

Zwitsal Circular Hub

WASTE AND ROBOTS

MSc 3/4 Graduation

Explore Lab Studio

2021-2022

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The built environment is currently responsible for

50% of all landfill waste



40% of all CO2 emissions



36% of all energy consumption



PROBLEM

PROBLEM

50% of all landfill waste

Bricks

Concrete



PROBLEM

50% of all landfill waste



Bricks

Concrete

Environmental

Financial

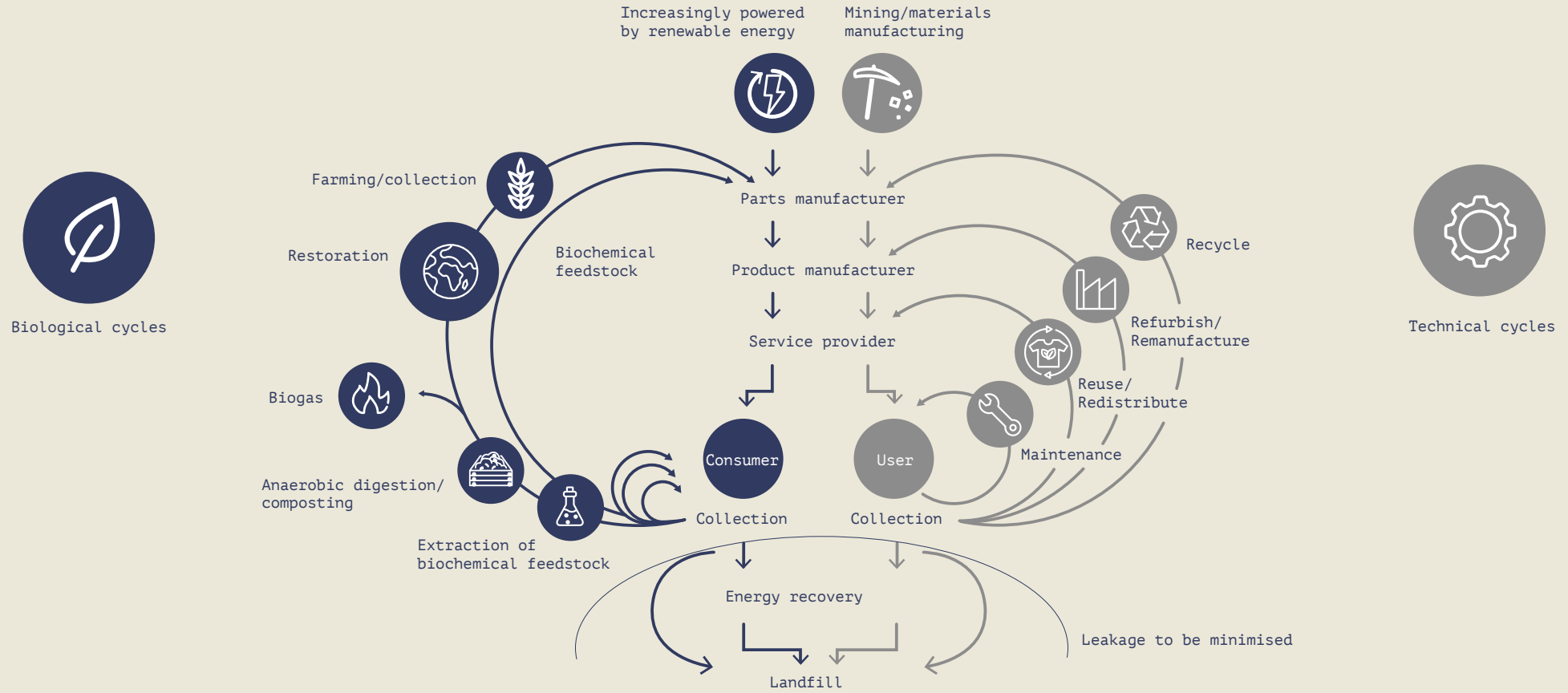
Social



● **A linear building process**

THE CAUSE

Circular Economy



TRANSITION



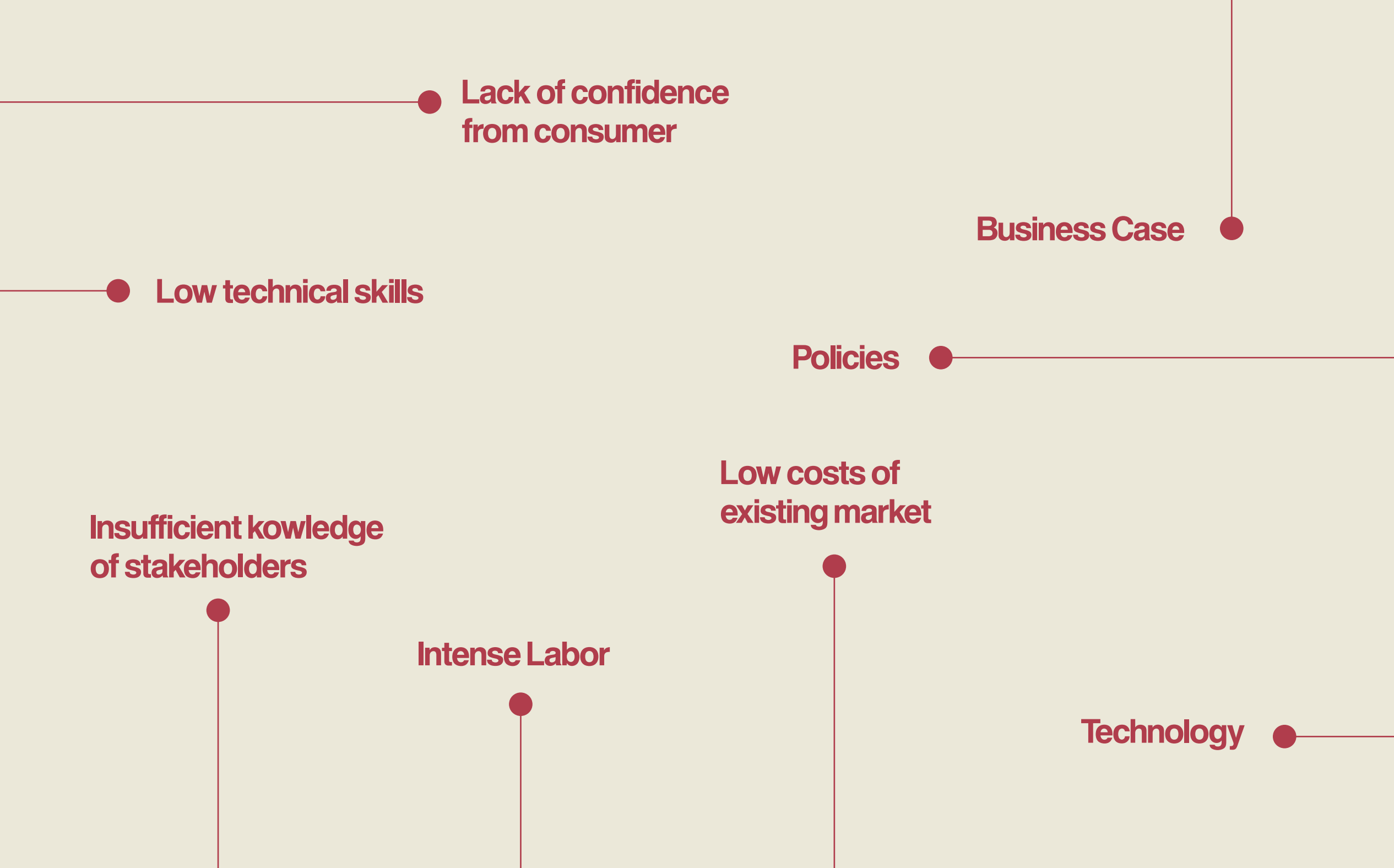
Design with waste

Design out waste



MIND-SET

WHAT IS TAKING SO LONG?



**Lack of confidence
from consumer**

Business Case

Low technical skills

Policies

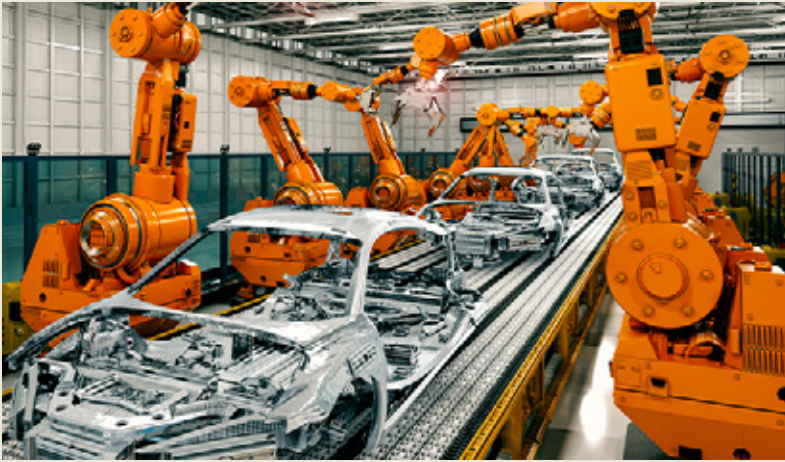
**Insufficient knowledge
of stakeholders**

**Low costs of
existing market**

Intense Labor

Technology

Technology ●————



Productivity: Lowered cost



Efficiency : Reduction on time



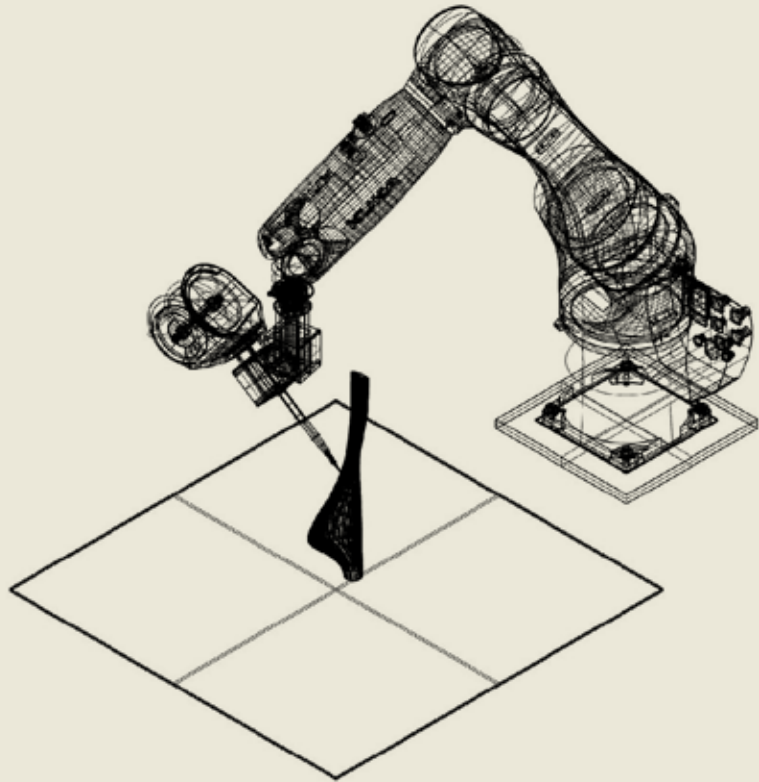
Precision : Reliability

Allows for a complete new design approach and process

Flexibility provides substantial range of composition and quality differences

Optimal material use

Can be used on and off site



AMoC (Additive Manufacturing of Concrete)

RESEARCH QUESTION

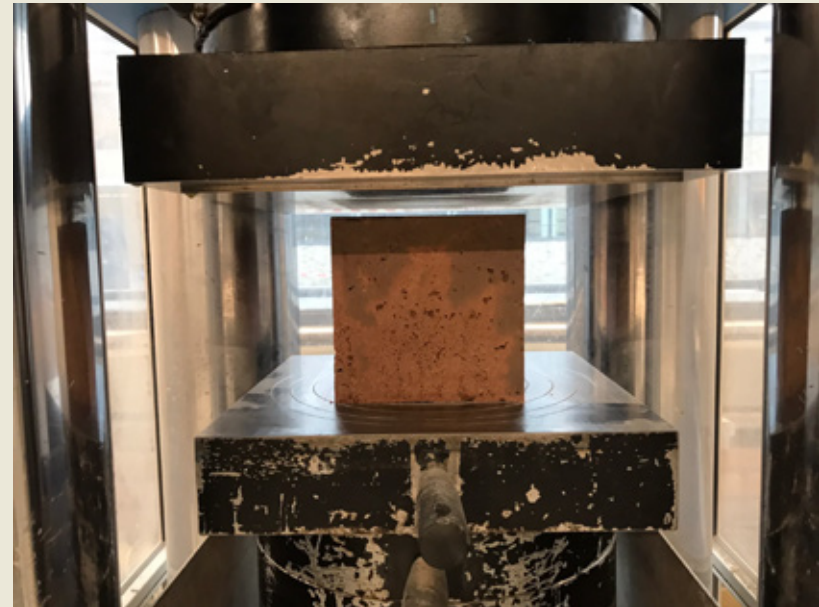
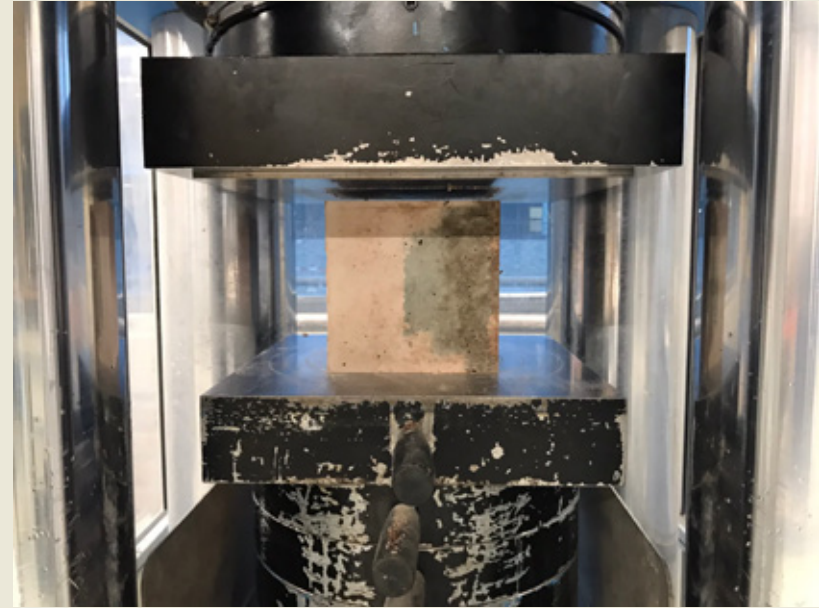
How can **bricks and concrete** from CDW be **upcycled** and integrated in the construction process through the aid of **robotic fabrication**, while improving the **architectural expression** of these materials, provide an **adaptable** solution to the changing future needs and achieve a **local circular economy**?

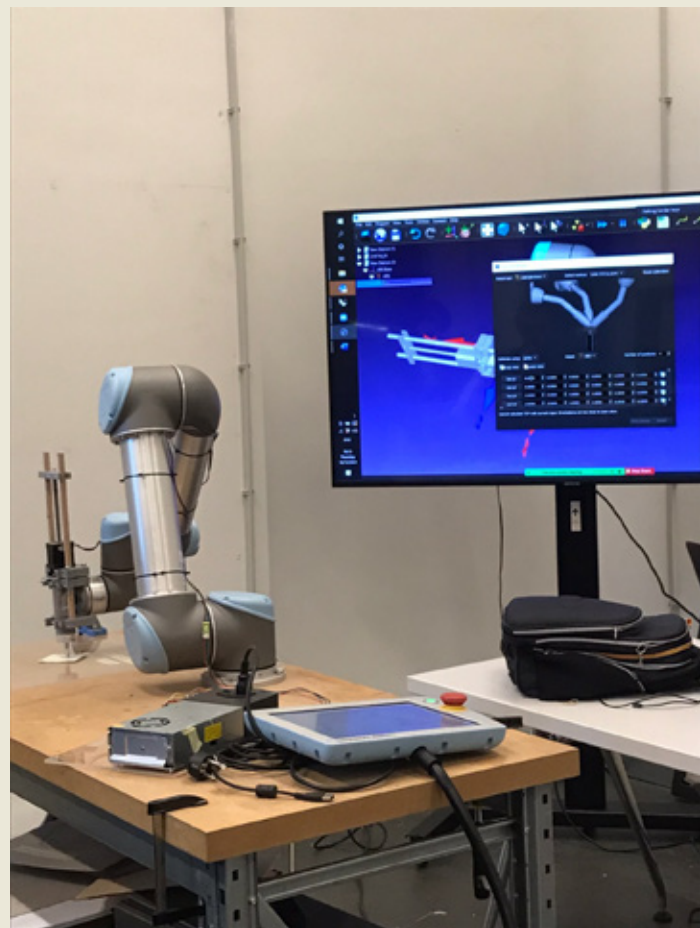
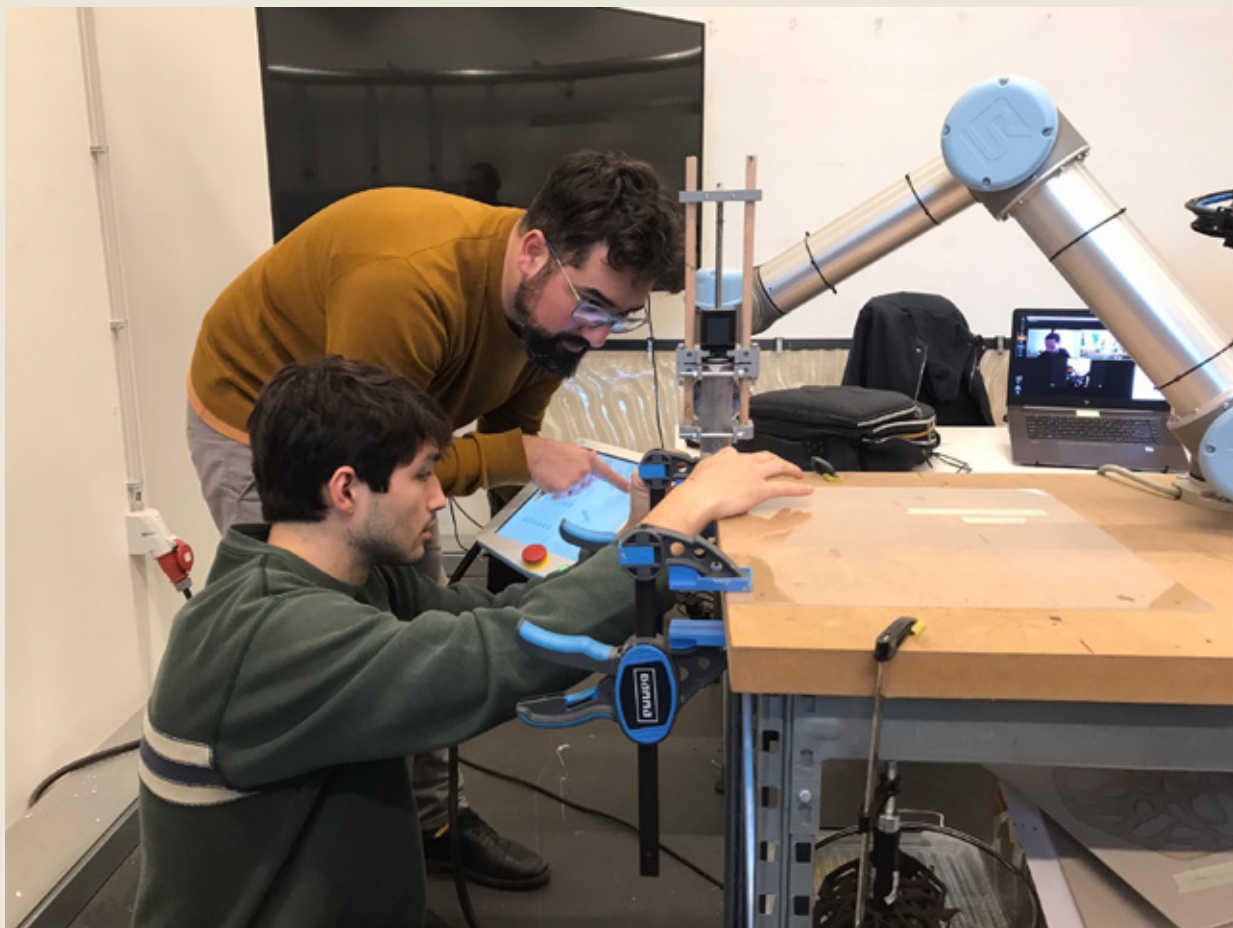


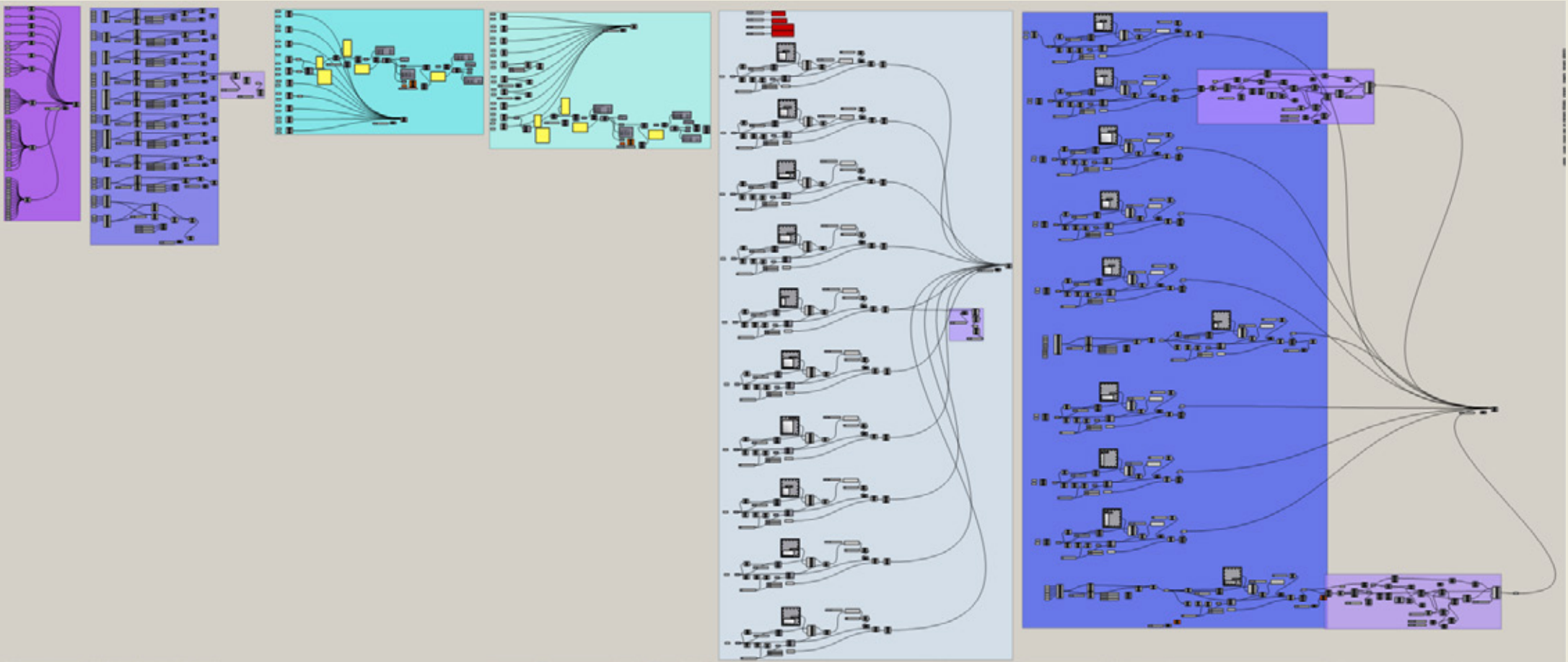
METHOD OF EXPERIMENTATION



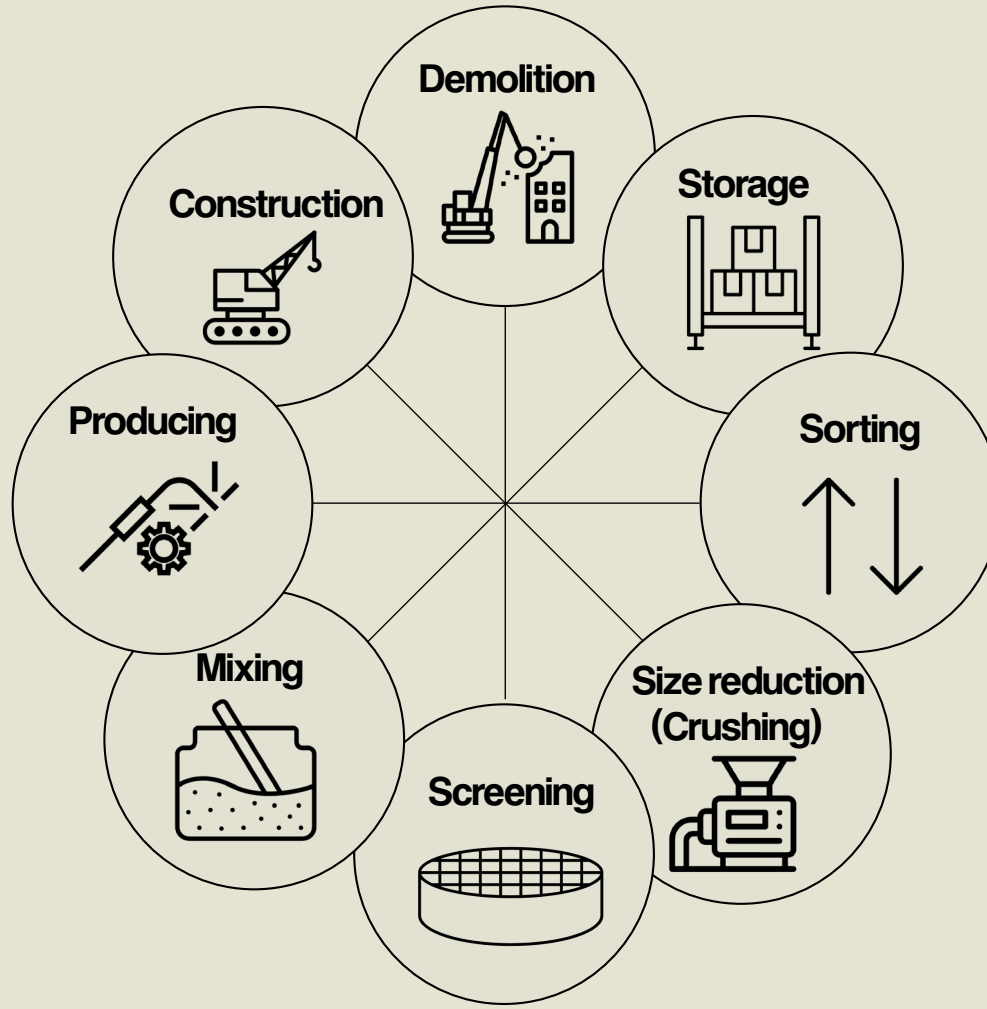








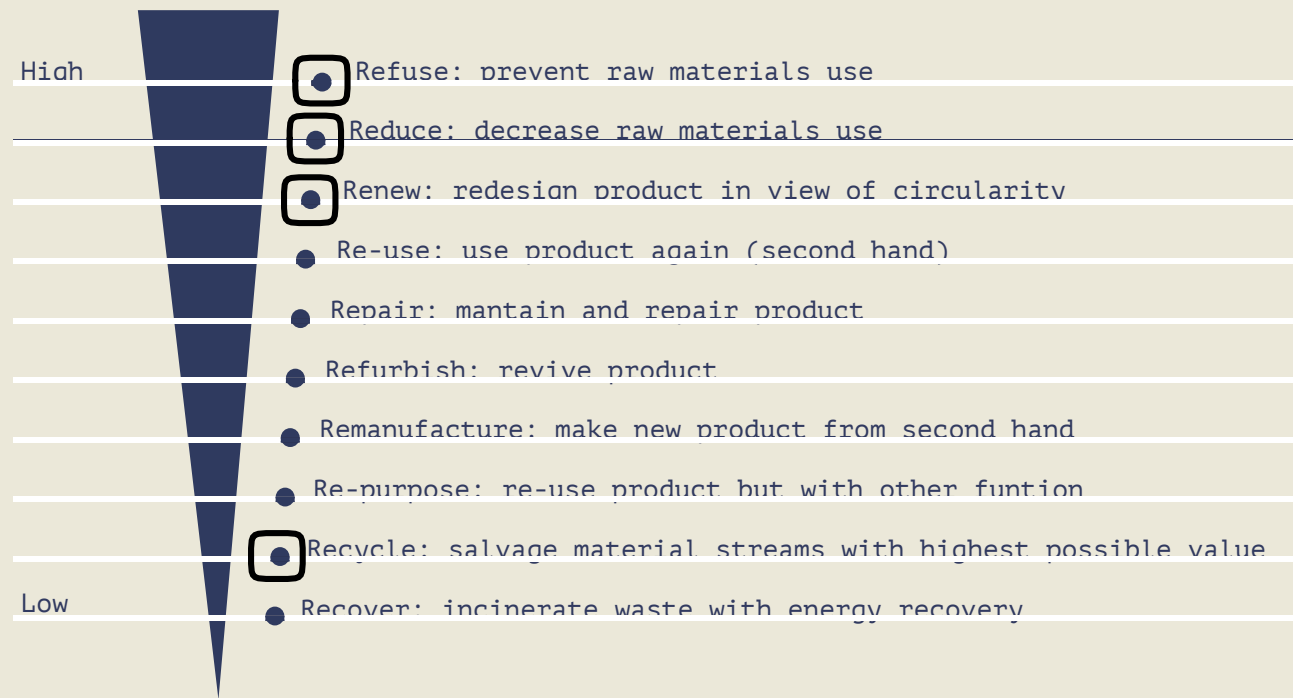
HOW?



MATERIAL FLOW

Levels of circularity: 10 R's

Order of priority



PRIORITIES



Waste bricks



Crushed brick and concrete



Material samples

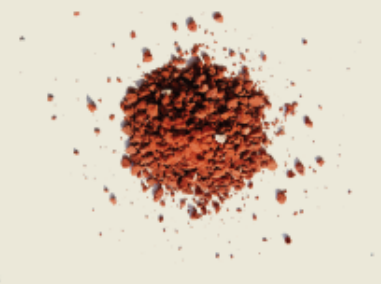




INGREDIENTS



M1



M1

10% Cement
70% Aggregates (50-50% brick-concrete)
10% CM Cement
10% Water



M1



M1

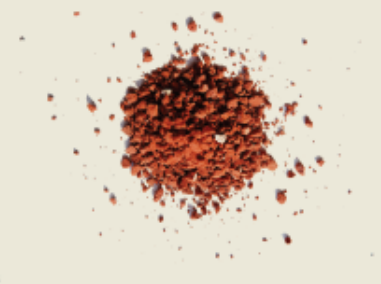


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M1



M1



M1



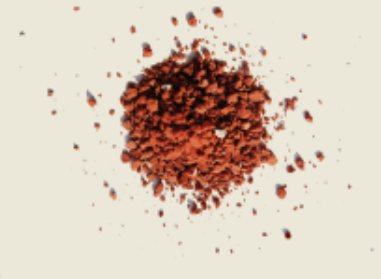
M1





M2

20% Cement
70% Aggregates (25-75% brick-concrete)
10% Water



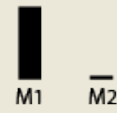
M2

20% Cement
70% Aggregates (25-75% brick-concrete)
10% Water



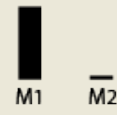
M2

20% Cement
70% Aggregates (25-75% brick-concrete)
10% Water



M2

20% Cement
70% Aggregates (25-75% brick-concrete)
10% Water

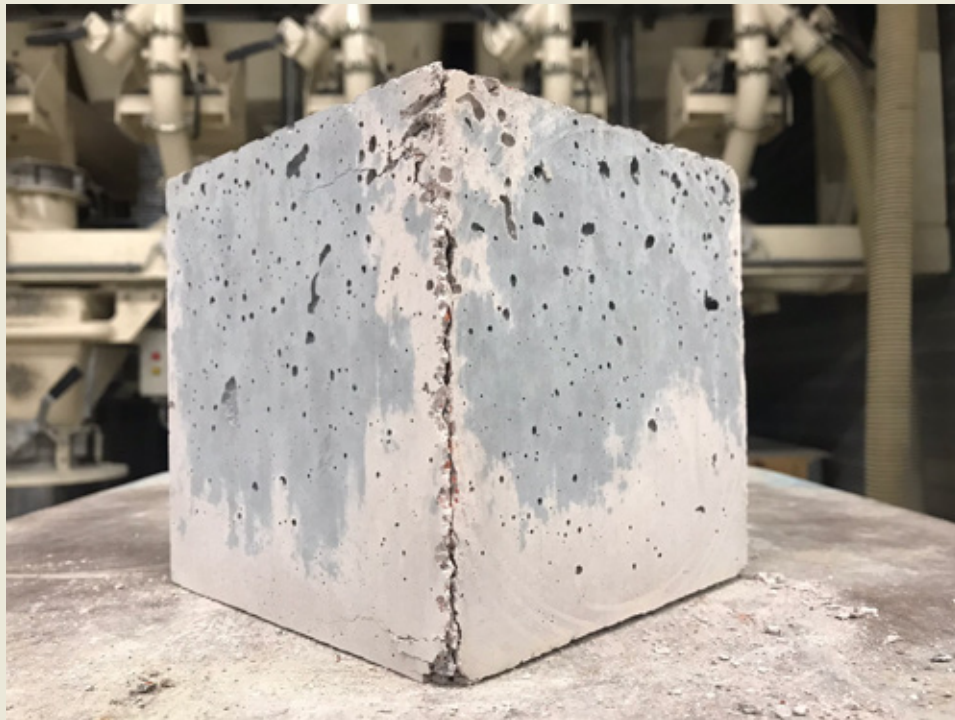
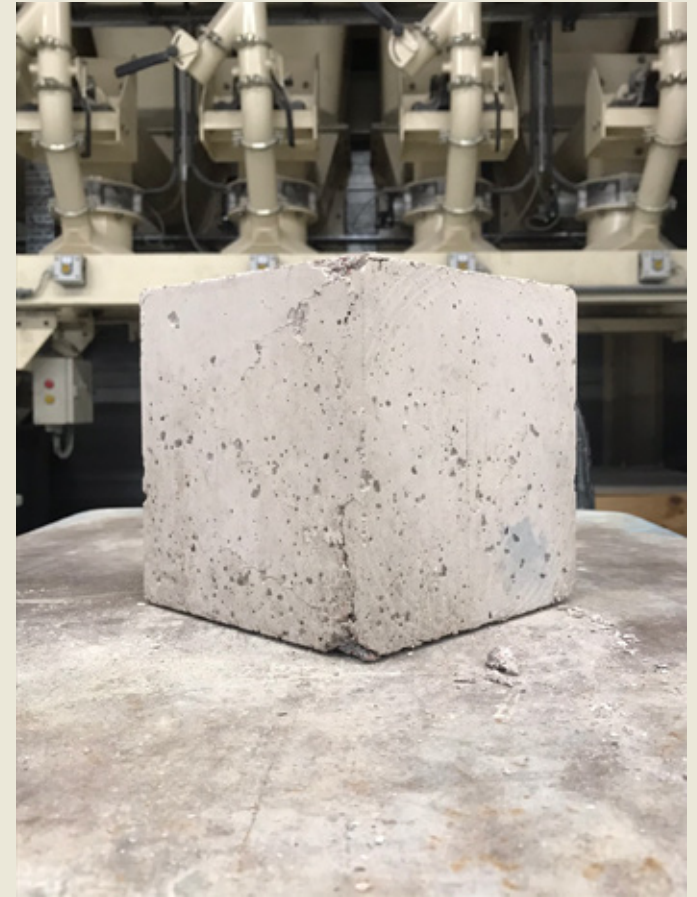


M1 Sustainable Mix

M2 Load Bearing Mix



Material testing samples





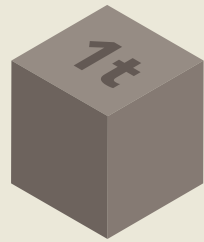
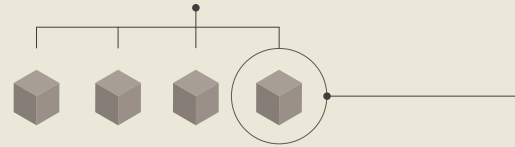
Current recycling



90%
aggregate



25% Virgin cement
25% Sand
35% Recycled agg.
15% Aggregate



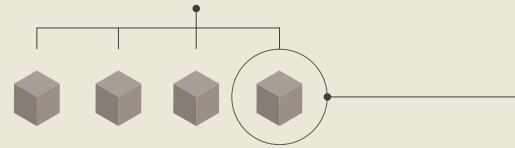
Improved recycling



98%
aggregate



7% Virgin cement
25% Recycled sand
50% Recycled agg.
18% Recycled cement



TRADITIONAL VS UPCYCLED

Recycled concrete volume in design

External walls	384 m ³
Floor slabs	785 m ³
Core	136 m ³
Columns	10 m ³
Ramp	100 m ³
Total	1415 m ³

