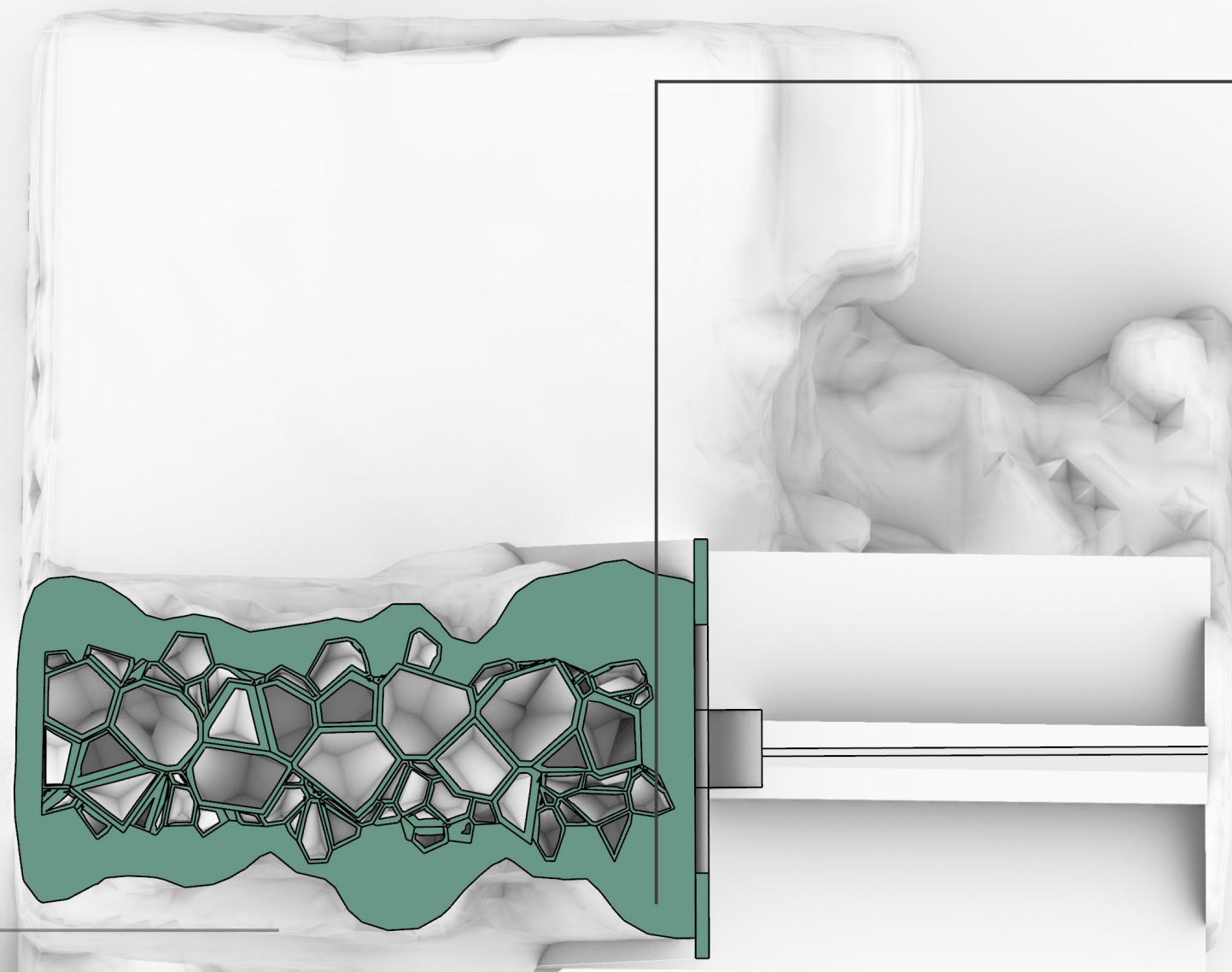
Rc of wall with structure=
5.1 W/m²K

Rc of wall with voronoi
structure = 4.7 W/m²K

300mm BFRPLA in
gradient voronoi

Printing layer height:
25mm

Structure
where
needed
50 50 100 50 50



Parametric Script Review

Locations in the City

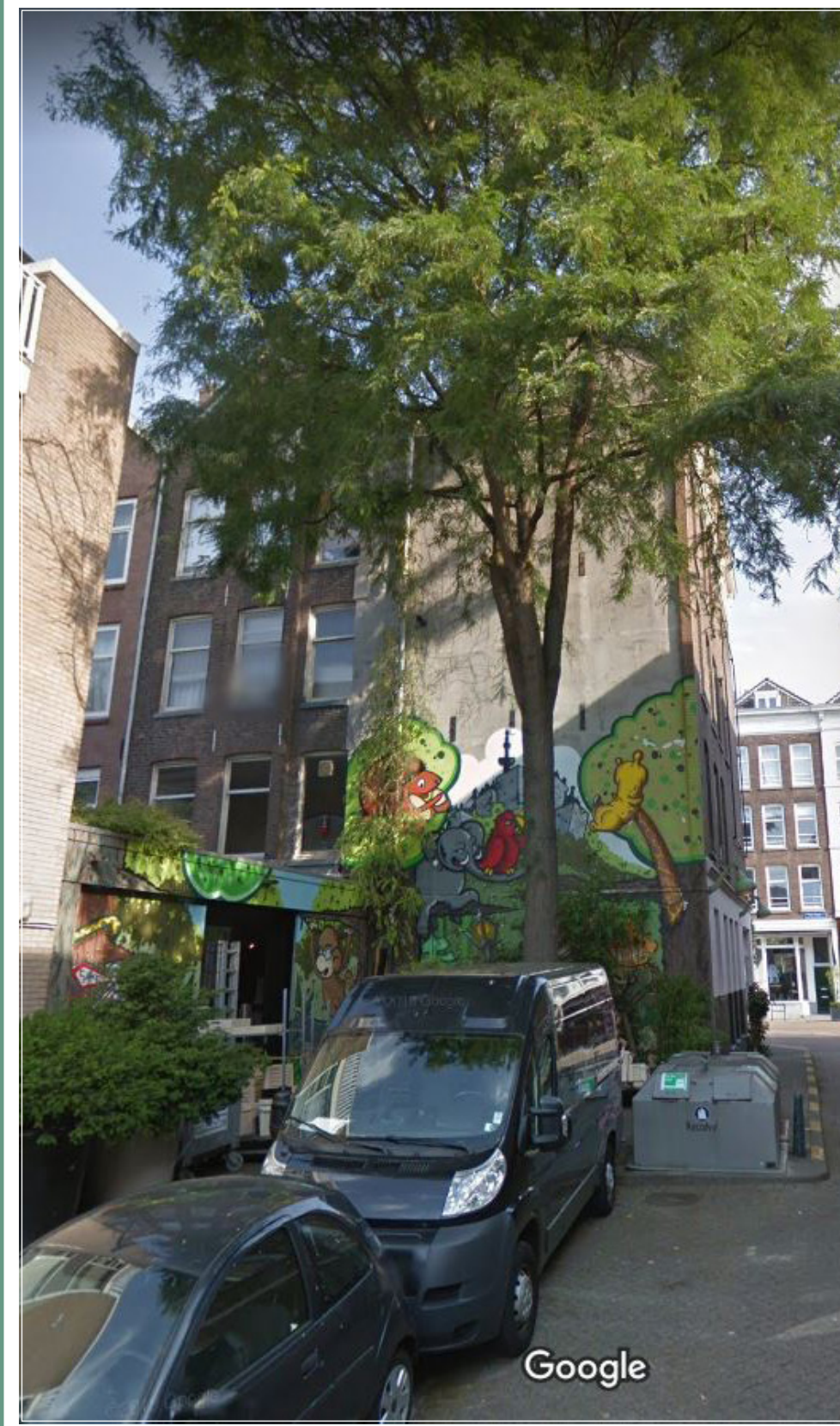
Reviewing Locations



Karel Doormanstraat



Jacobusstraat A



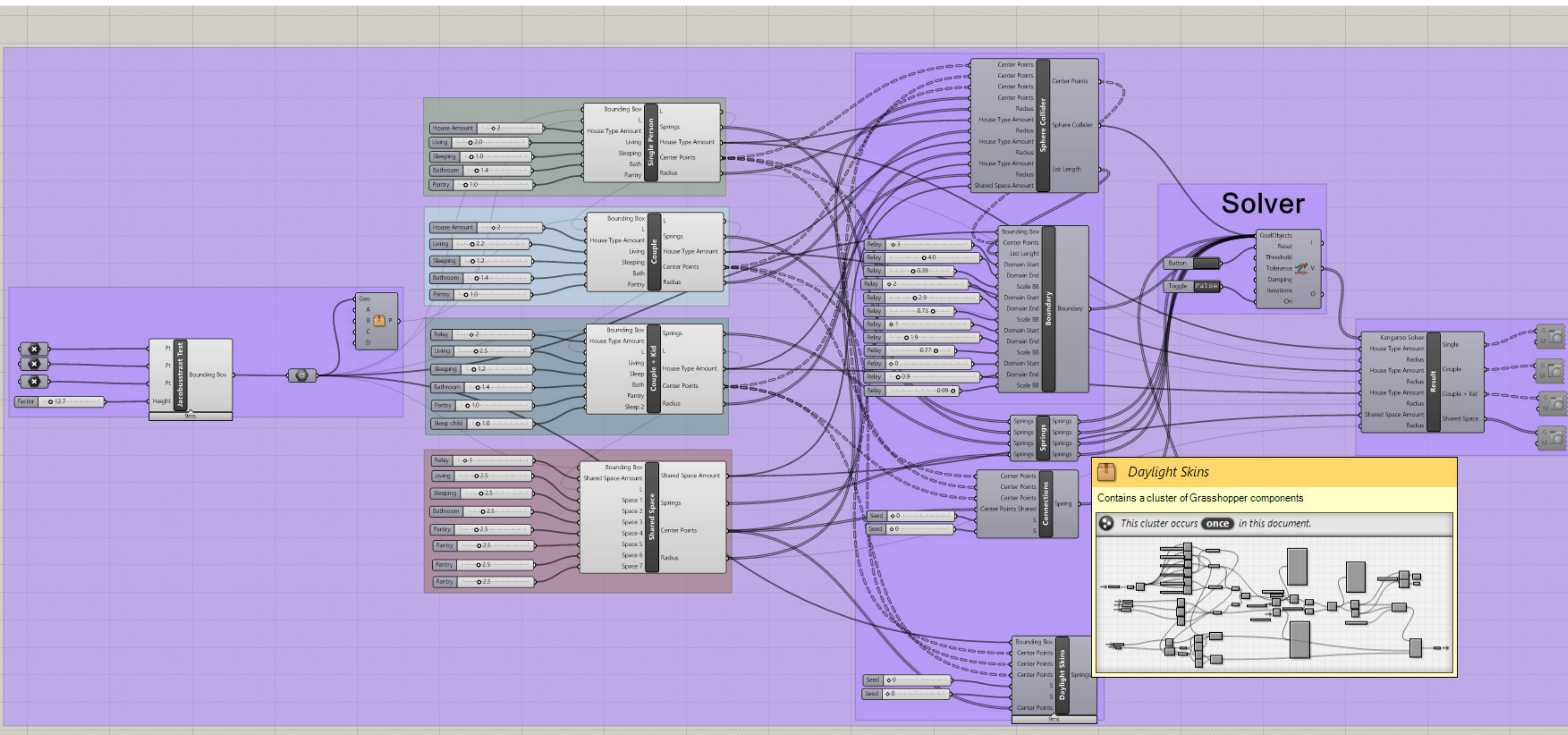
Jacobusstraat B

Reviewing Locations

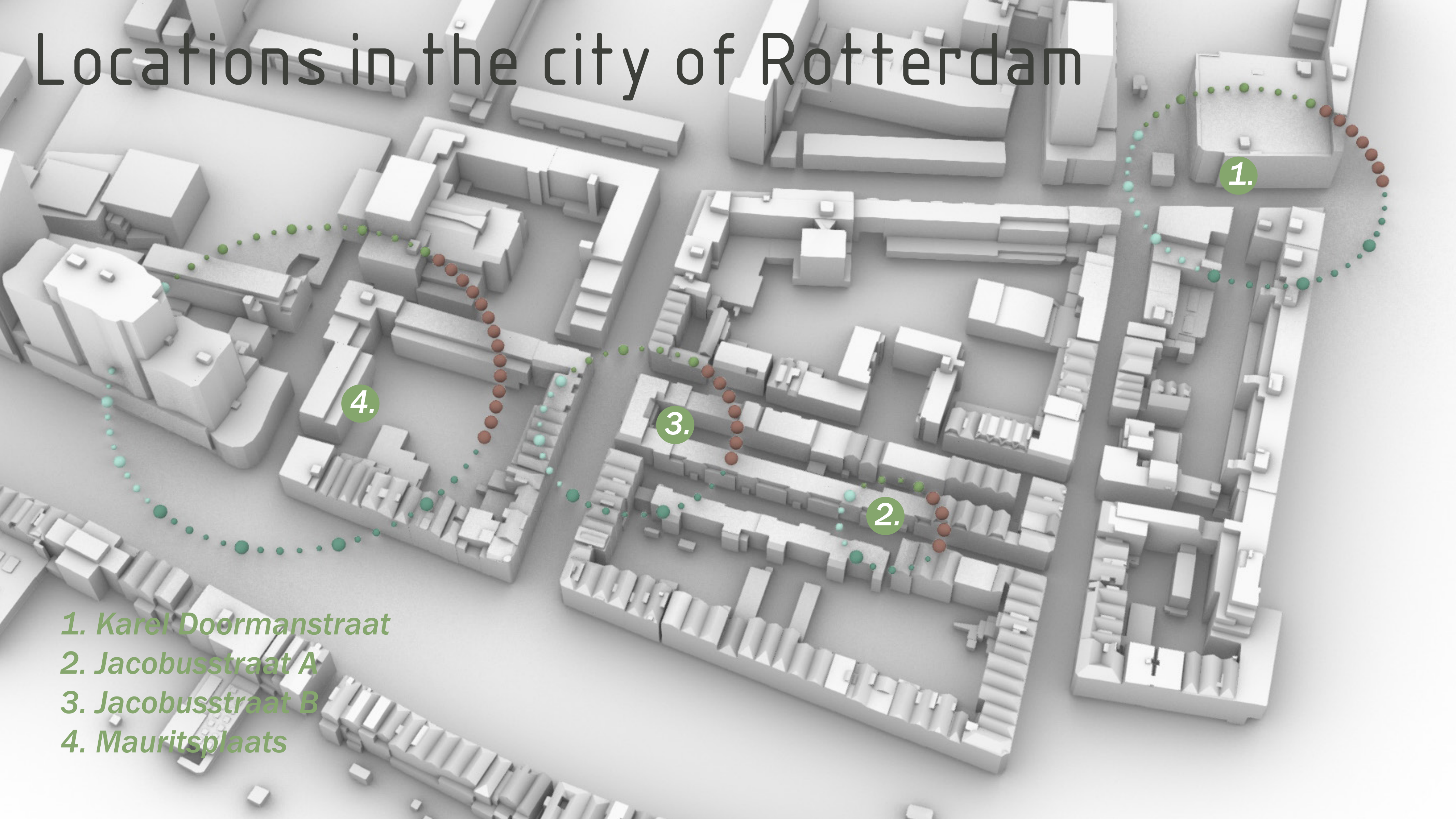


Mauritsplaats

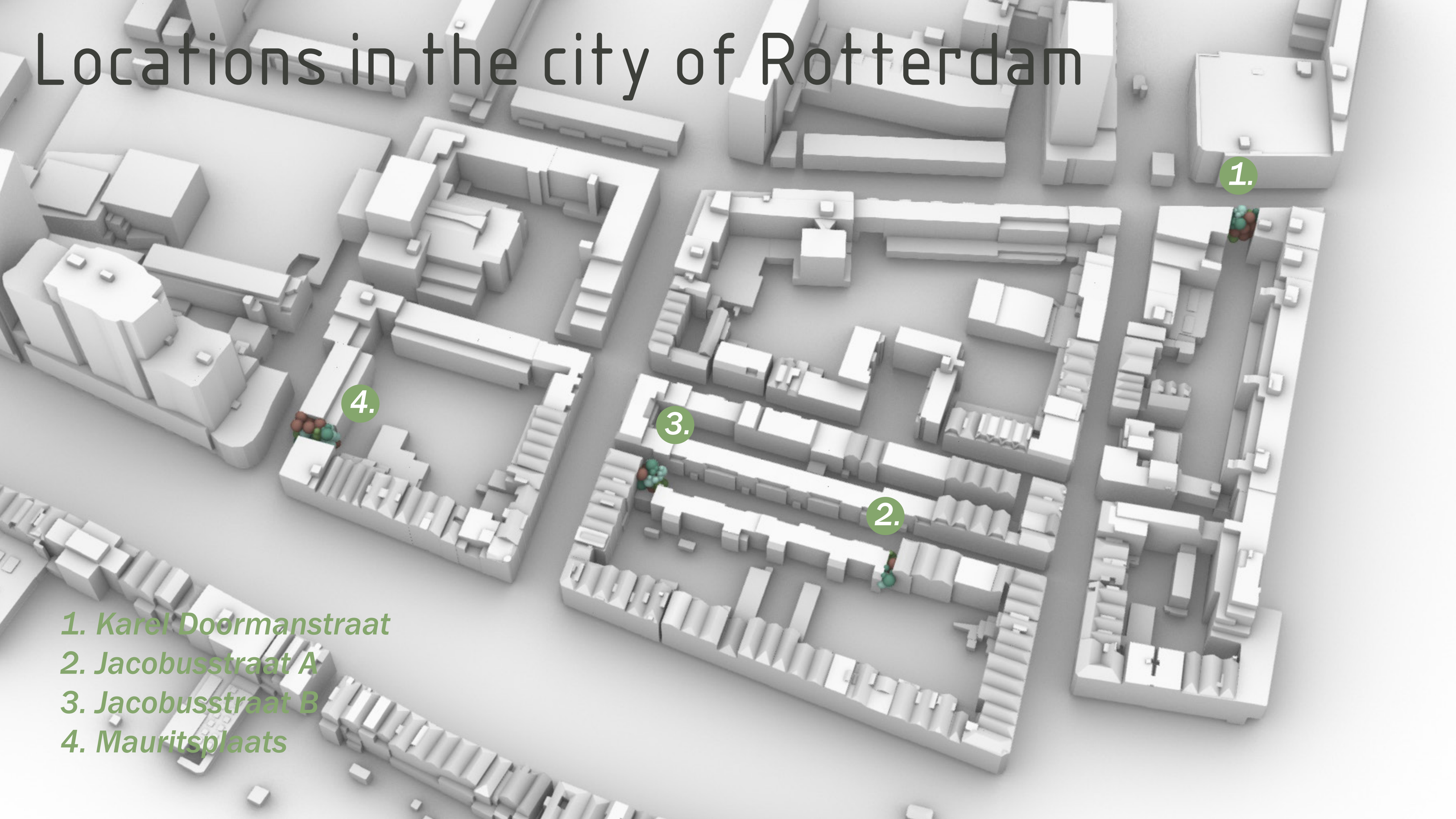
Parametric Bubble Script



Locations in the city of Rotterdam



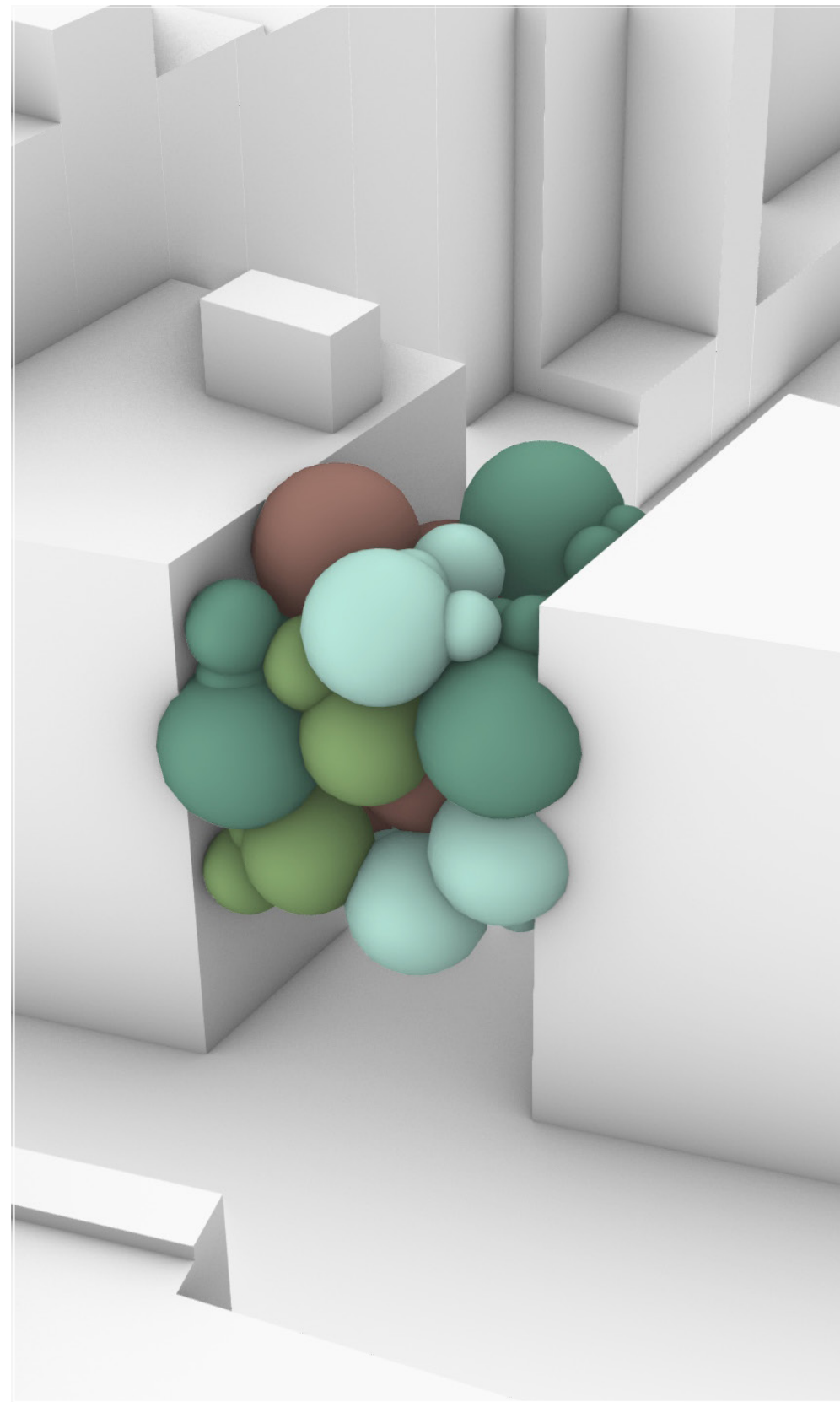
- 1. Karel Doormanstraat
- 2. Jacobusstraat A
- 3. Jacobusstraat B
- 4. Mauritsplaats



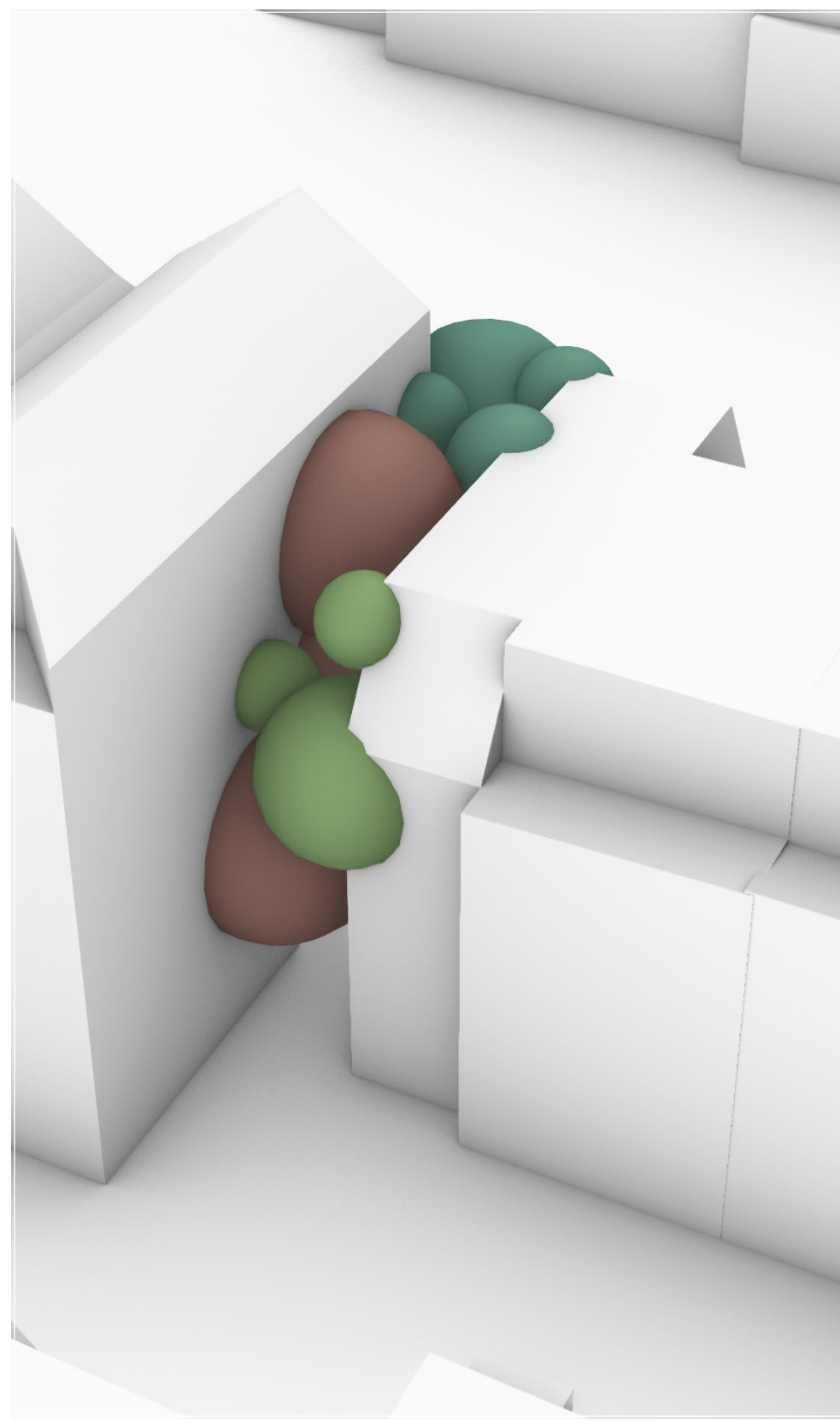
Locations in the city of Rotterdam

- 1. Karel Doormanstraat
- 2. Jacobusstraat A
- 3. Jacobusstraat B
- 4. Mauritsplaats