1415 m³ = 3400 t

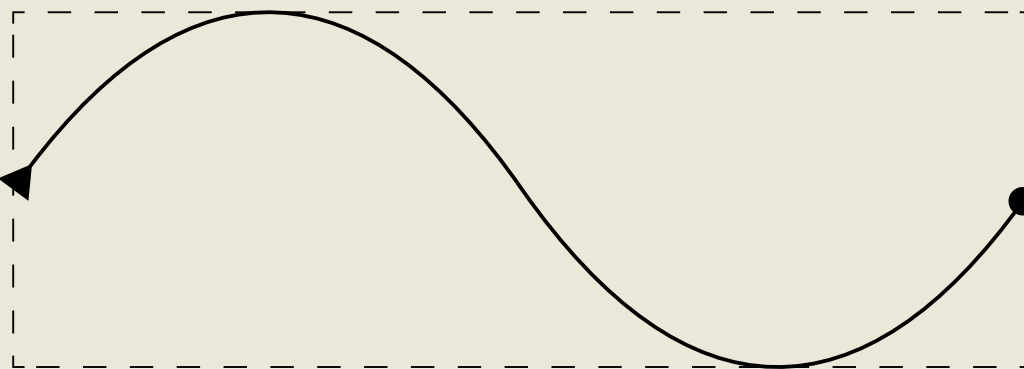
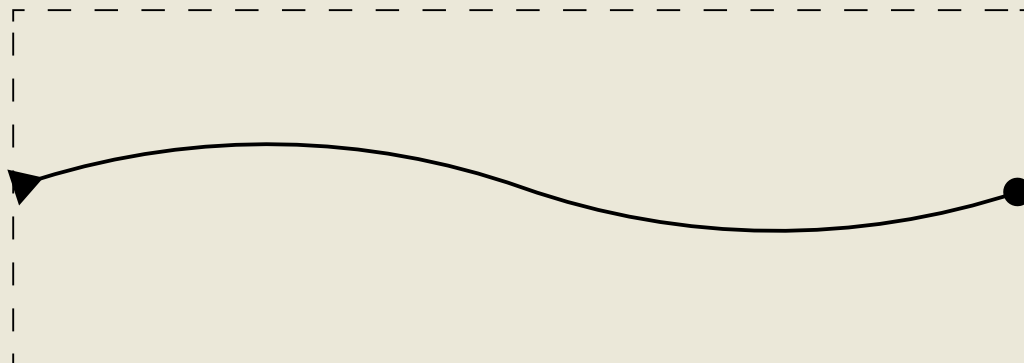
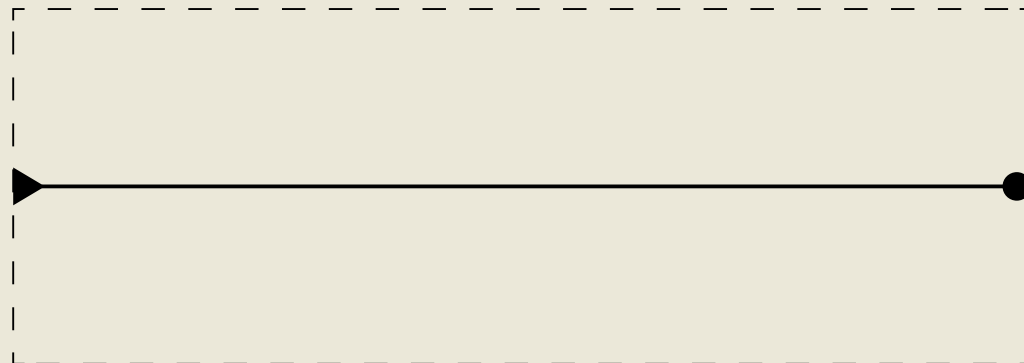
1t of virgin concrete =
900 kg of CO₂

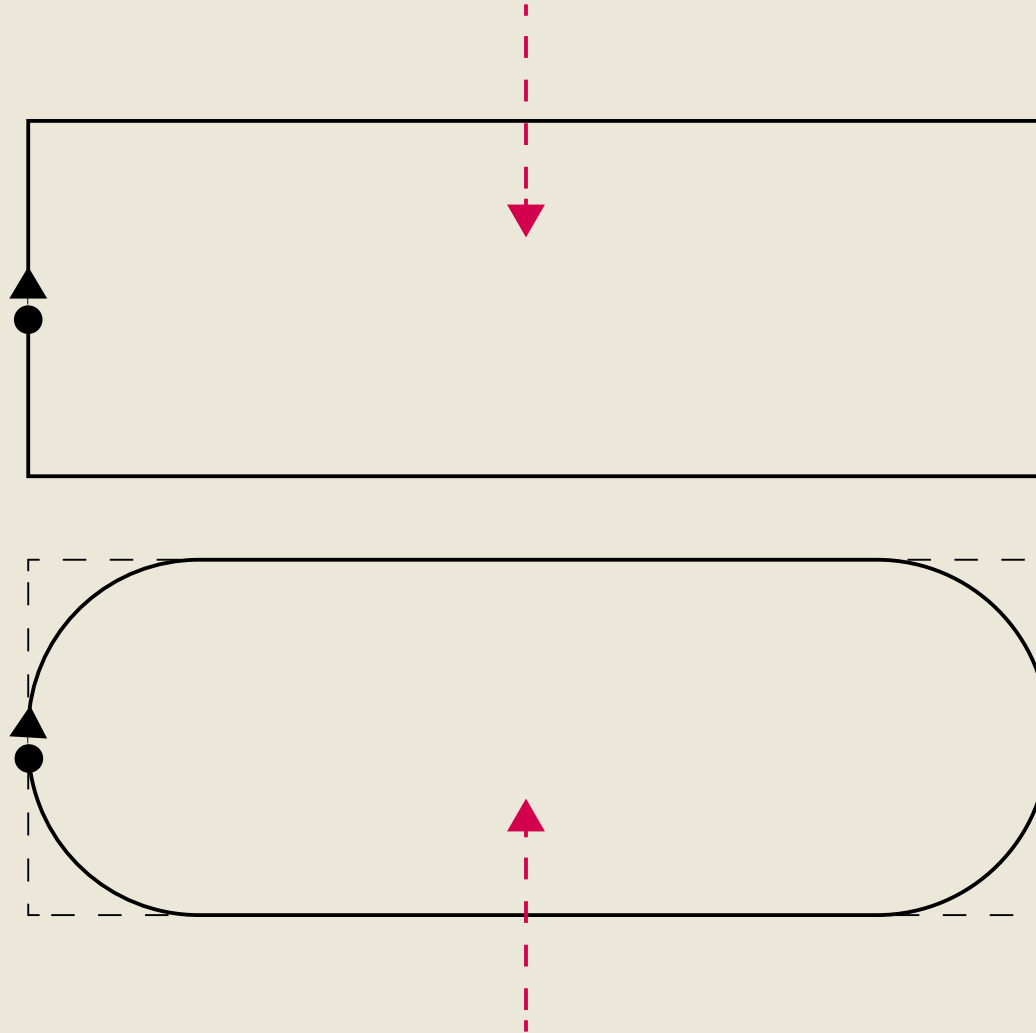
CO₂ production for 3400t

Virgin concrete	3060 t CO ₂	} - 25%
Current recycling	2295 t CO ₂	
Improved recycling	643 t CO ₂	} - 72%

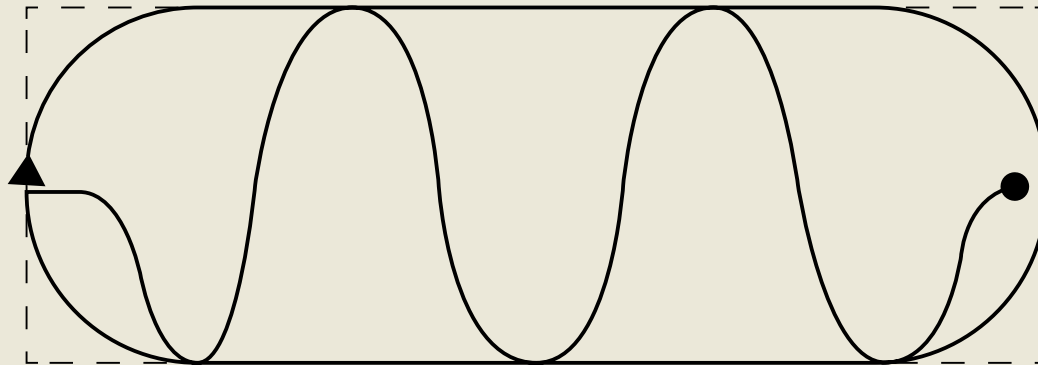
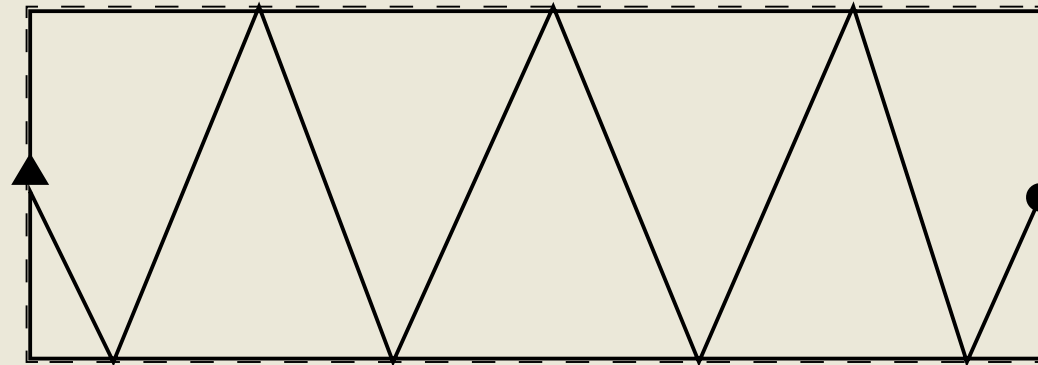
72% CO₂ reduction compared to current recycling

TOOLPATH

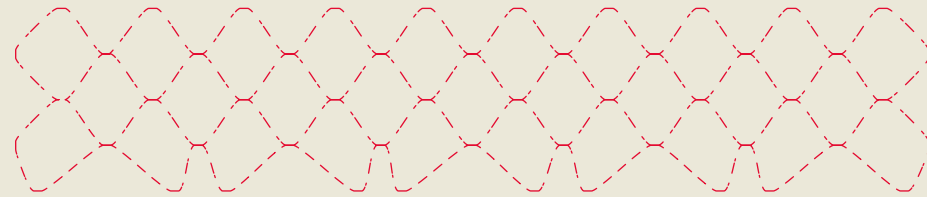




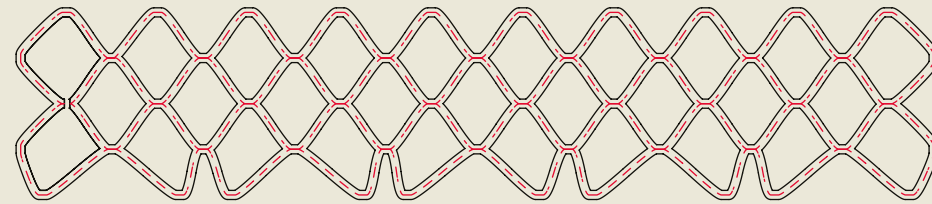
LACK OF STABILITY



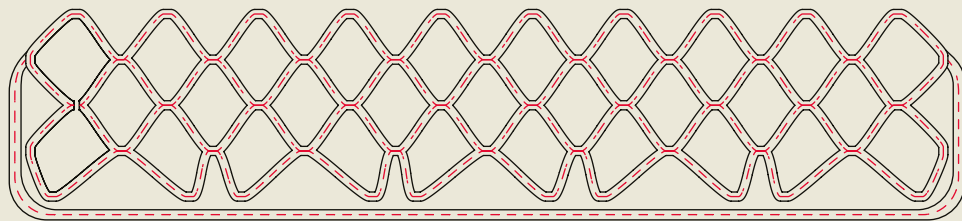
BRACING



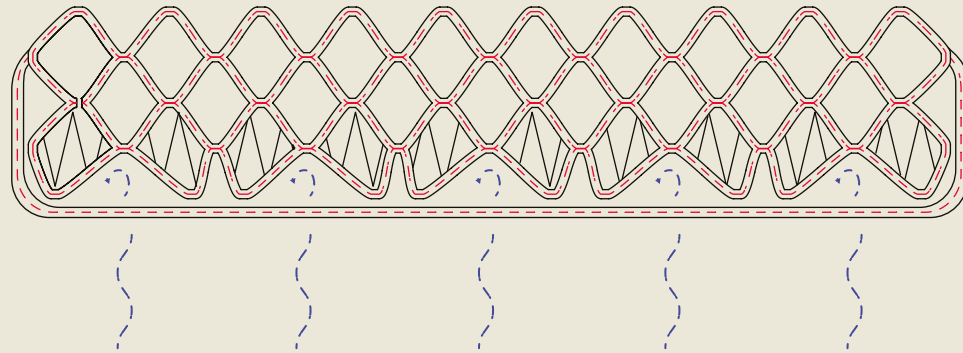
PATTERN



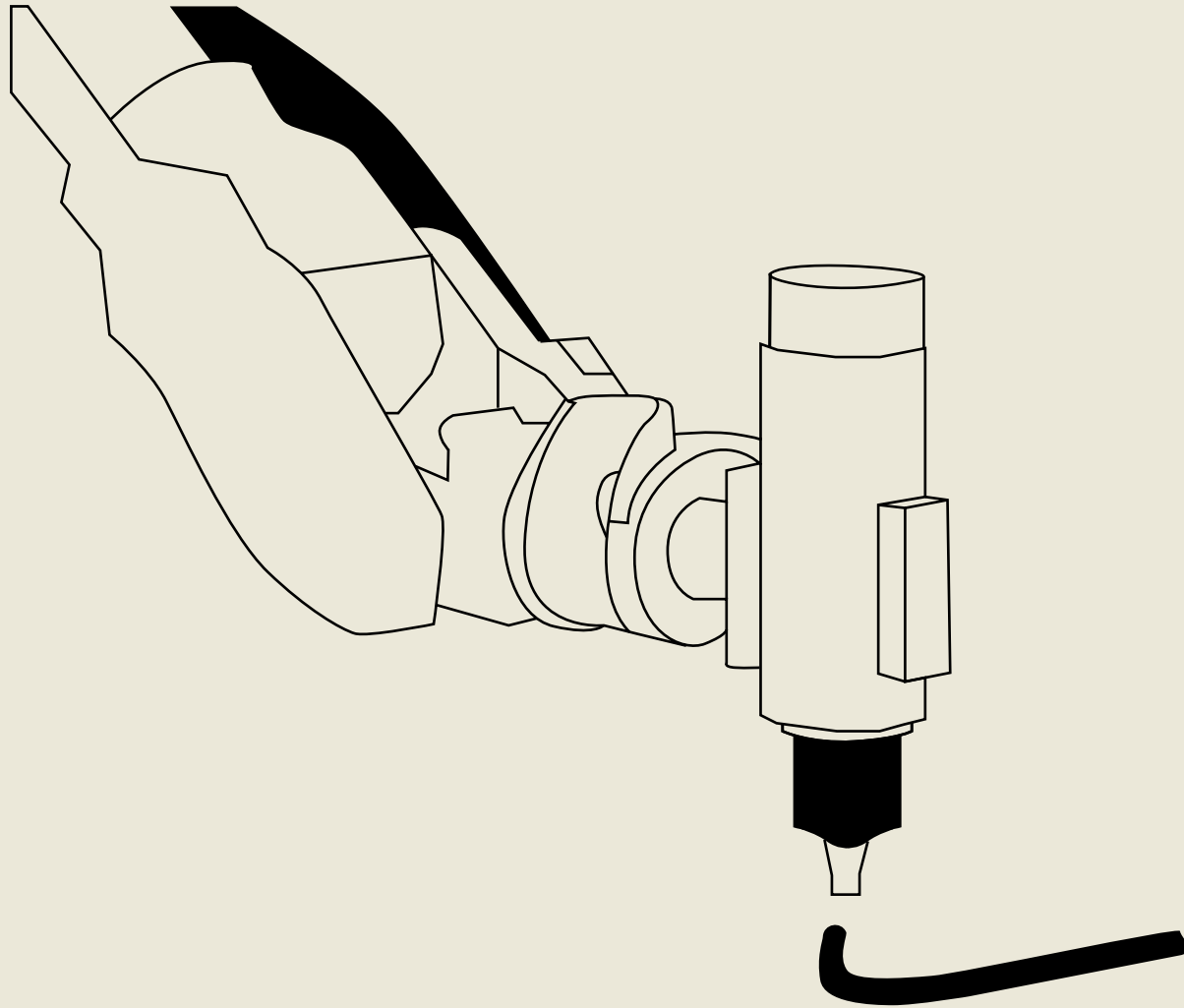
PRINT THICKNESS



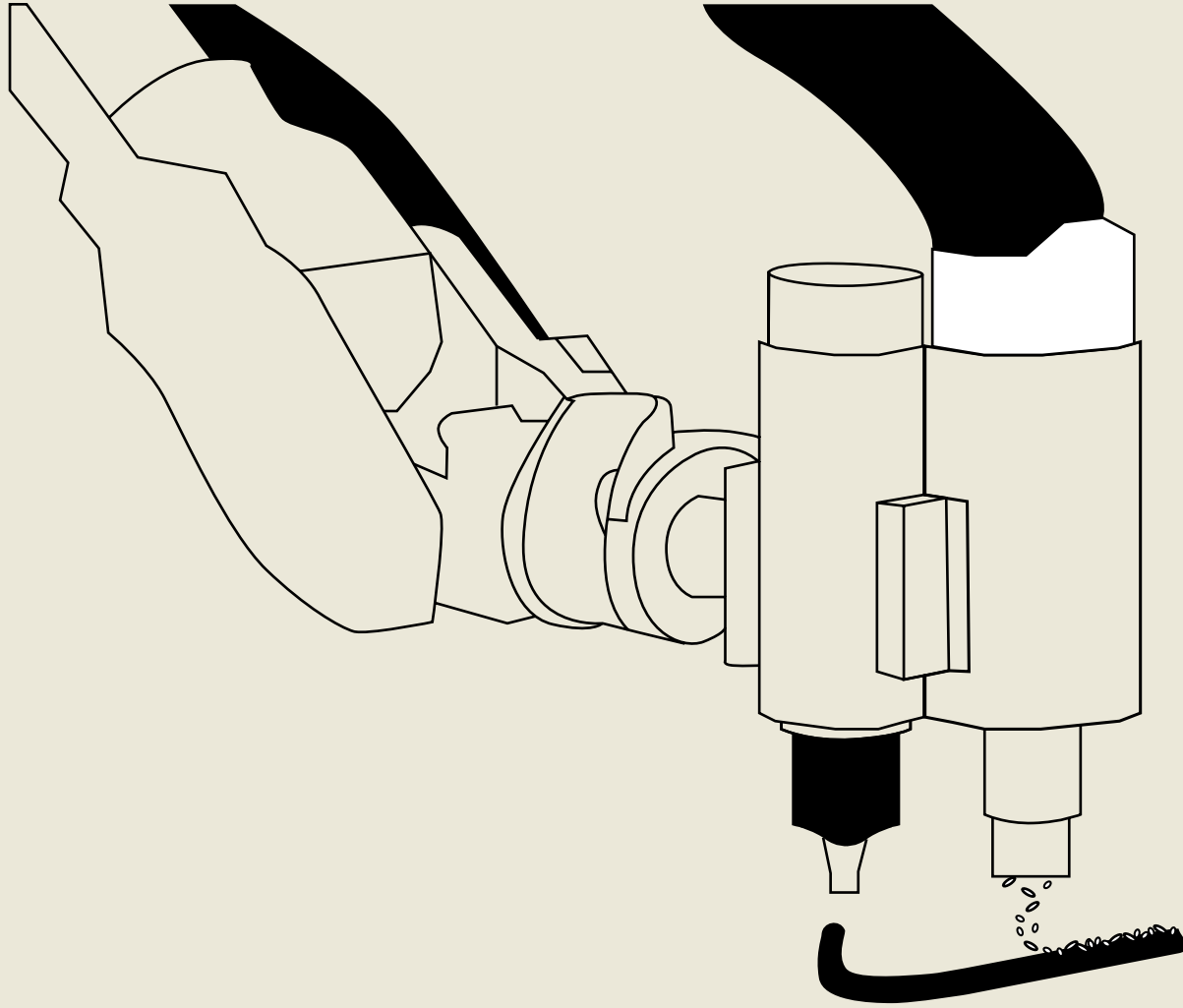
OUTER SKIN



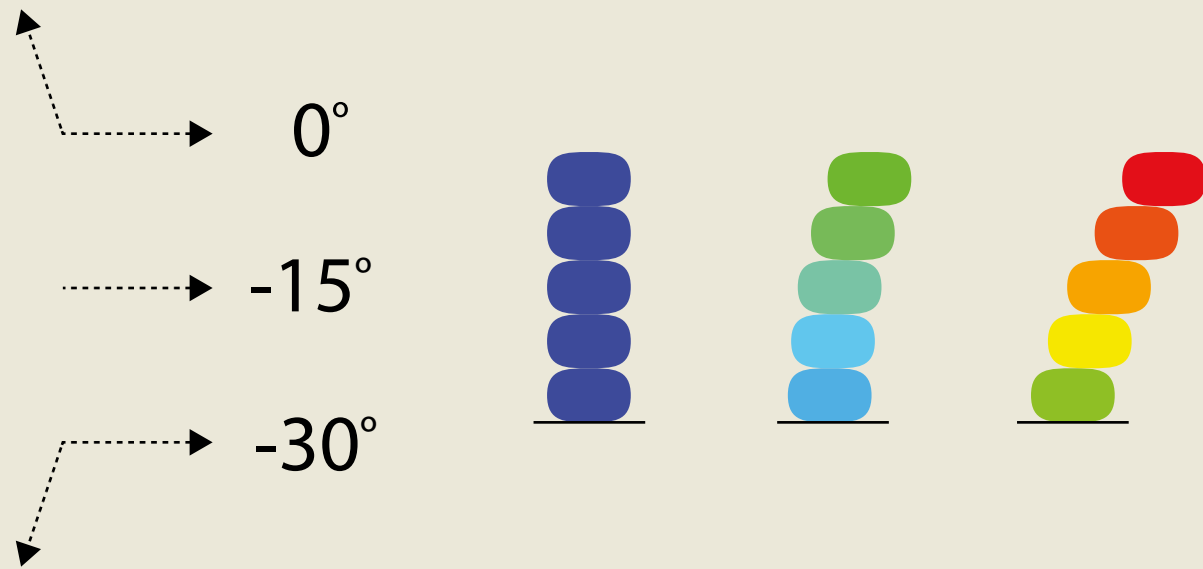
BREATHABLE STRUCTURE + INSULATION



FINE AGGREGATE MIX

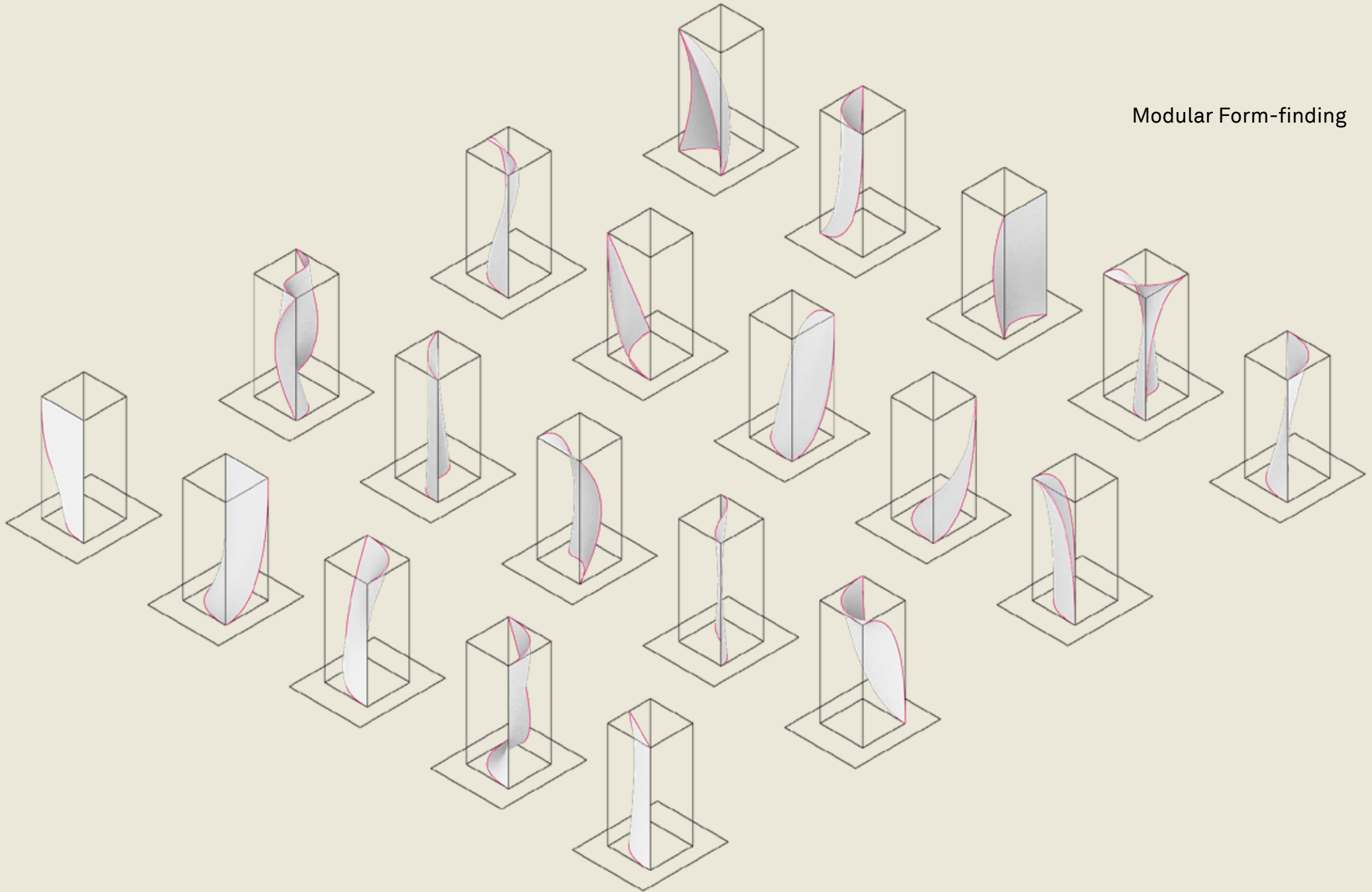


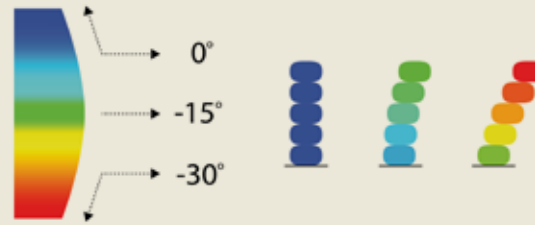
COARSE AGGREGATE REINFORCEMENT



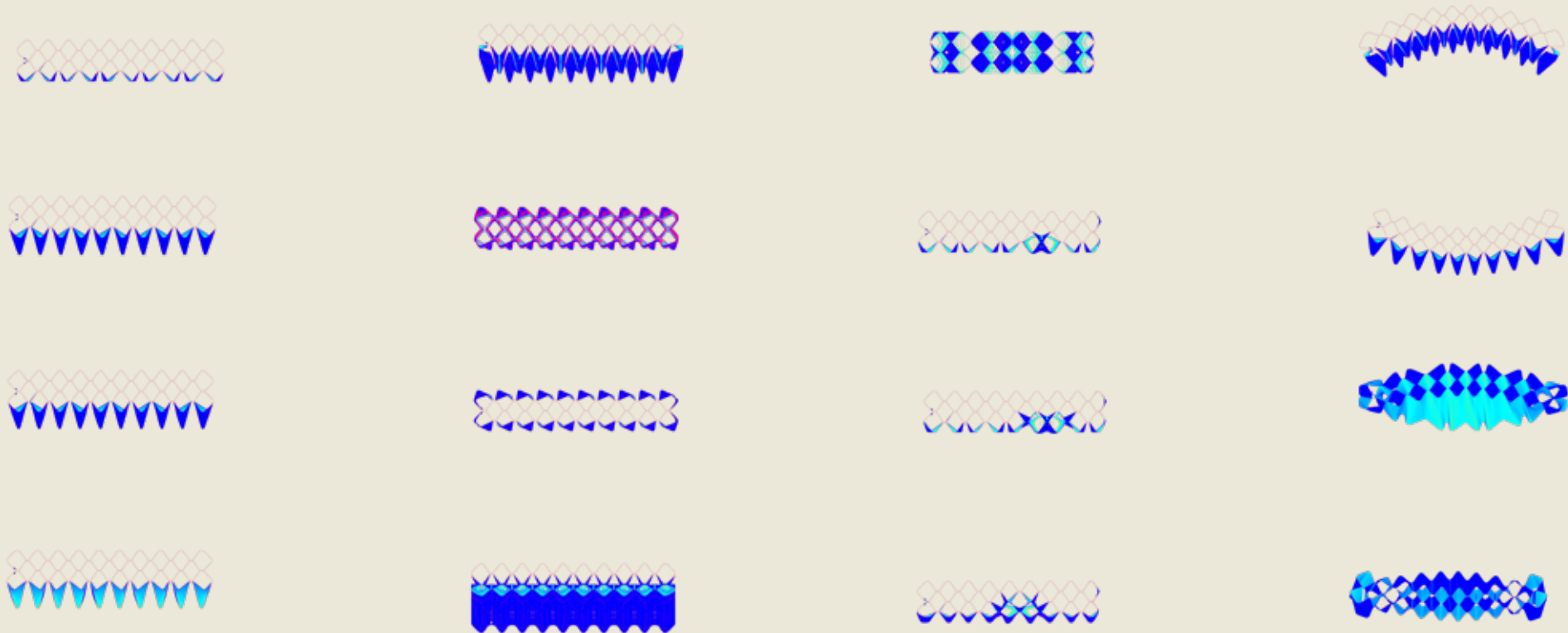
BOUNDARY CONDITIONS

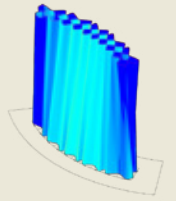
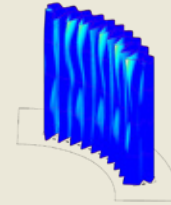
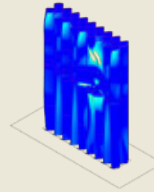
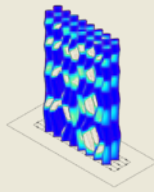
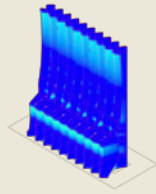
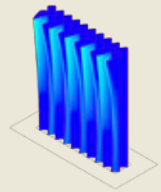
Modular Form-finding





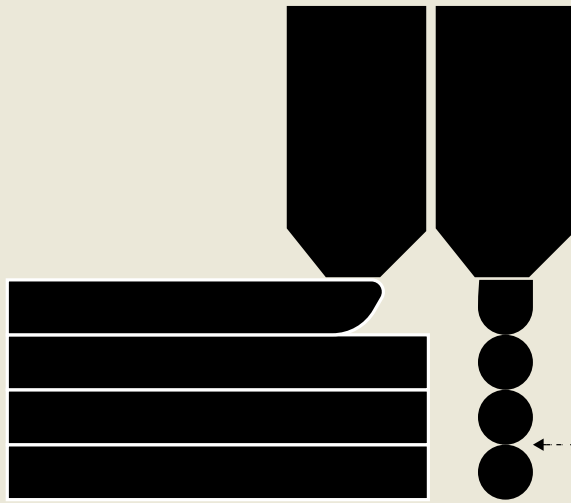
Angle of 30 degrees as boundary condition for 3D print of designs.
Simulation show which toolpath is better suited for the printing process with the 6DOF





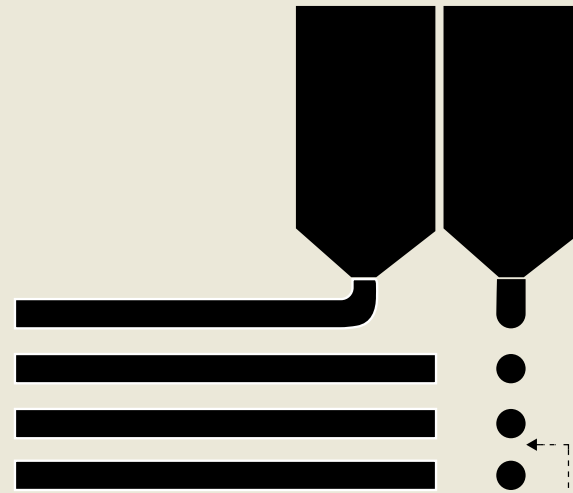
PROTOTYPES

40x10mm Nozzle Printing at 10mm Layer Height



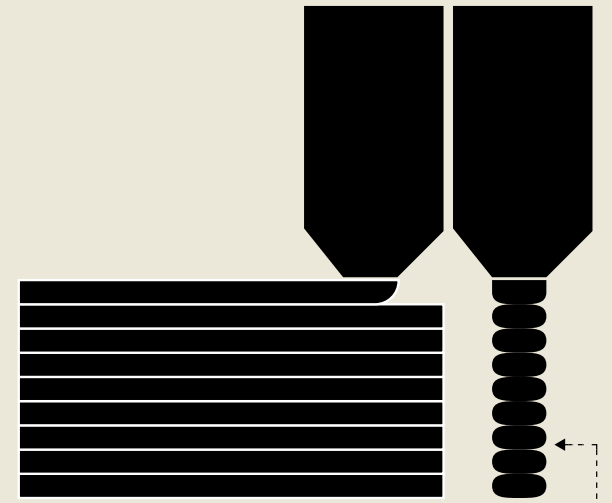
Layers just touching each other create weak joints. Difficult to bind together.

10x5mm Nozzle Printing at 10mm Layer Height



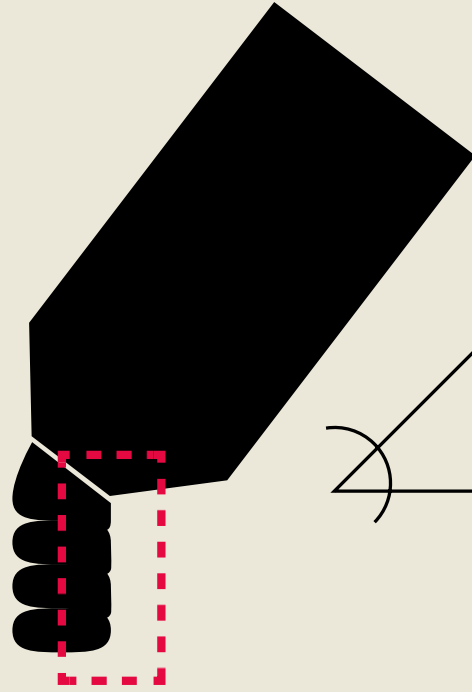
Layers too far apart to touch causes an error in the integrity of the print.

40x10mm Nozzle Printing at 5mm Layer Height



Lower layer height allows for layers to merge into each other forming strong joints.

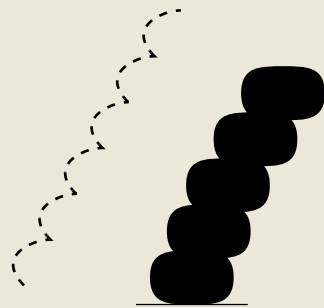
NOZZLE SIZE AND LAYER HEIGHT



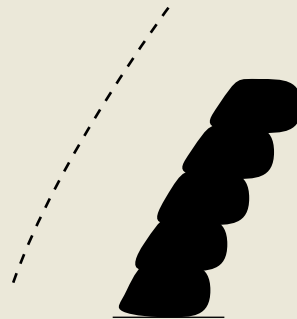
- Angle of End Effector
- Design Effects
 - Structural Effects

ANGLE EFFECTS

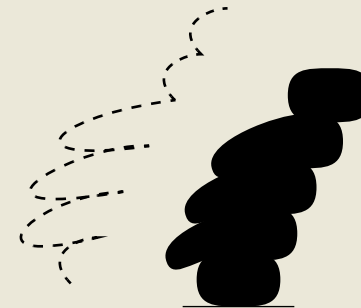
Seams and Texture



Seams visible!