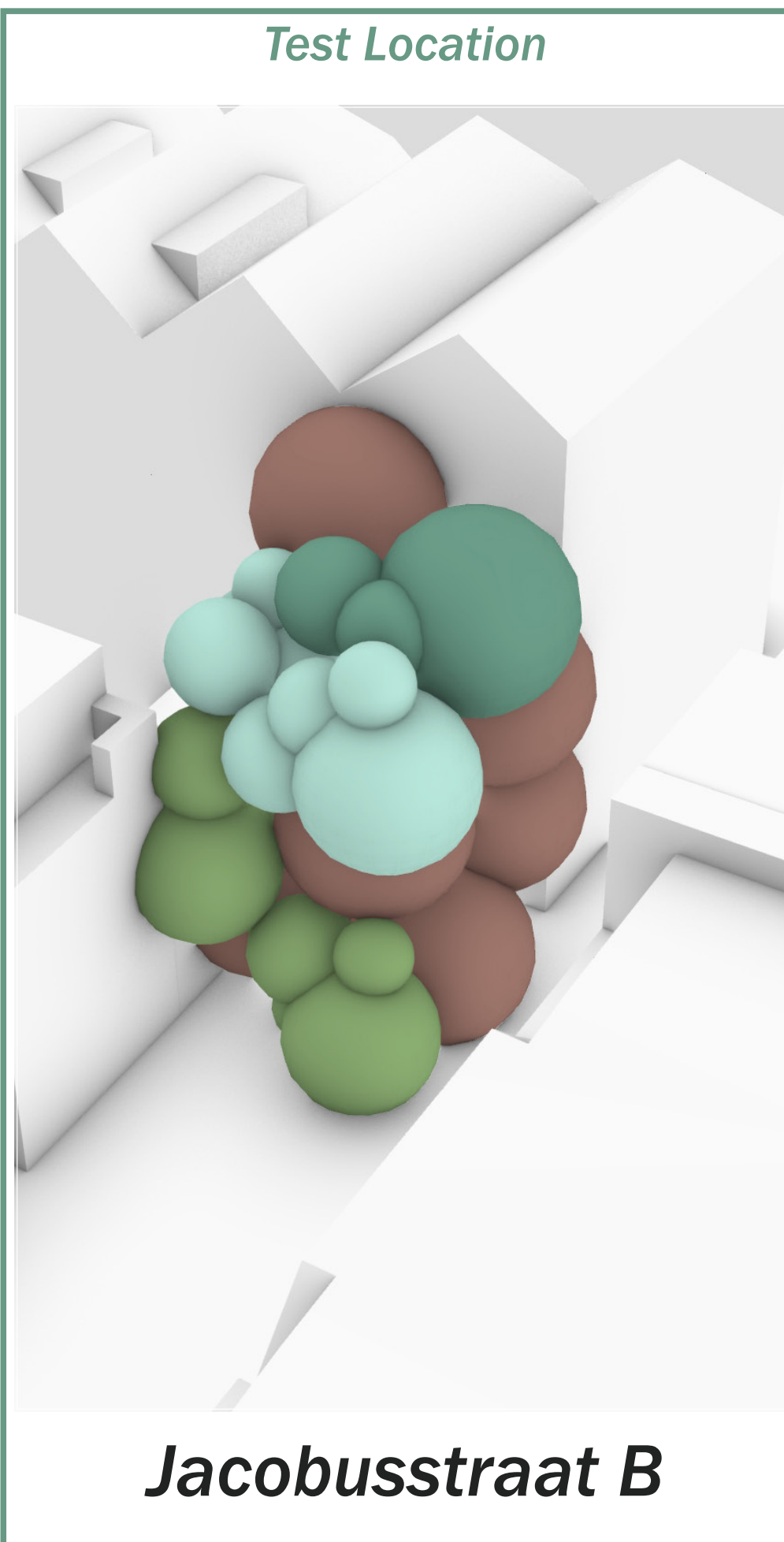
Locations in the City



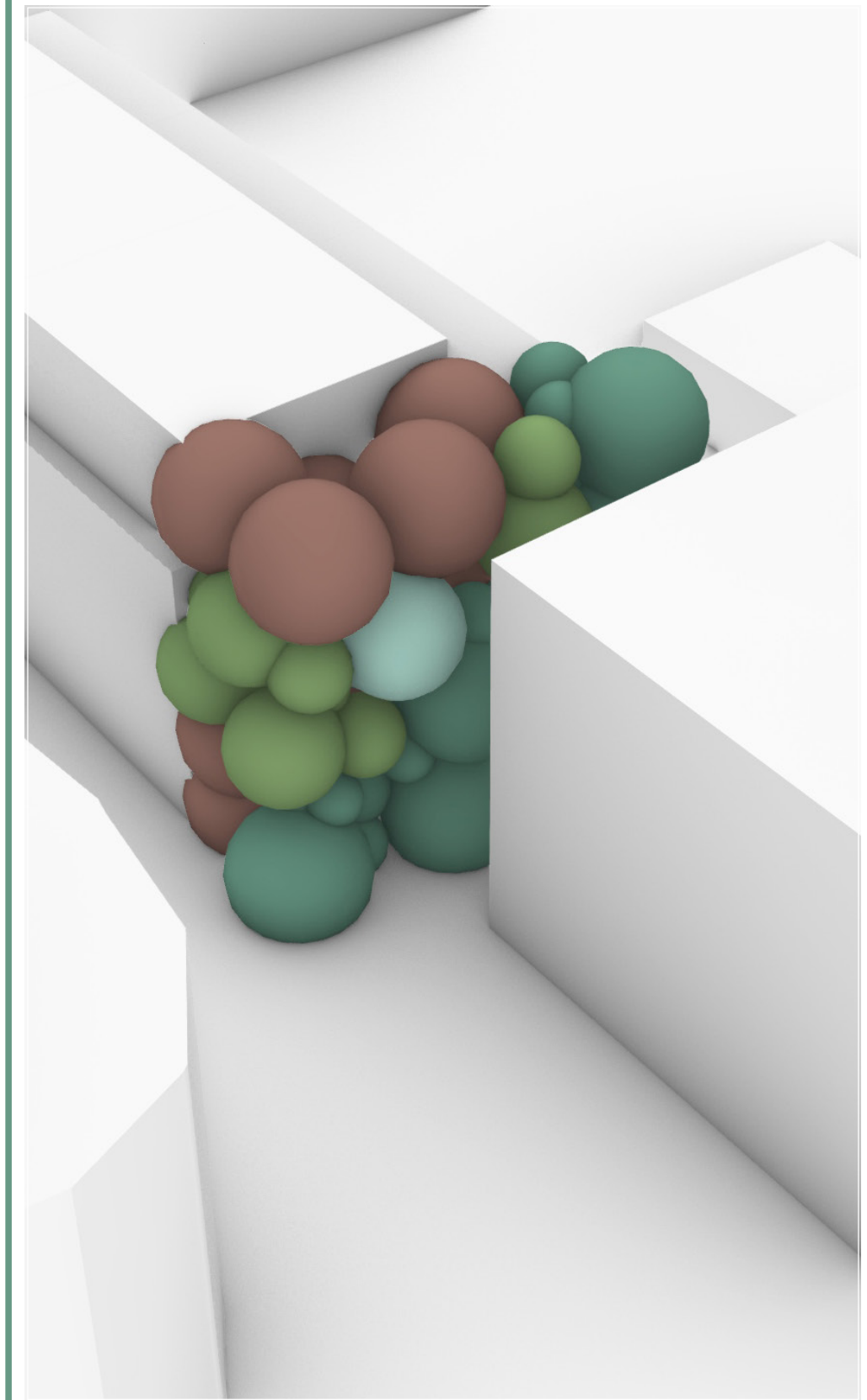
Karel Doormanstraat



Jacobusstraat A

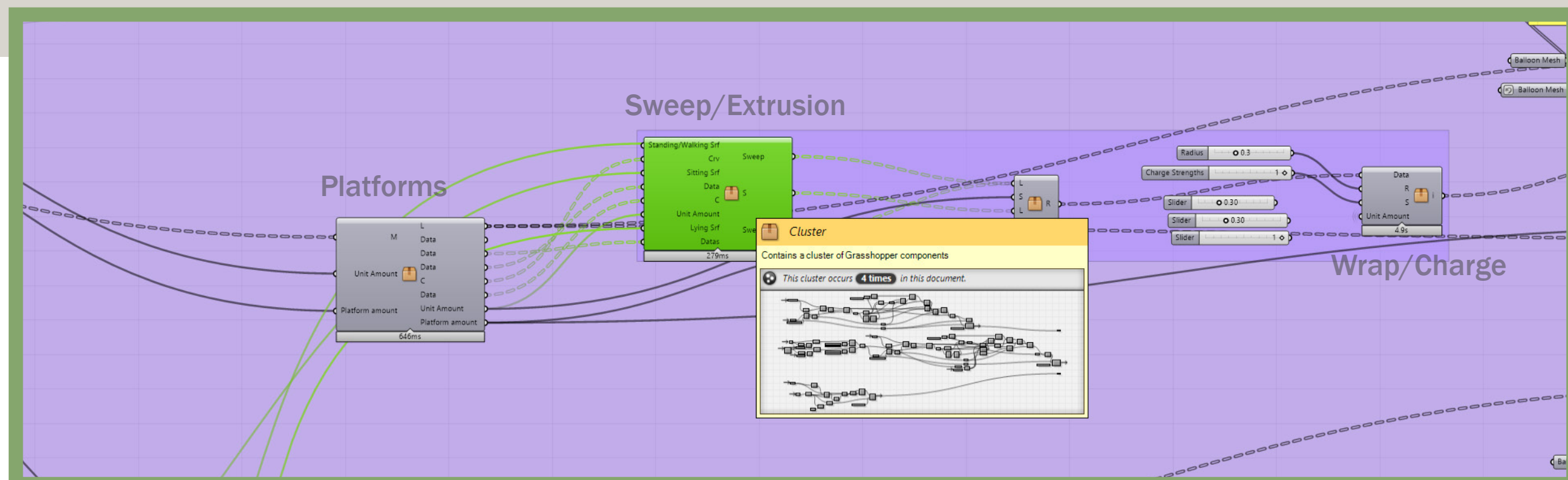
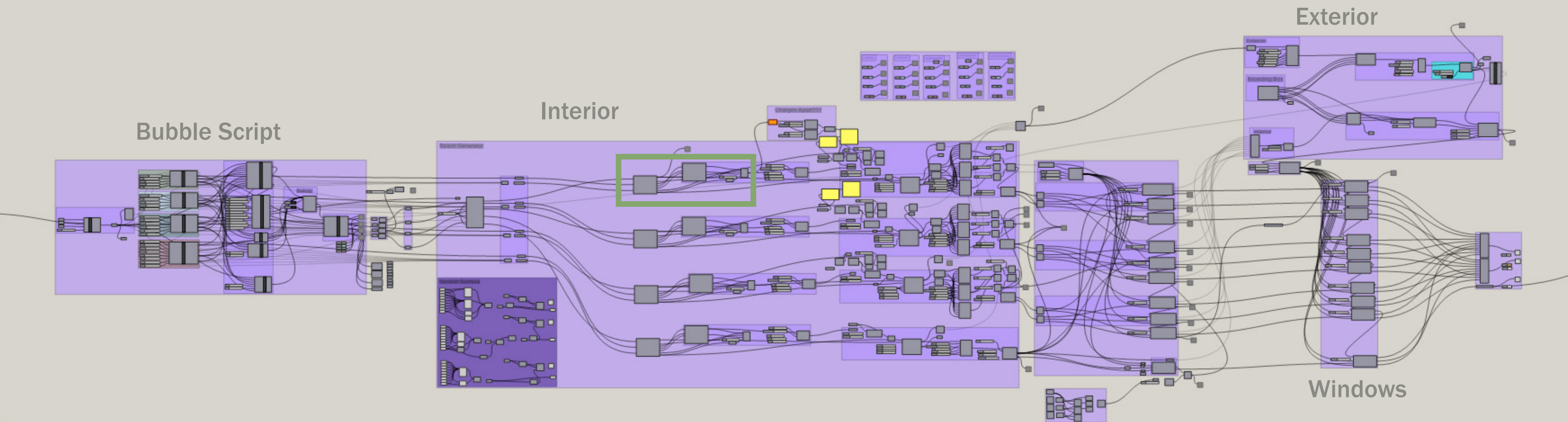