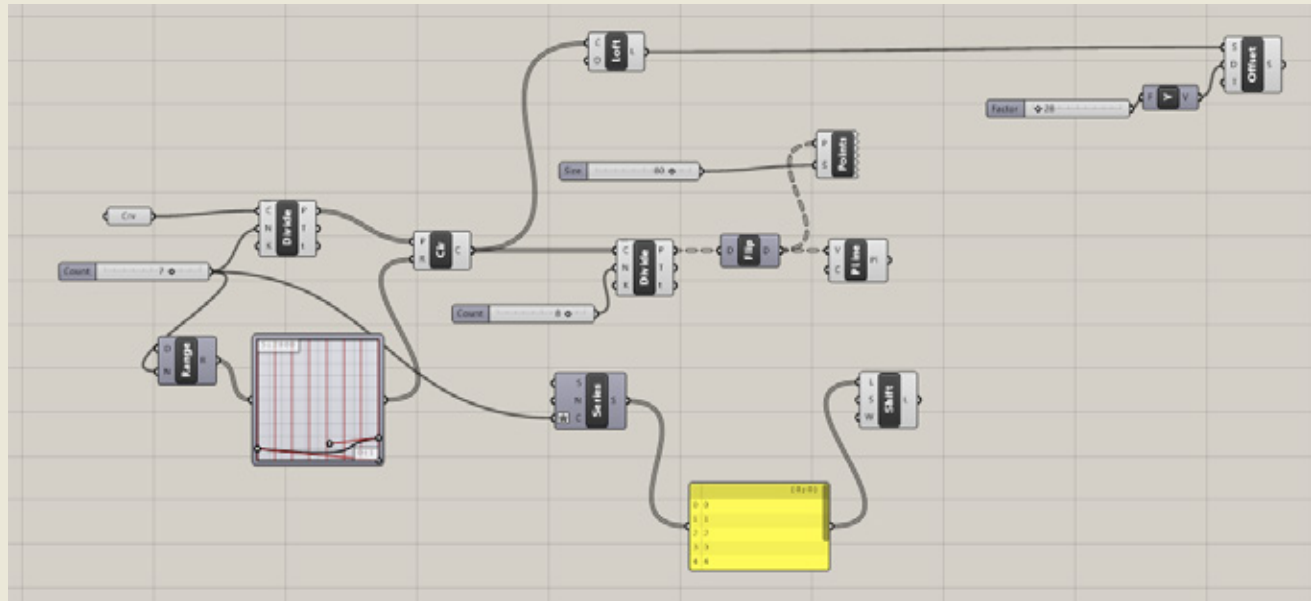
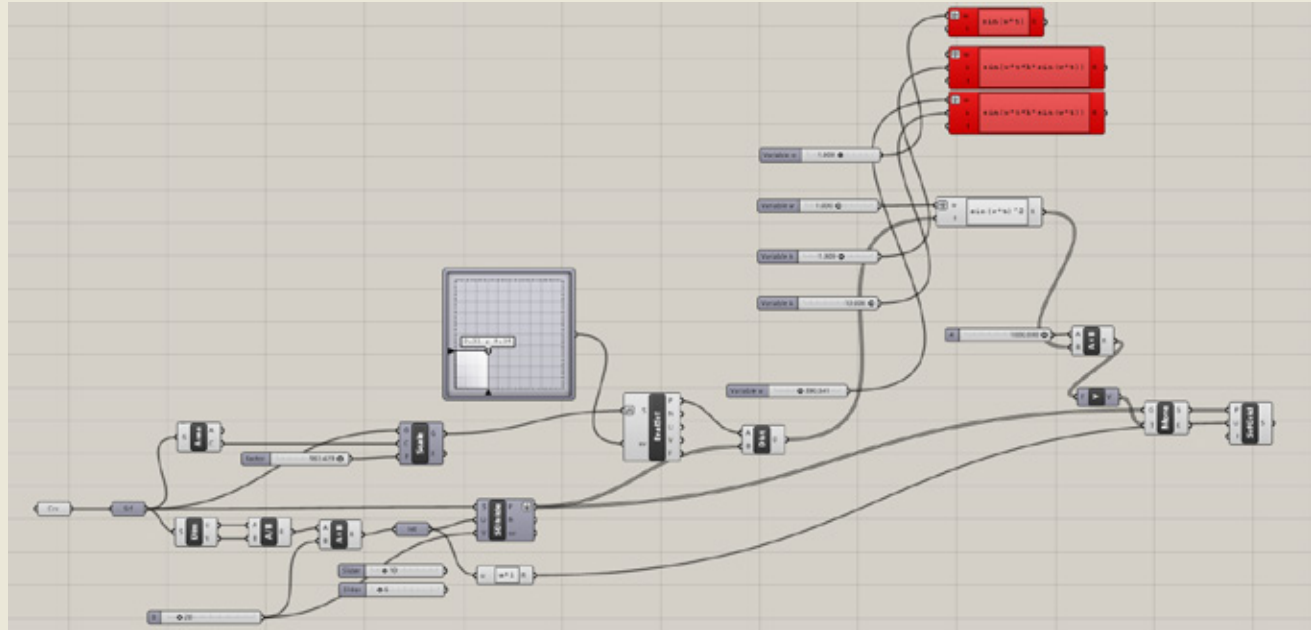
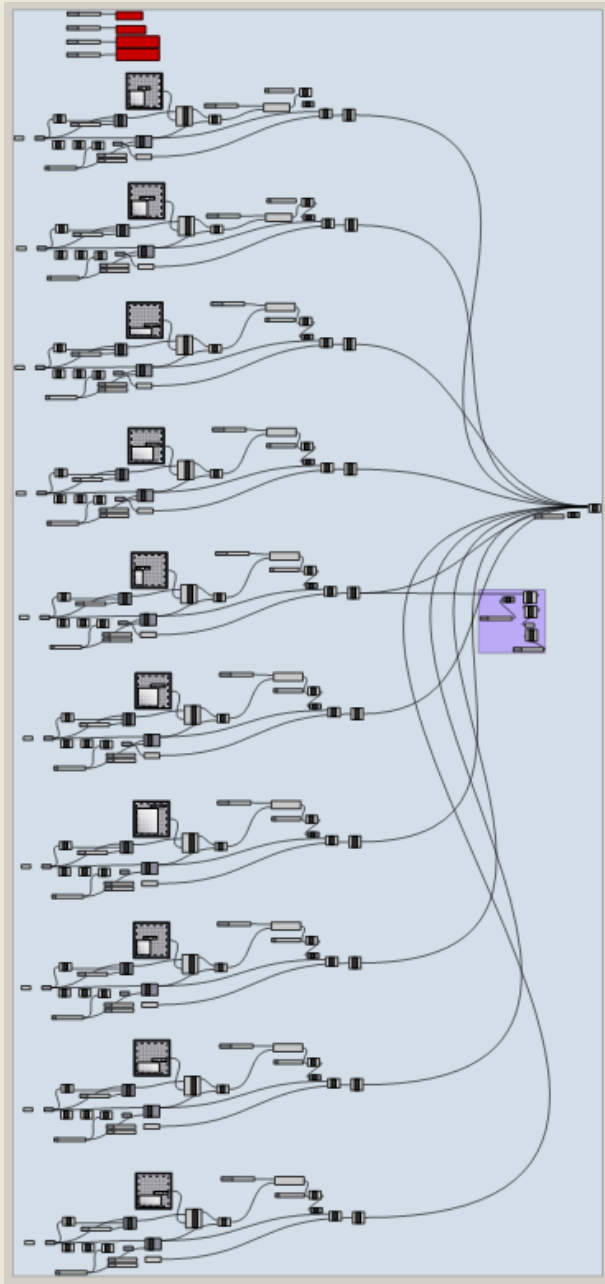


Seams less visible



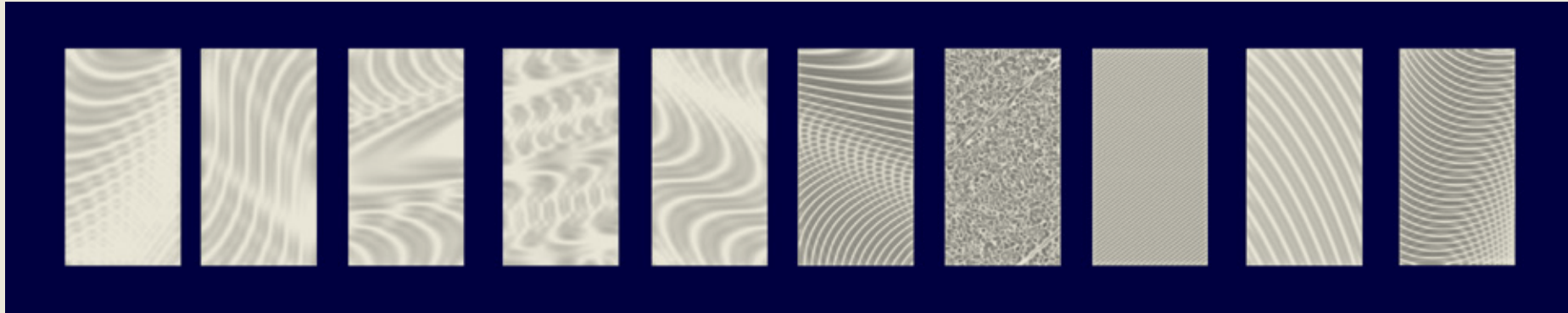
Seams very visible

SURFACE DESIGN



Parametric design script for form-finding and printability boundary conditions

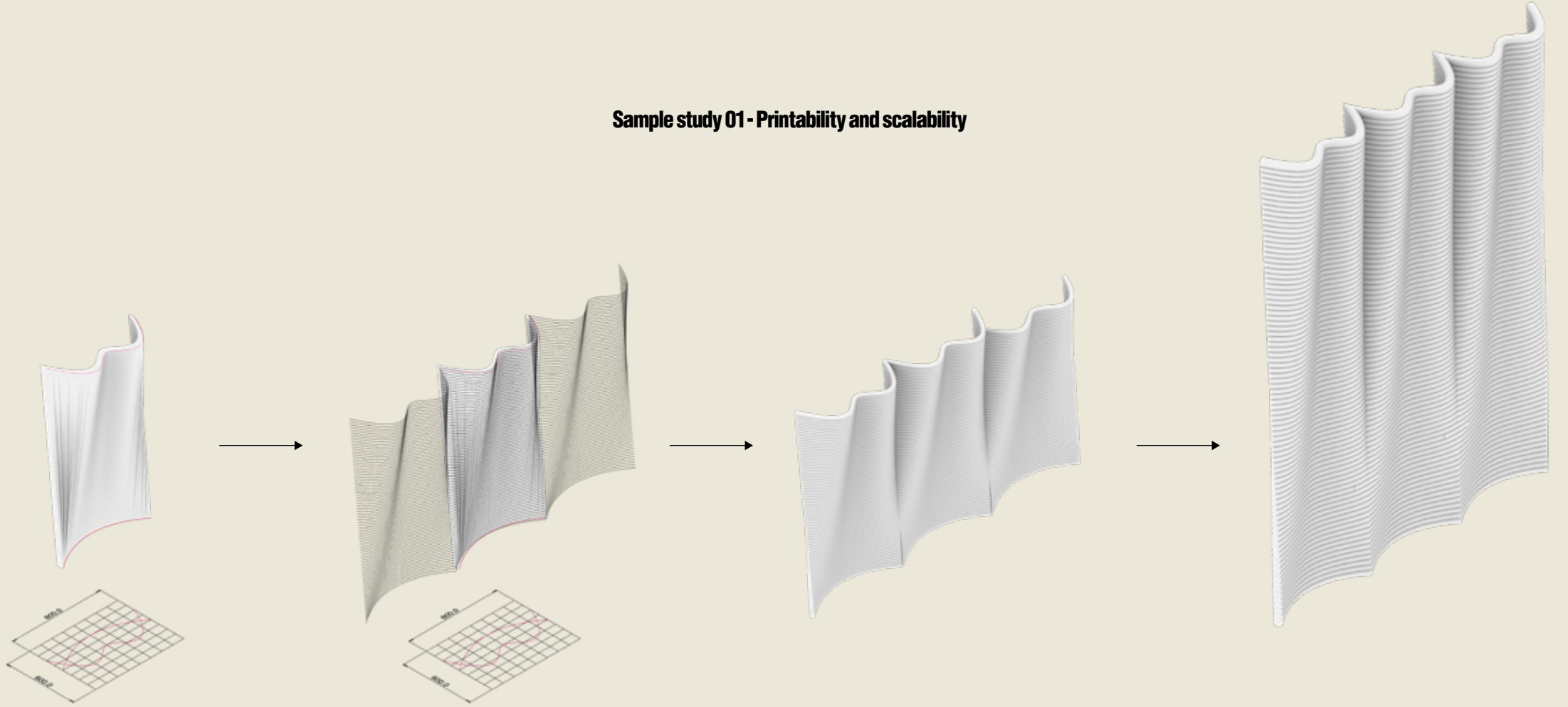
Finishing surface textures



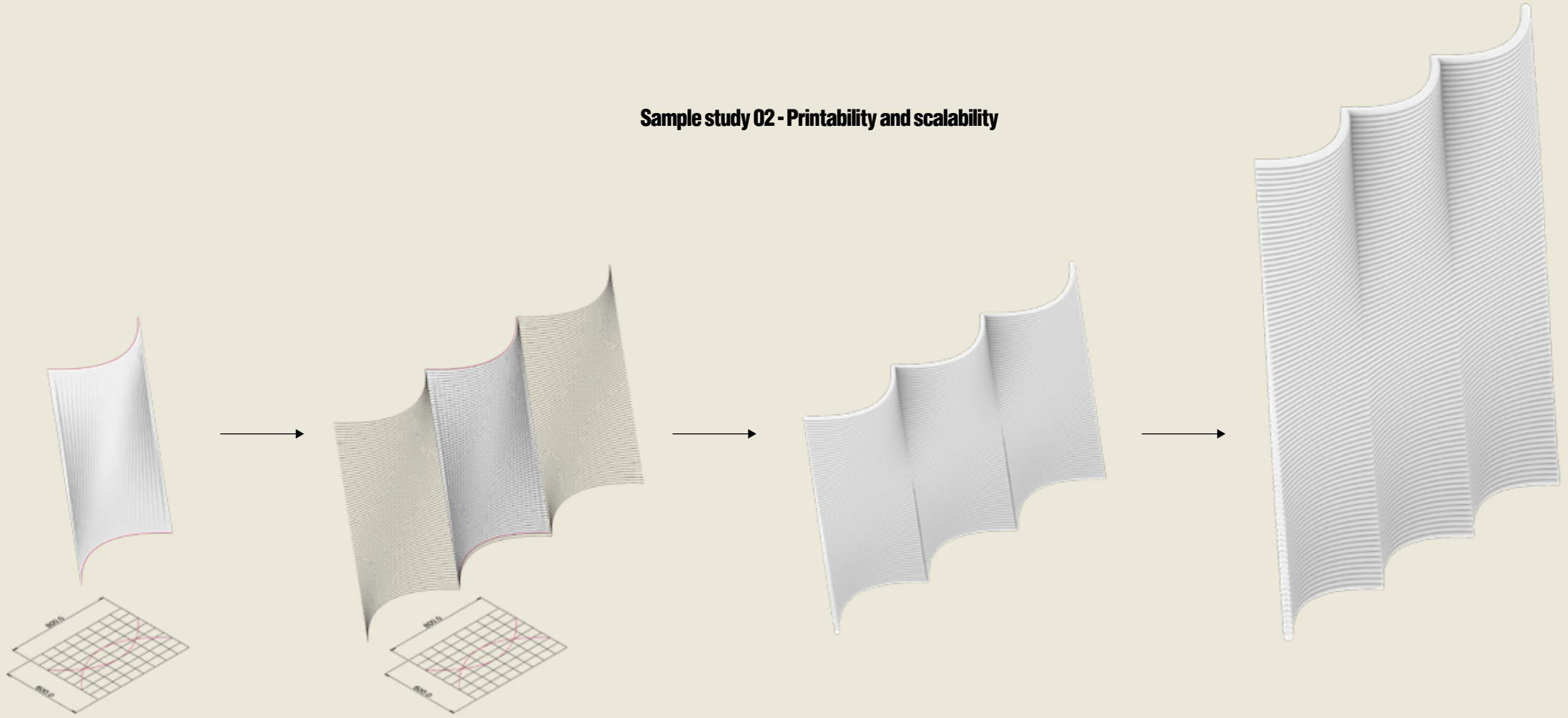


Sample study - Printability: Angle of print + Layering

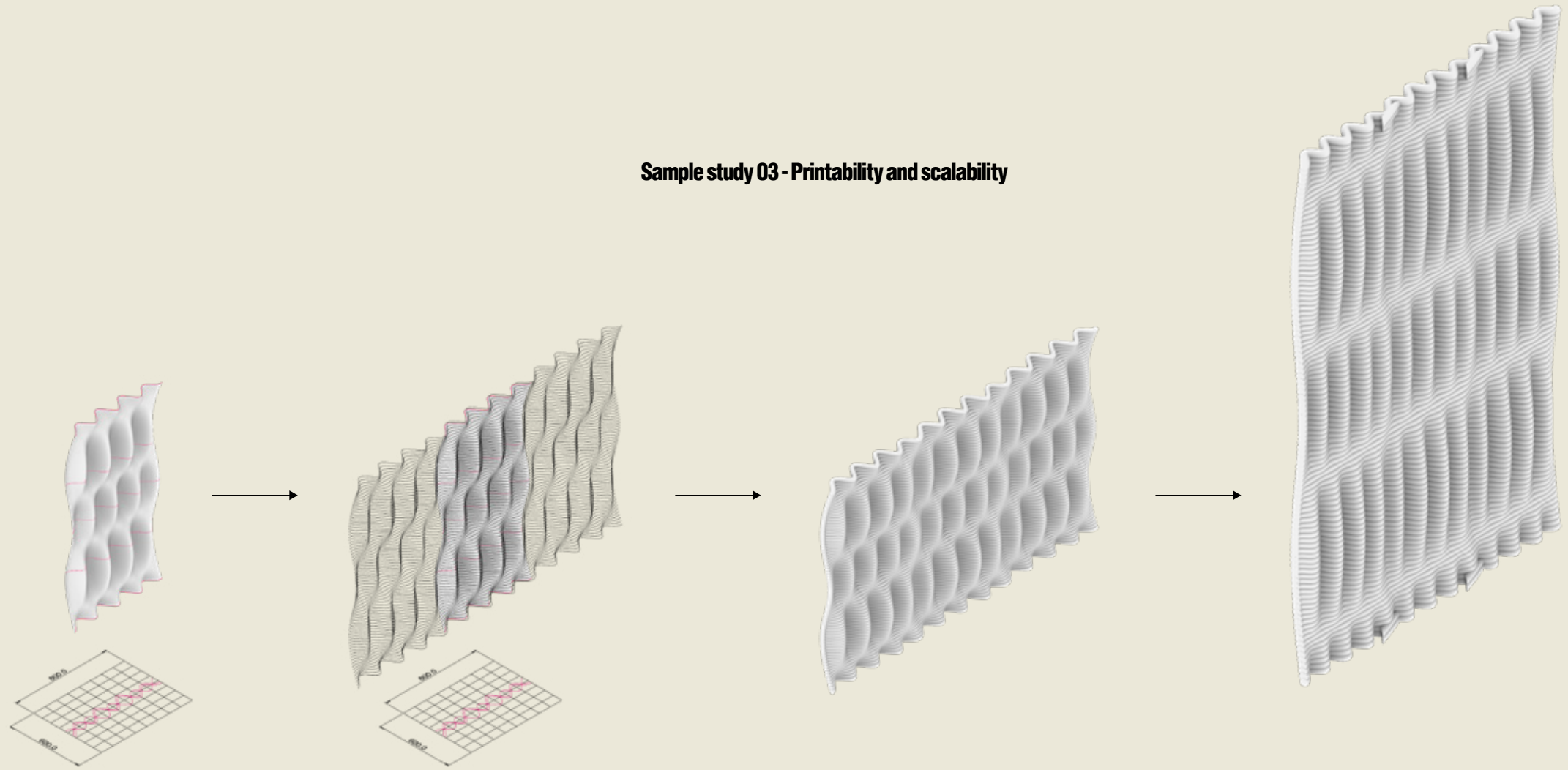
Sample study 01 - Printability and scalability



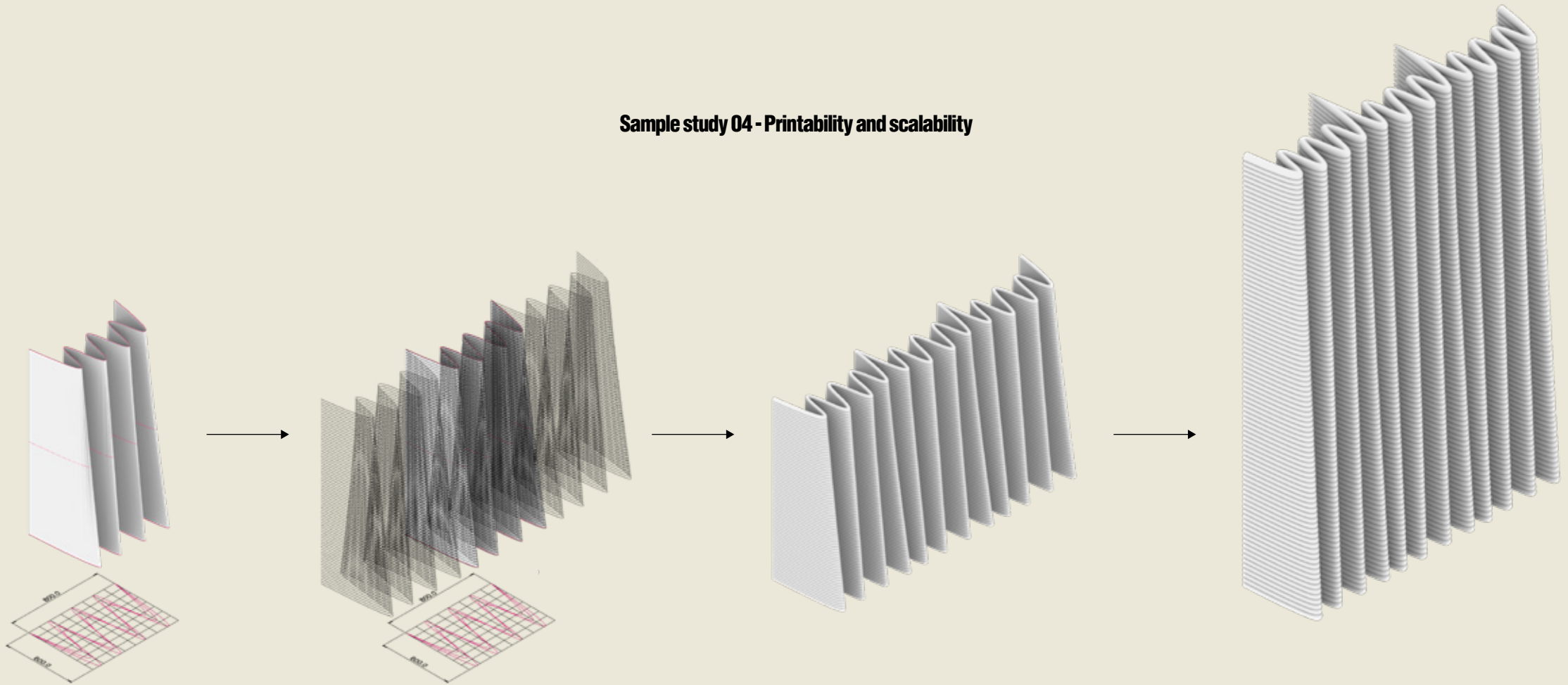
Sample study 02 - Printability and scalability



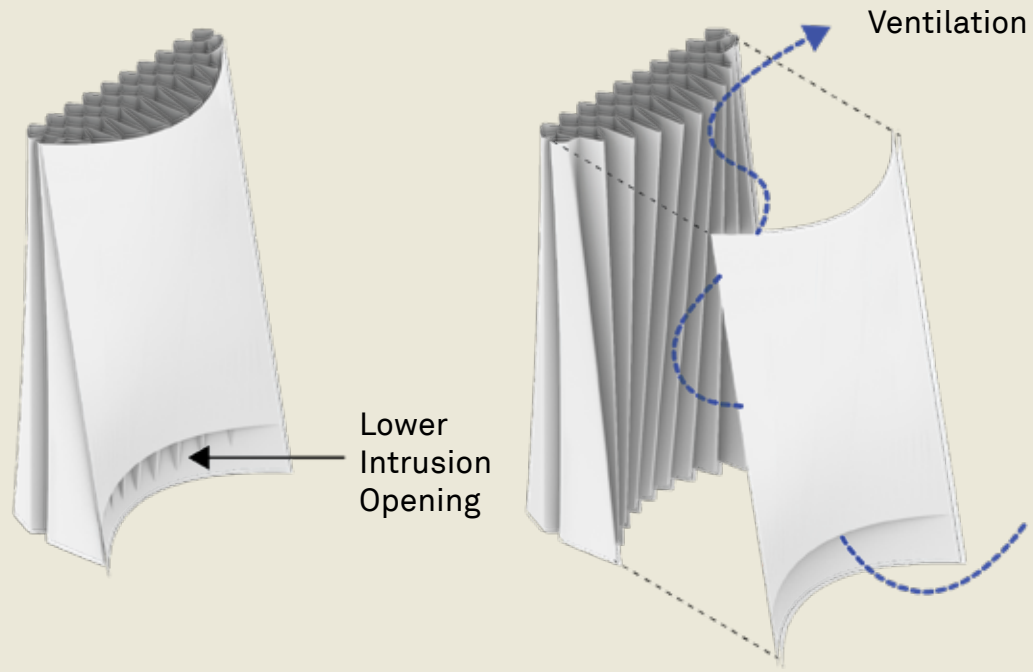
Sample study 03 - Printability and scalability

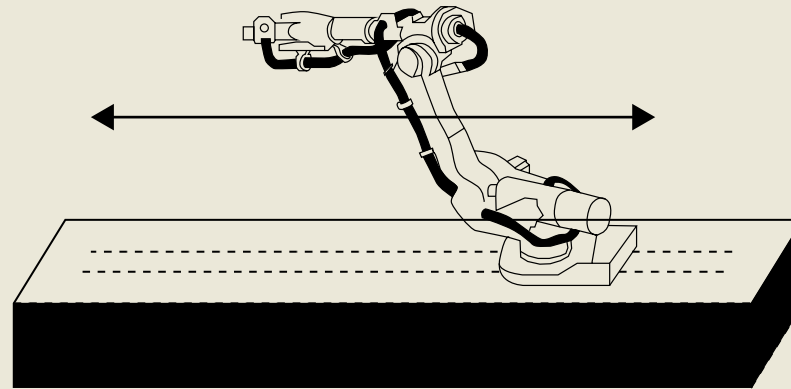
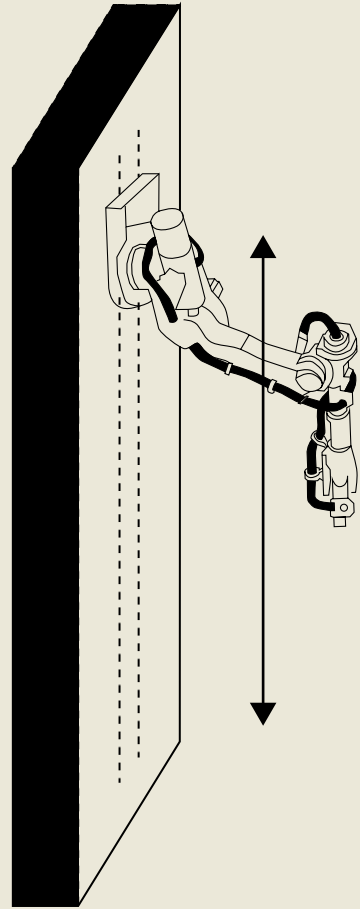