Jacobusstraat B



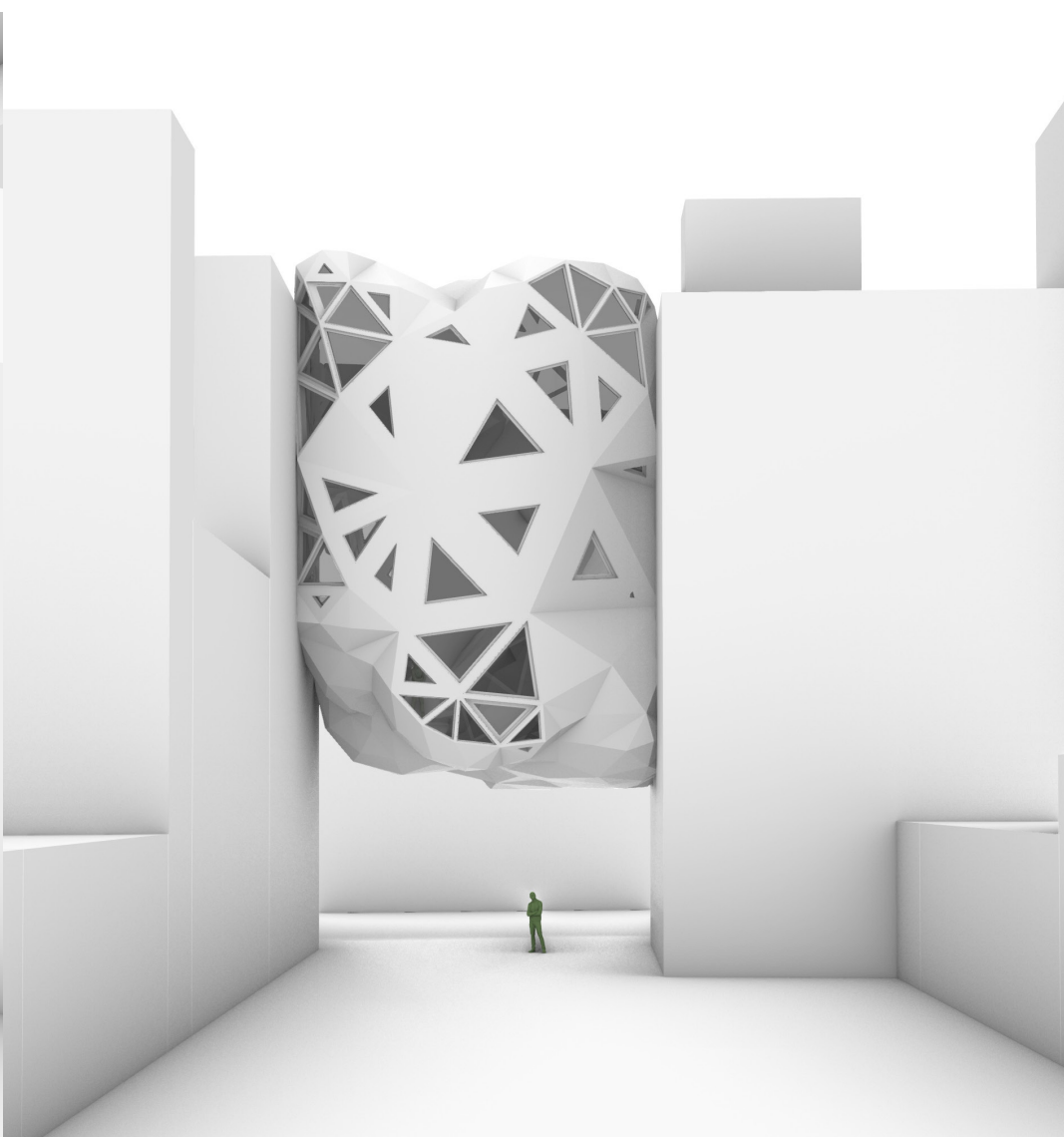
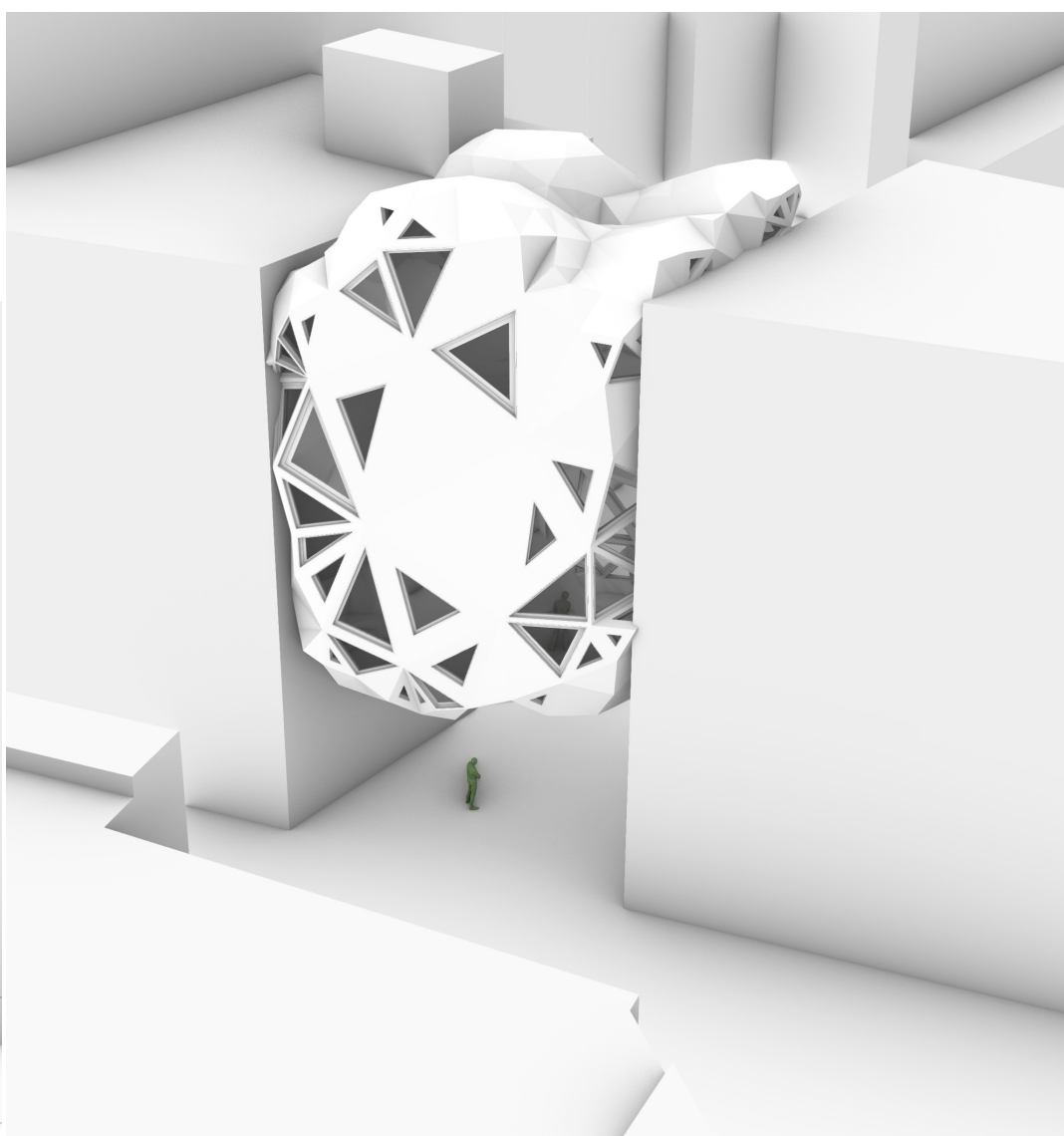
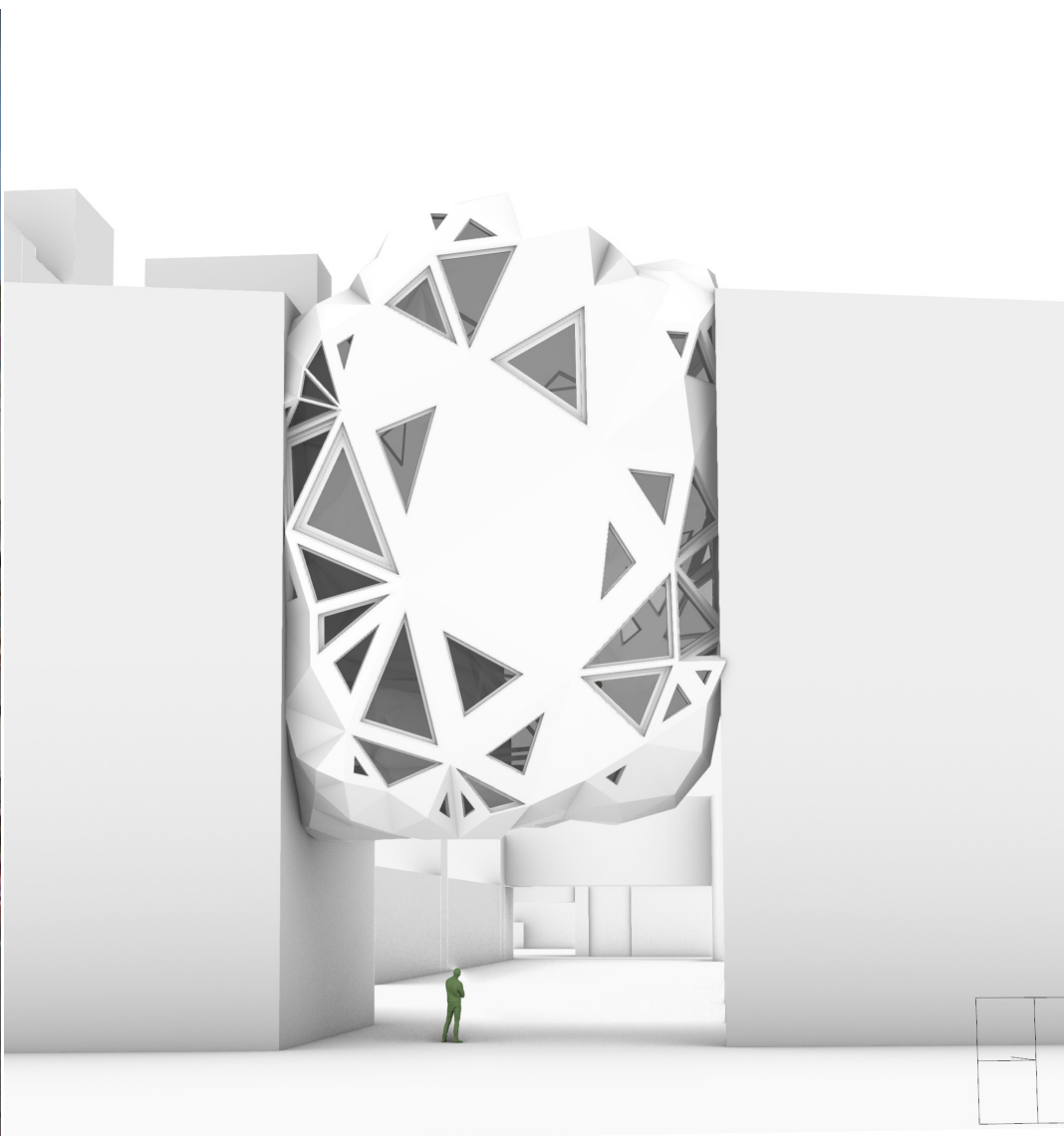
Mauritsplaats

Parametric Script



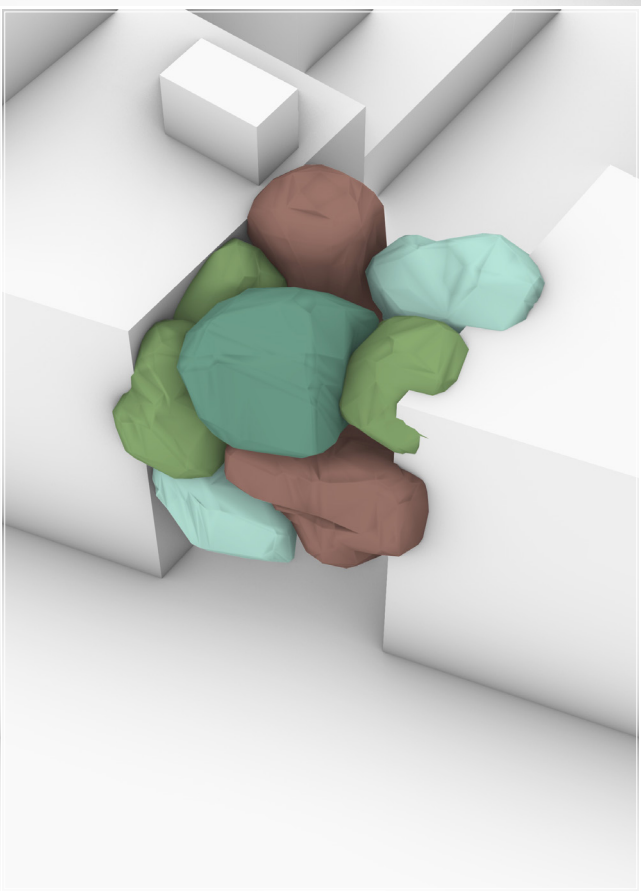
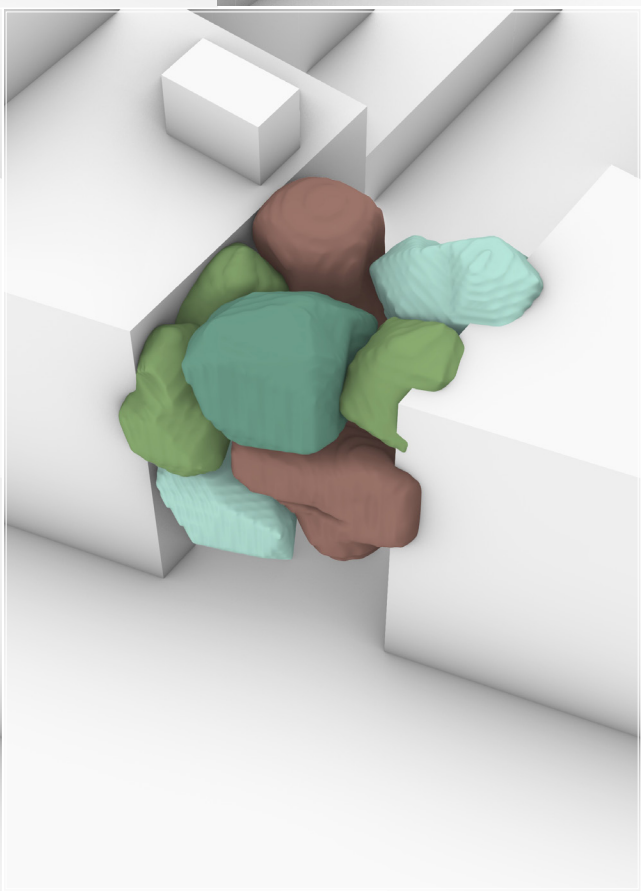
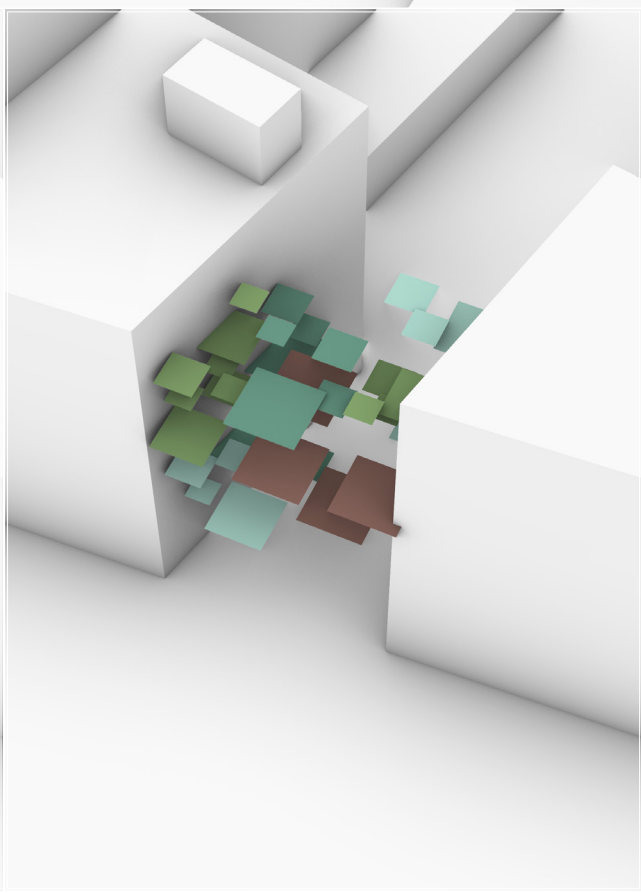
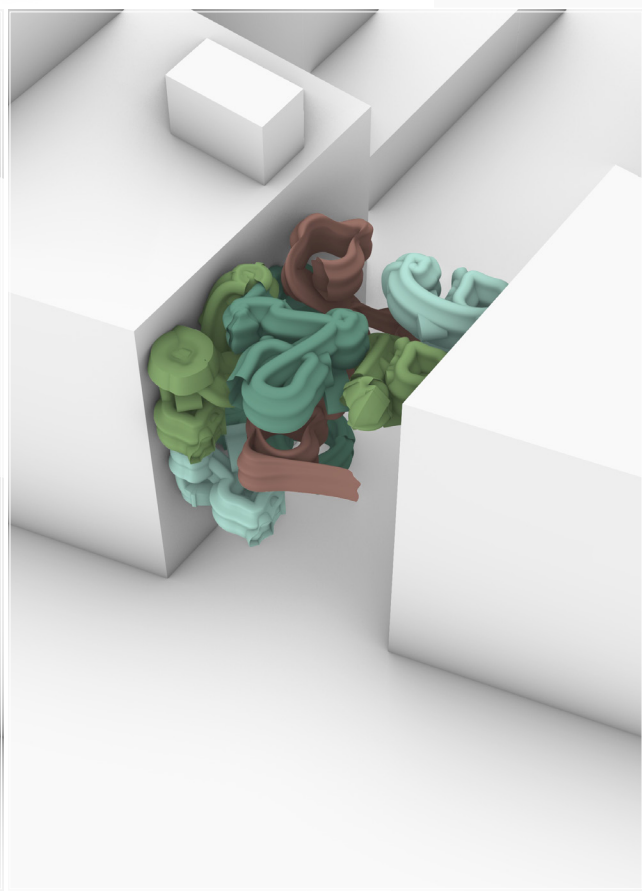
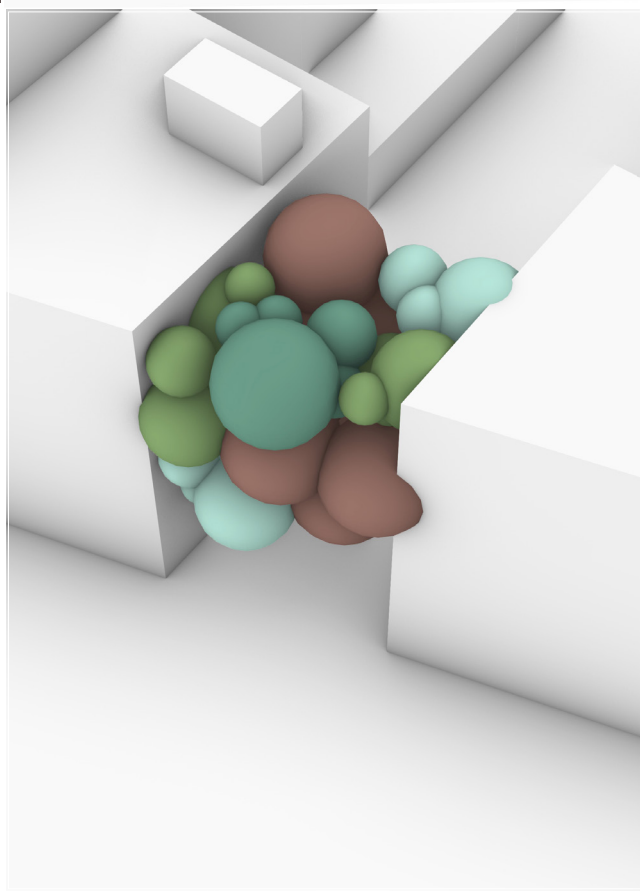
Custom script consists of many clusters that can be altered with sliders

Locations in the City: Karel Doormanstraat

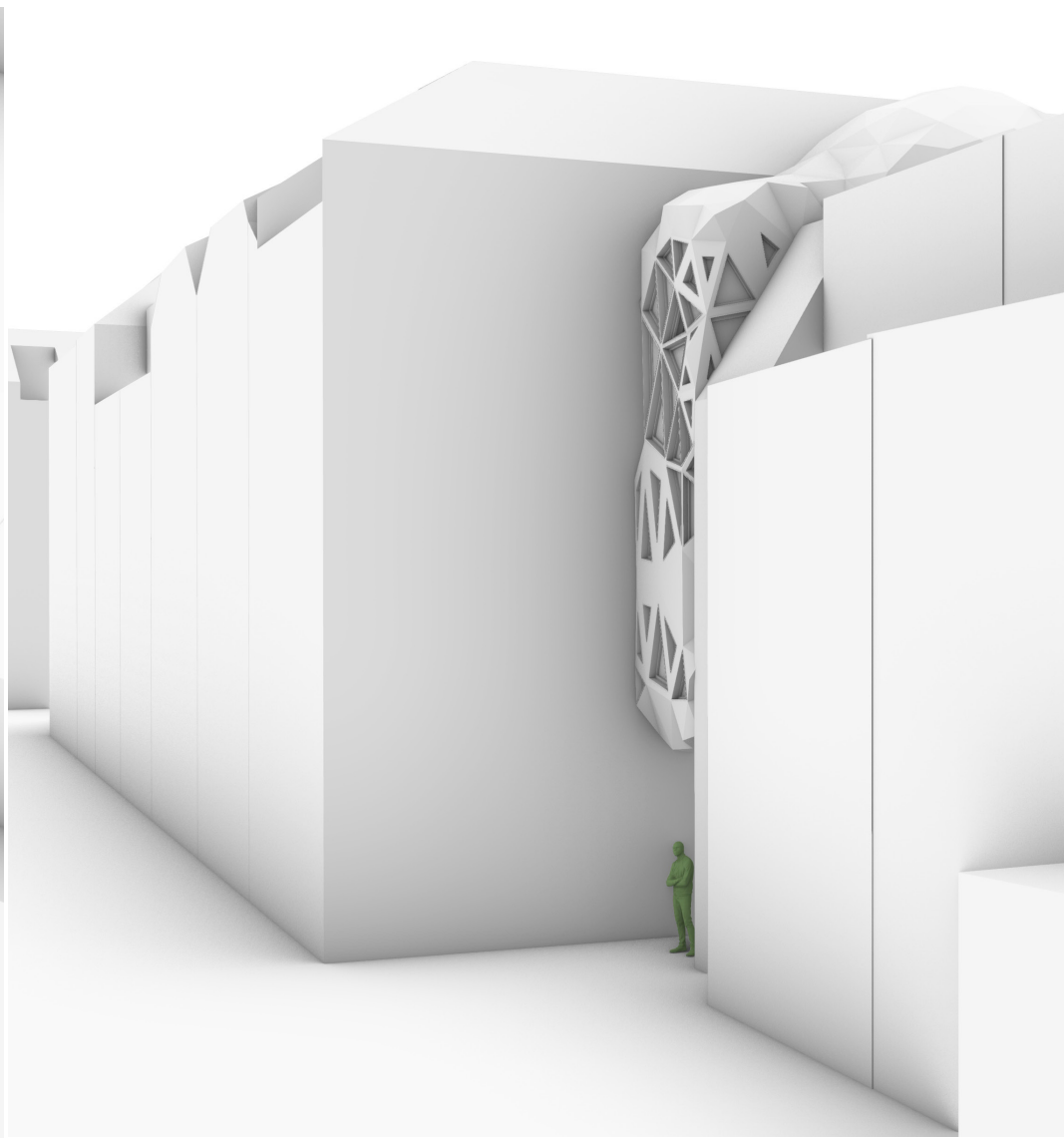
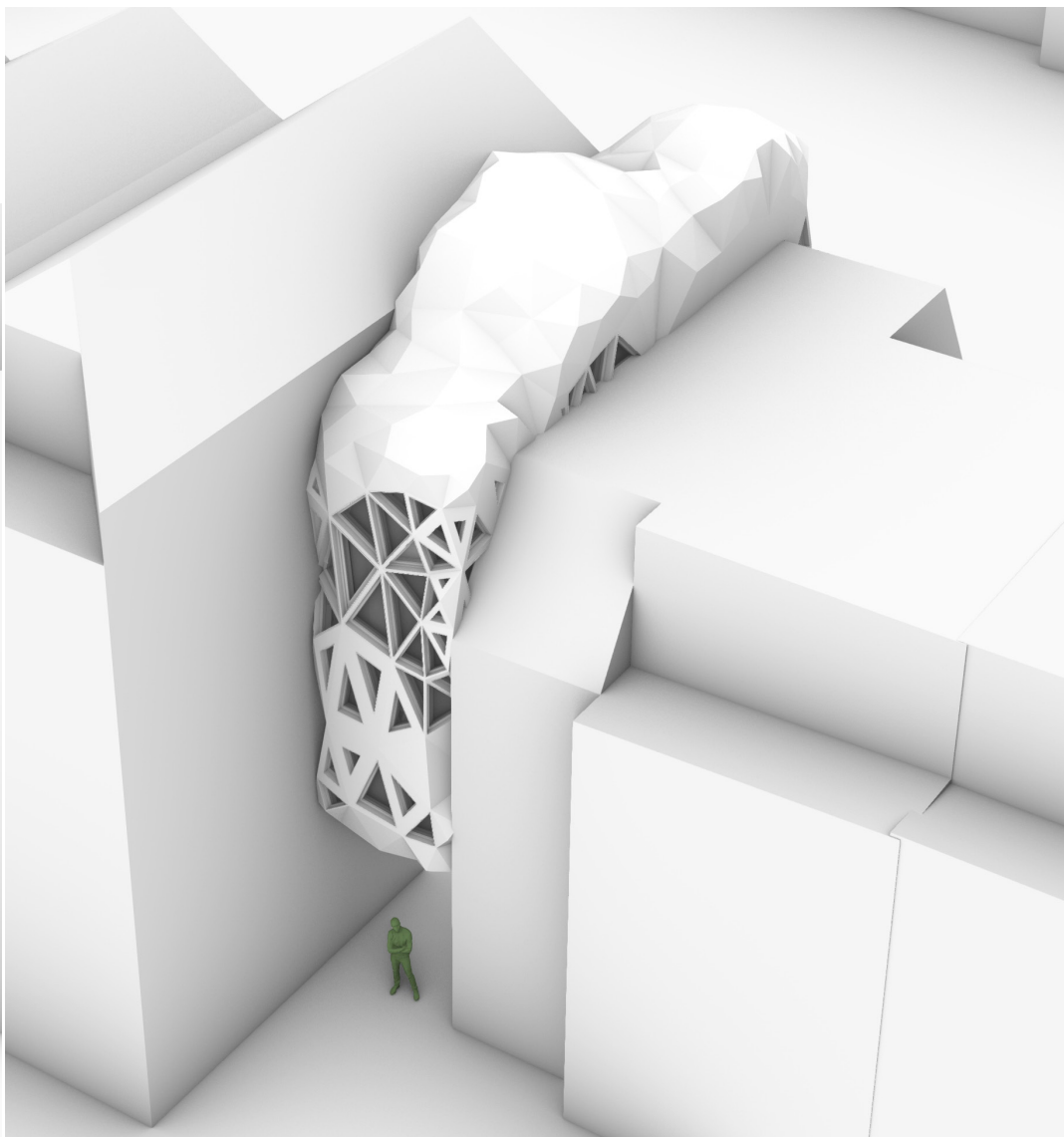
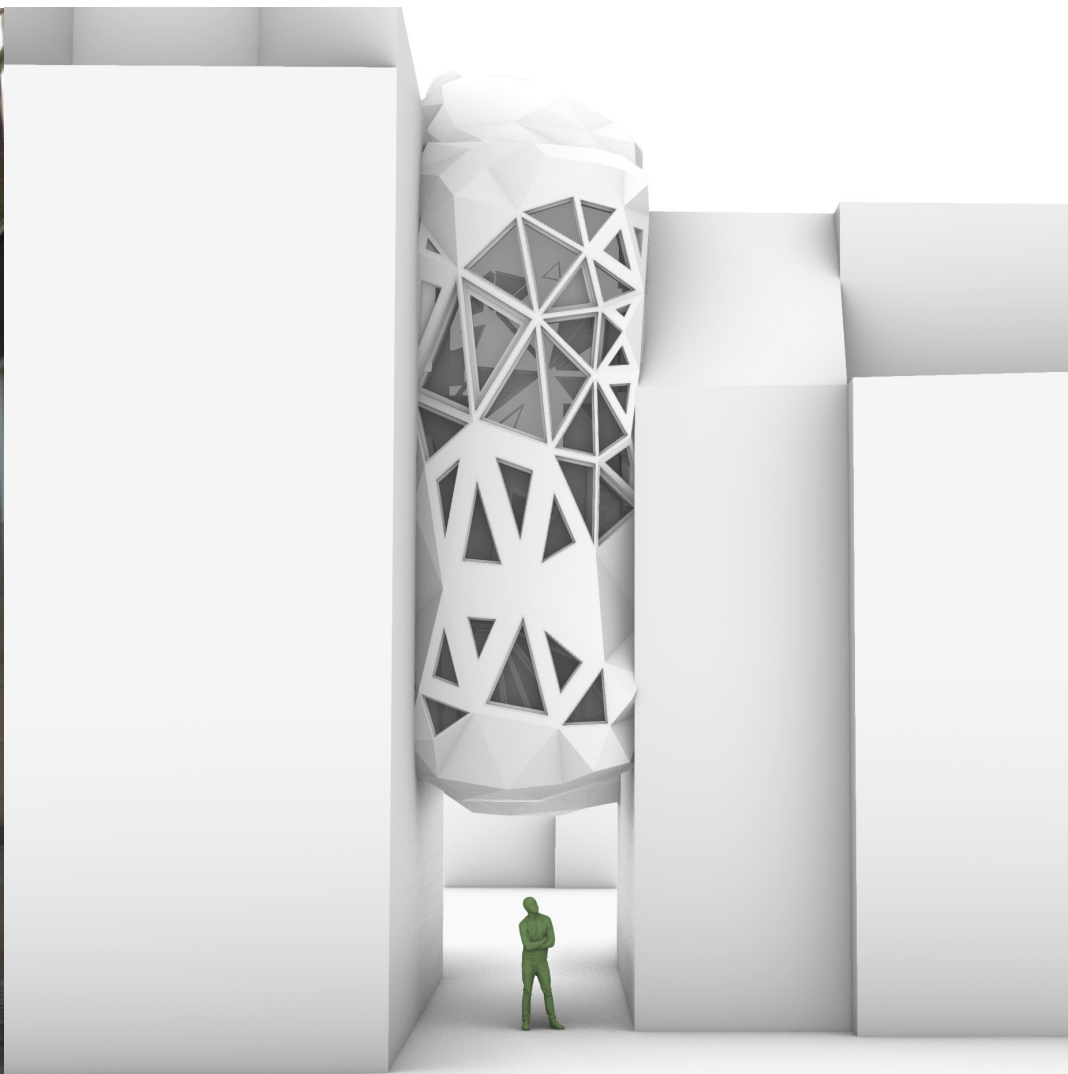