Sample study 04 - Printability and scalability

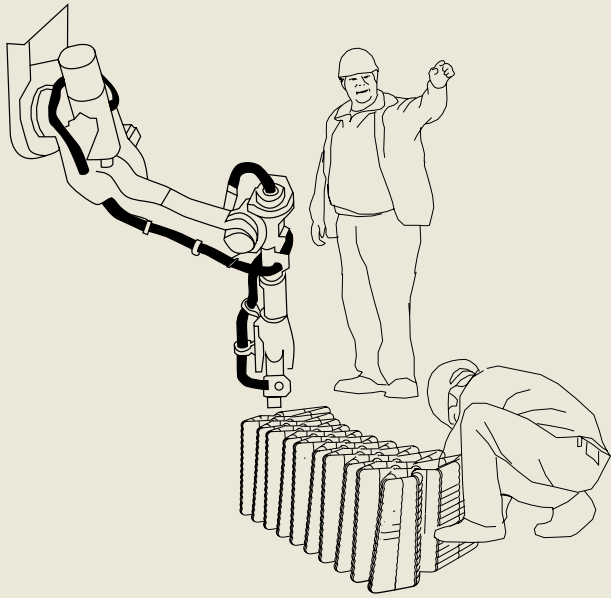


Sample study 02

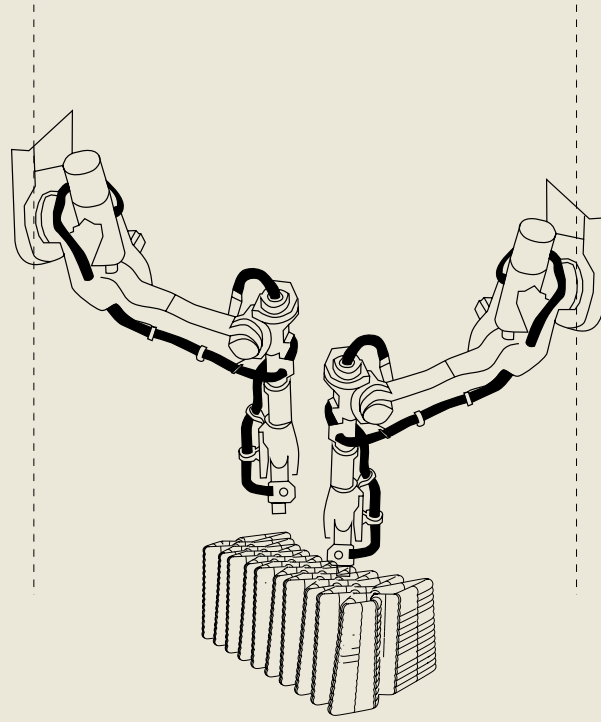




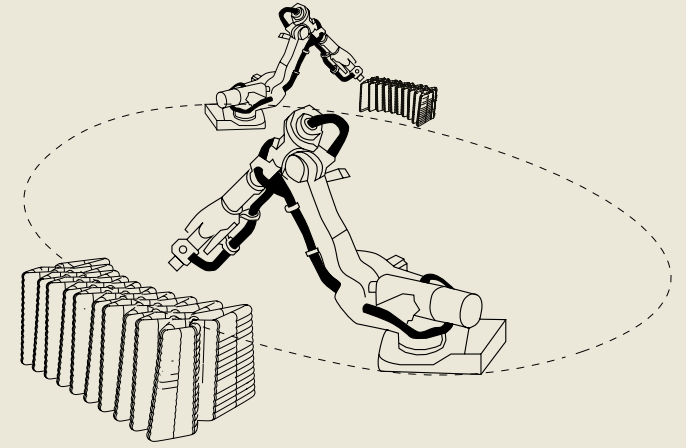
ROBOTIC AXES



Standard
Robot - worker collaboration



Vertical
Robot - robot collaboration

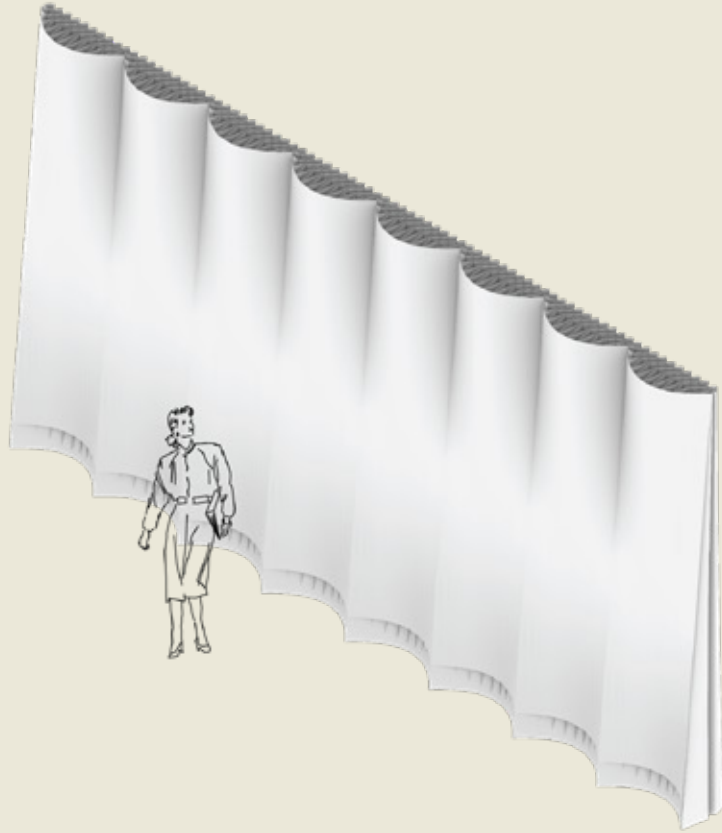


Horizontal
Robot - robot collaboration

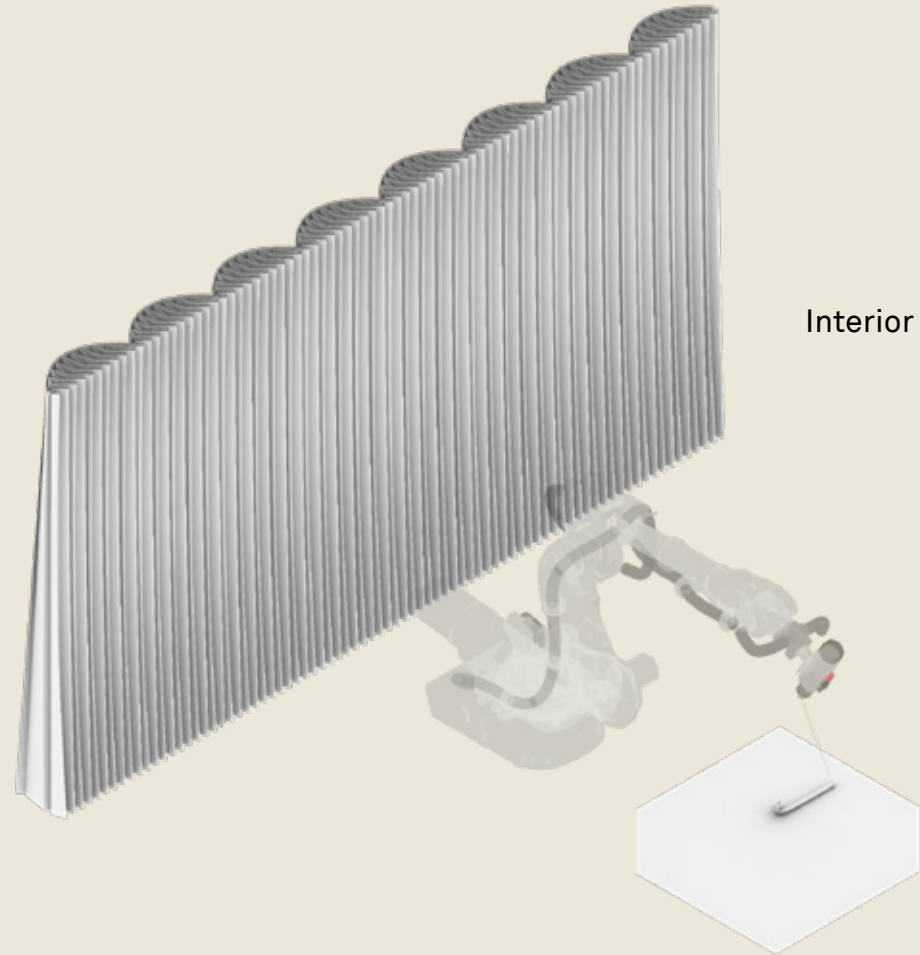
3D PRINTING AND INSULATING

Sample study 02

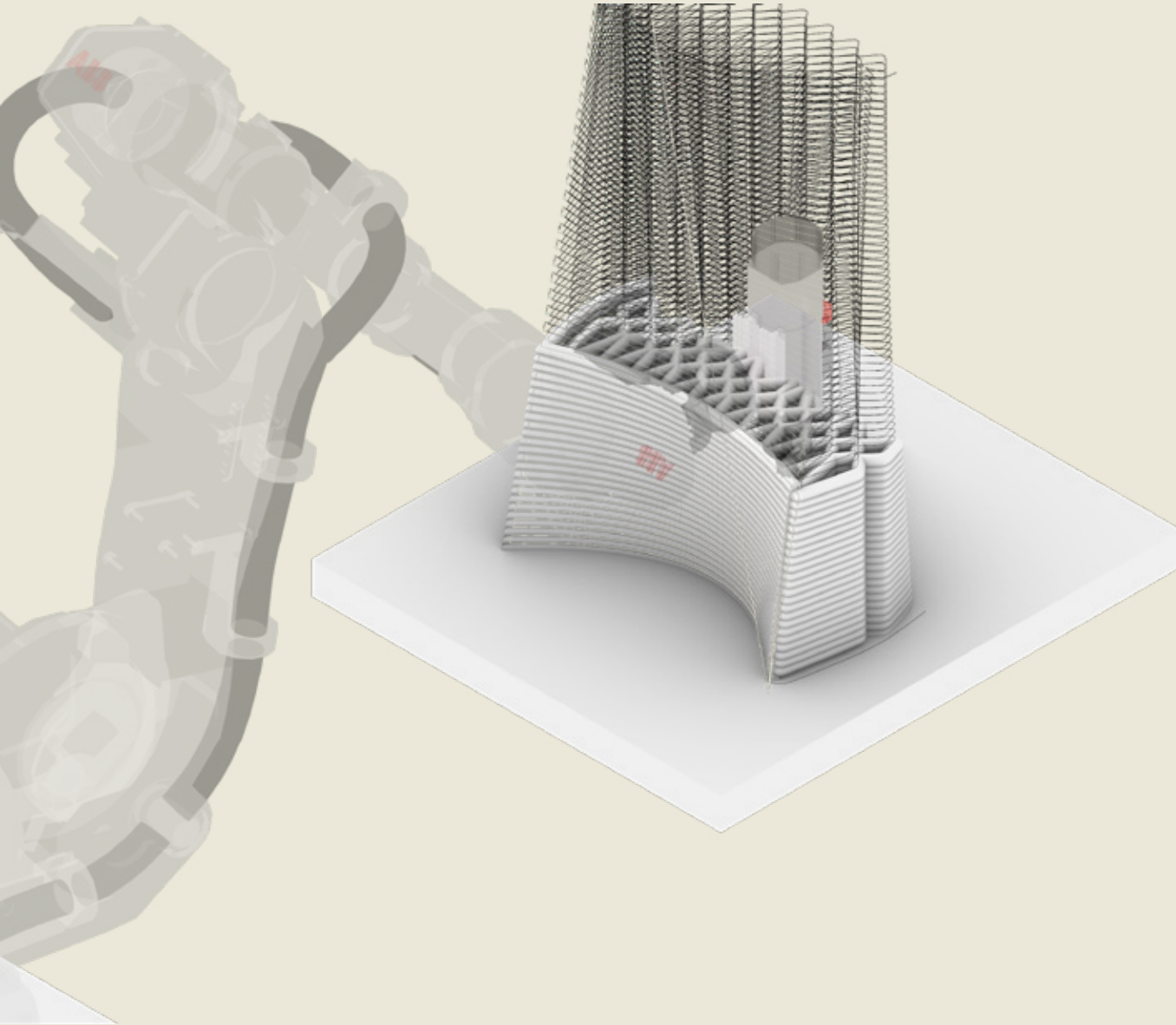
Exterior



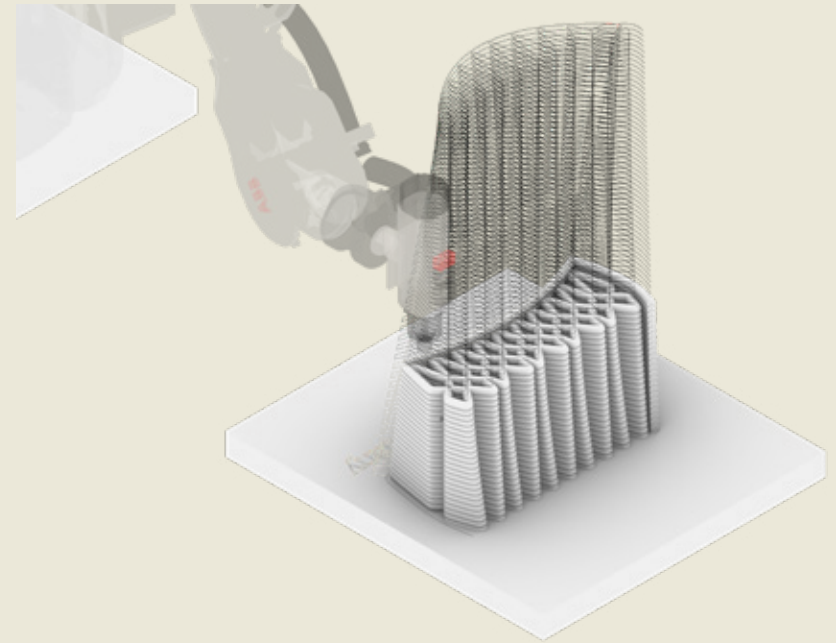
Interior



Printing process - exterior



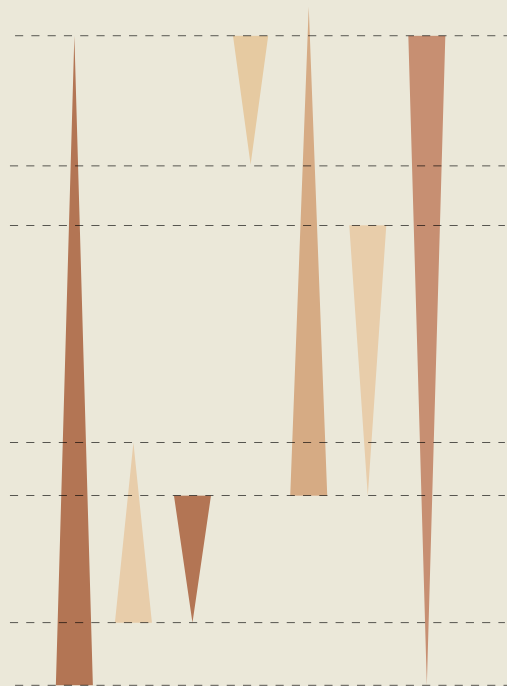
Printing process - interior



Side Elevation



Front Elevation



COLOR CONTROL



Materiality in 3D print





Material sampling
- colors, textures, finishings



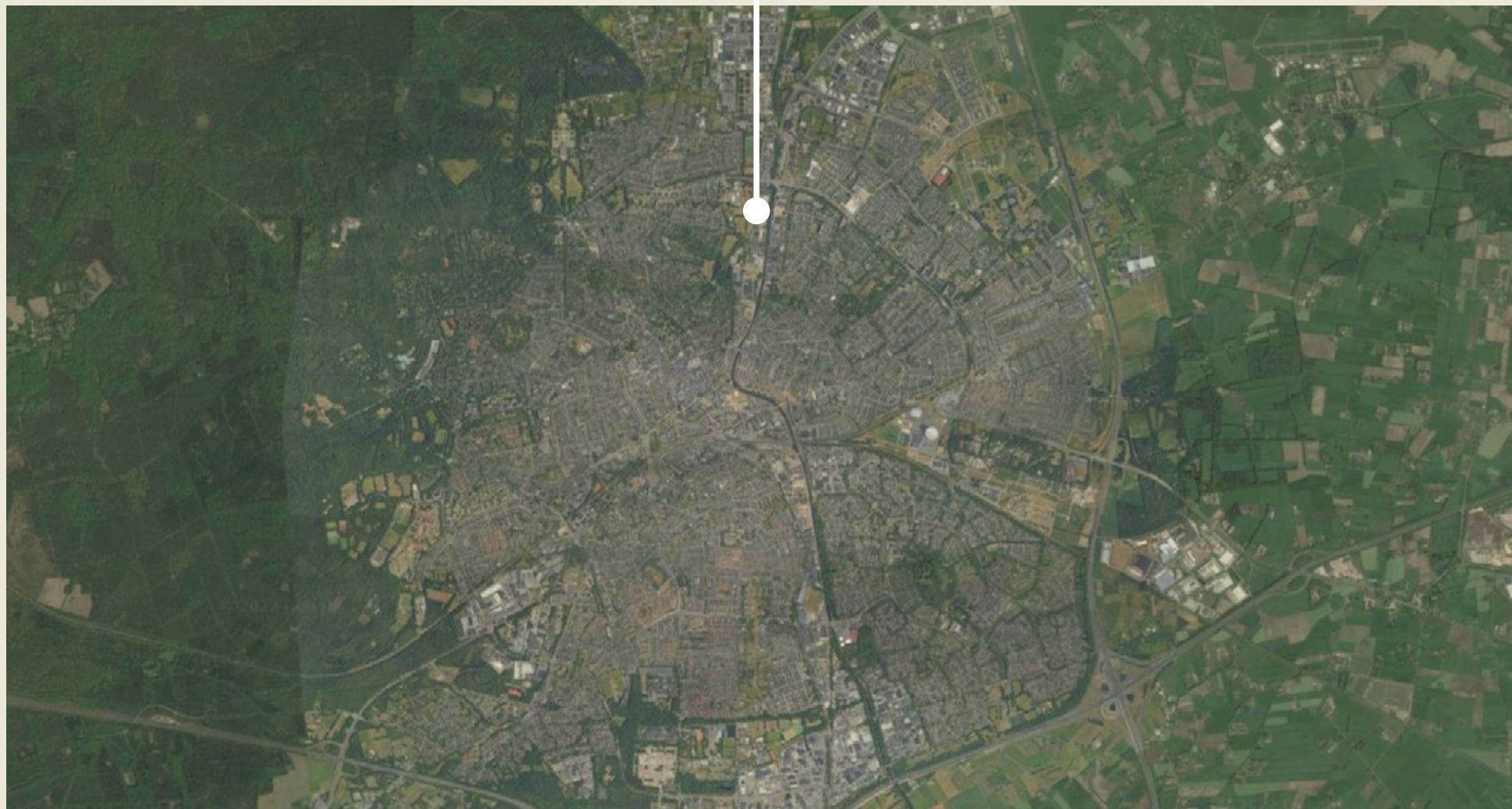
ZWITSAL, APELDOORN



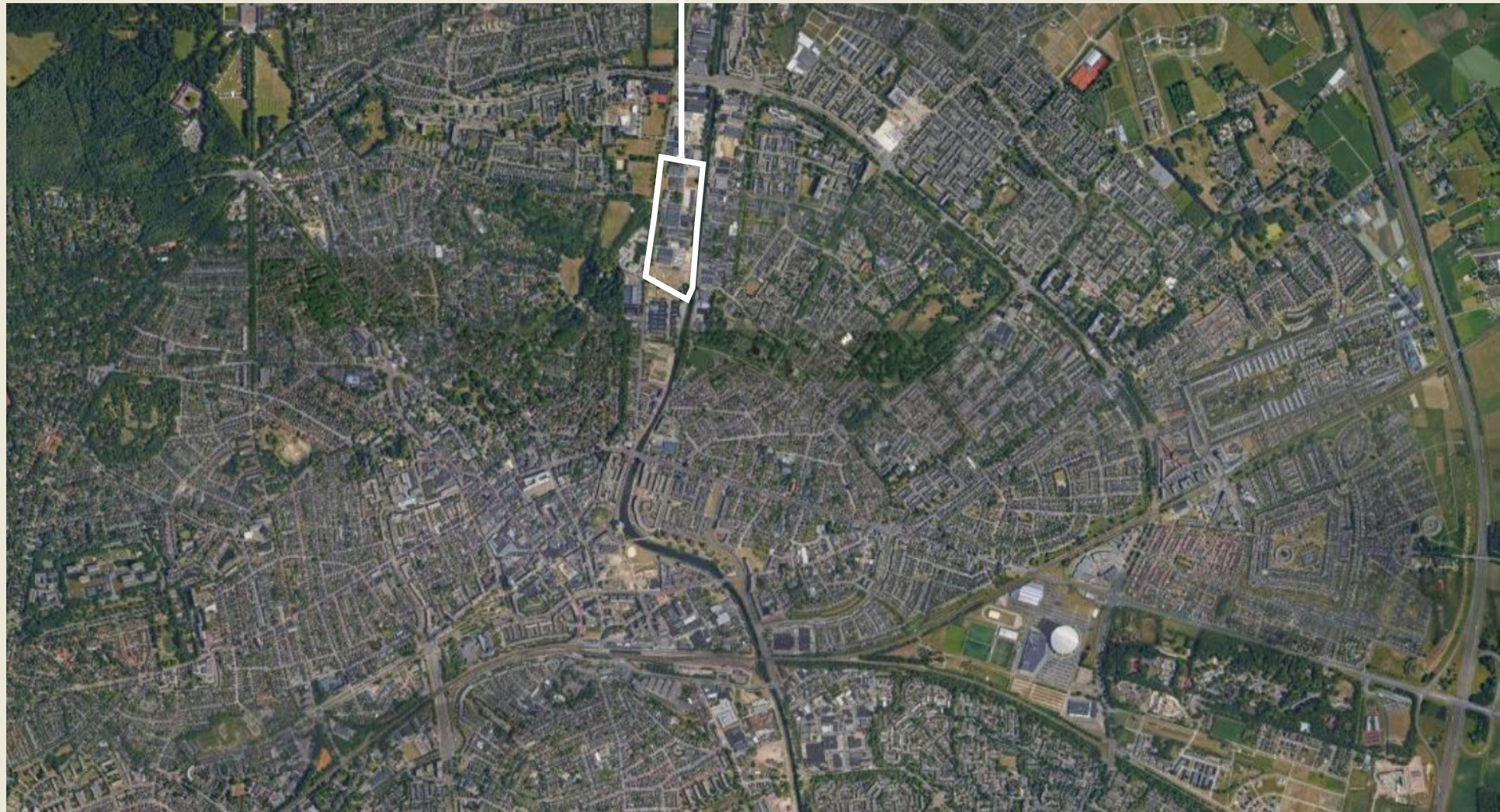
Apeldoorn

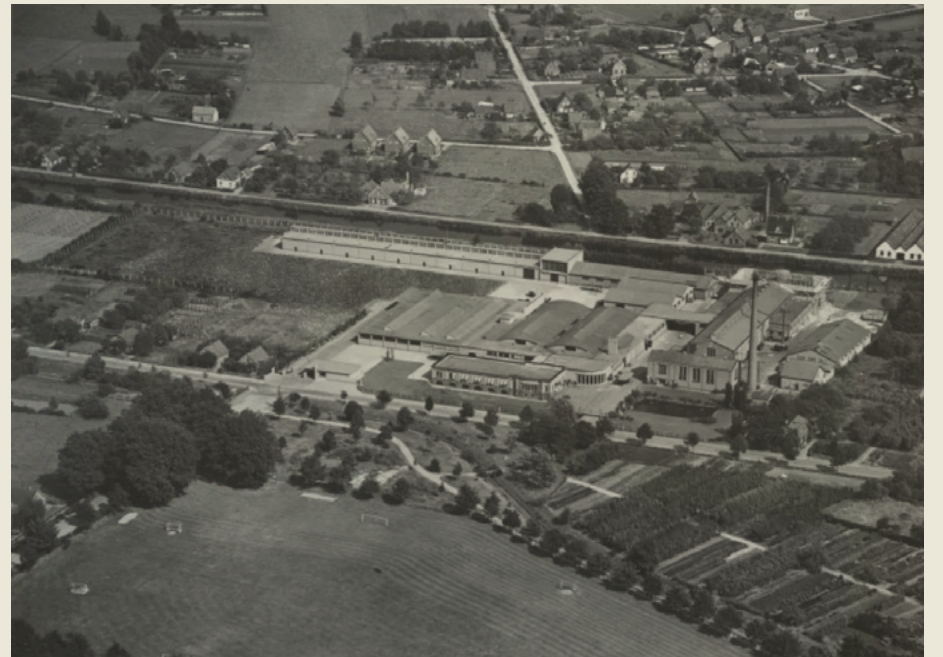


Zwitsal, brownfield along the canal



North of the city center

















Former industrial factory district into
the new heart of the city Apeldoorn.

APELDOORN VISION:

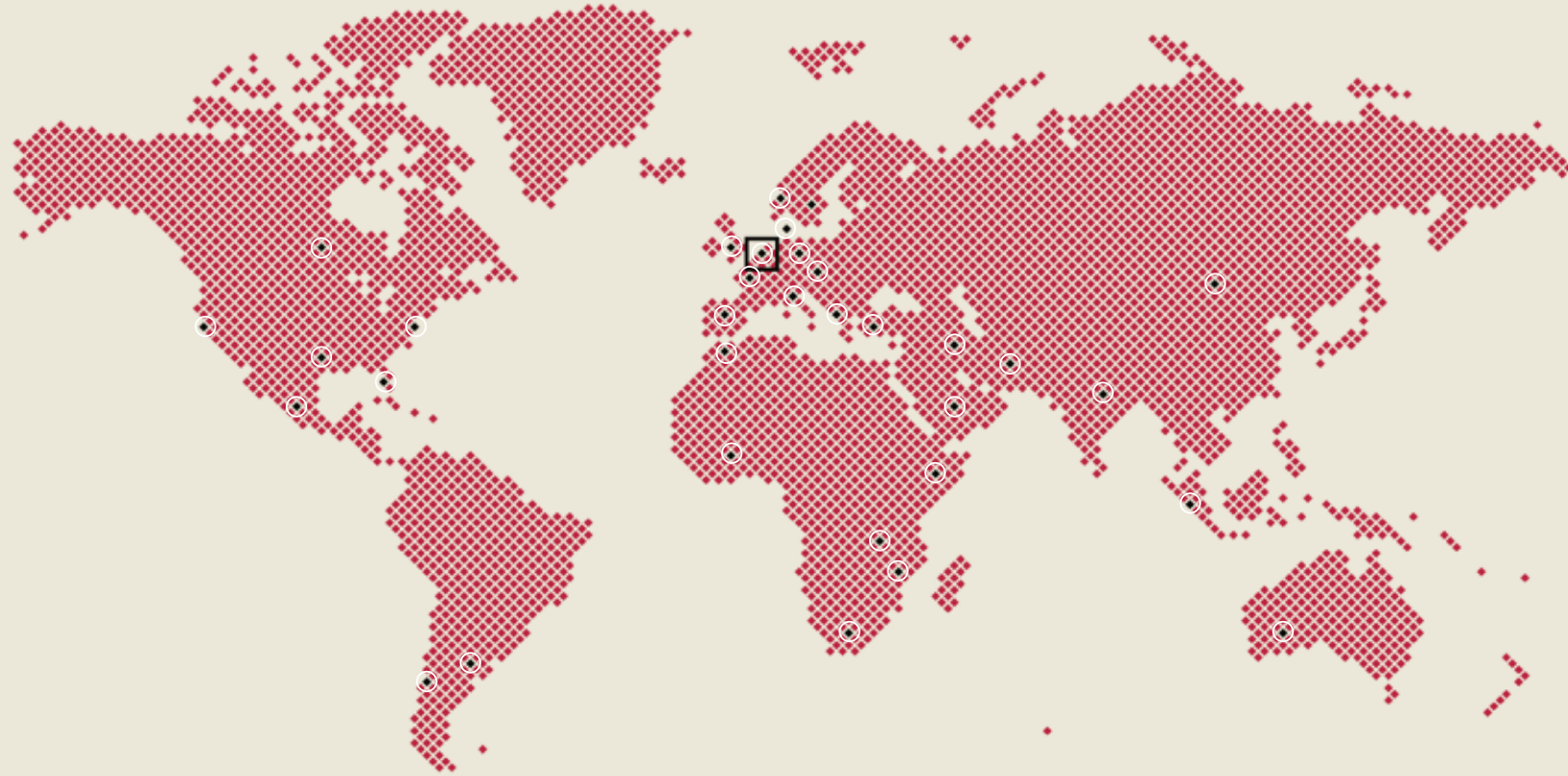
Live, play, experience, create

Desired functions like:

- Residential
- Commercial
- Horeca
- Education
- Innovation
- Culture

ZWITSAL Brownfield
A NEW CIRCULAR TECH-HUB FOR THE CITY

Global waste upcycling network



Global upcycling networks



Regional positioning

2022



2028



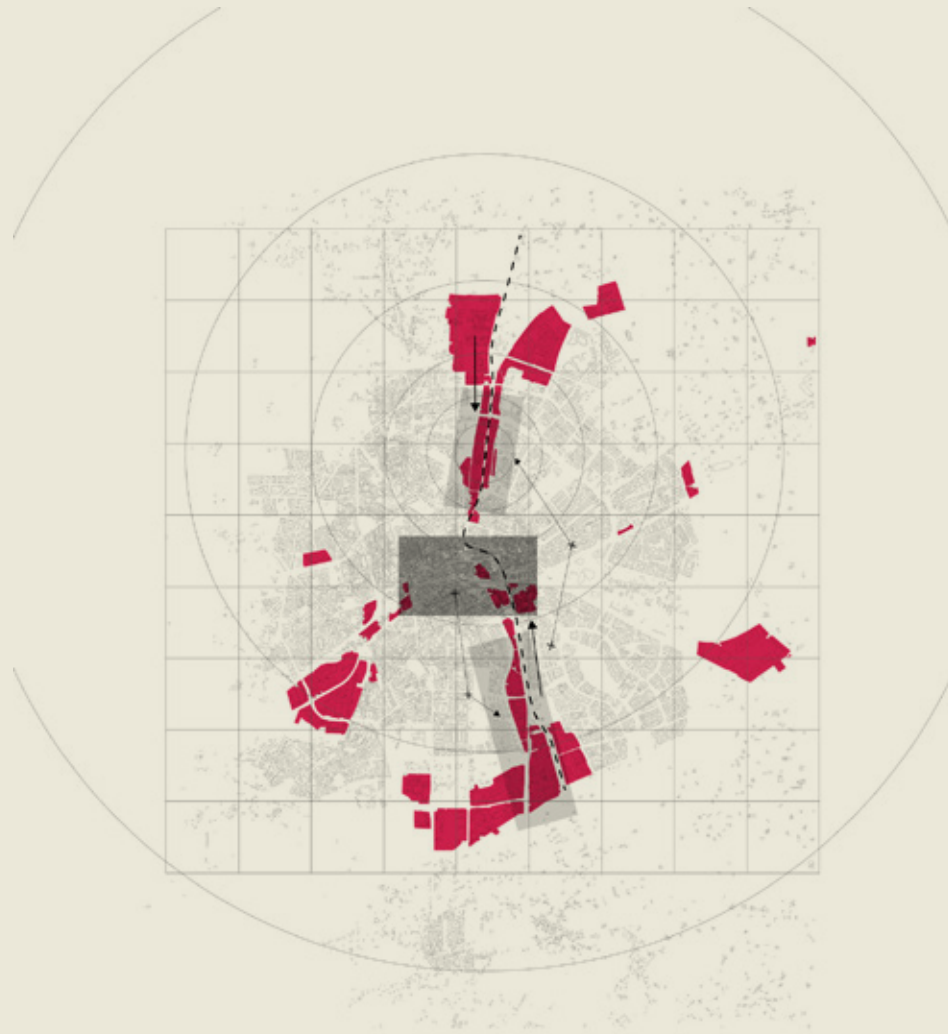
2034



2040



2040 Ambition of Apeldoorn



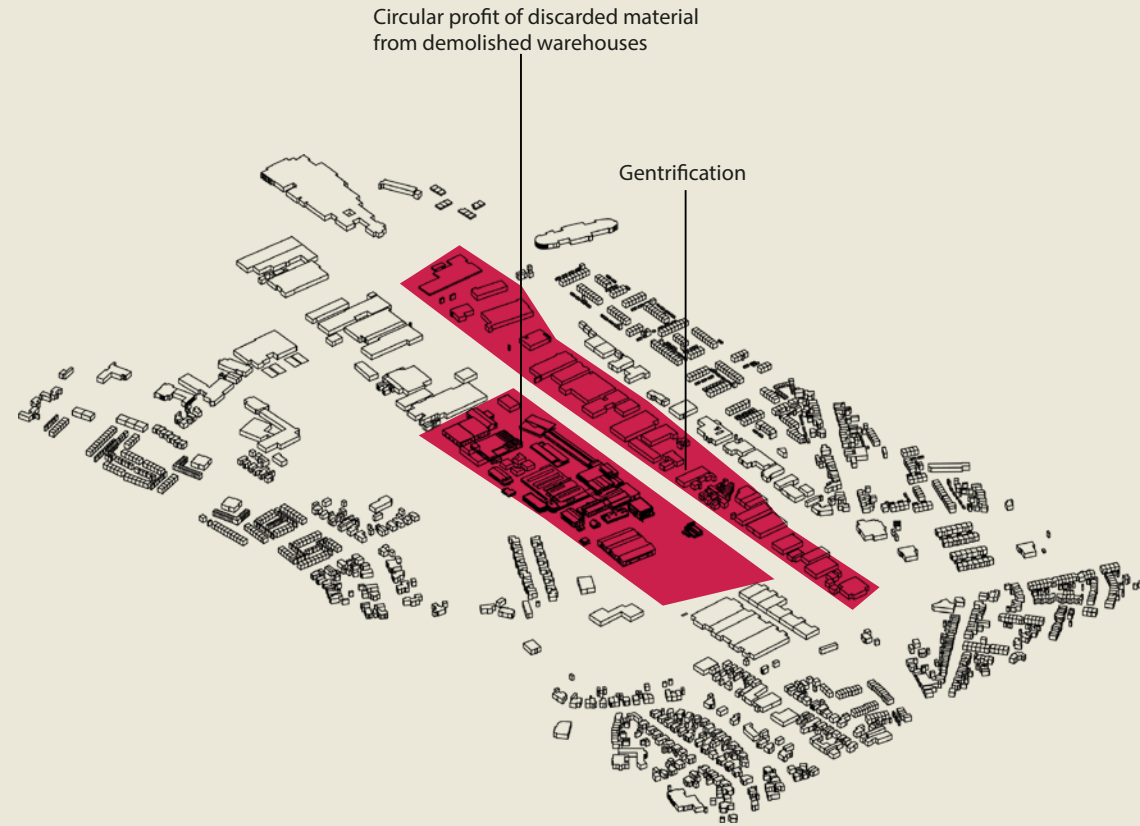
Existing urban fabric



Local distances

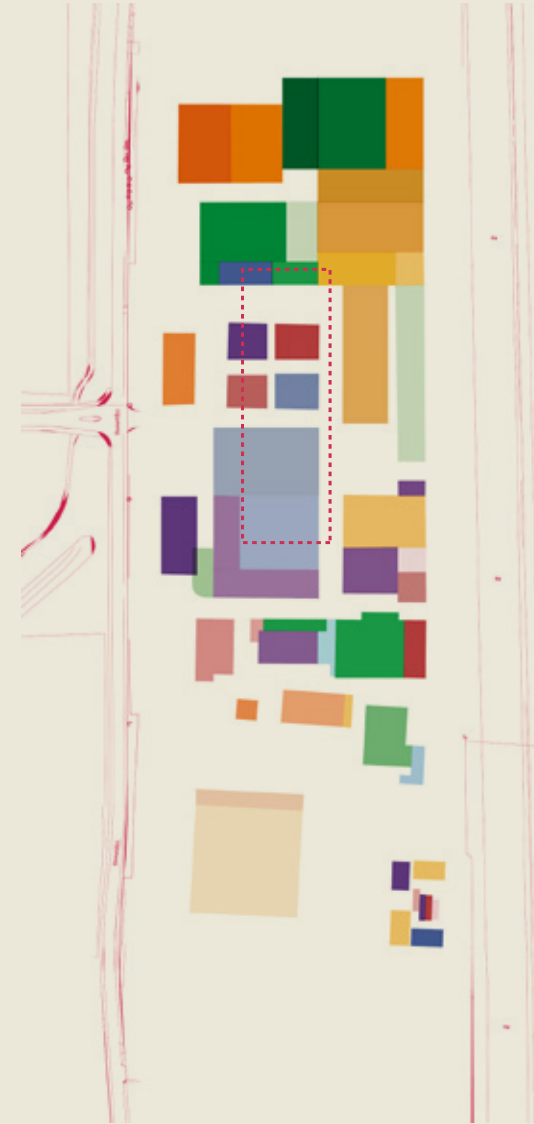
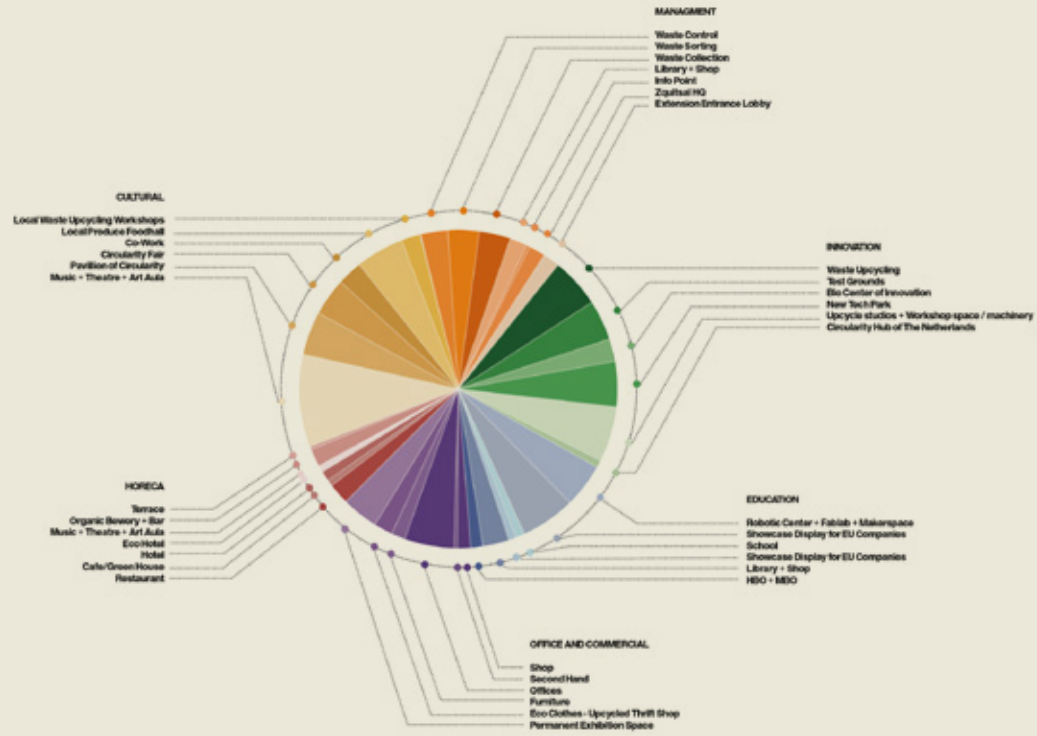


Reactivate canal



Opportunity for the city

Program



Management

- Waste Control
- Waste Sorting
- Waste Collection
- Library + Shop
- Info Point
- Zquitsal HQ
- Extension Entrance Lobby

Innovation

- Waste Upcycling
- Test Grounds
- Bio Center of Innovation
- New Tech Park
- Upcycle studios + Workshop space / machinery
- Circularity Hub of The Netherlands

Education

- Robotic Center + Fablab + Makerspace
- Showcase Display for EU Companies
- School
- Showcase Display for EU Companies
- Library + Shop
- HBO + MBO

Office and Commercial

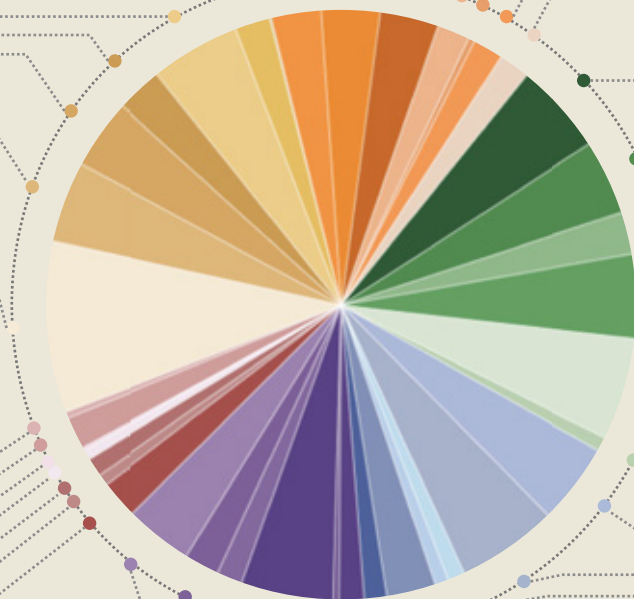
- Shop
- Second Hand
- Offices
- Furniture
- Eco Clothes - Upcycled Thrift Shop
- Permanent Exhibition Space

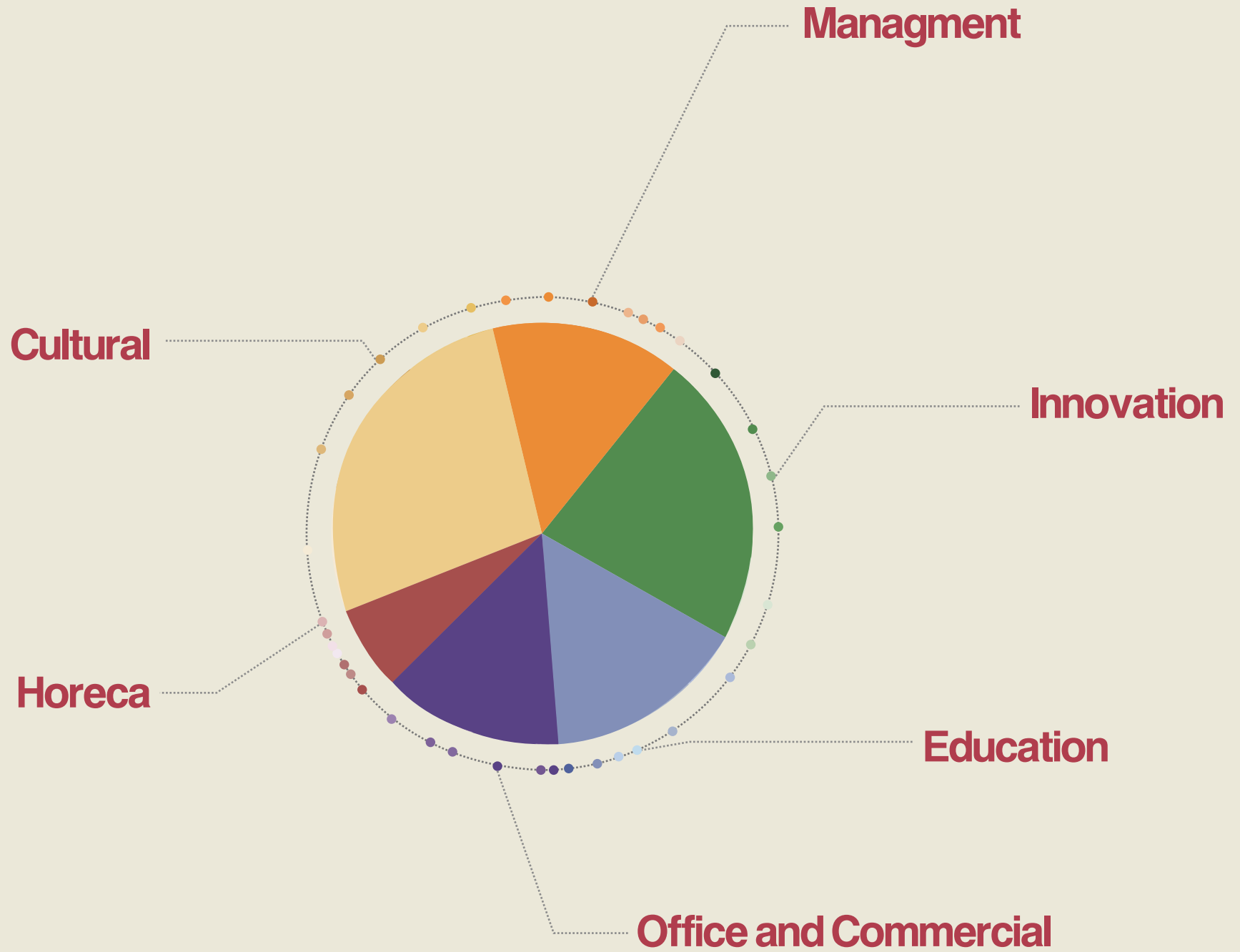
Cultural

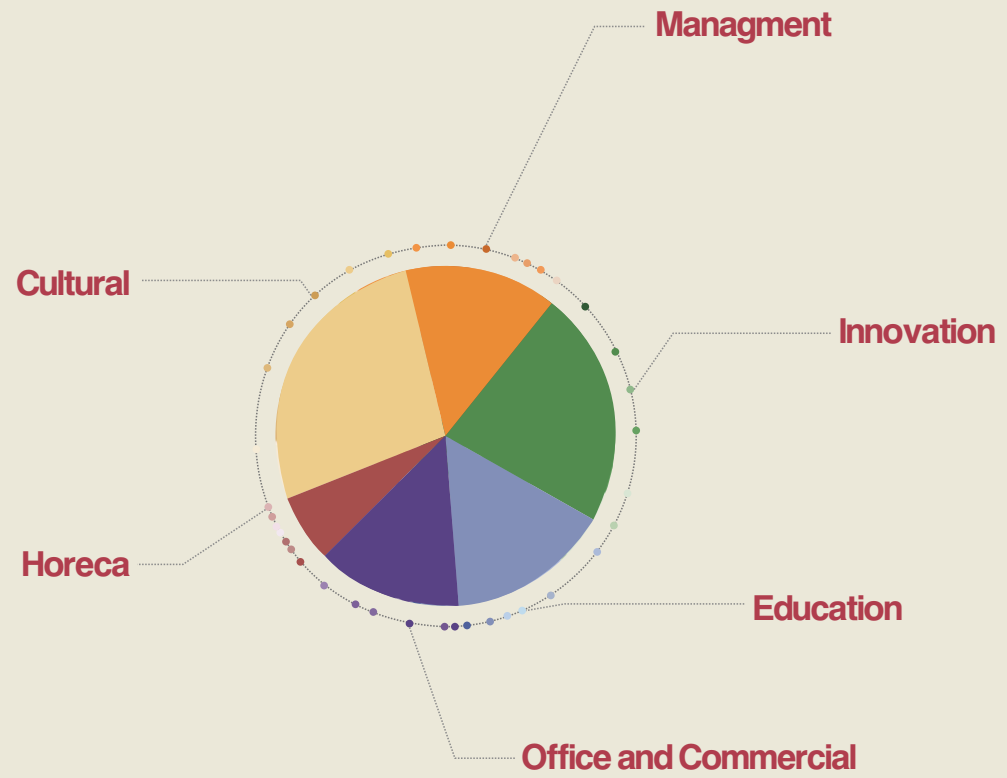
- Local Waste Upcycling Workshops
- Local Produce Foodhall
- Co-Work
- Circularity Fair
- Pavillion of Circularity
- Music + Theatre + Art Aula

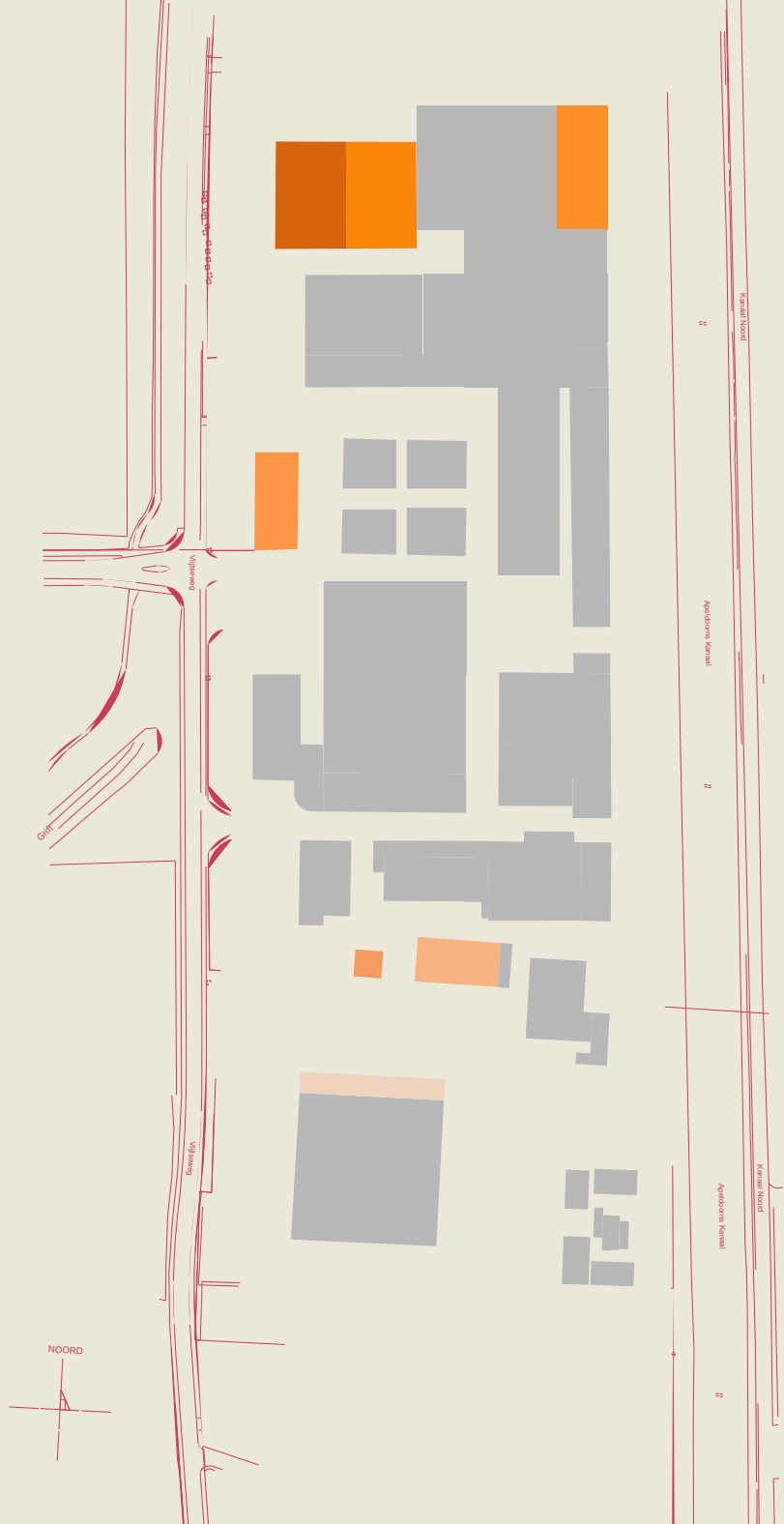
Horeca

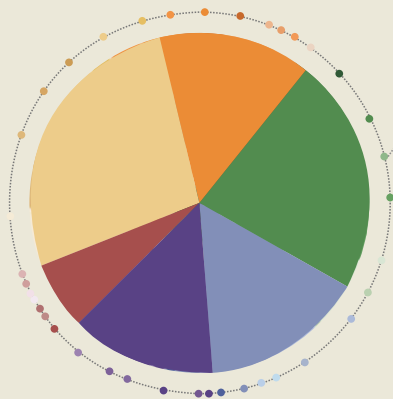
- Terrace
- Organic Bewery + Bar
- Music + Theatre + Art Aula
- Eco Hotel
- Hotel
- Cafe/Green House
- Restaurant