Karel Doormanstraat

Footprint: 136m²
Height: 18m
Floors: 4

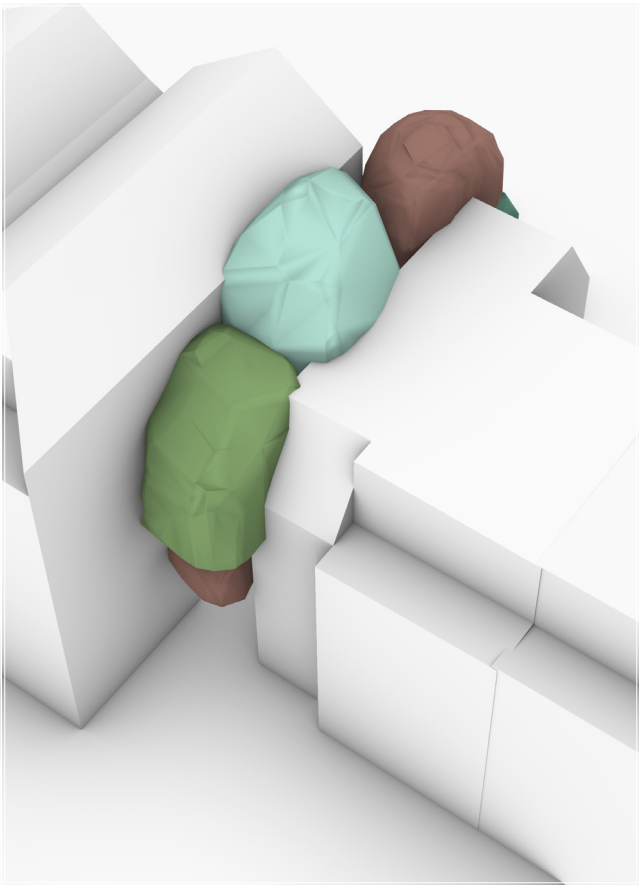
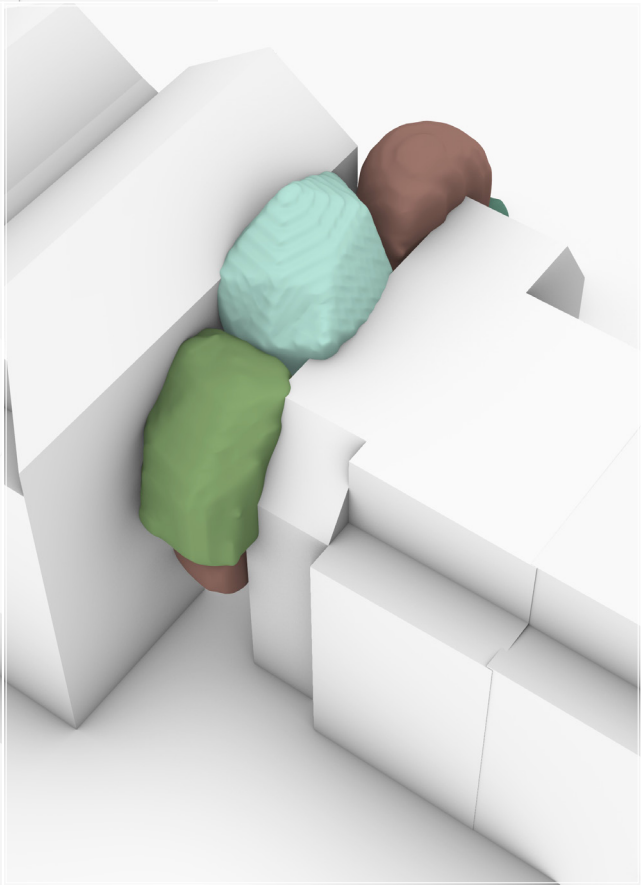
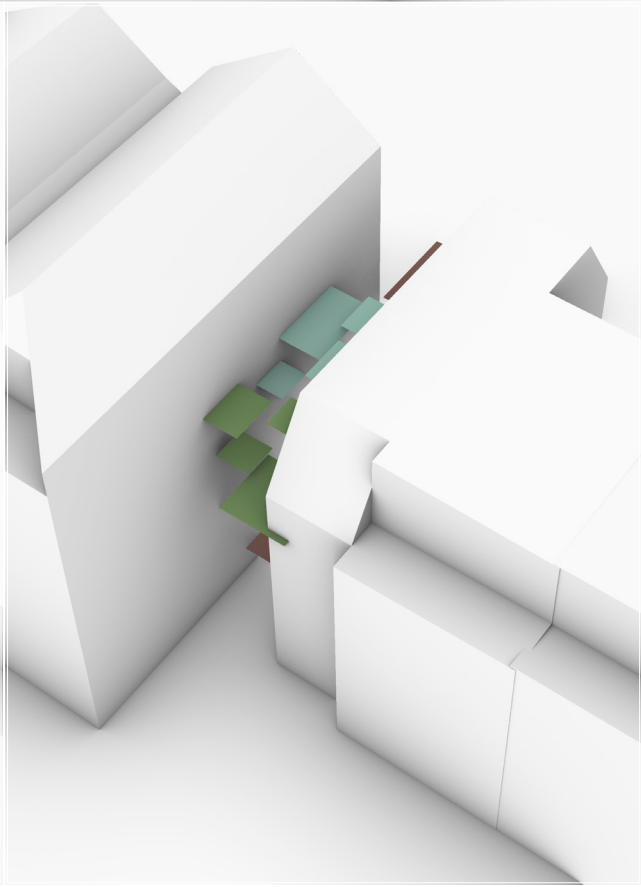
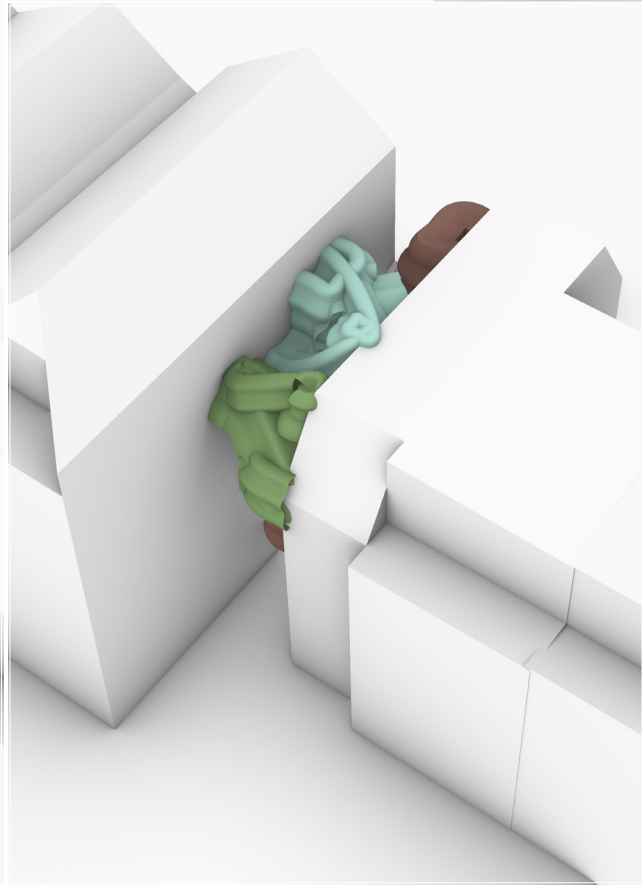
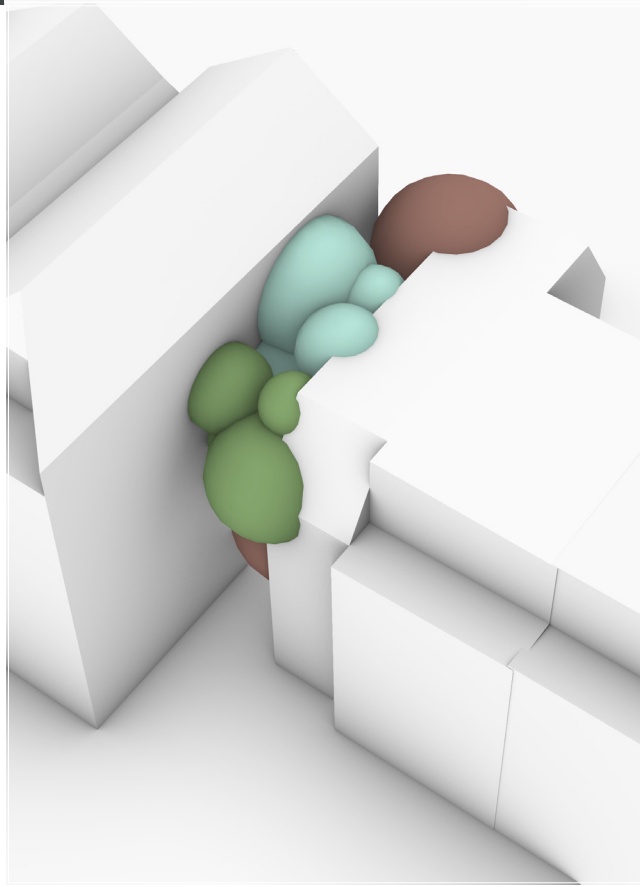


Locations in the City: Jacobusstraat A

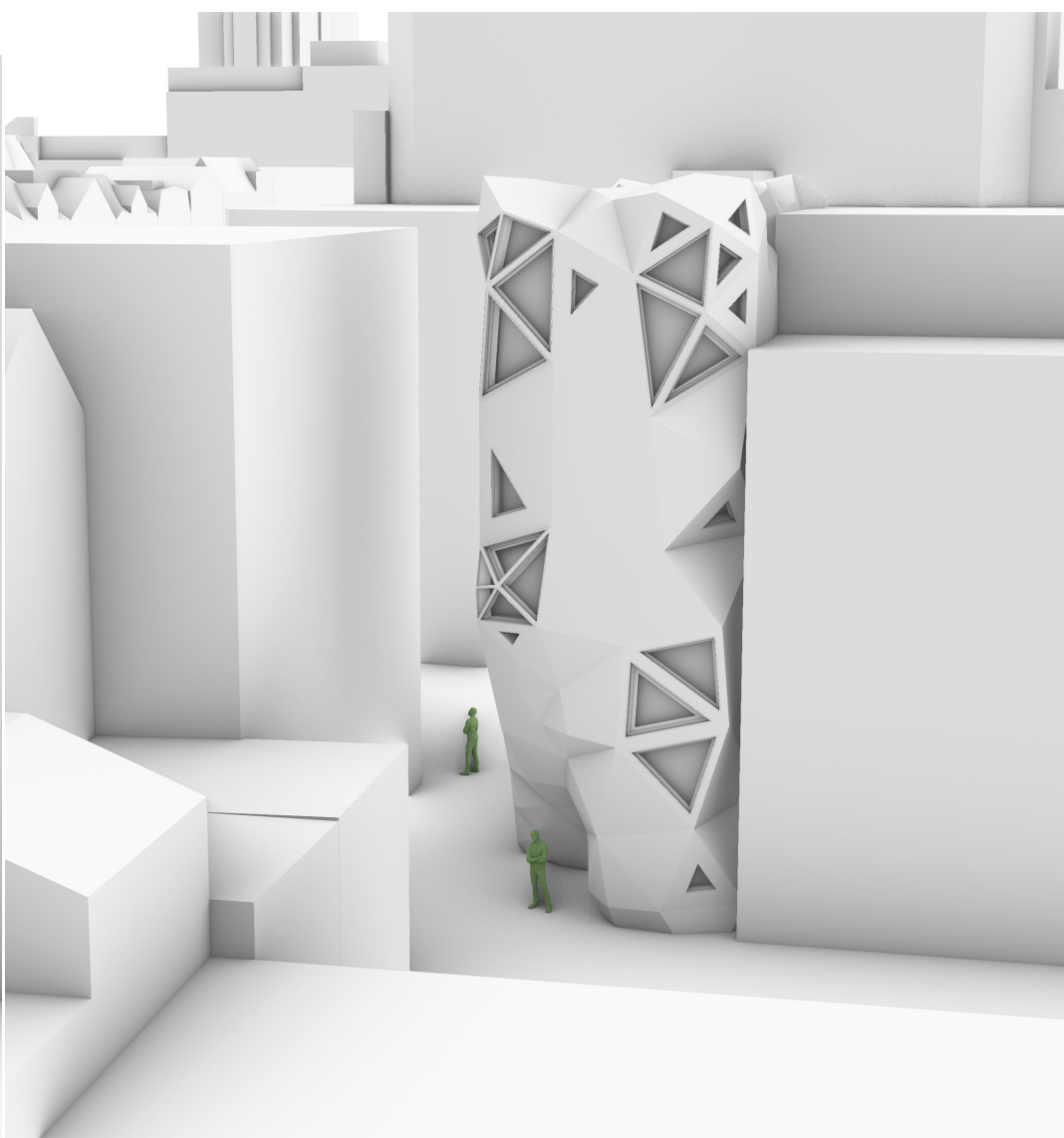
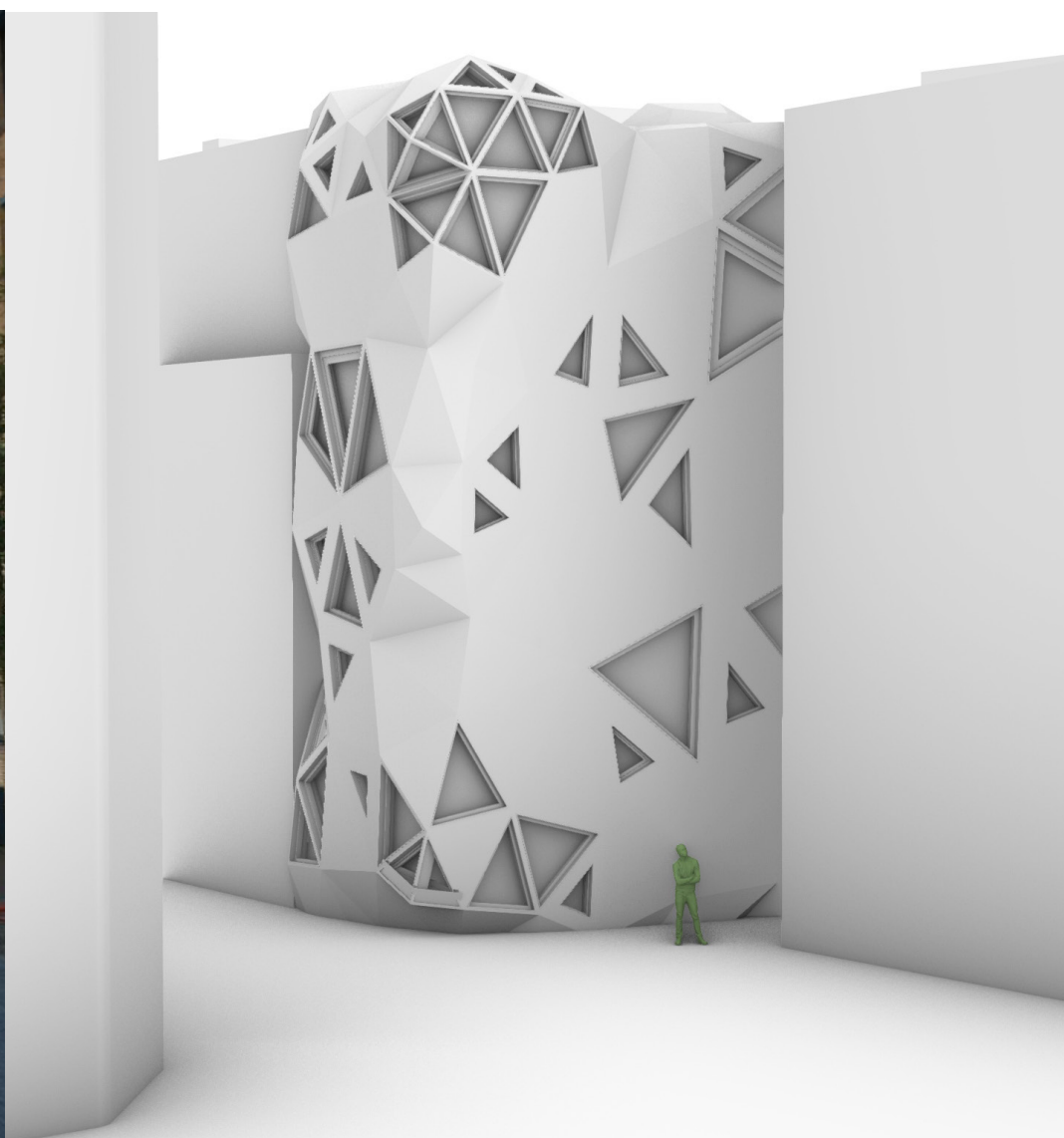
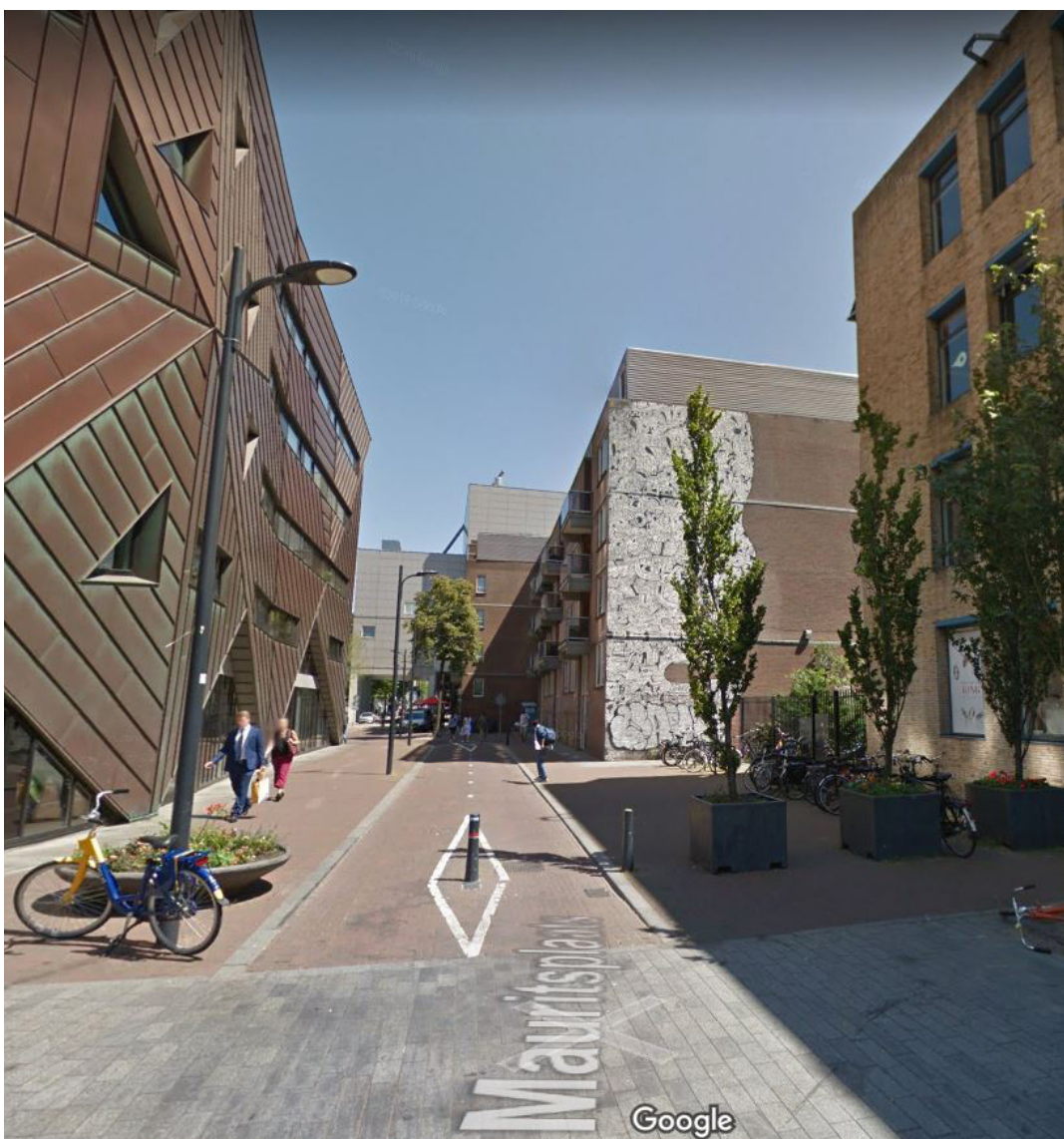


Jacobusstraat A

Footprint: 39m²
Height: 13m
Floors: 3

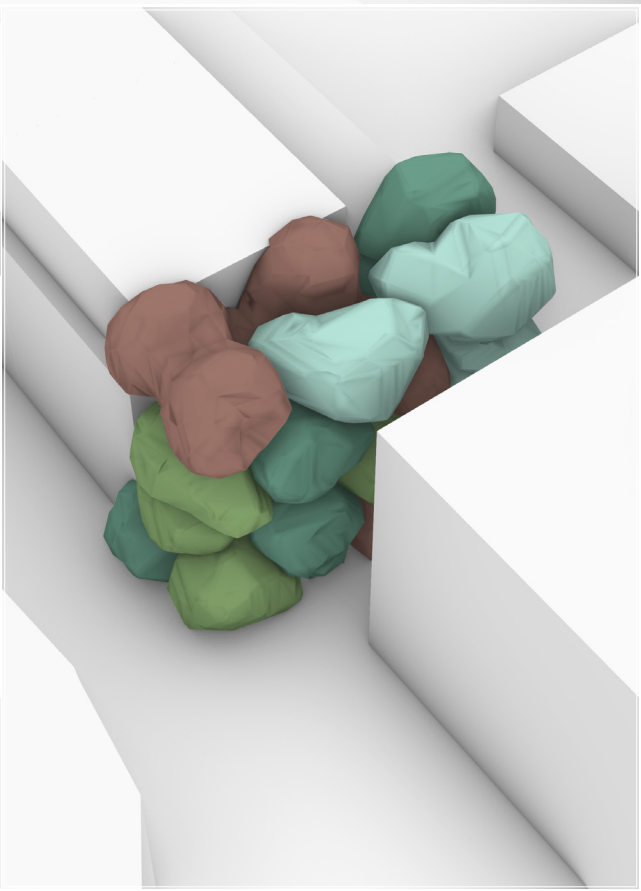
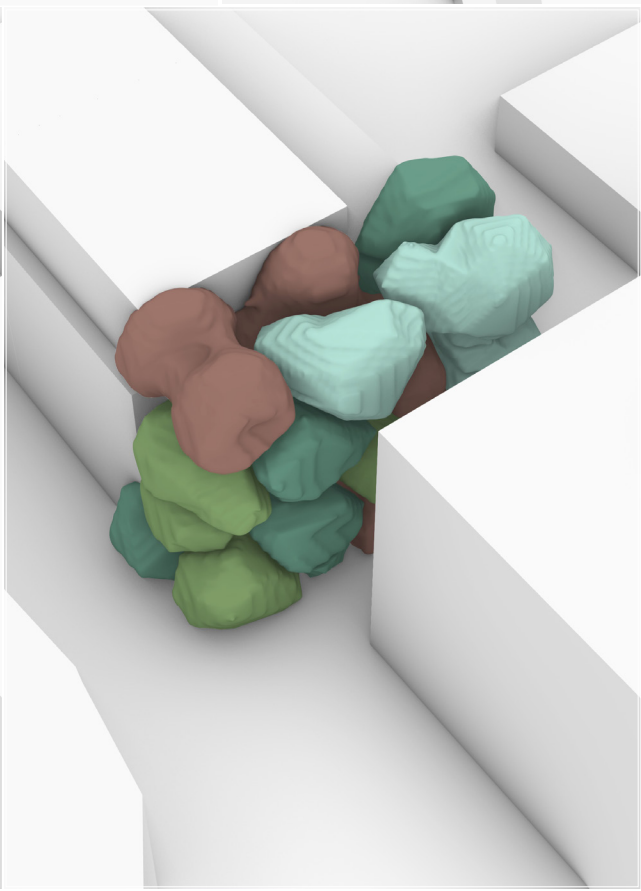
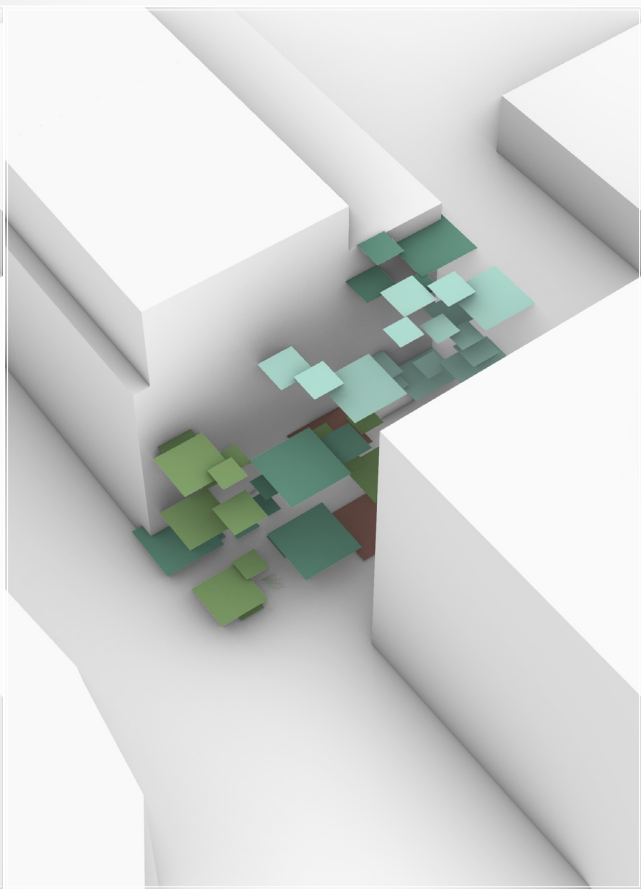
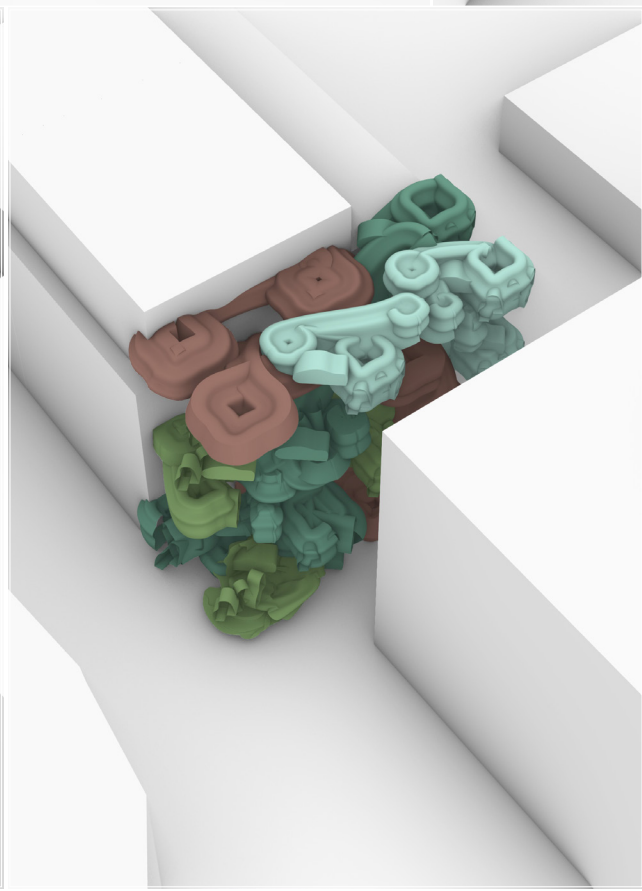
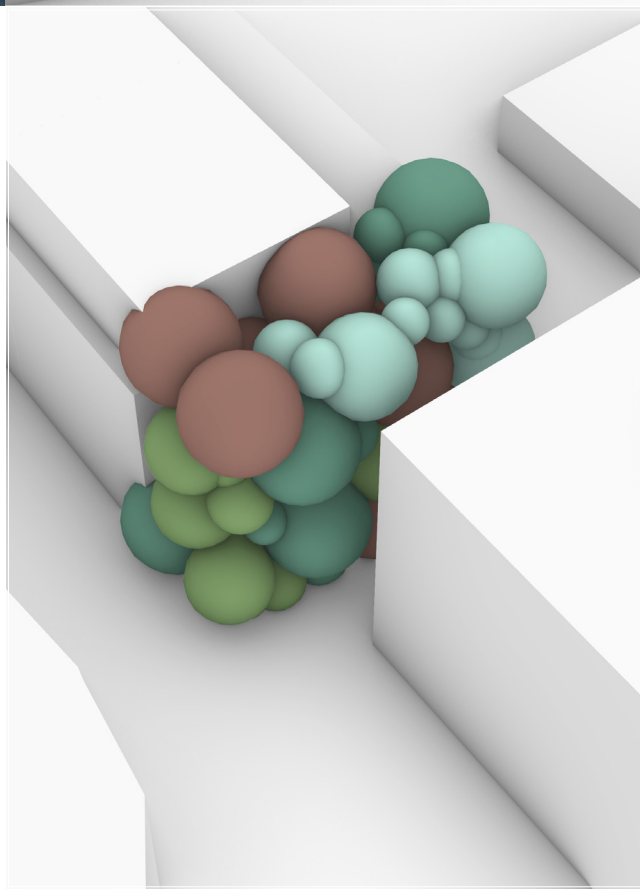