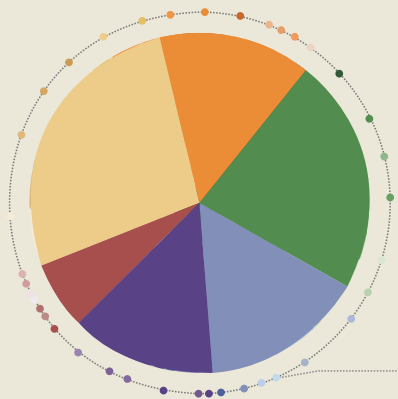






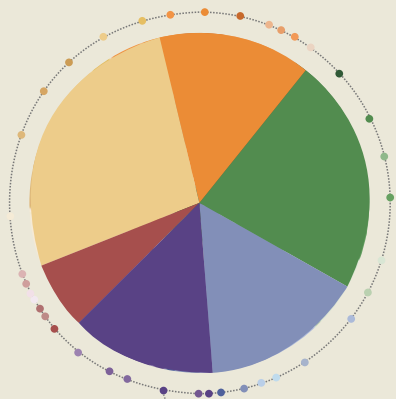
Innovation



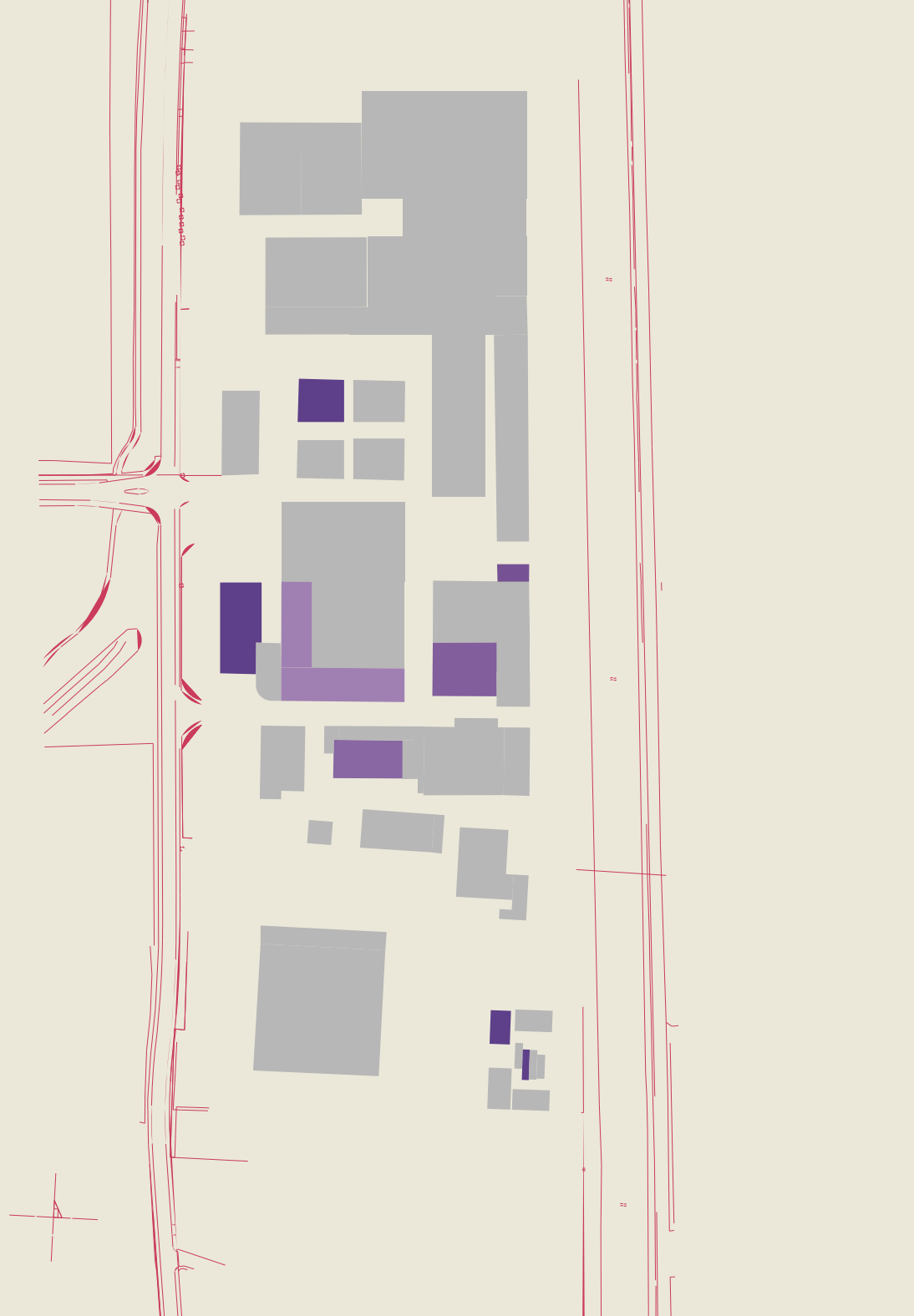


Education

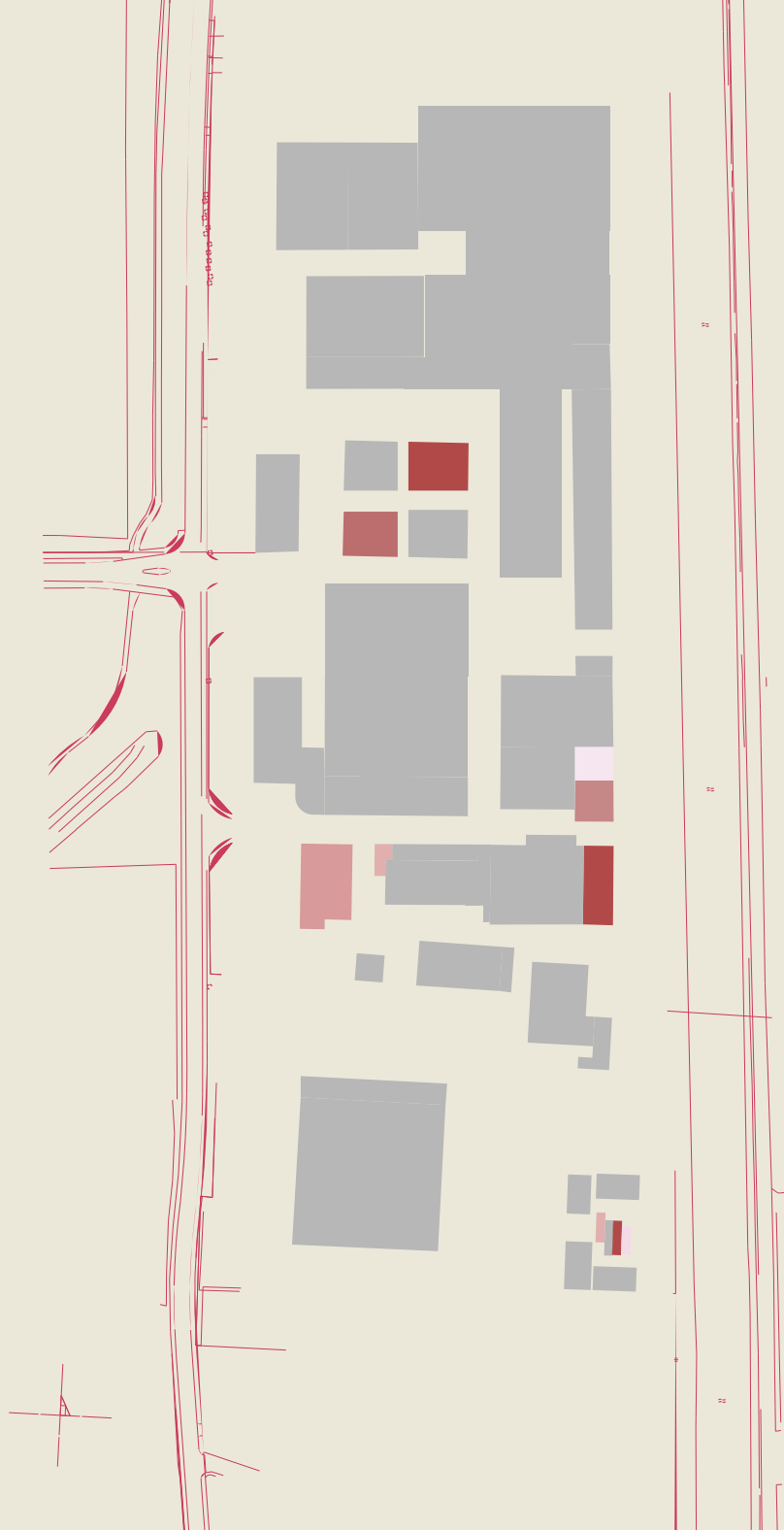
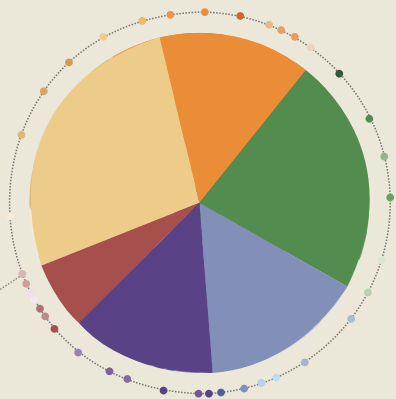




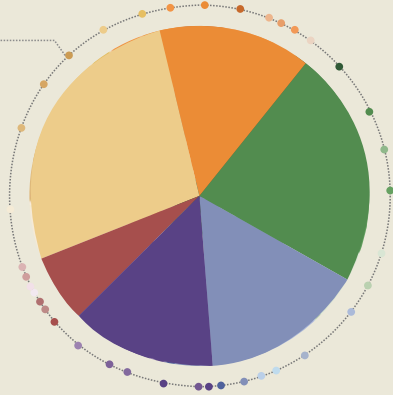
Office and Commercial

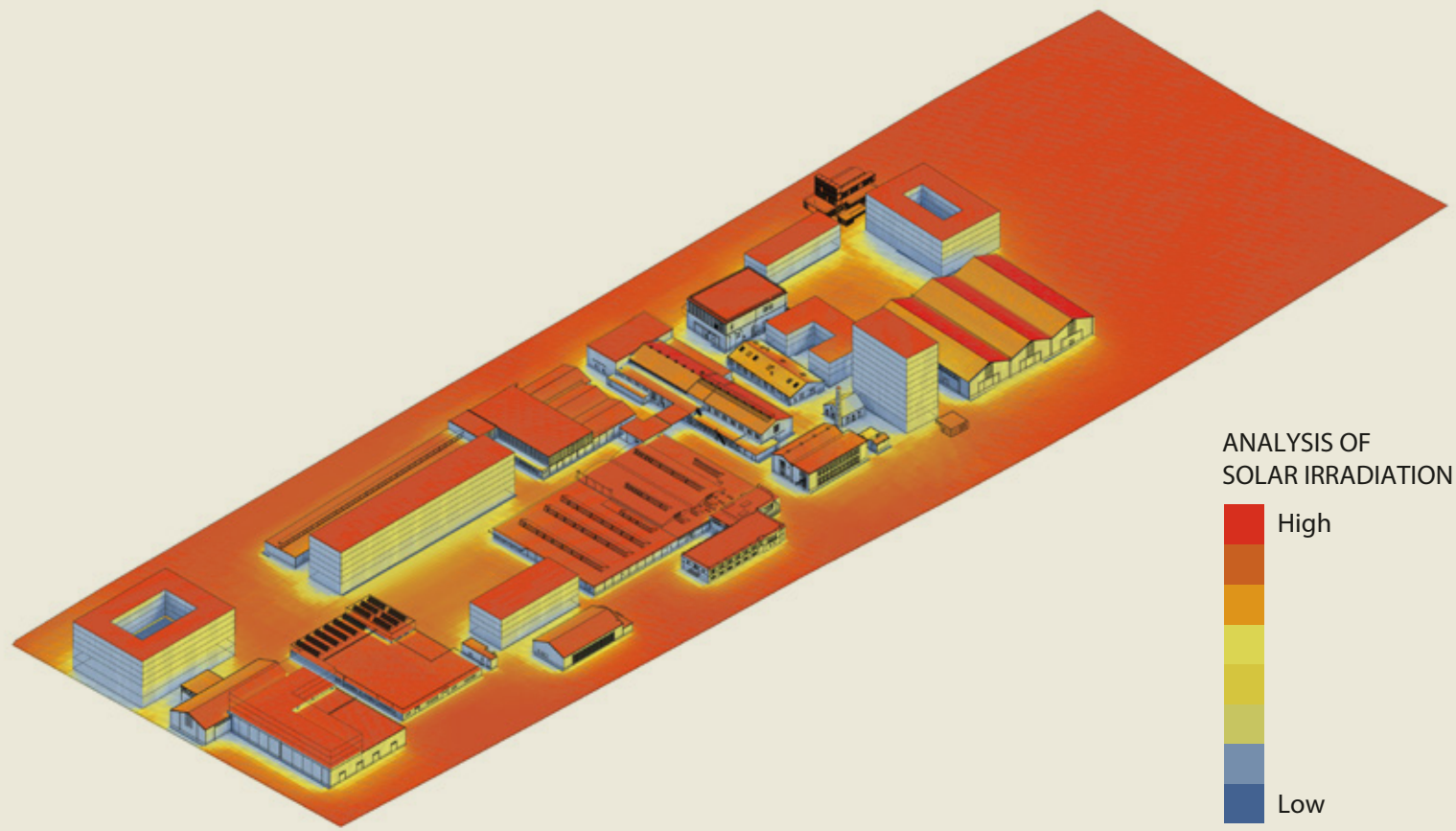


Horeca



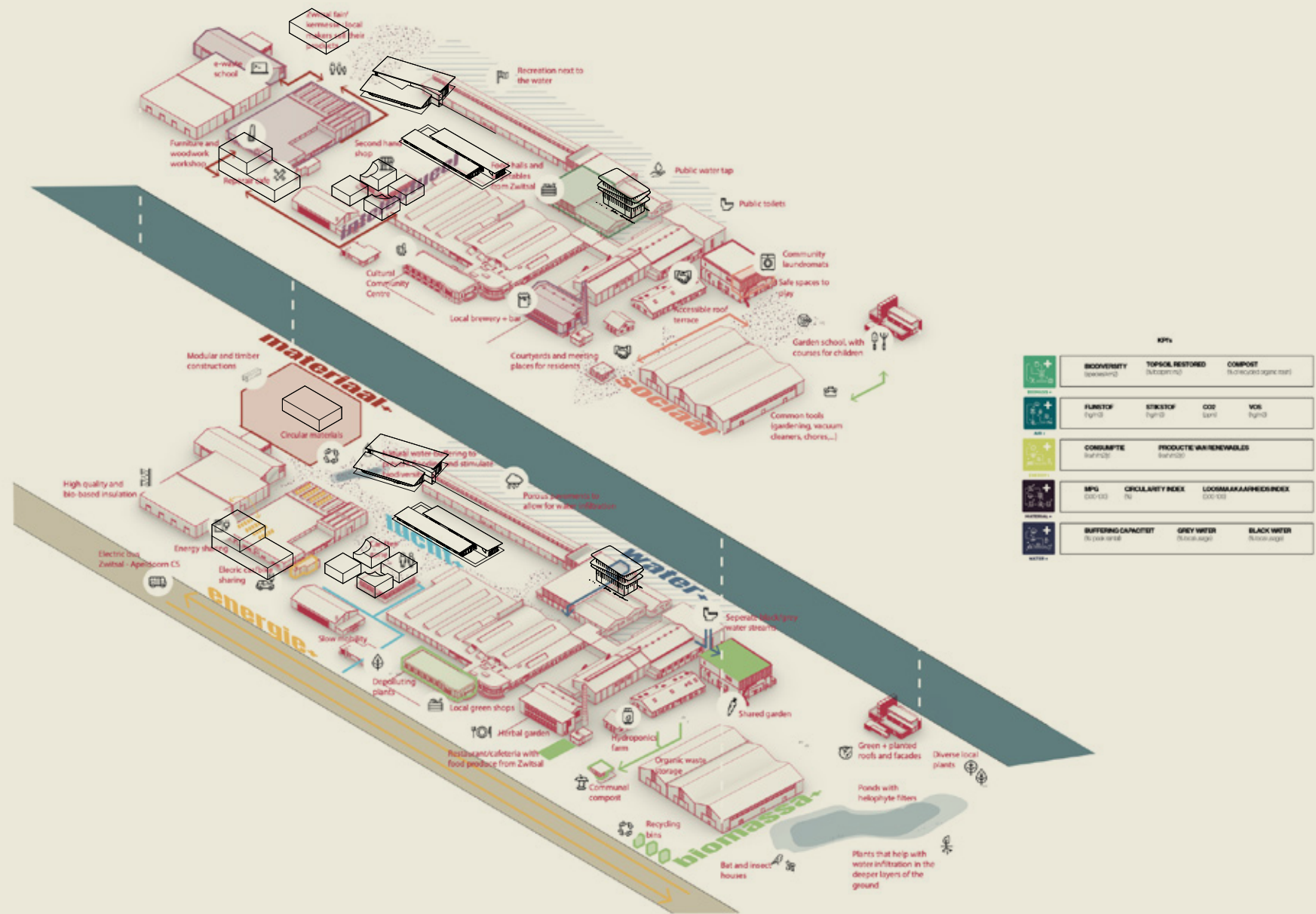
Cultural



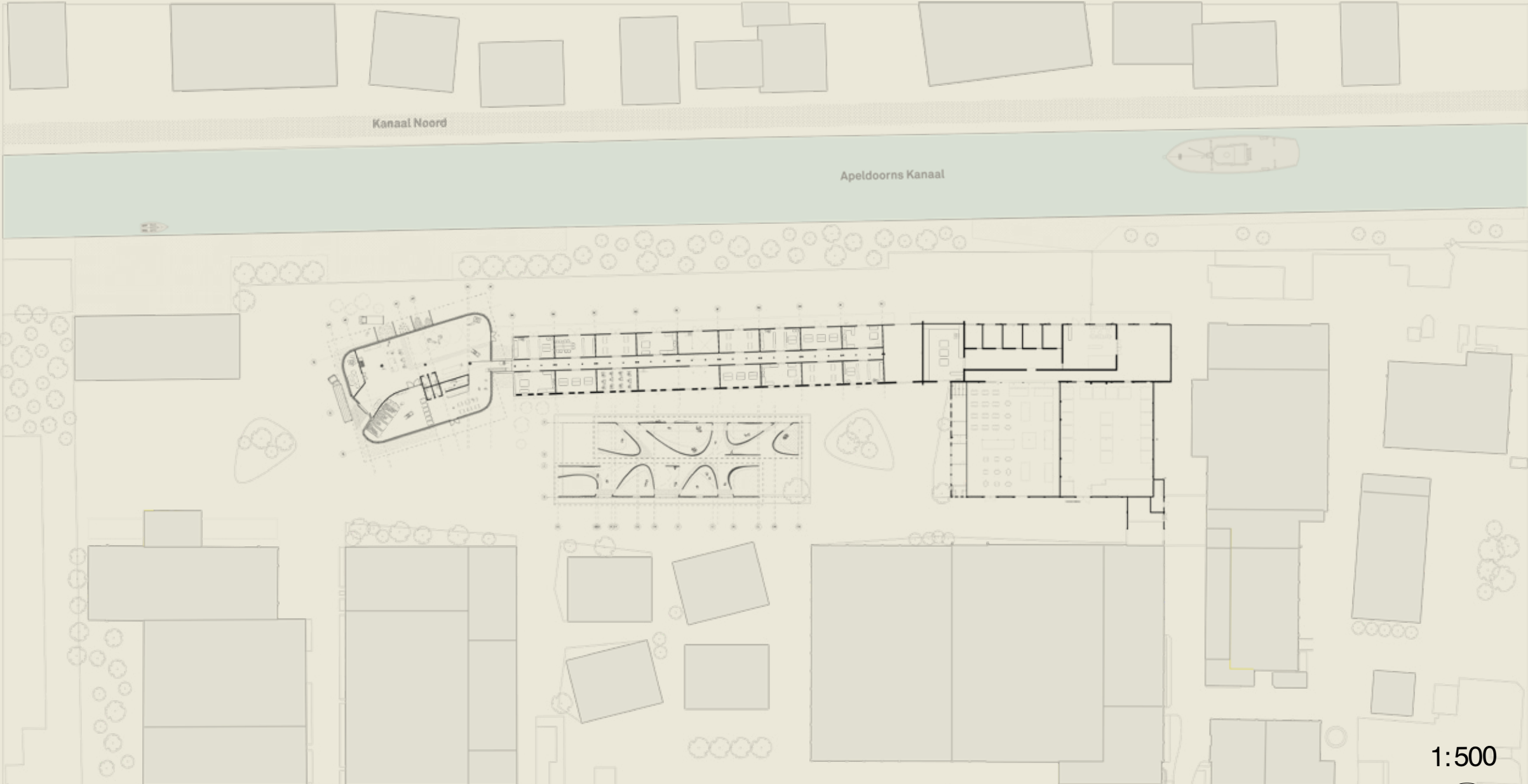


ANALYSIS OF SOLAR IRRADIATION





NET+ APPROACH

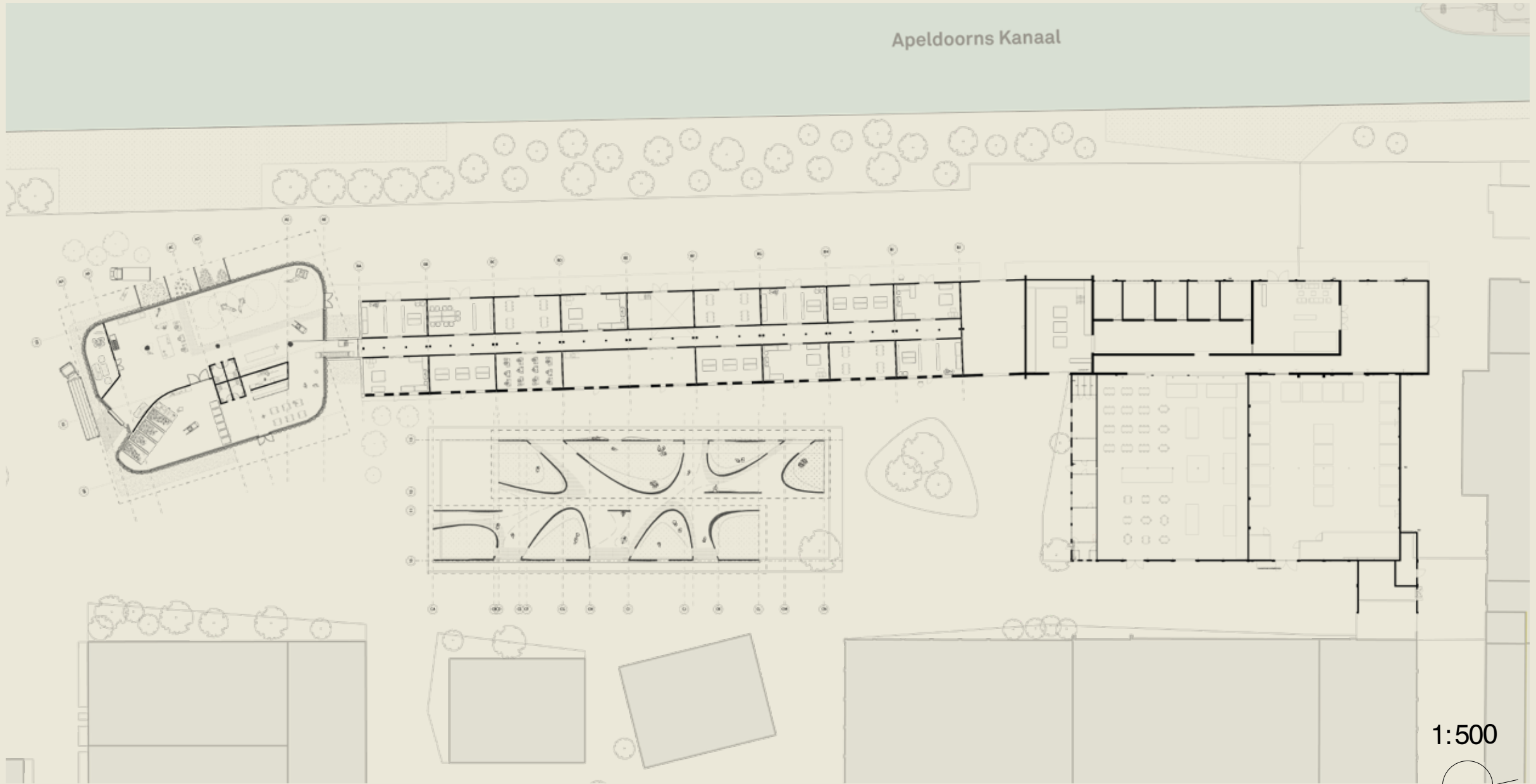


MASTER PLAN

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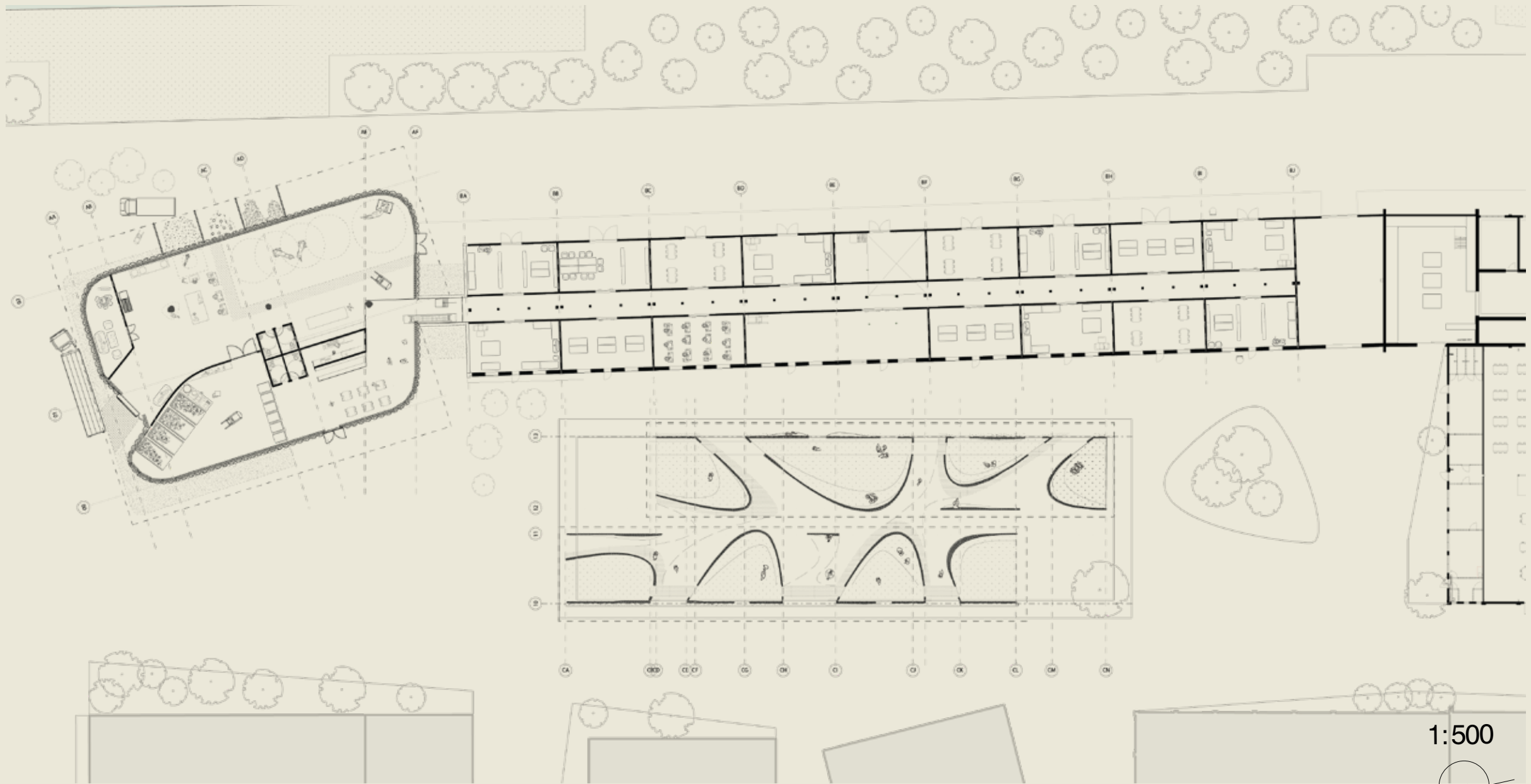


Apeldoorns Kanaal



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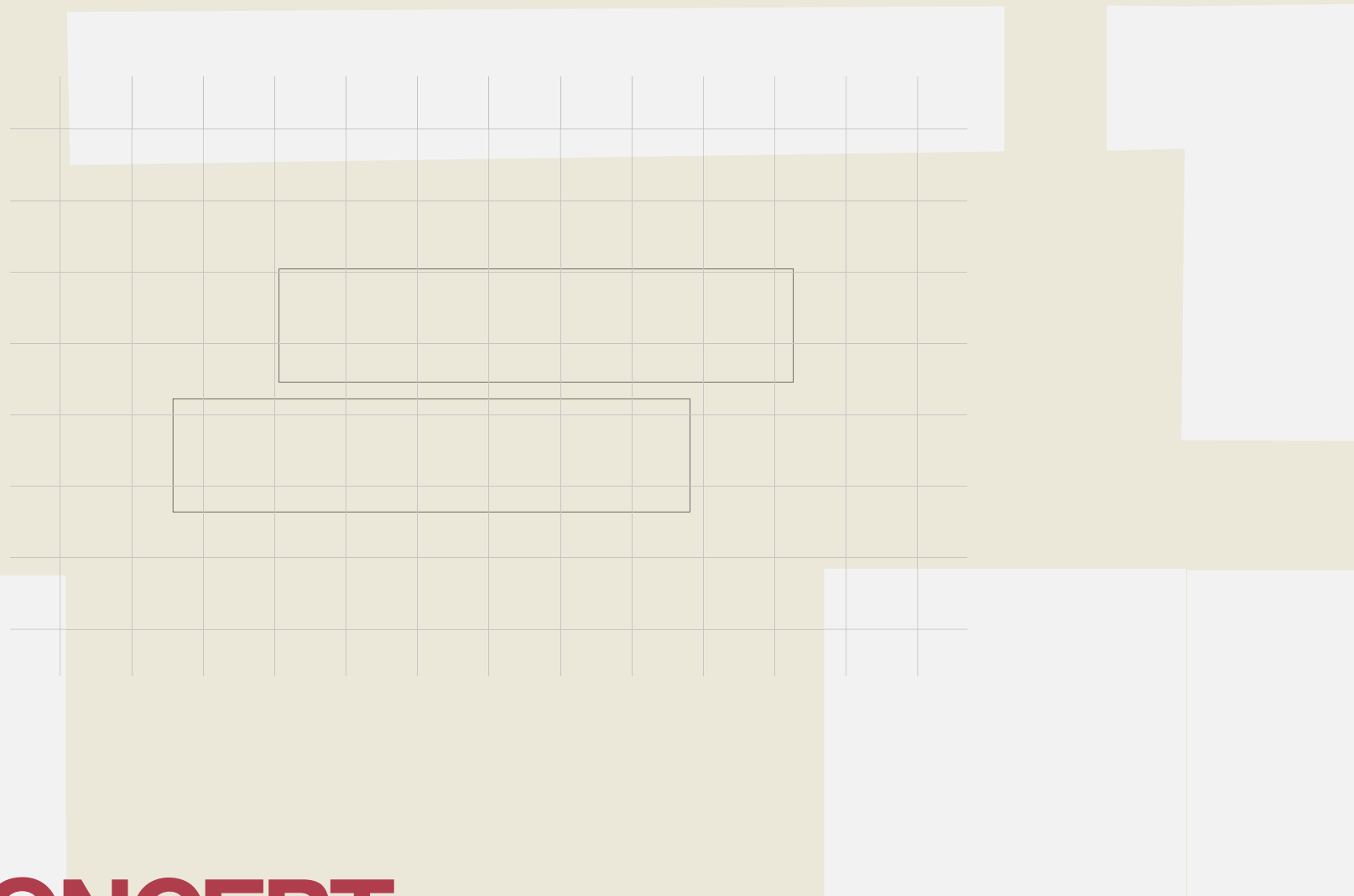




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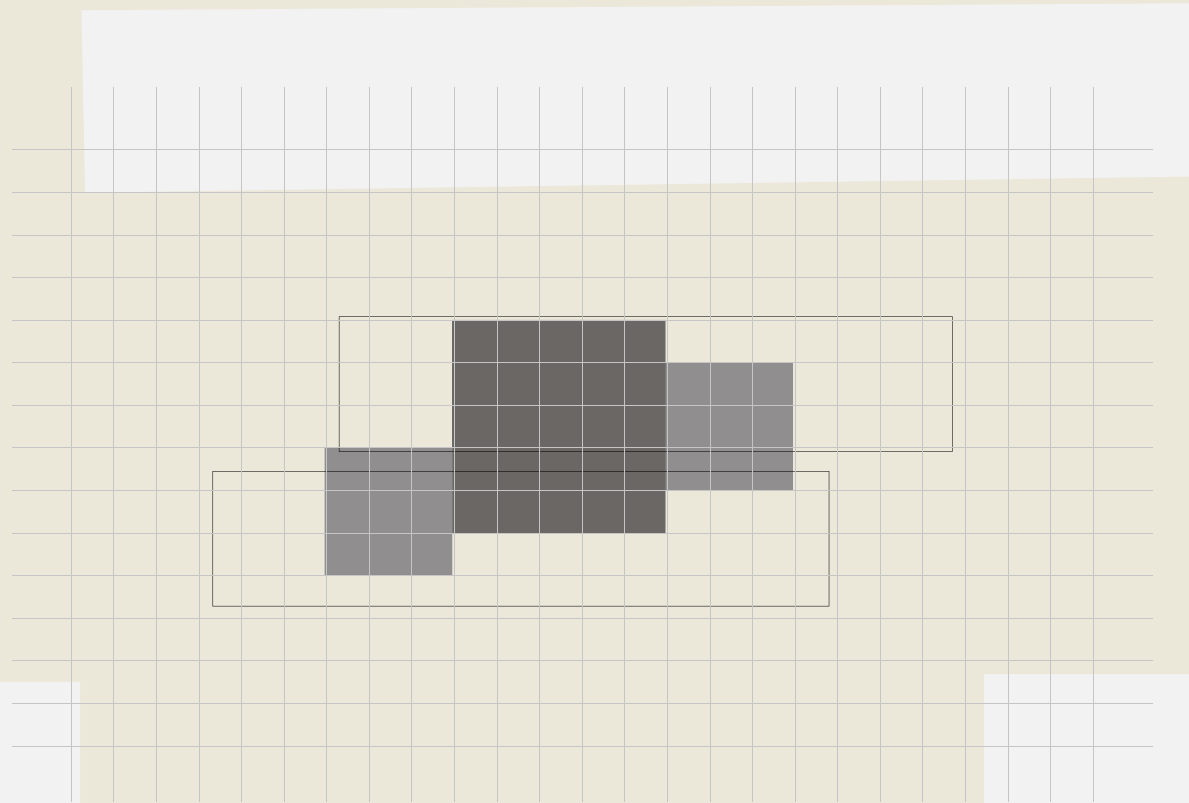


DESIGN CONCEPT

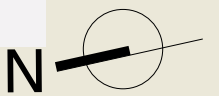


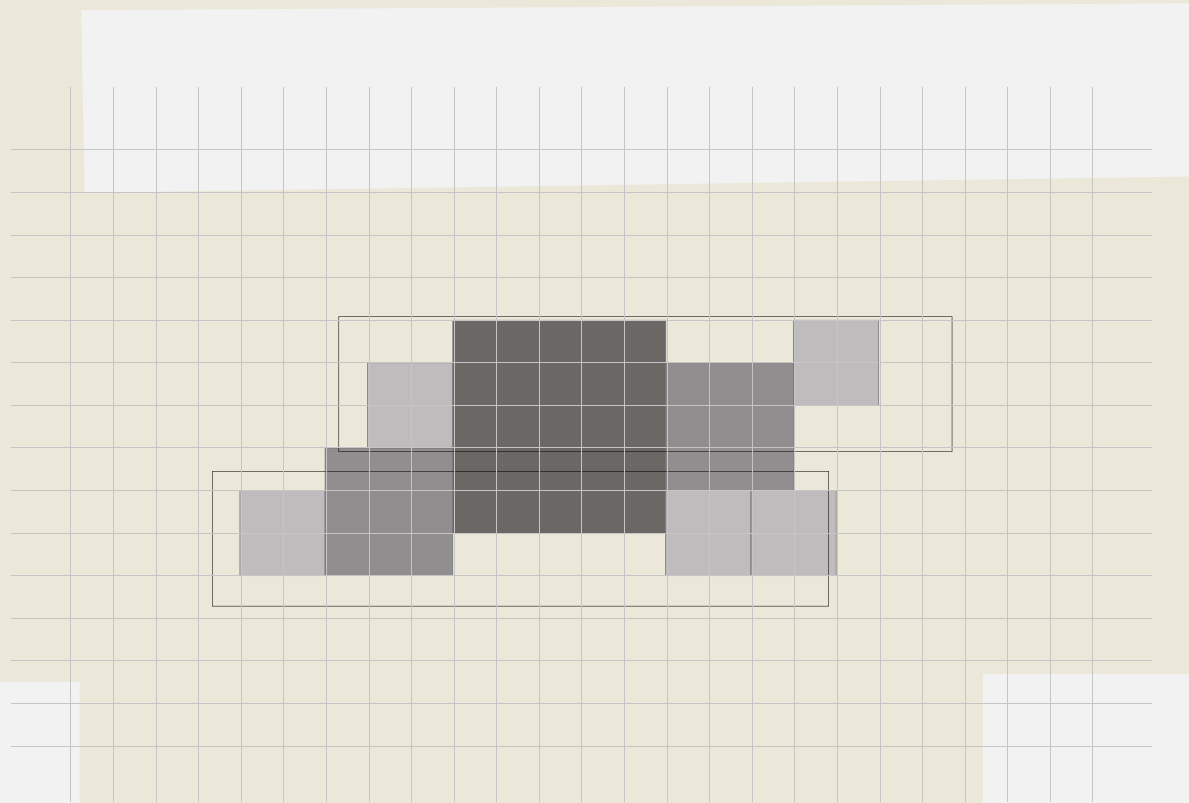
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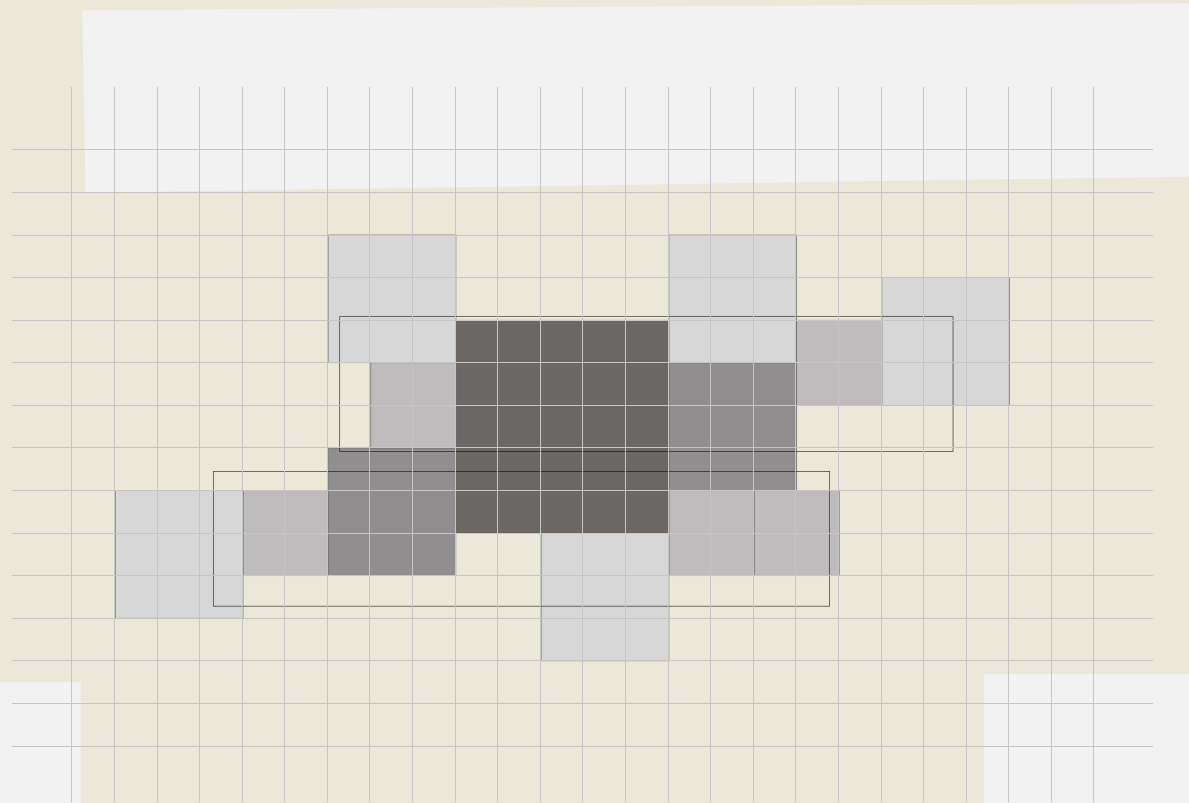
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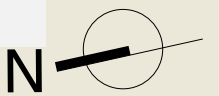


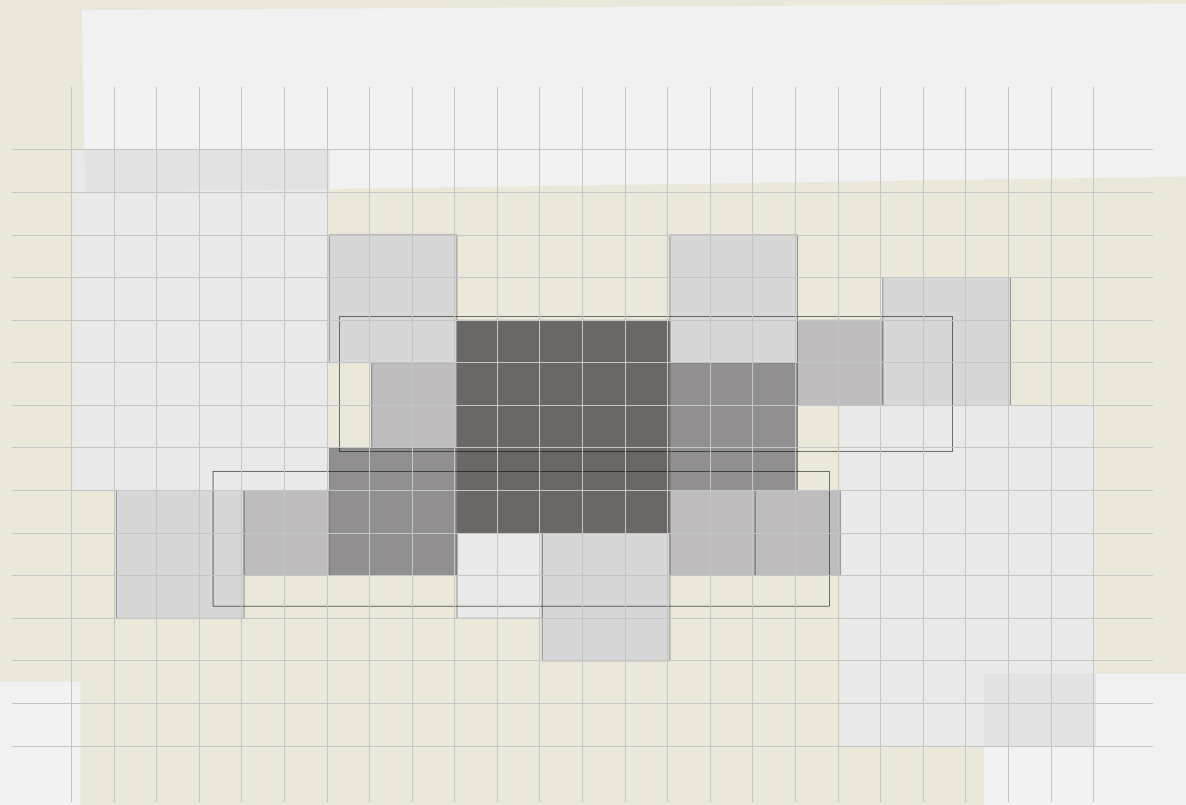
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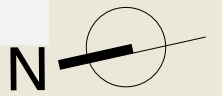


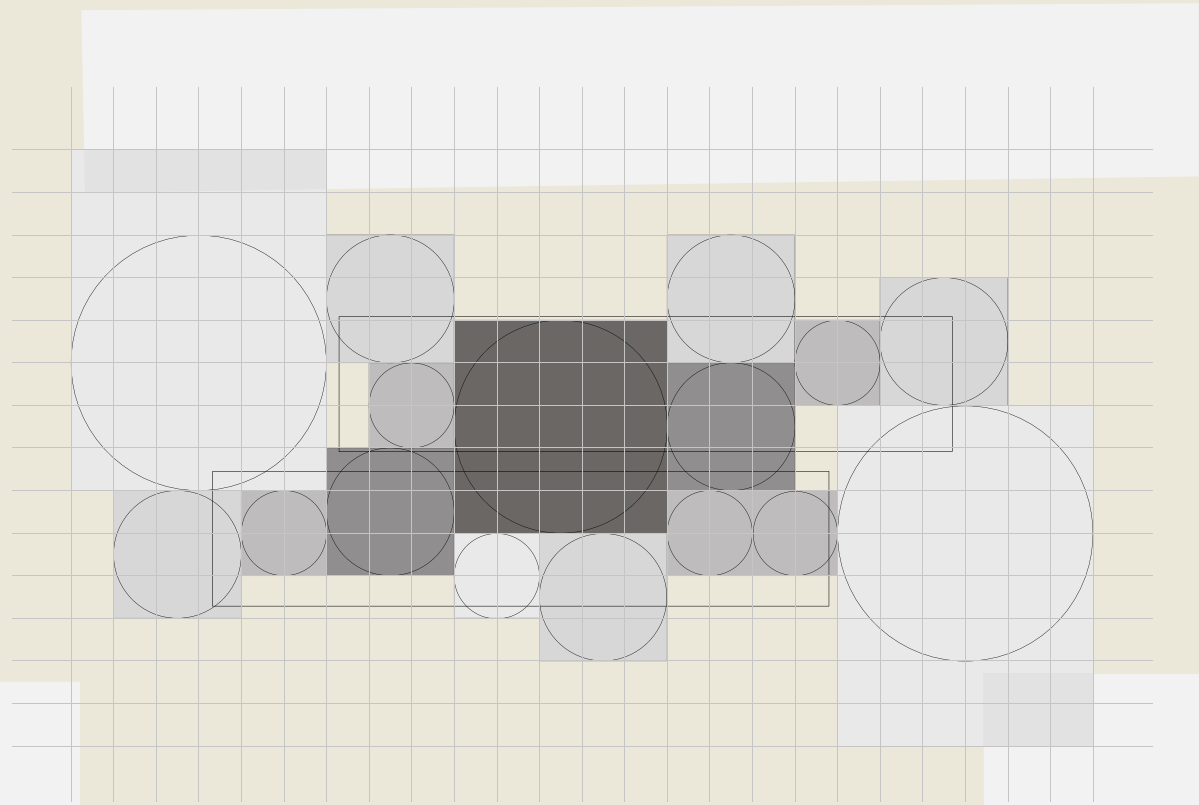
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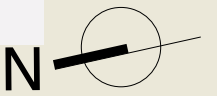


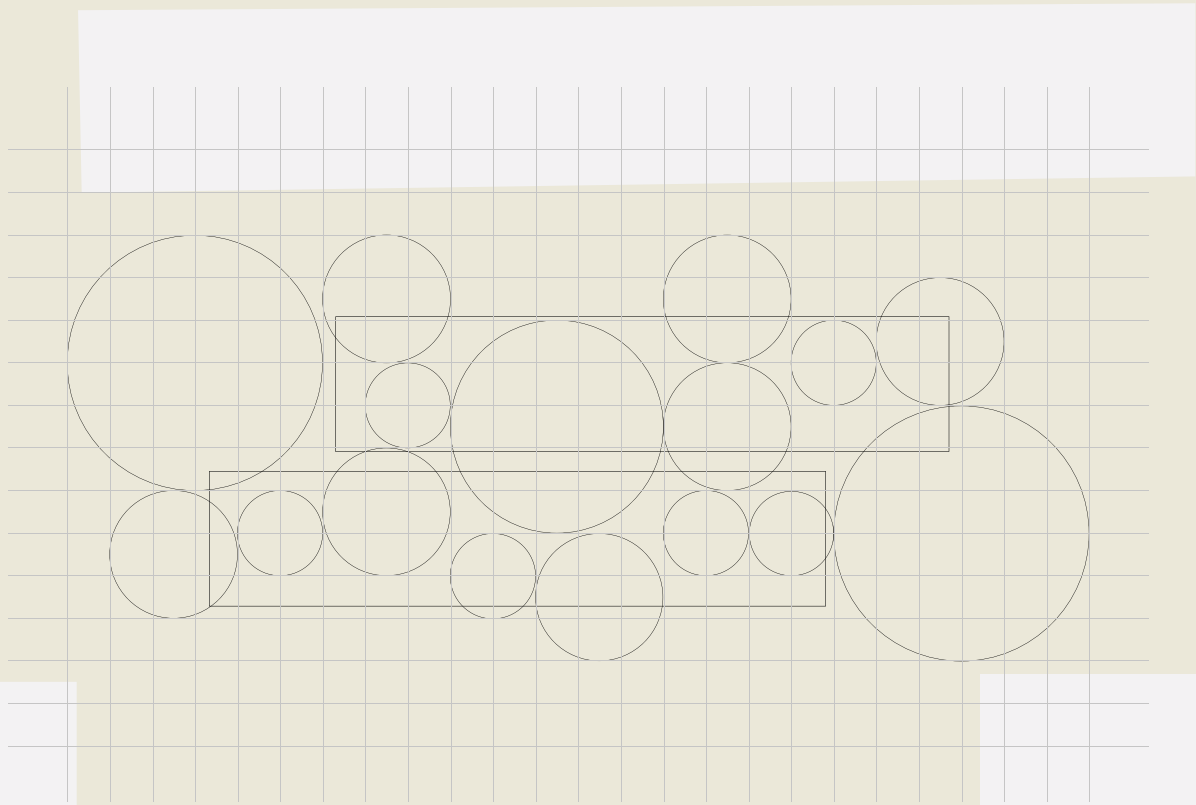
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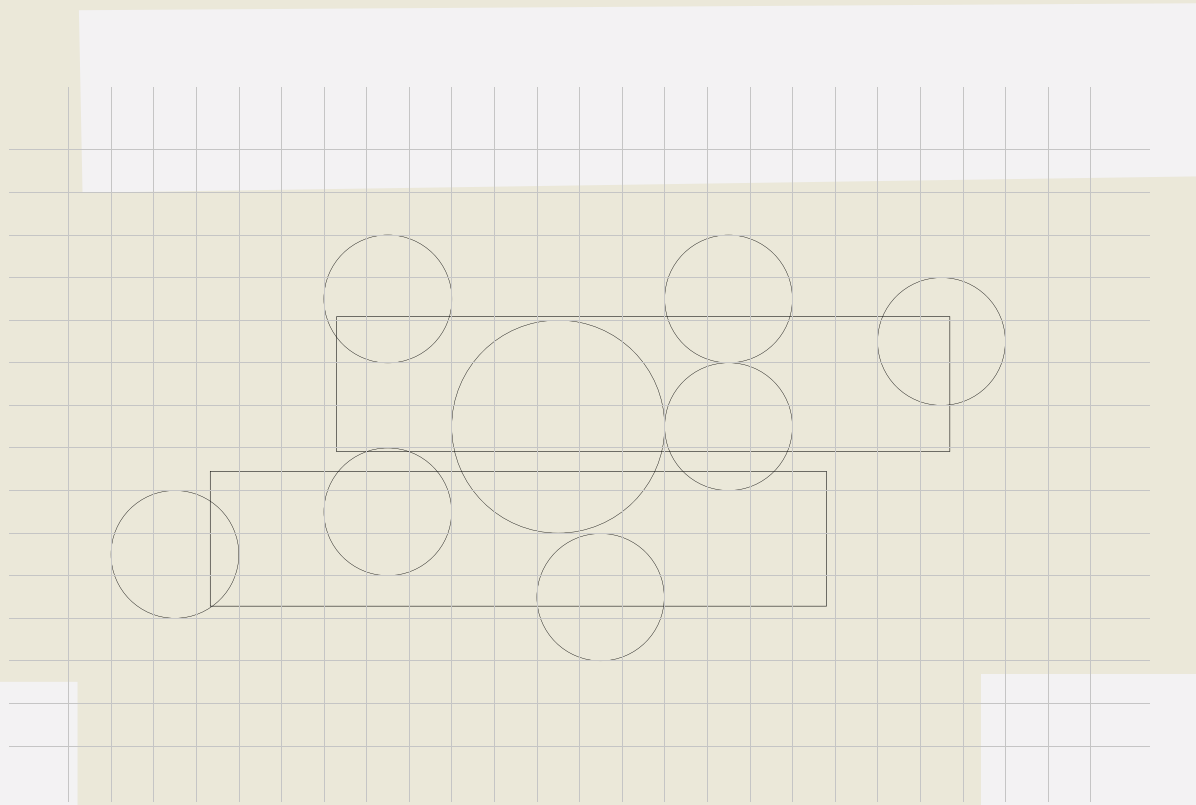
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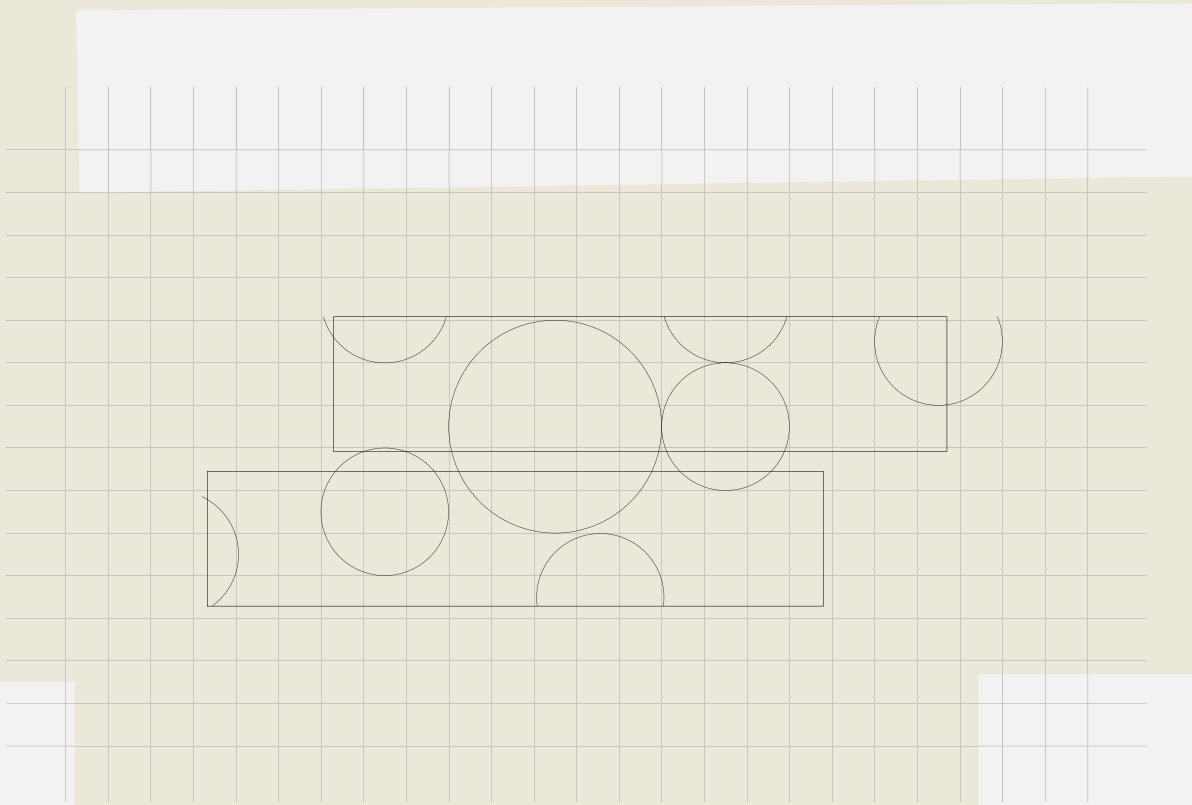
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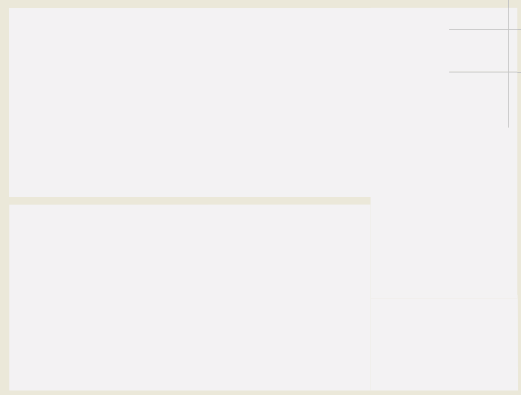
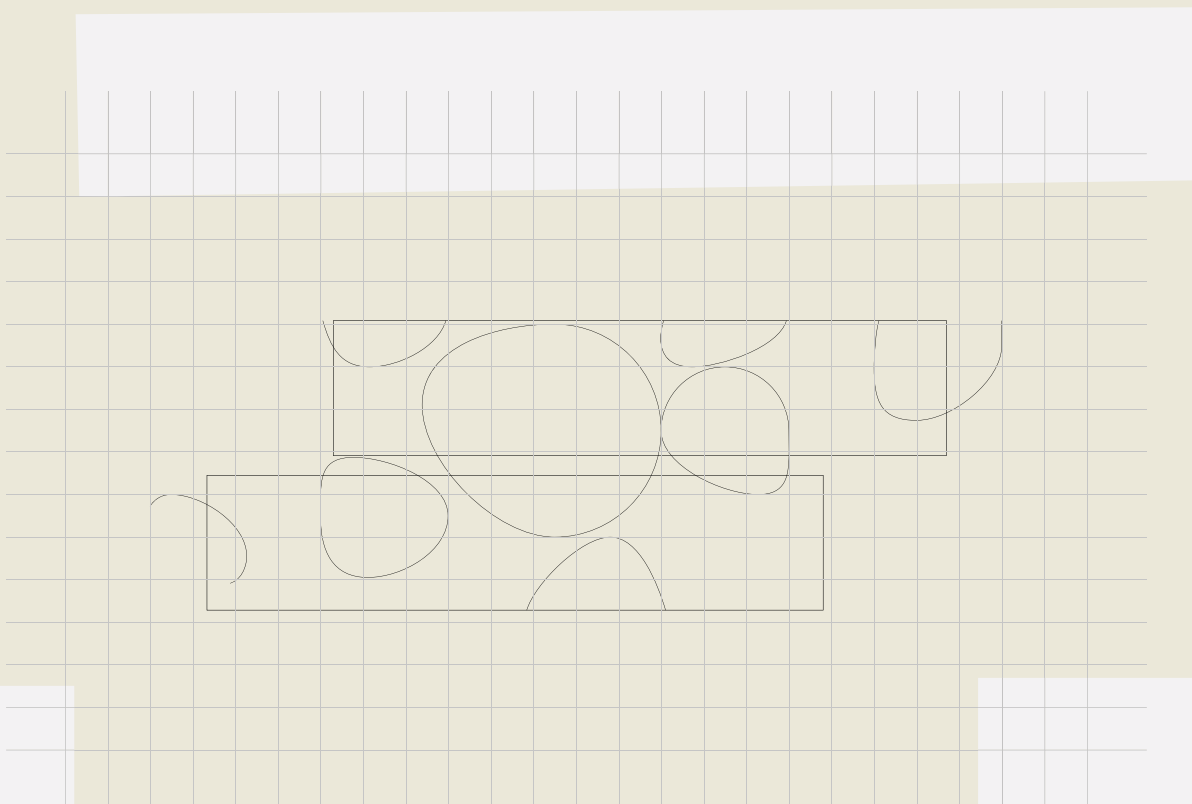
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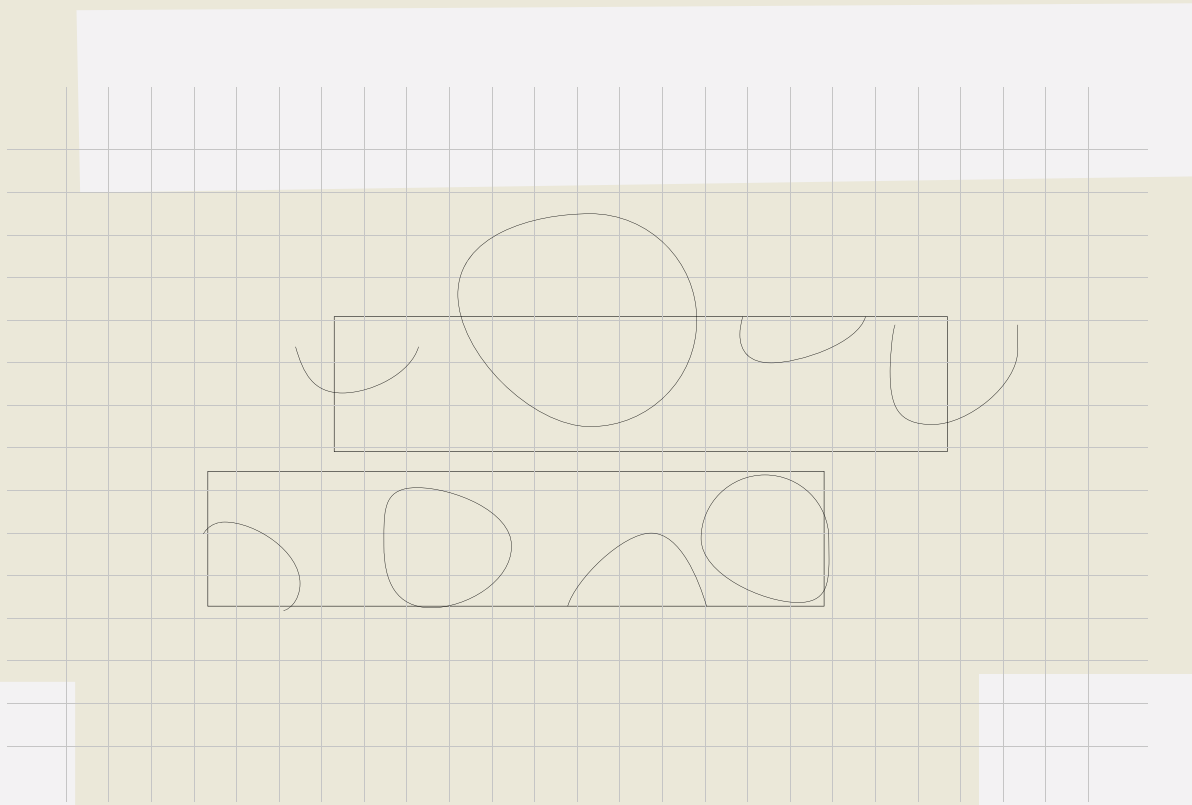
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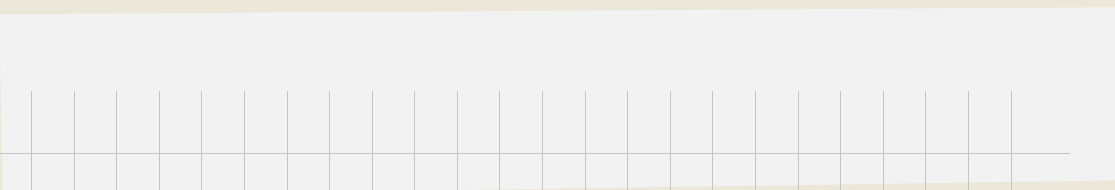
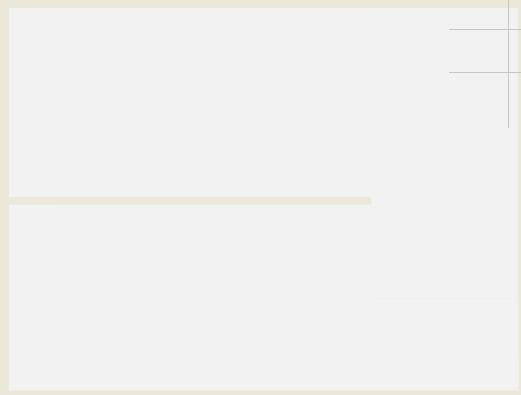
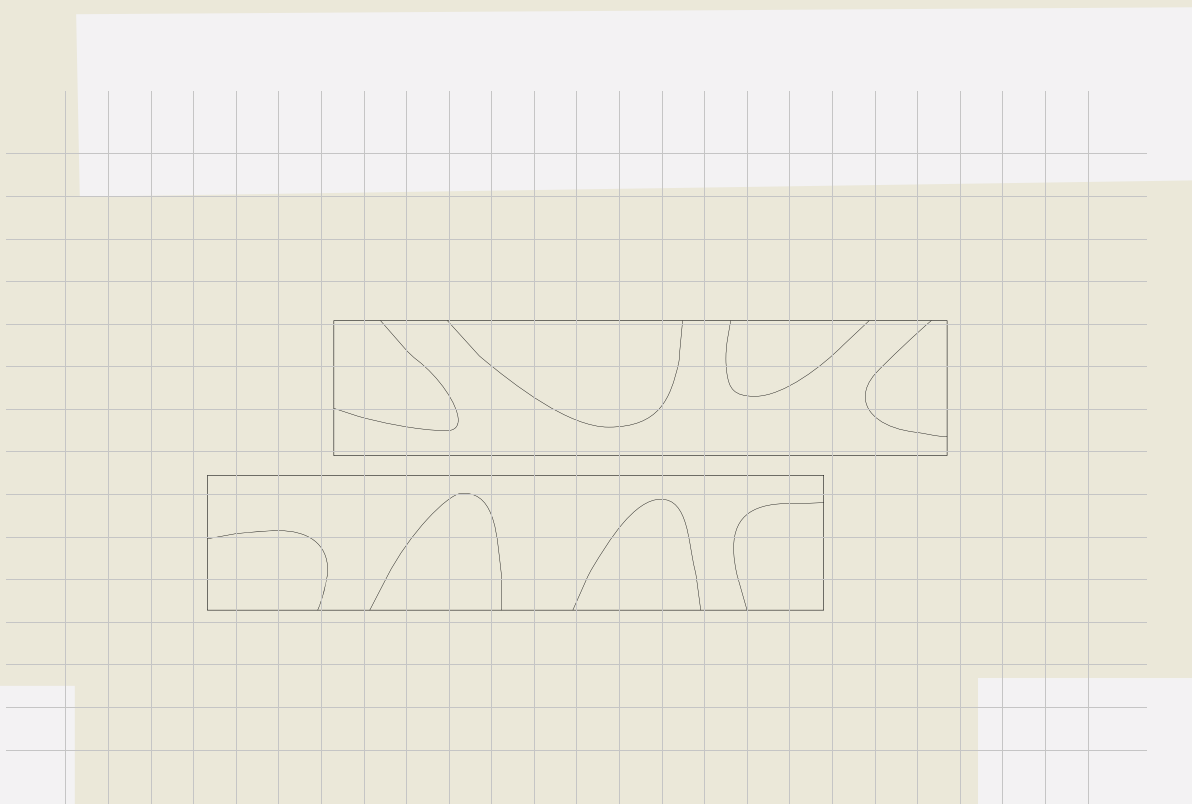
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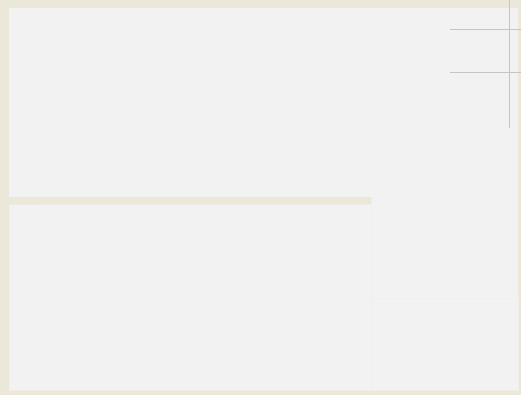
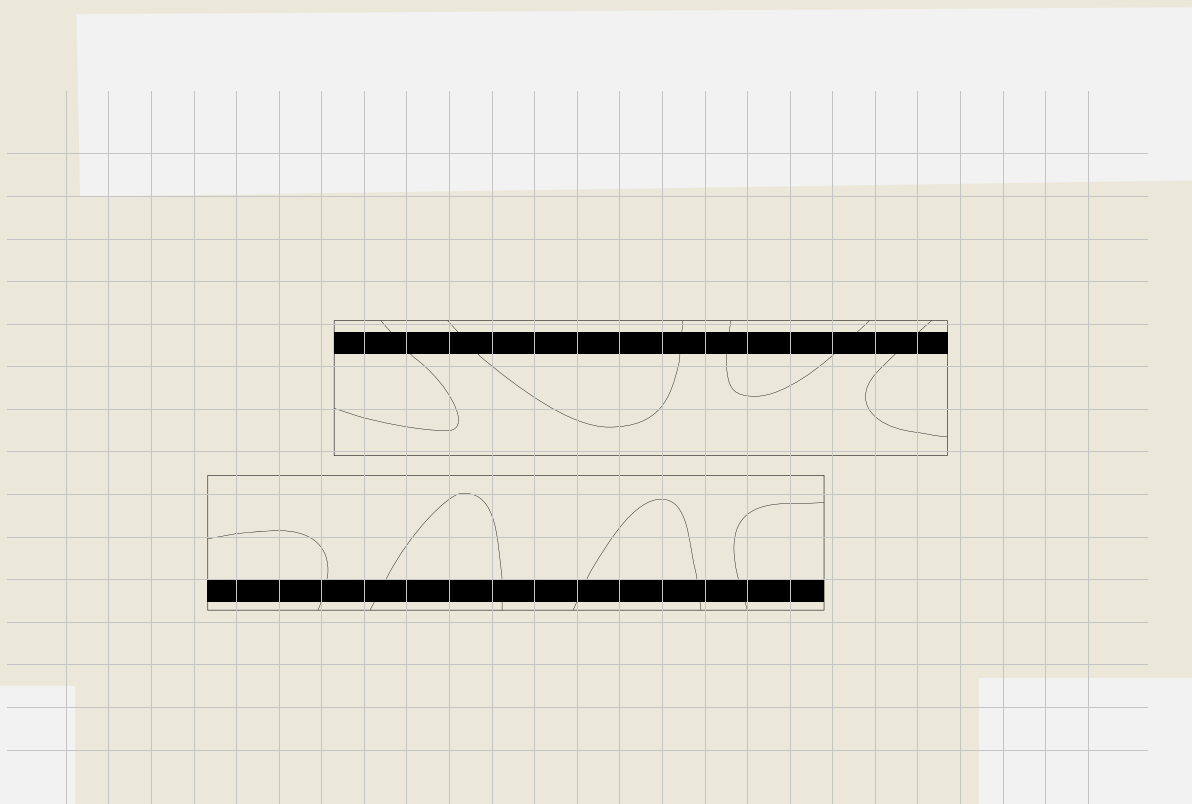
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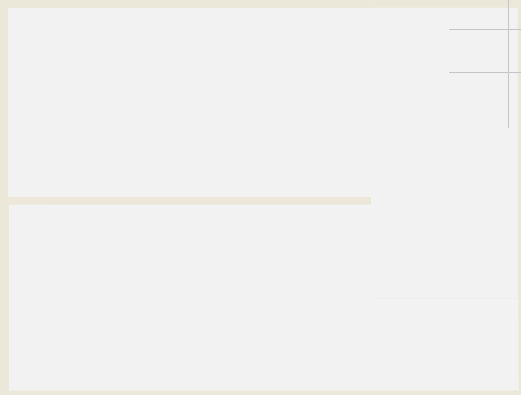
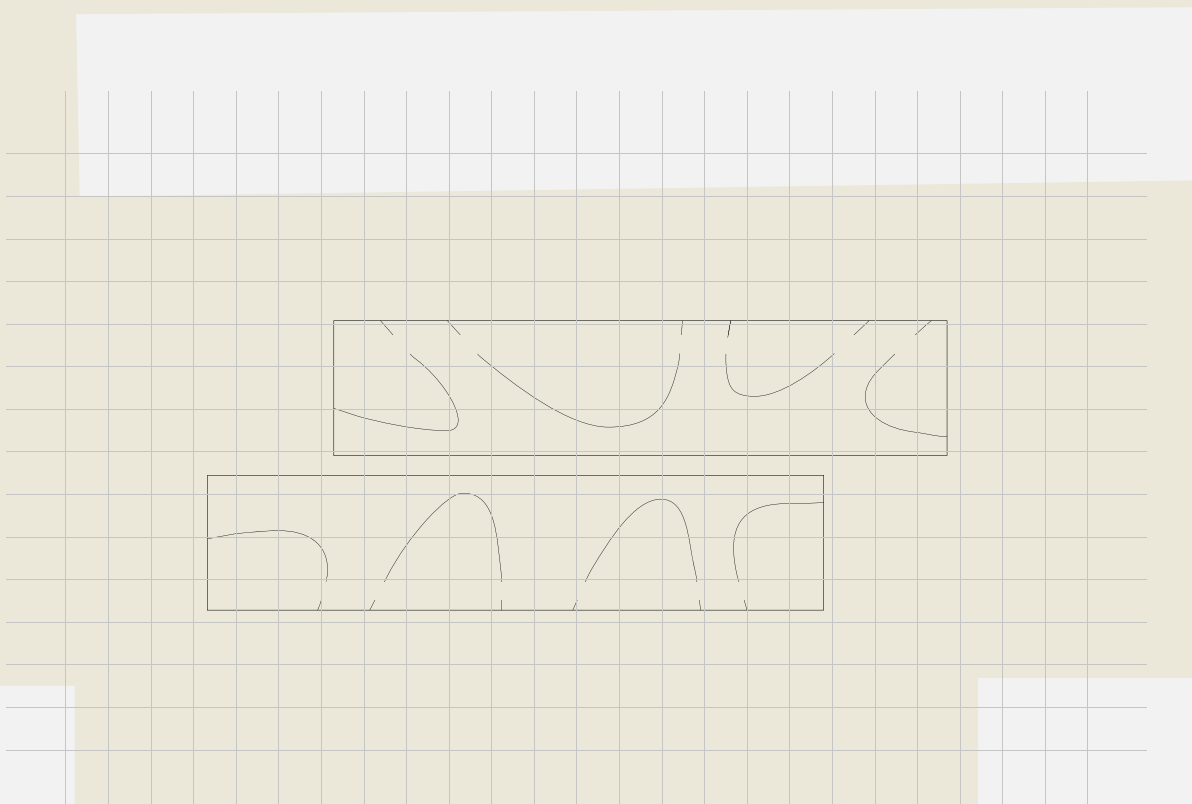
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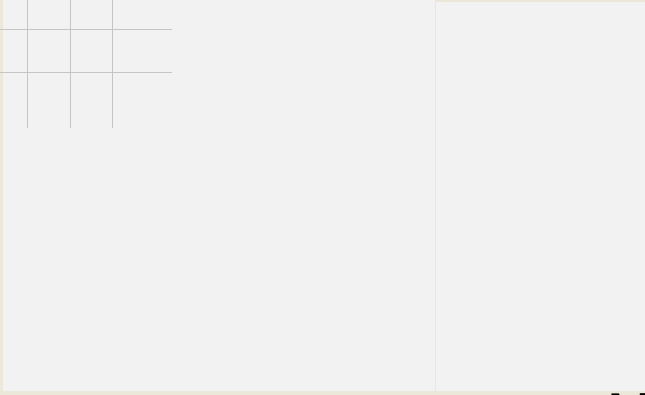
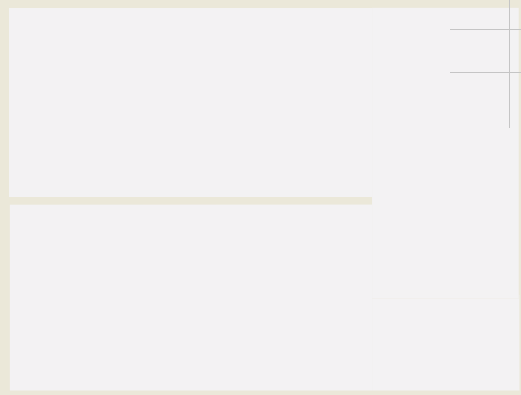
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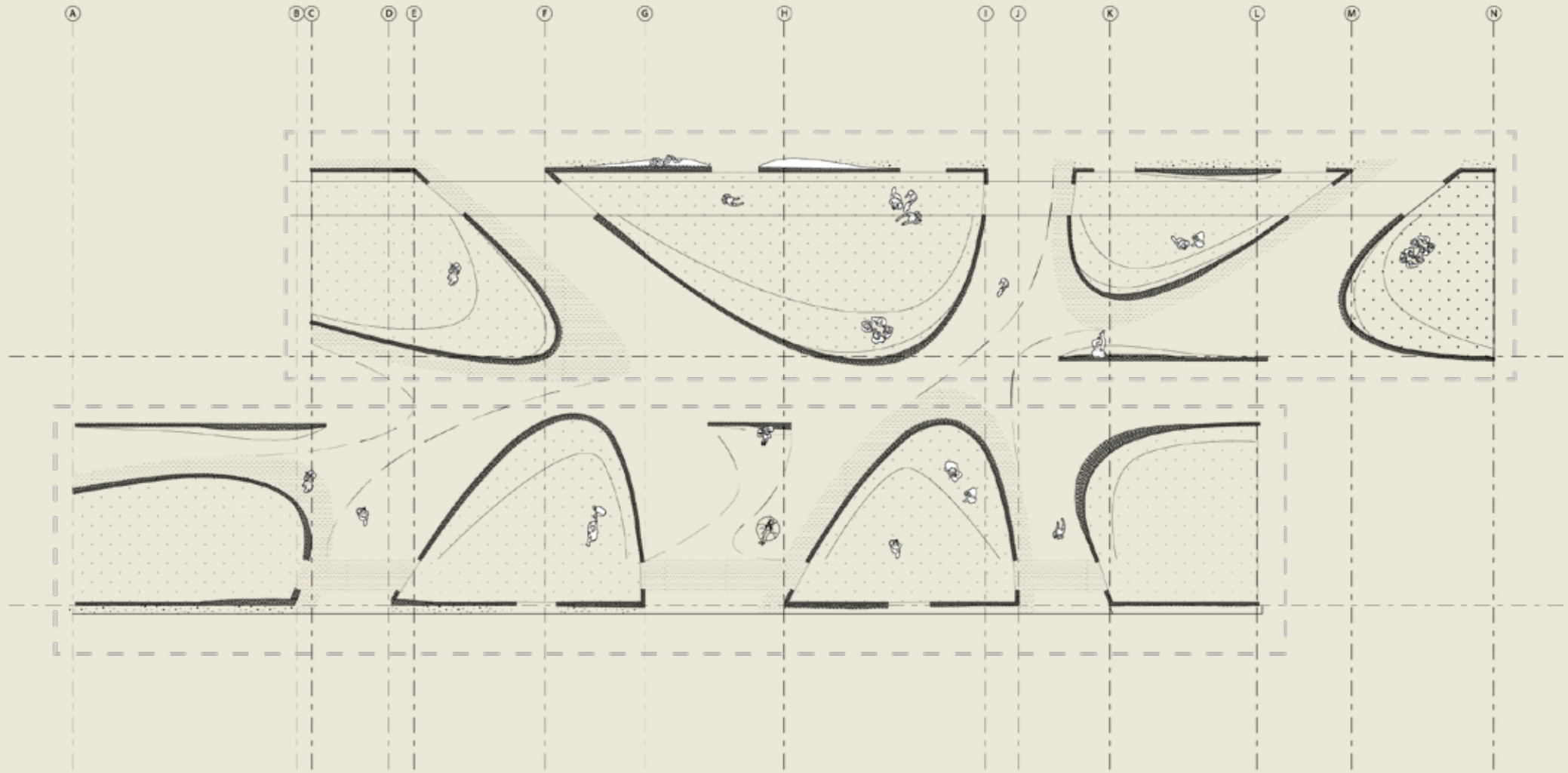
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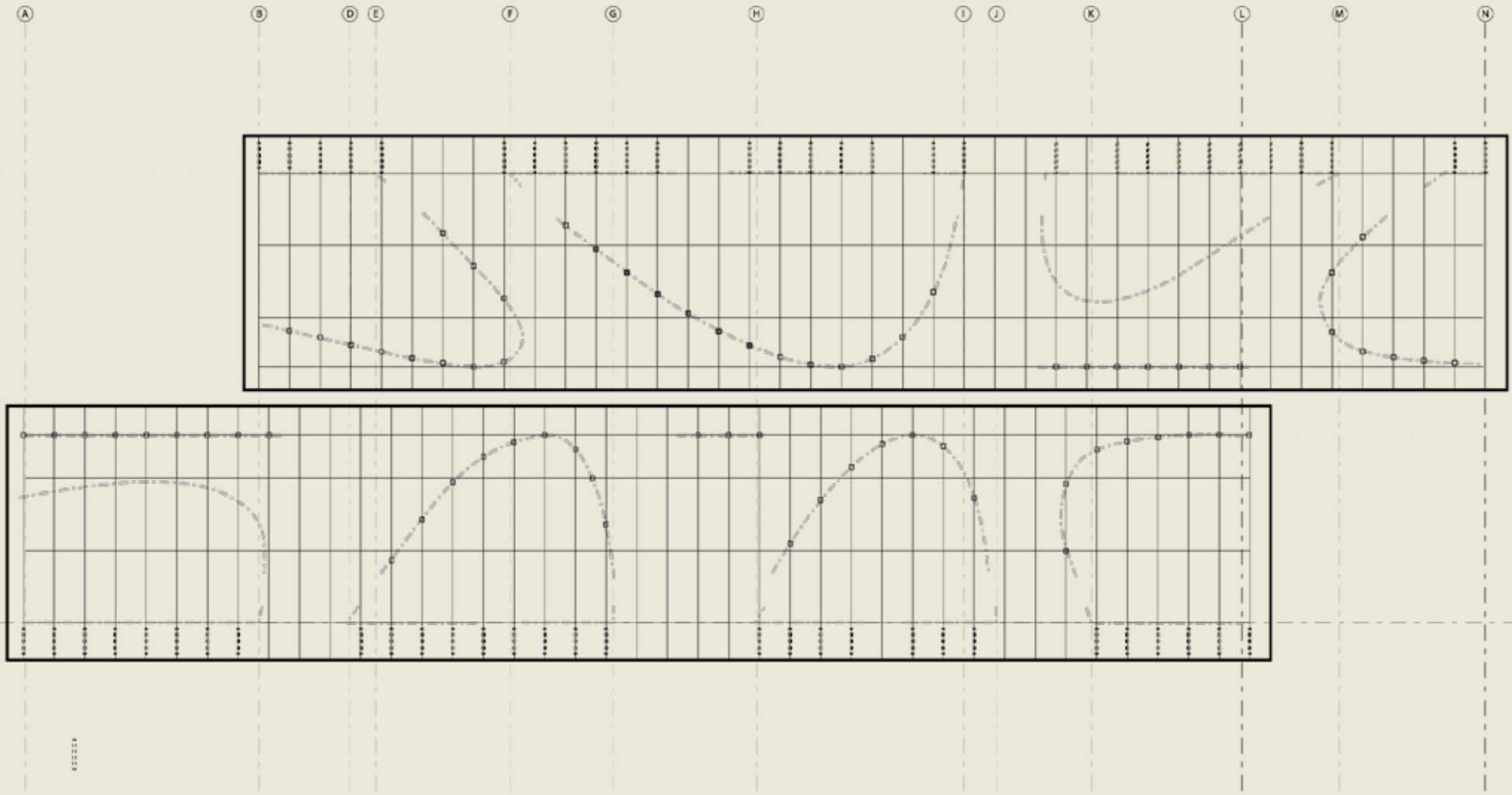
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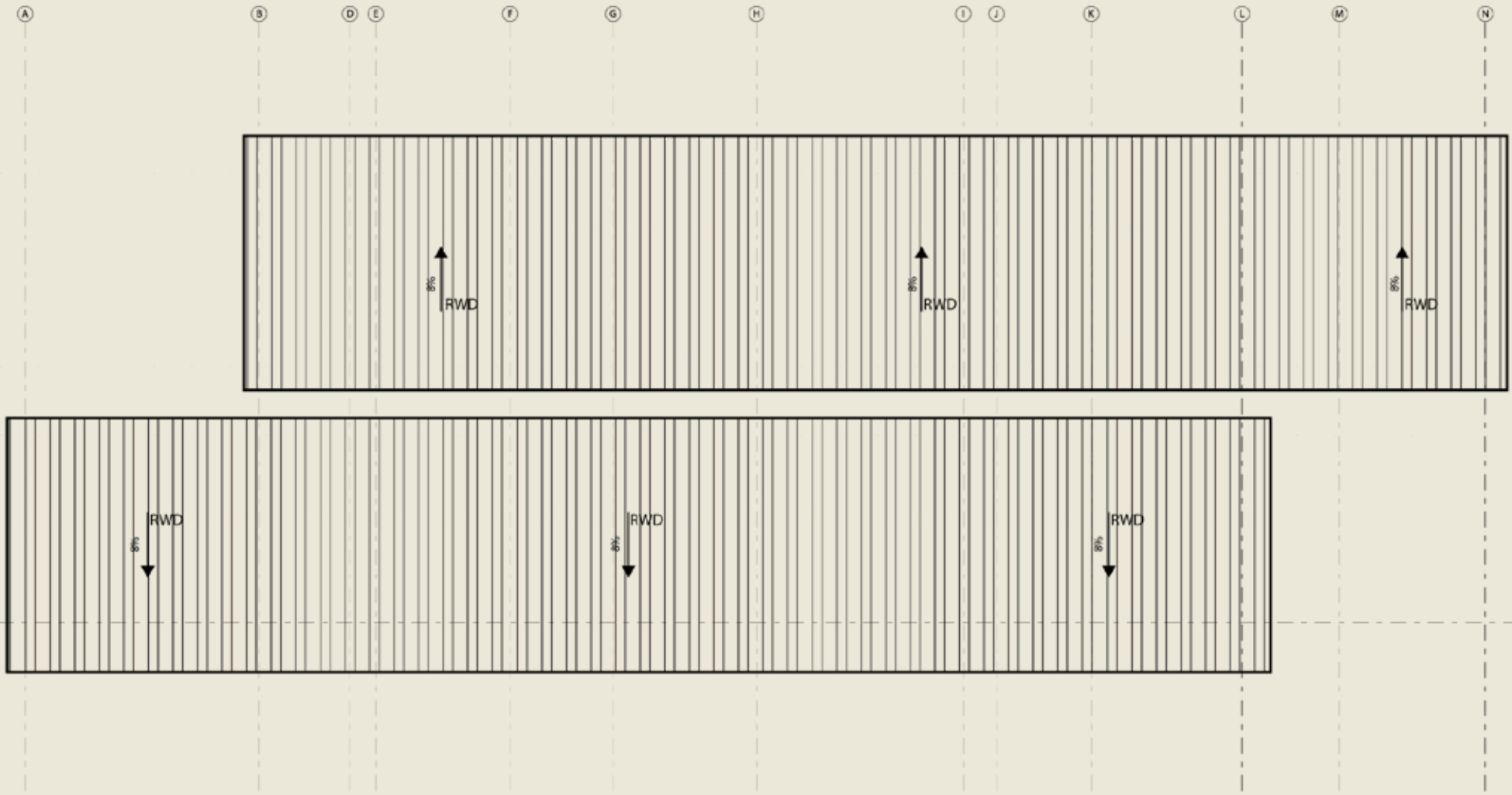