Locations in the City: Mauritsplaats

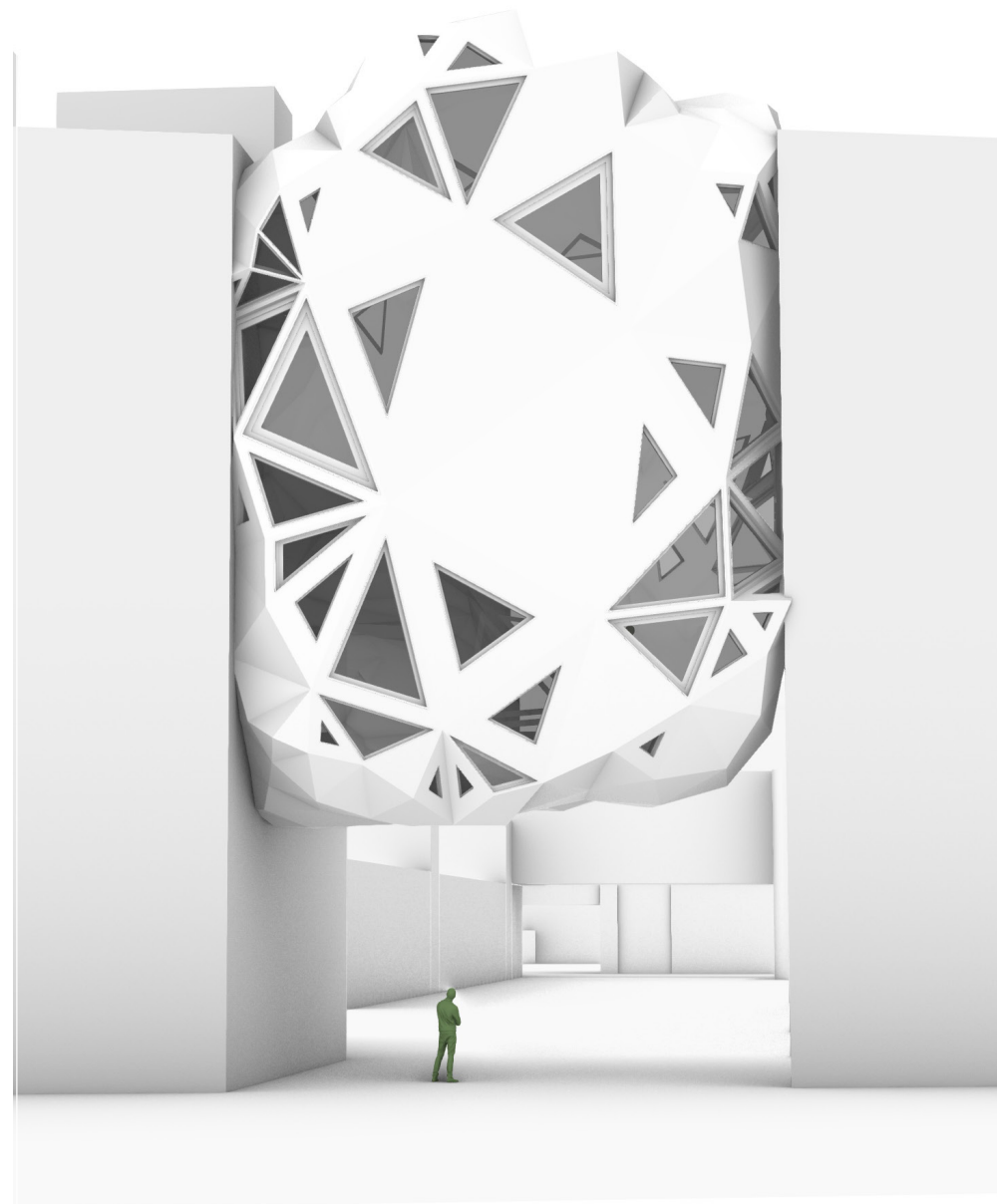


Mauritsplaats

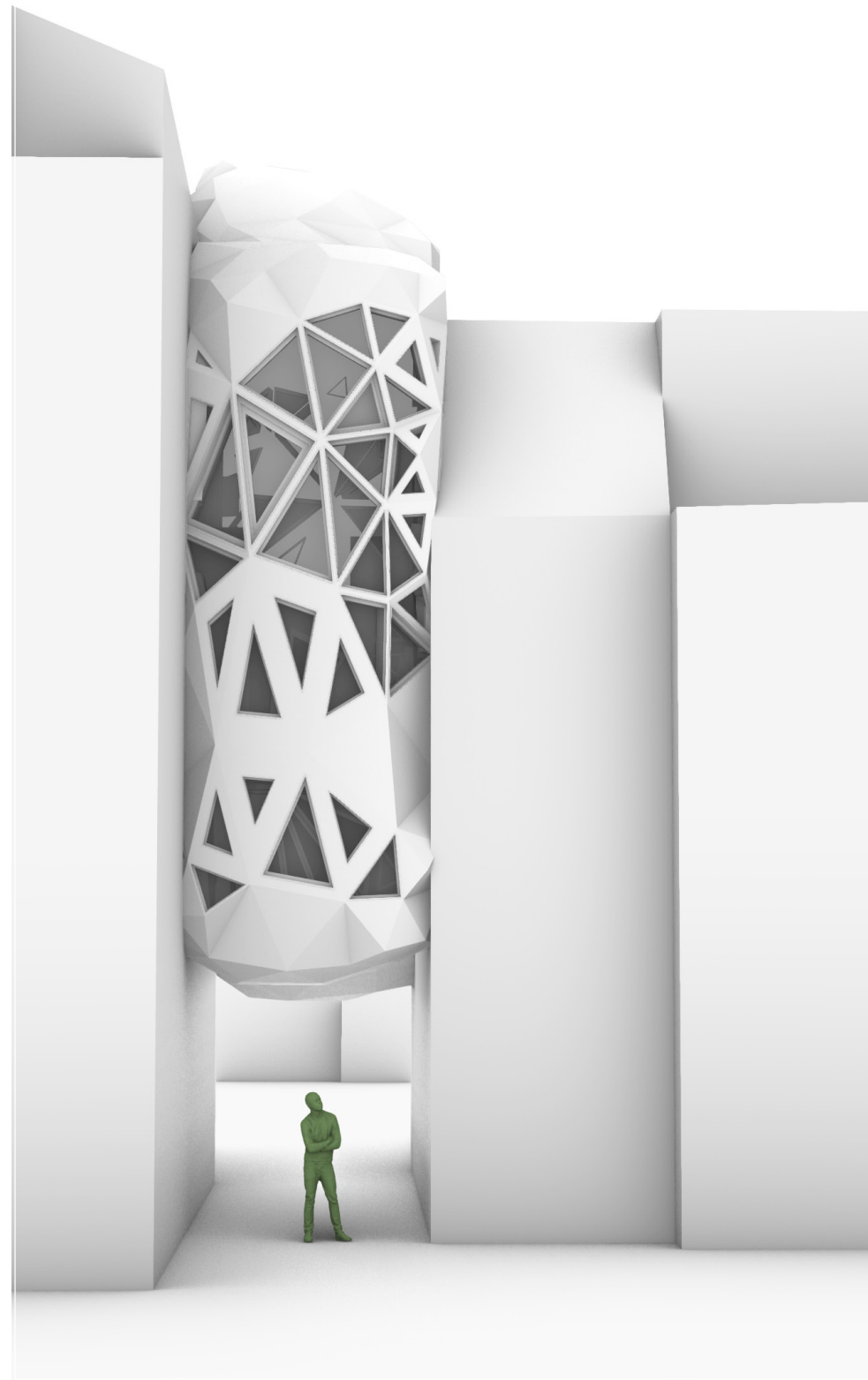
Footprint: 74m²
Height: 15m
Floors: 5



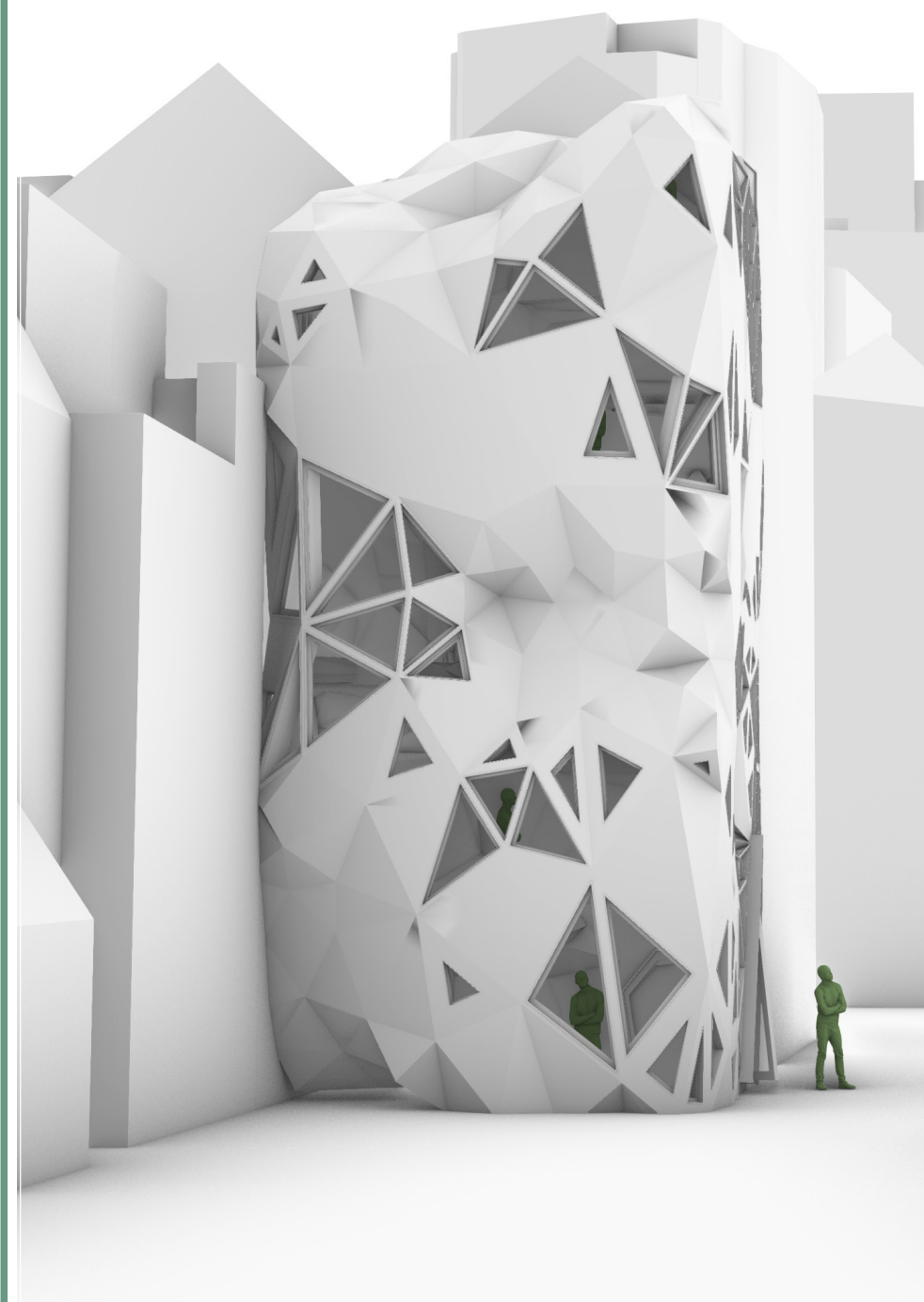
Locations in the City



Karel Doormanstraat



Jacobusstraat A



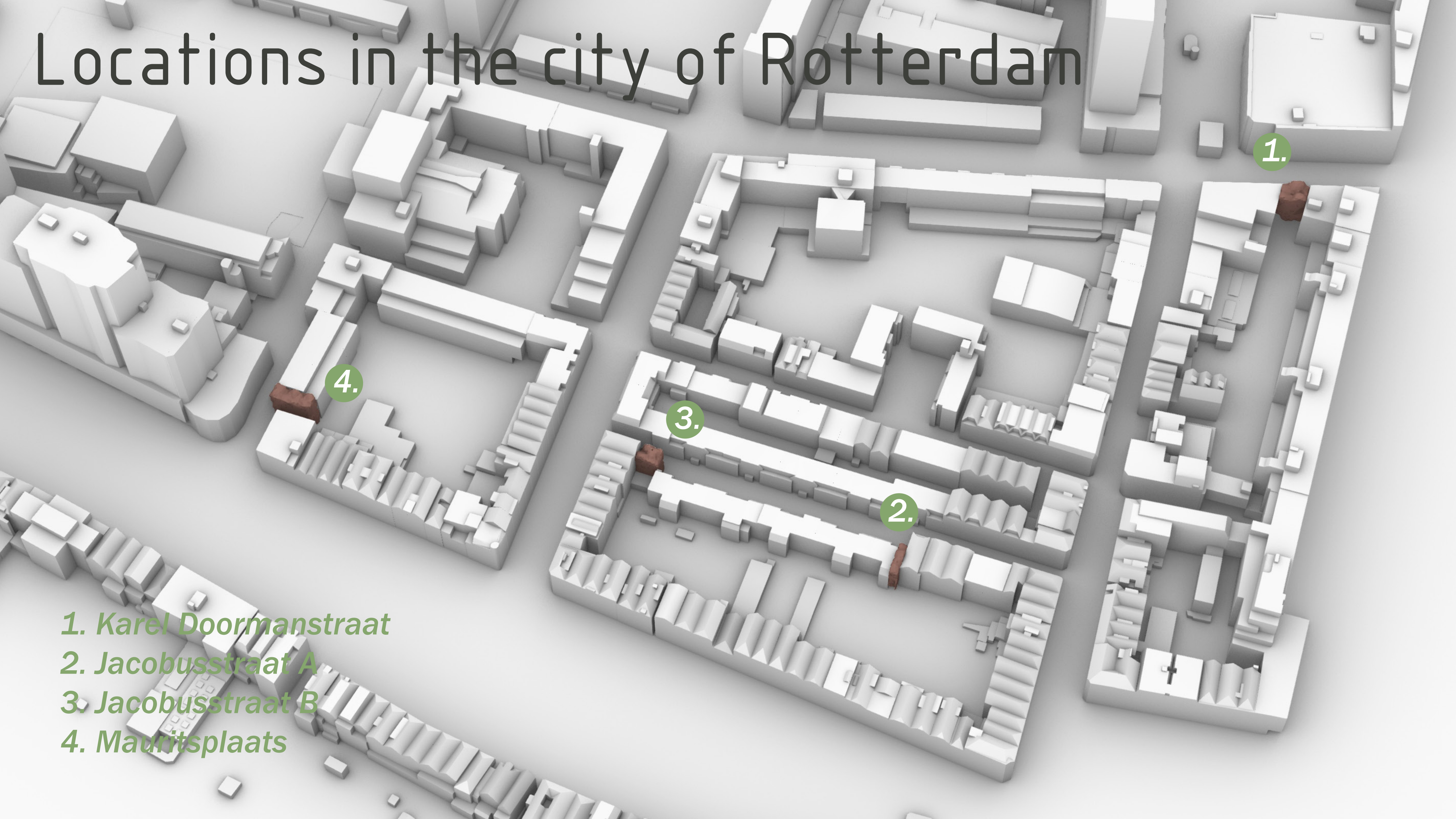
Jacobusstraat B



Mauritsplaats

Test Location

Locations in the city of Rotterdam



- 1. Karel Doormanstraat
- 2. Jacobusstraat A
- 3. Jacobusstraat B
- 4. Mauritsplaats

Conclusion

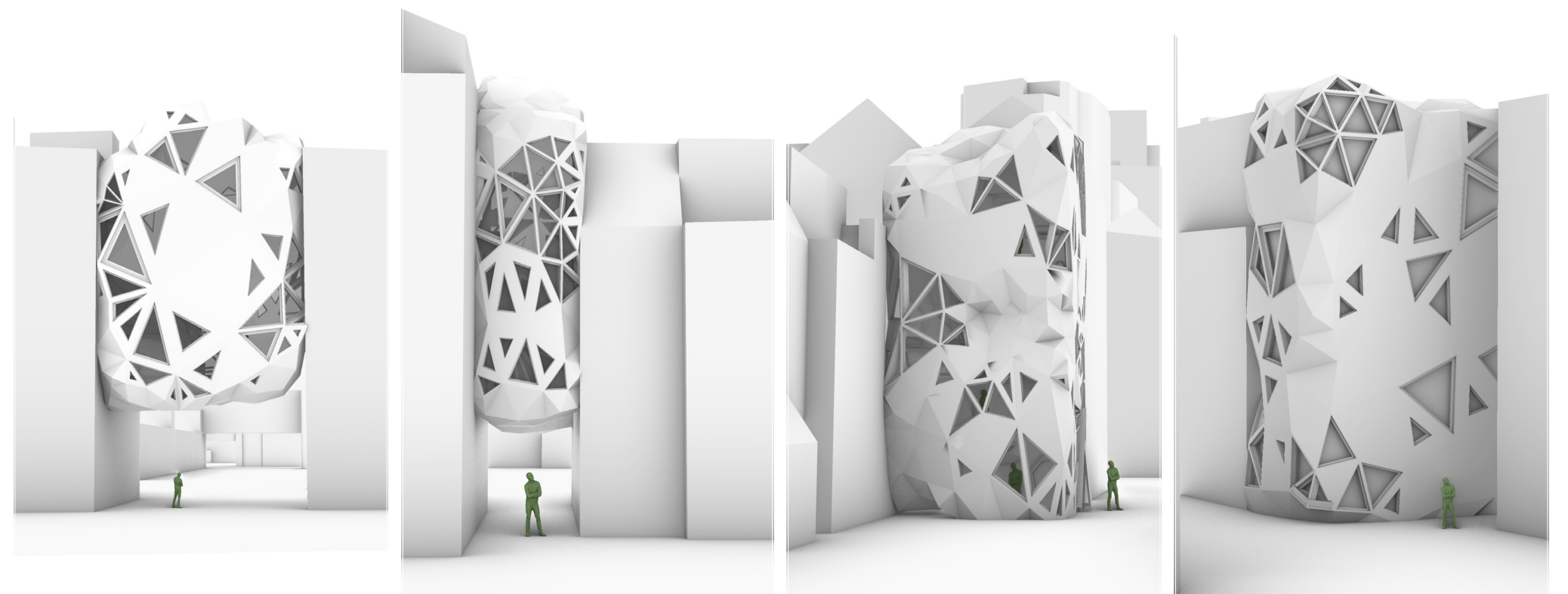
Conclusion/Reflection

Design for 1 Million Houses Aspects:

- Parametrically Designed Tiny Houses
- Fixing/Strengthen Existing City Structures
- Parametric Script Applicable to Other Cities
- Optimized Interior Spaces for Maximized Densification in the City

Design Question

How can the inner city be densified by filling in empty building plots using innovative construction techniques like the 3D printer?



Conclusion/Reflection

Research Question

*How can this building be 3D printed with renewable/
natural/fewest possible materials & sourced as local
as possible*

Sustainability Aspects:

- Renewable/Reusable & Natural Materials
- Locally Sourced Materials
- High Tech Construction, Low Tech Building with High Performance Materials
- In-Situ Construction
- Innovative Construction Techniques