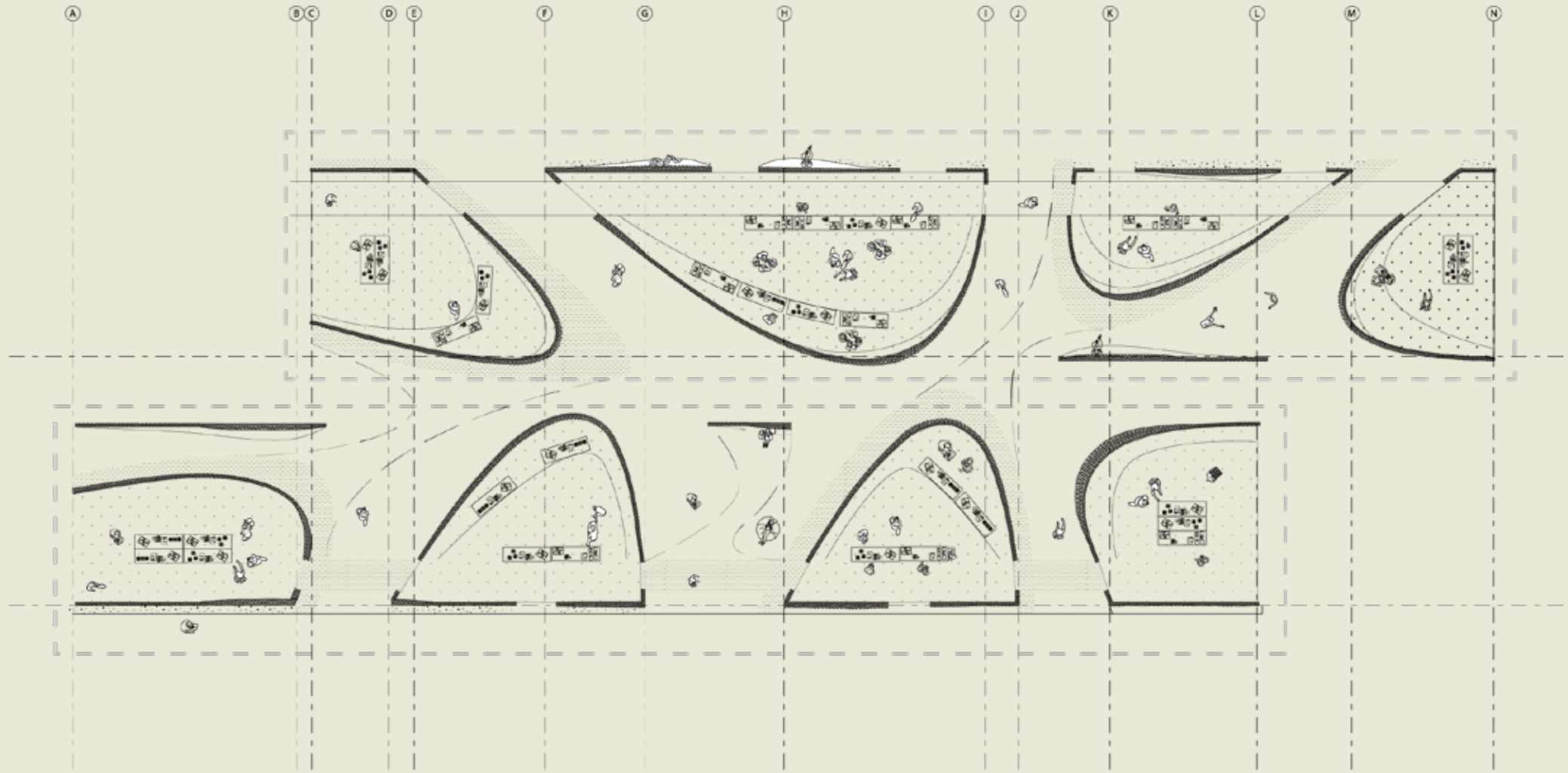
ZWITSAL CIRCULAR PAVILLION





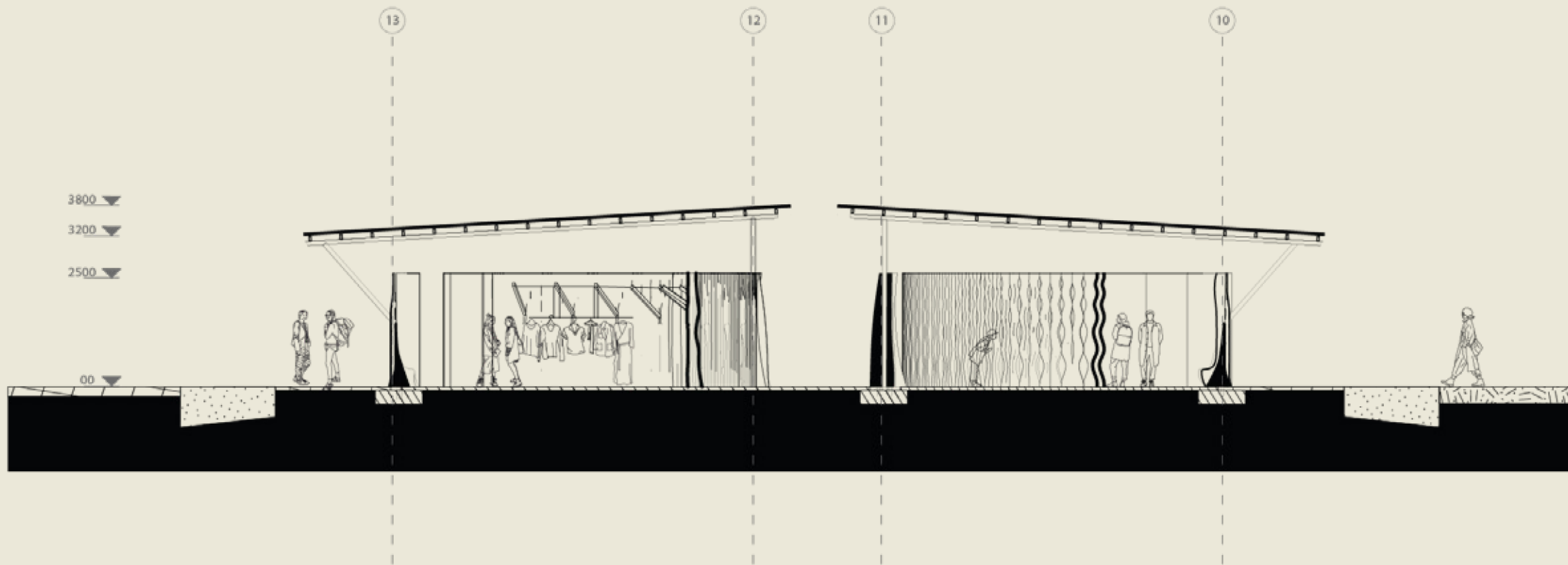
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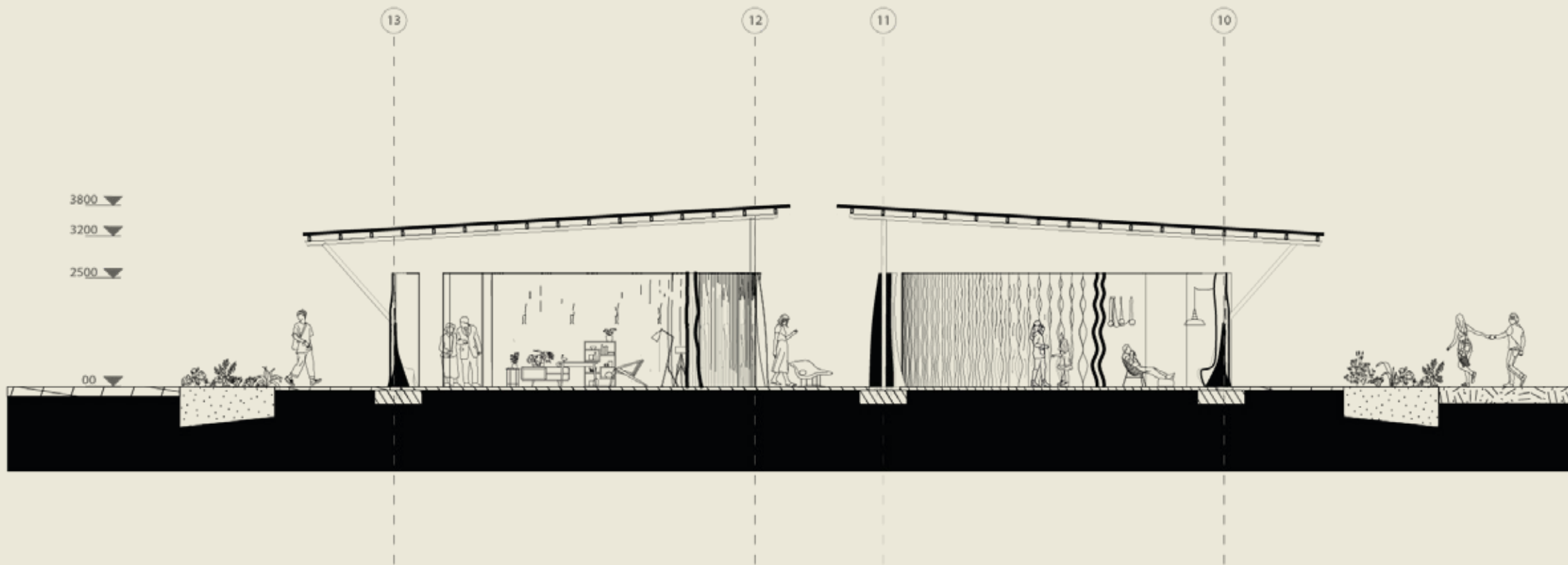
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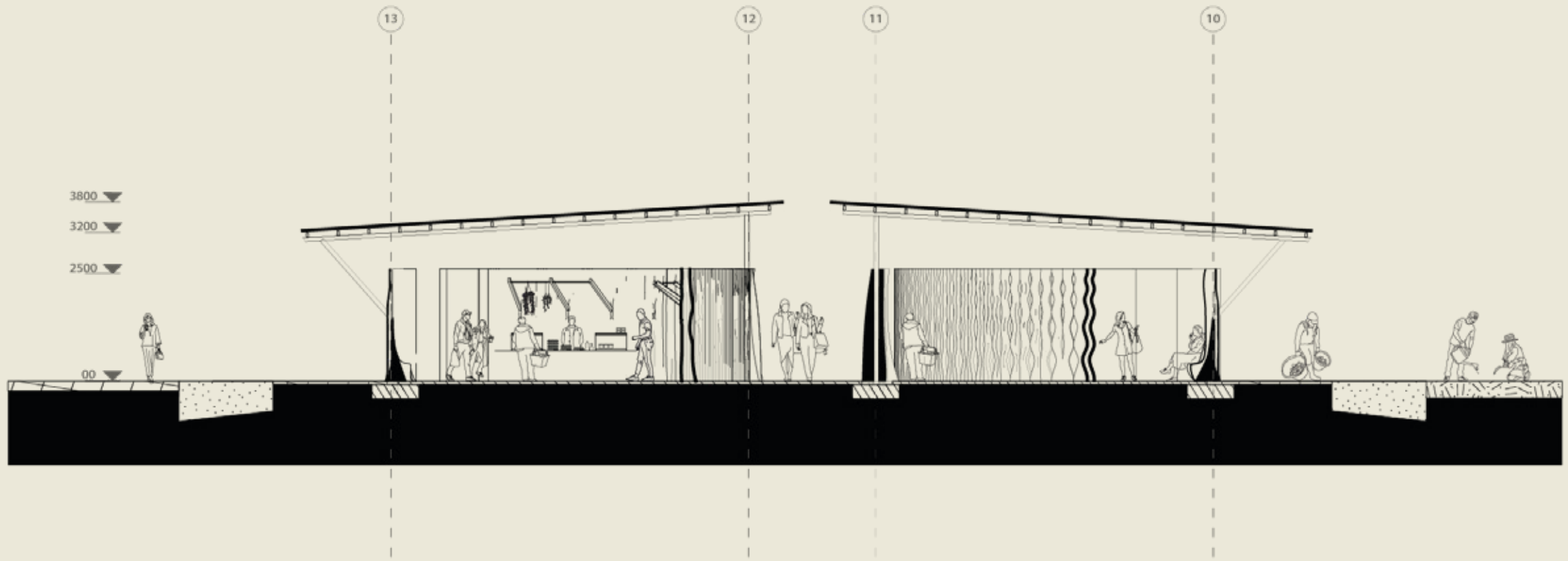
SECOND HAND MARKET

1:100



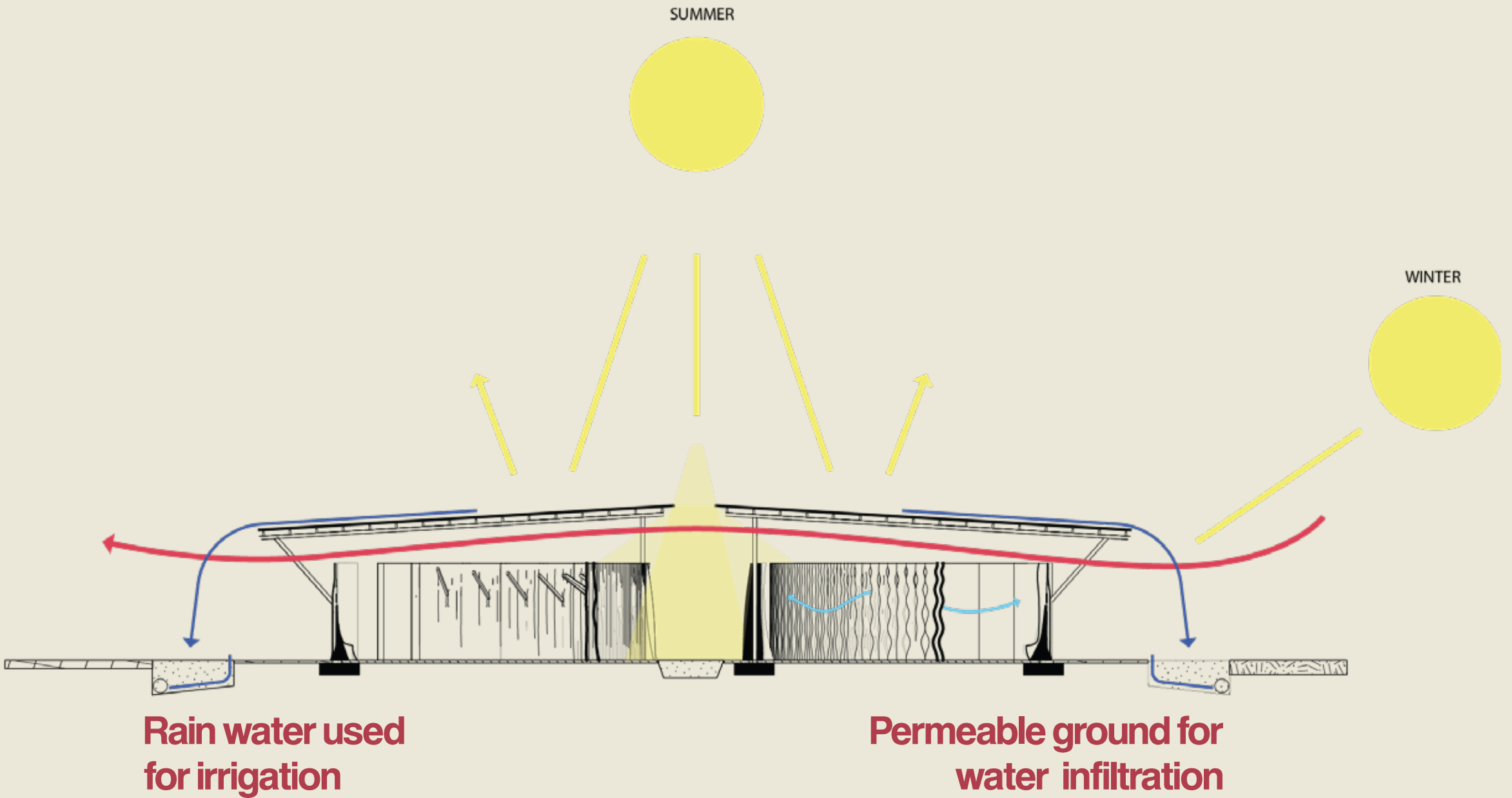
CIRCULAR DESIGN FAIR

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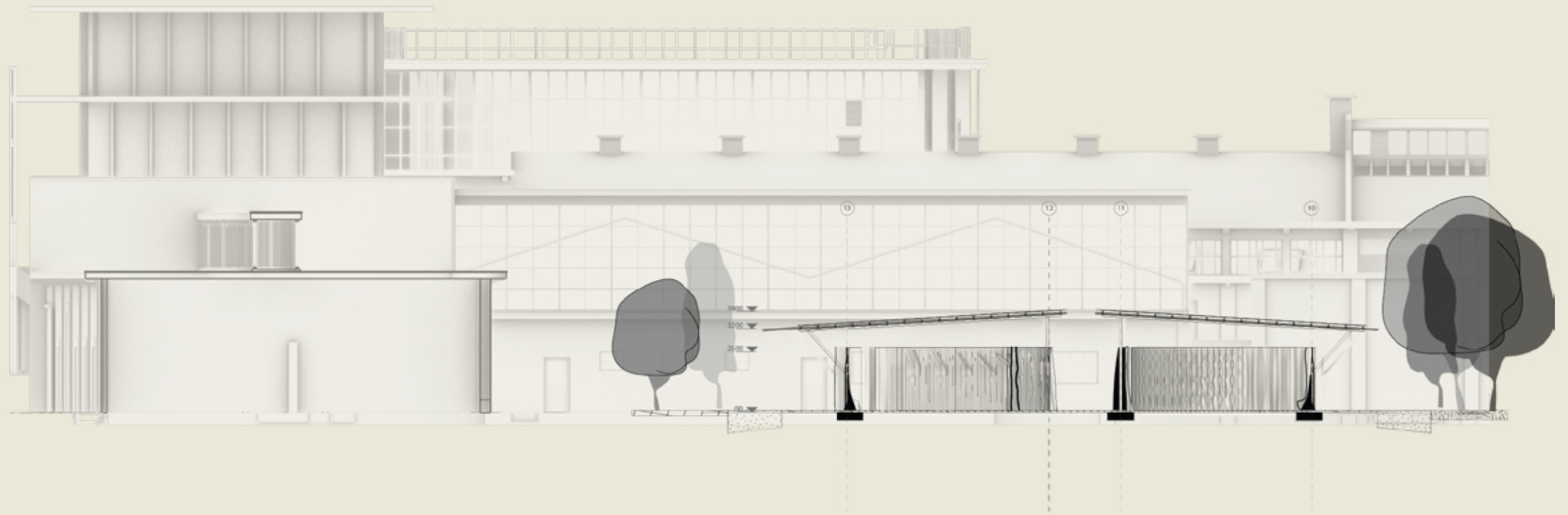


LOCAL PRODUCE FOOD MARKET

1:100

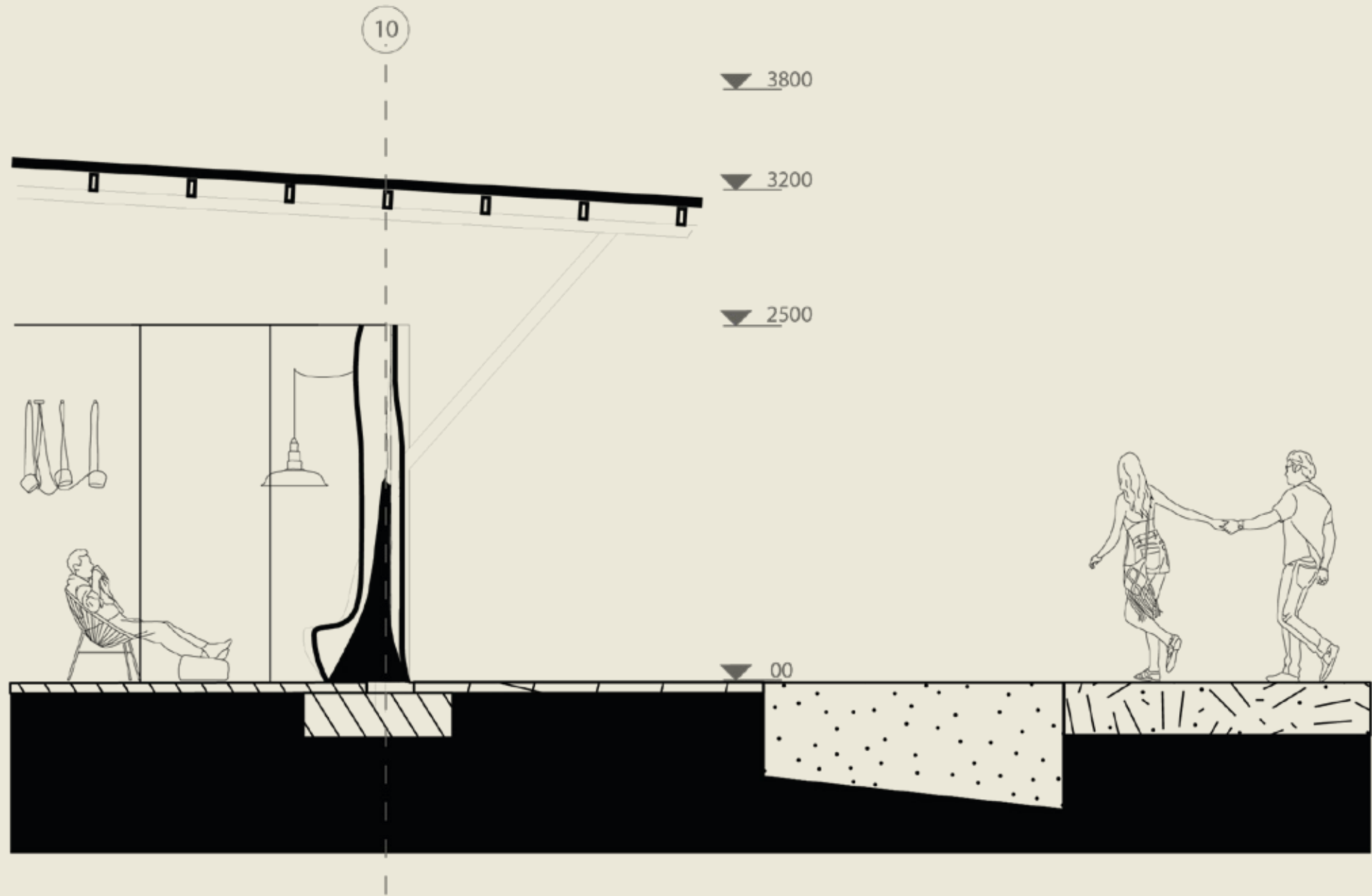


CLIMATE DESIGN

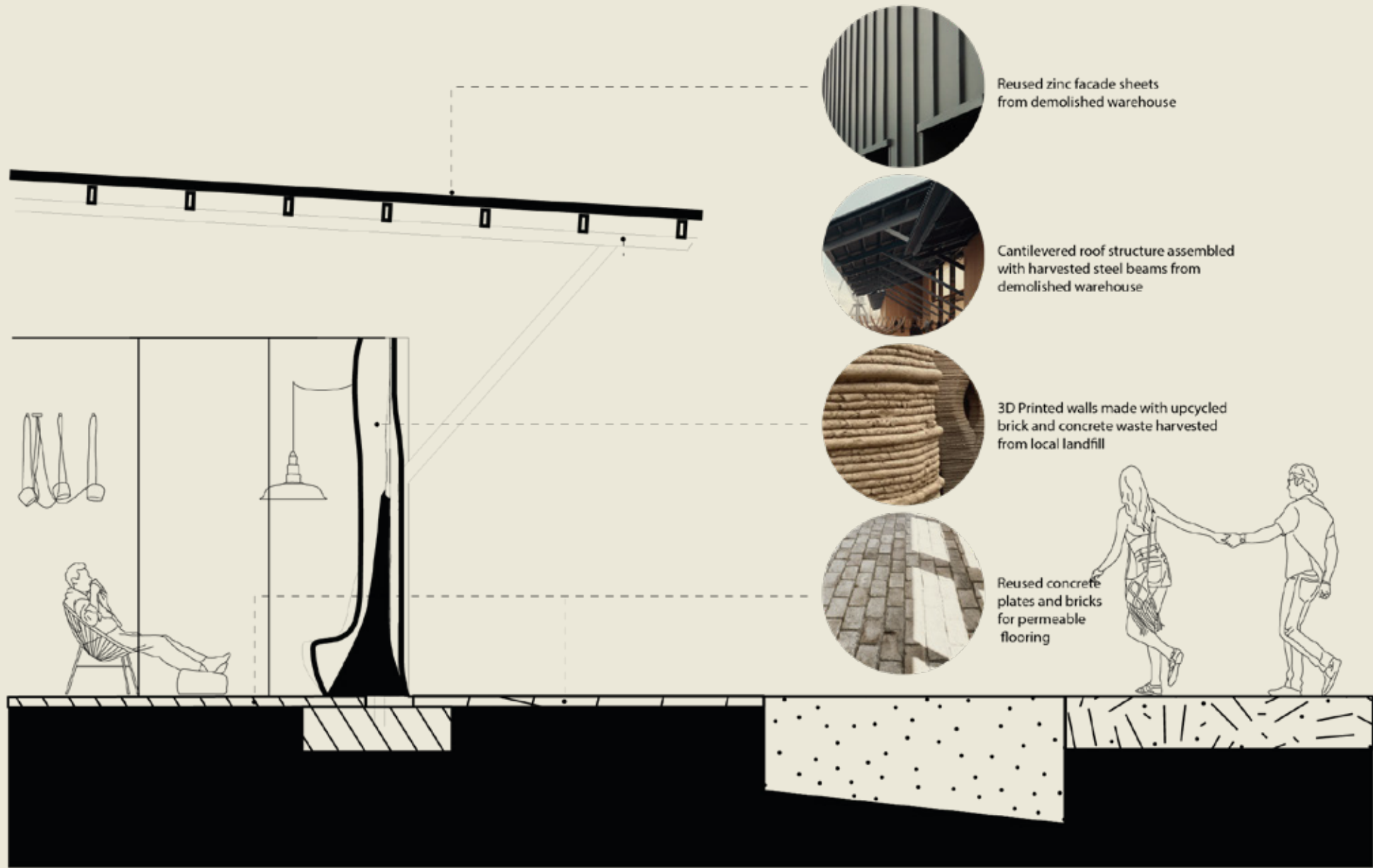


SCALE OF INTEGRATION

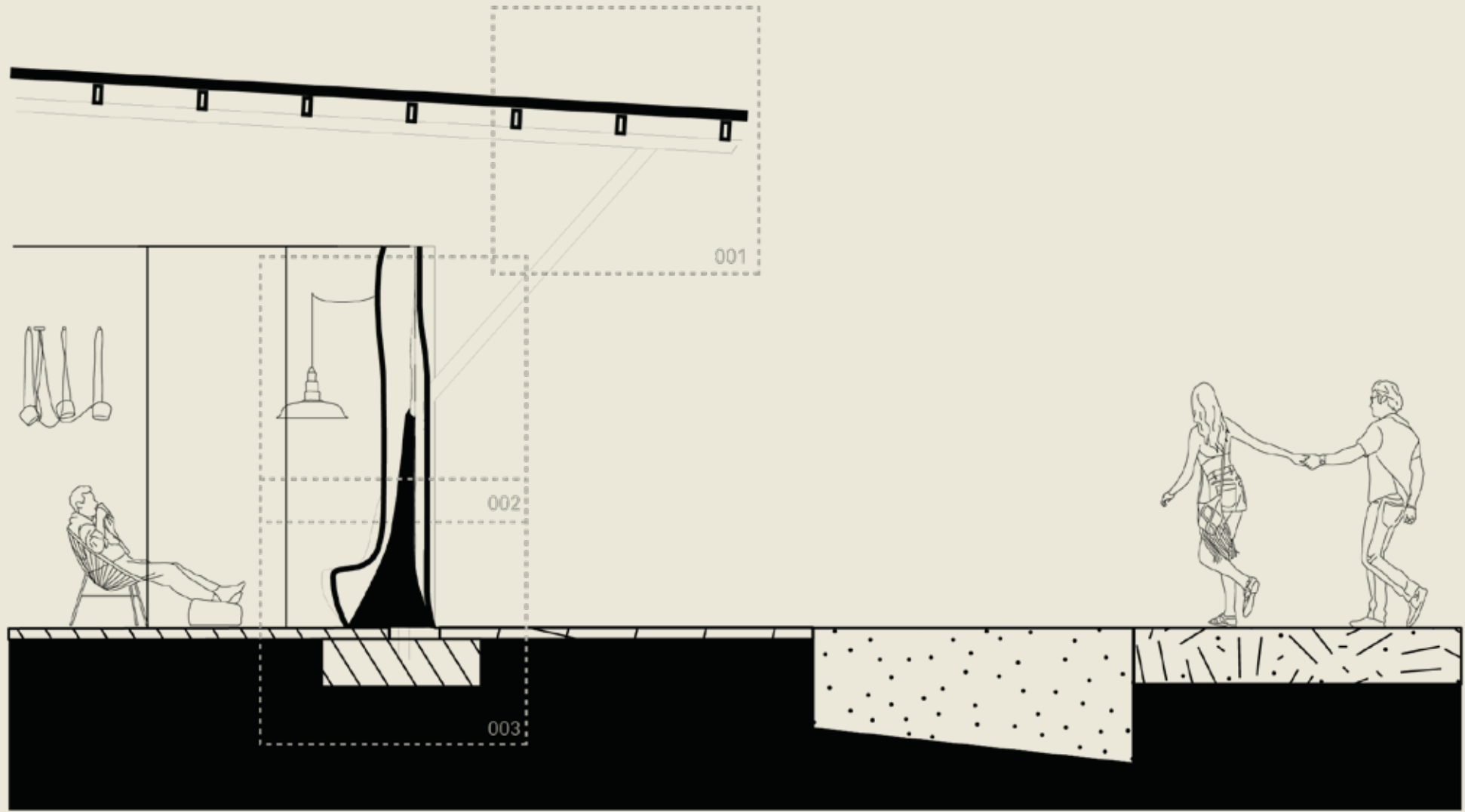
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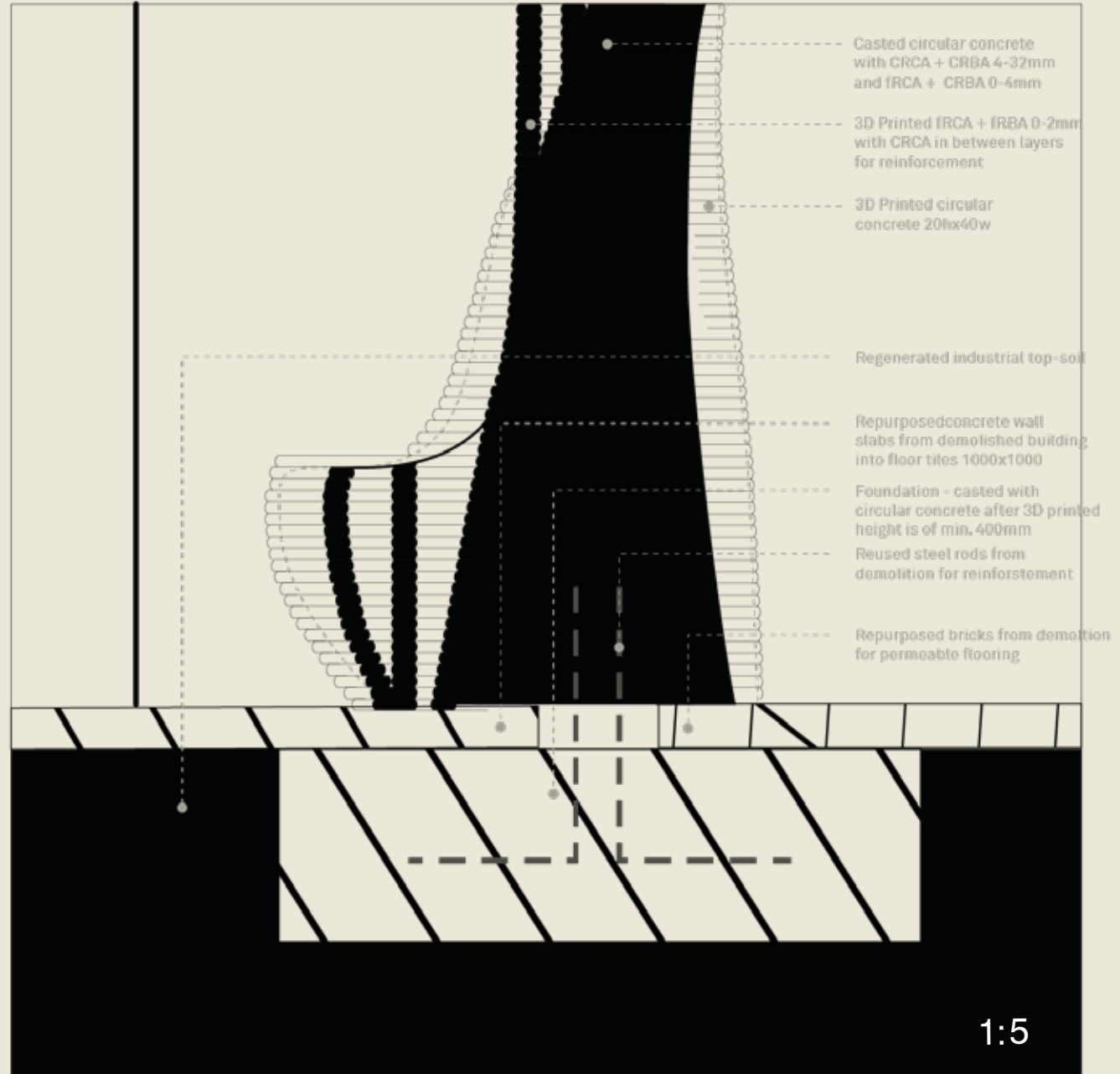
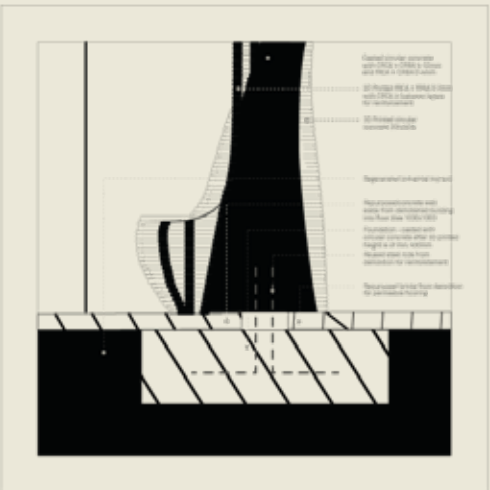
SCALE OF INTEGRATION



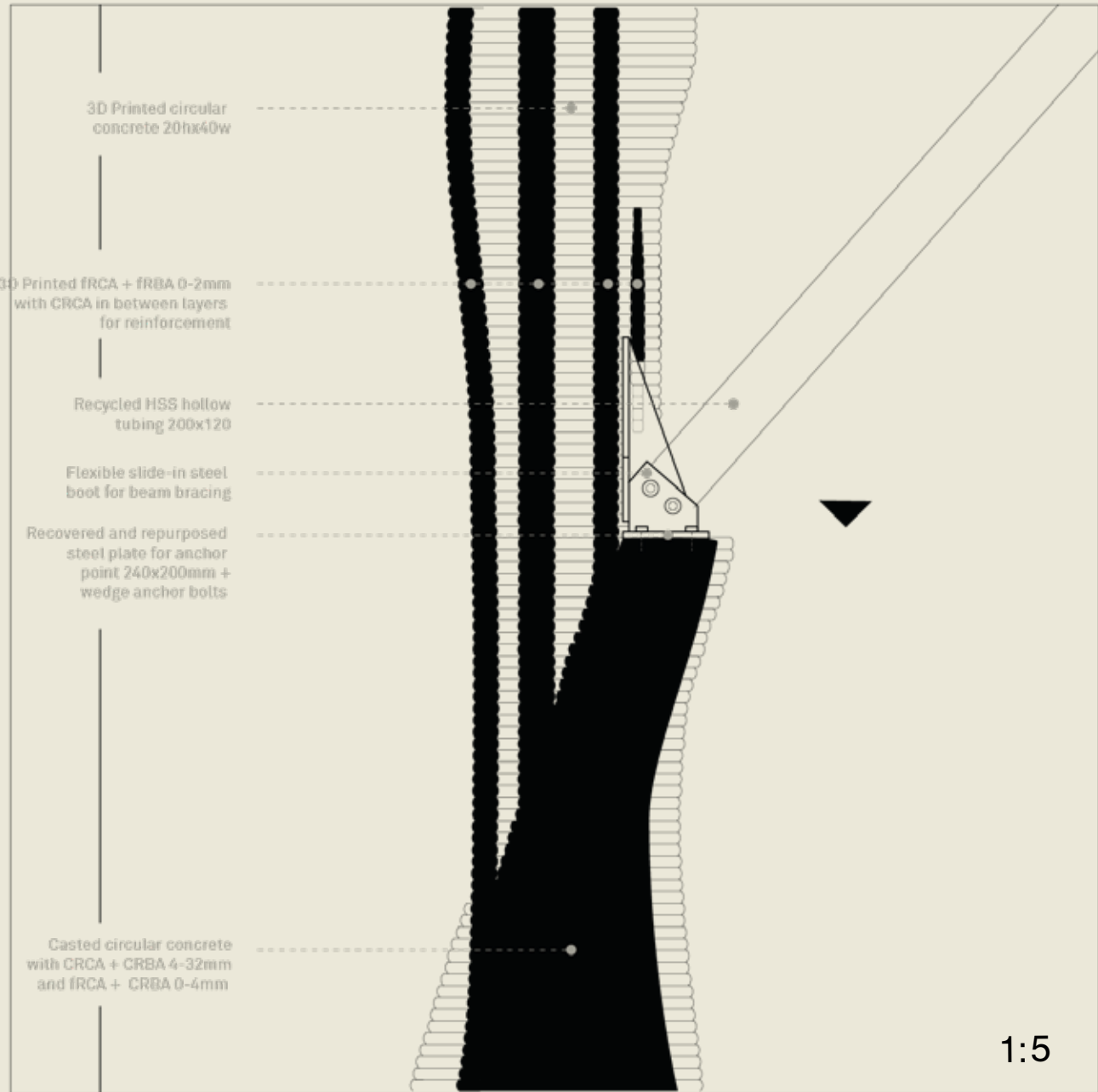
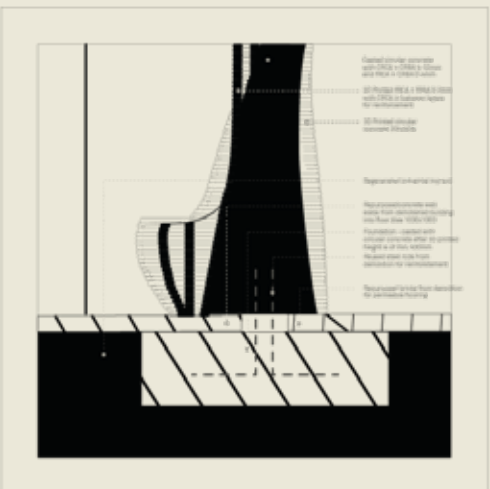
MATERIAL HARVEST AND USE



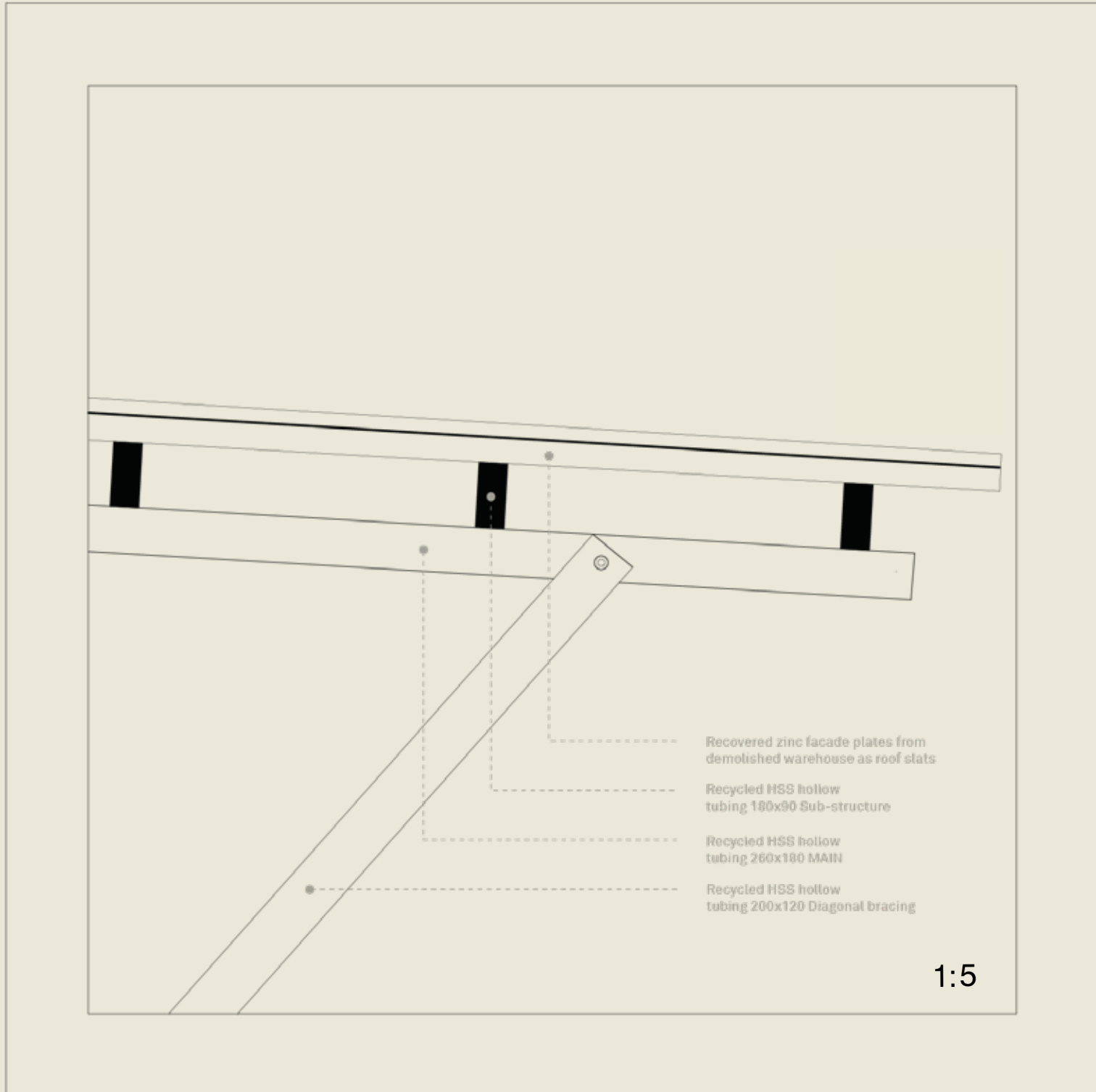
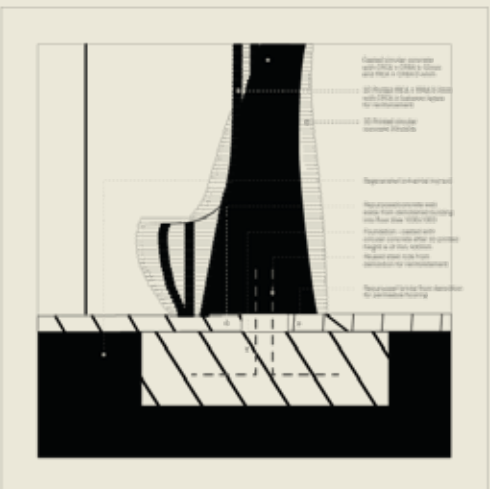
DETAILS

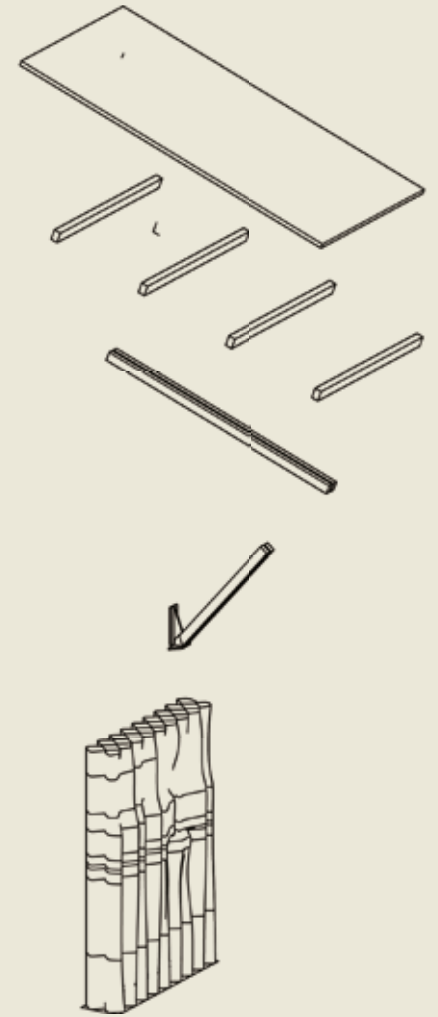
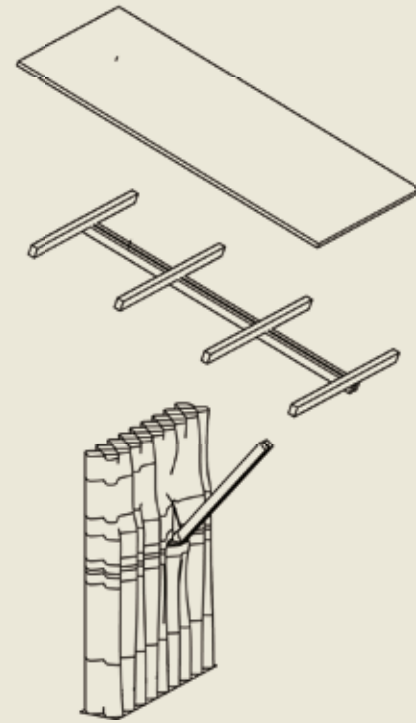
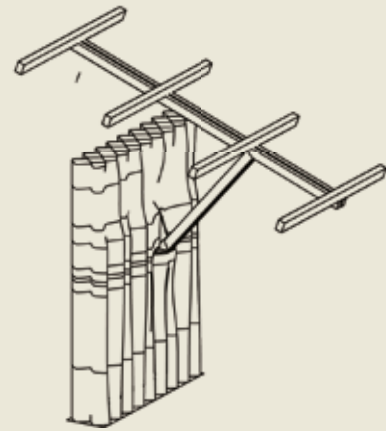
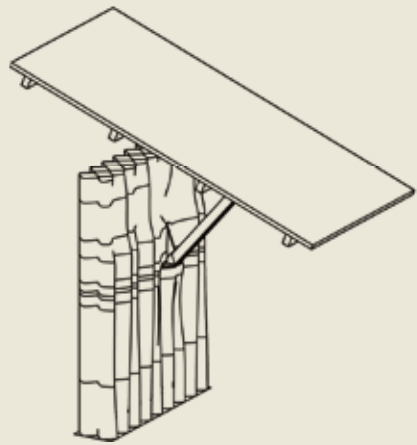


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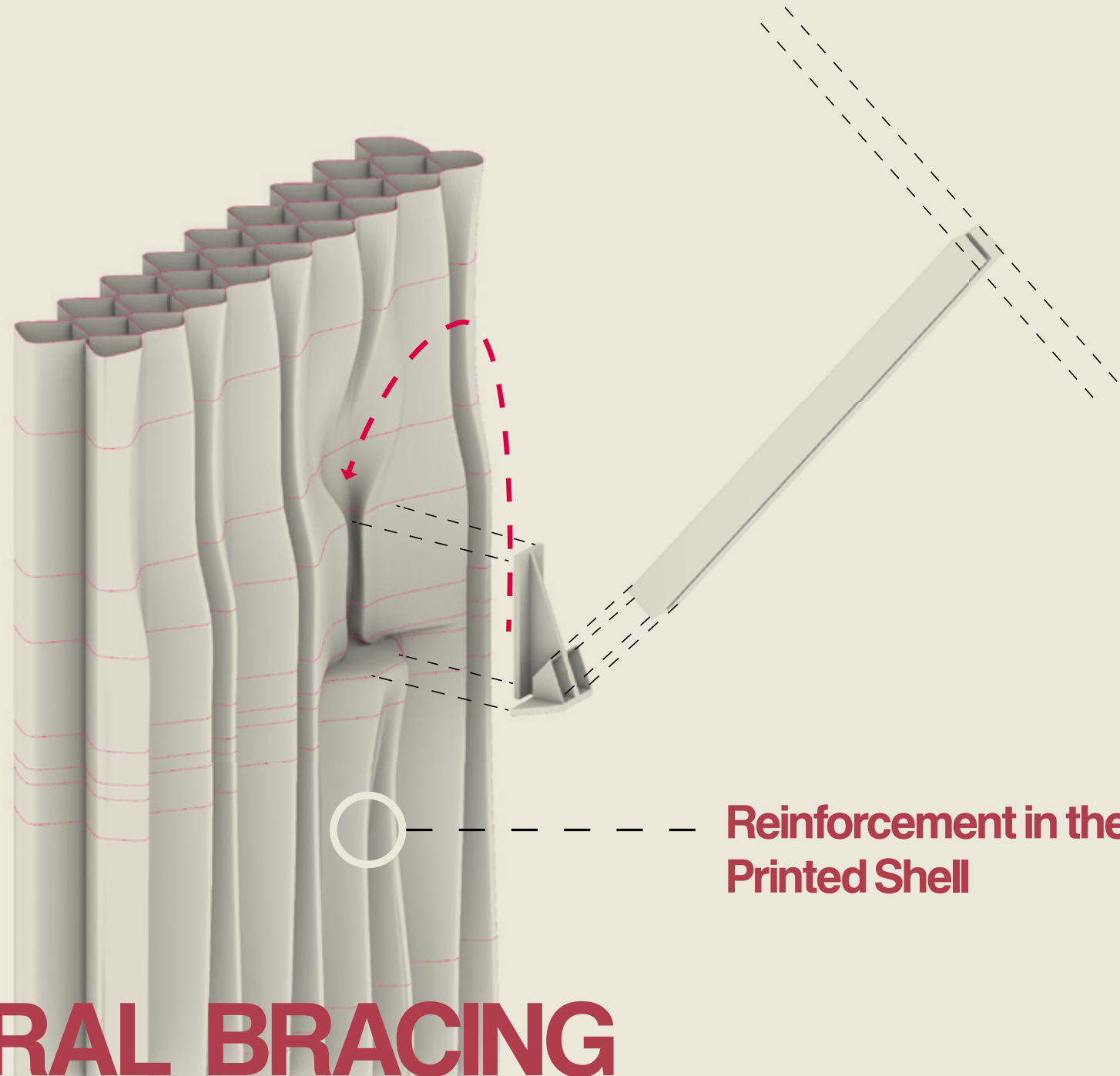


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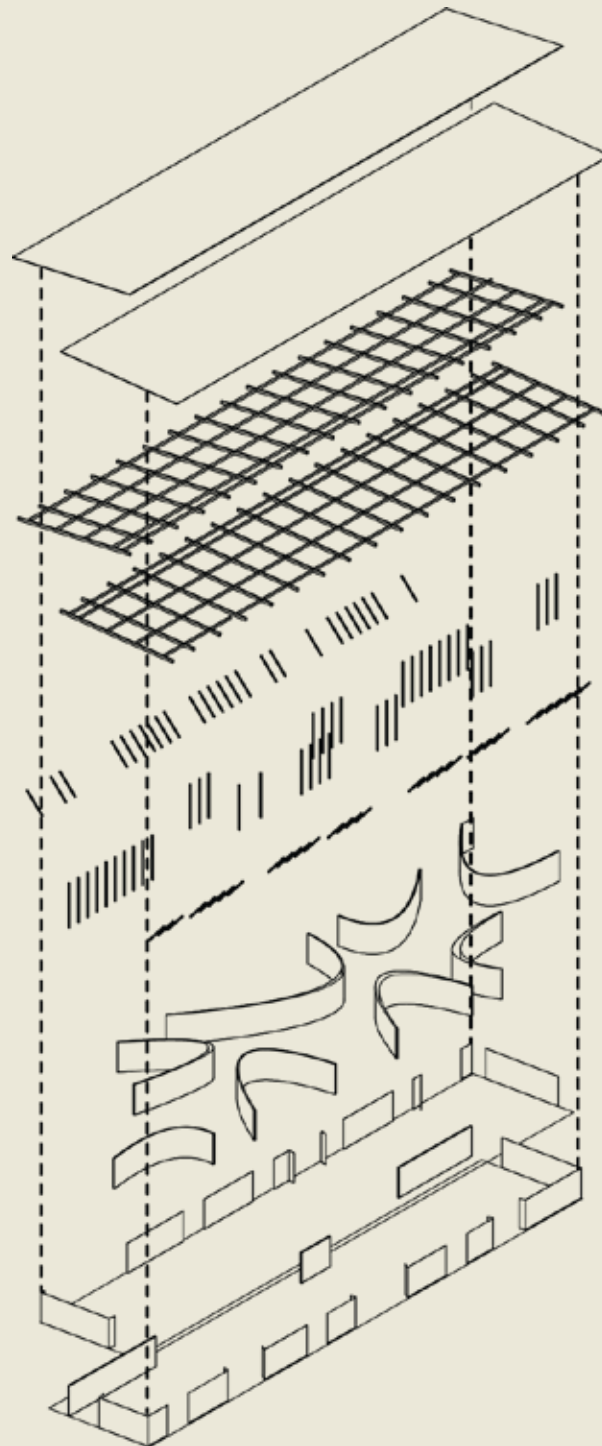
ASSEMBLY



**Reinforcement in the 3D
Printed Shell**

STRUCTURAL BRACING

BUILD-UP



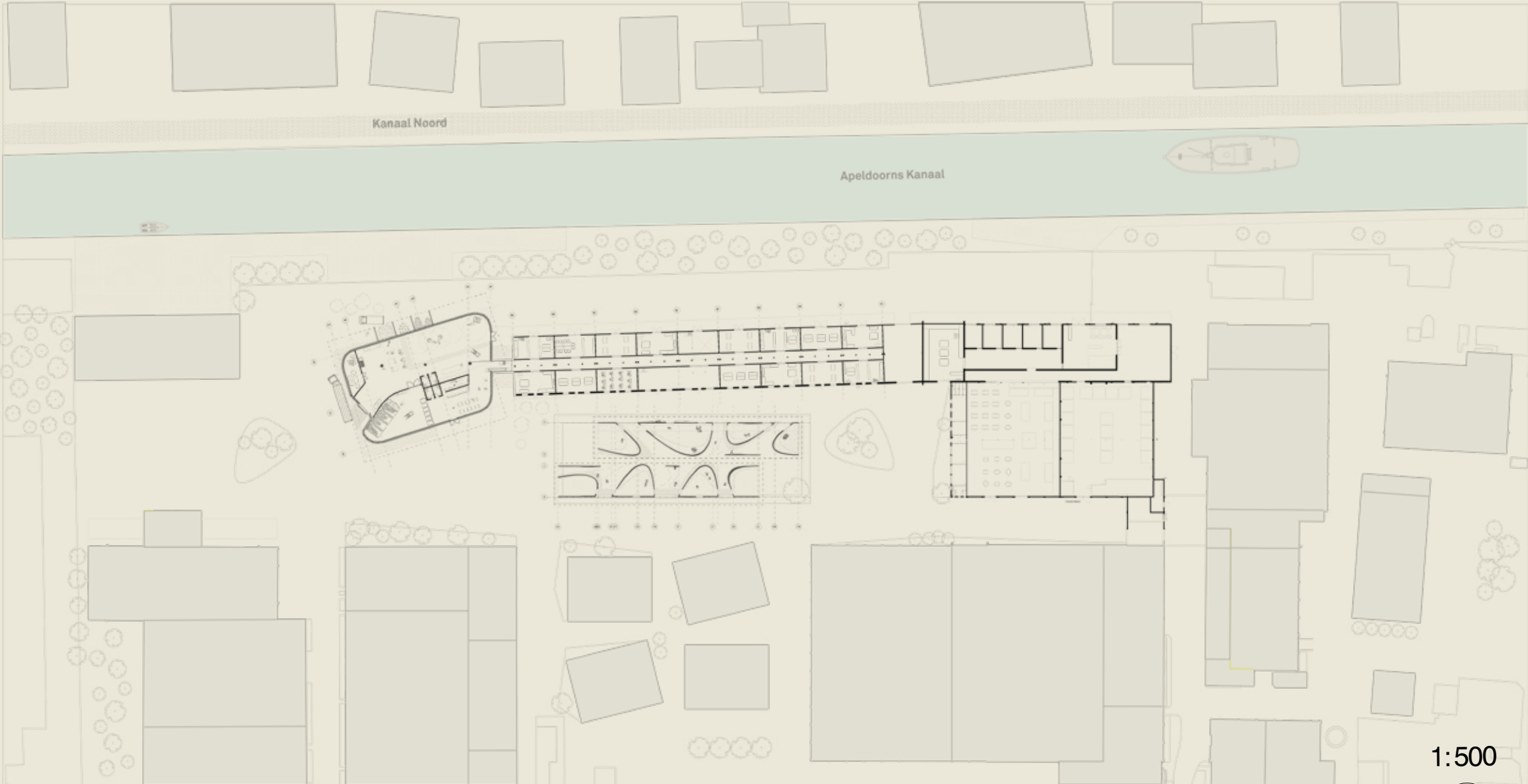
Corrugated Zinc Panels

Steel Substructure

**Columns/Beams
Bracing**

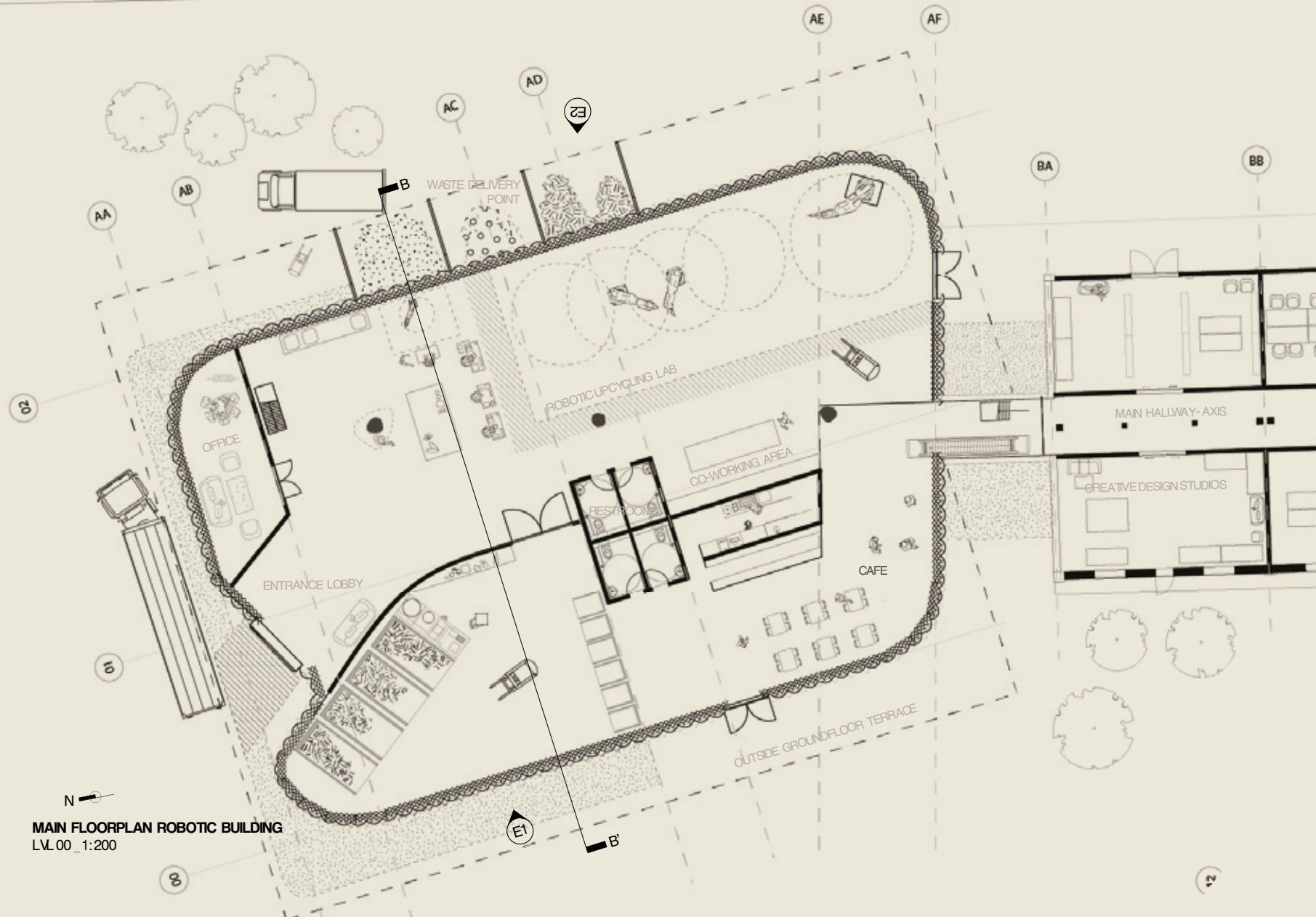
**3d Printed Waste
Stability**

Main Load Bearing Walls



MASTER PLAN

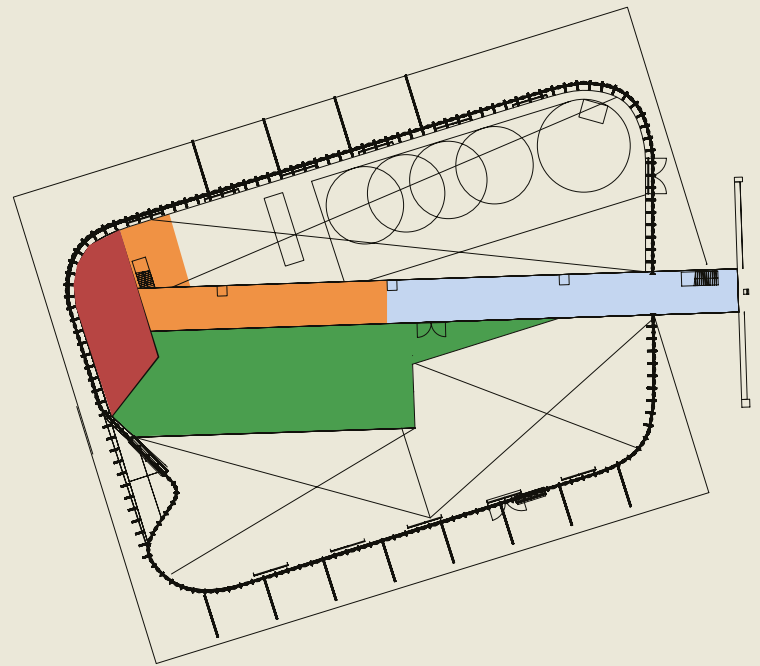
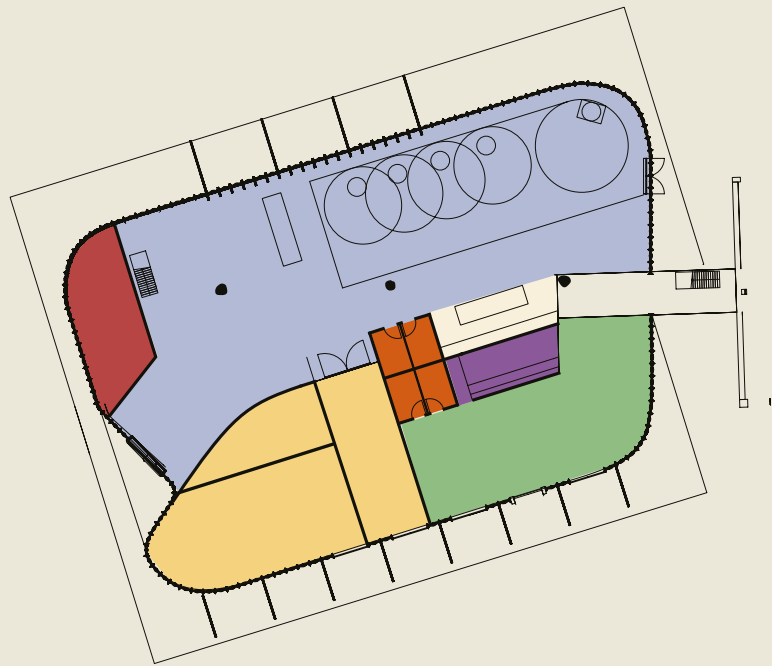
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N



N
MAIN FLOORPLAN ROBOTIC BUILDING
LV.00_1:200

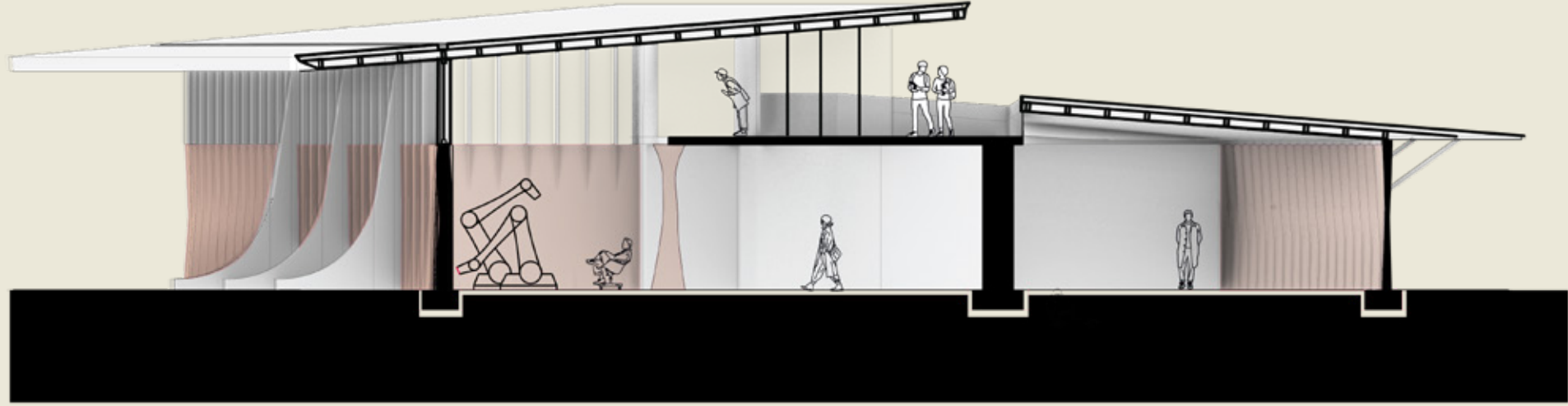
NORTH-EAST VIEW

1:100
N



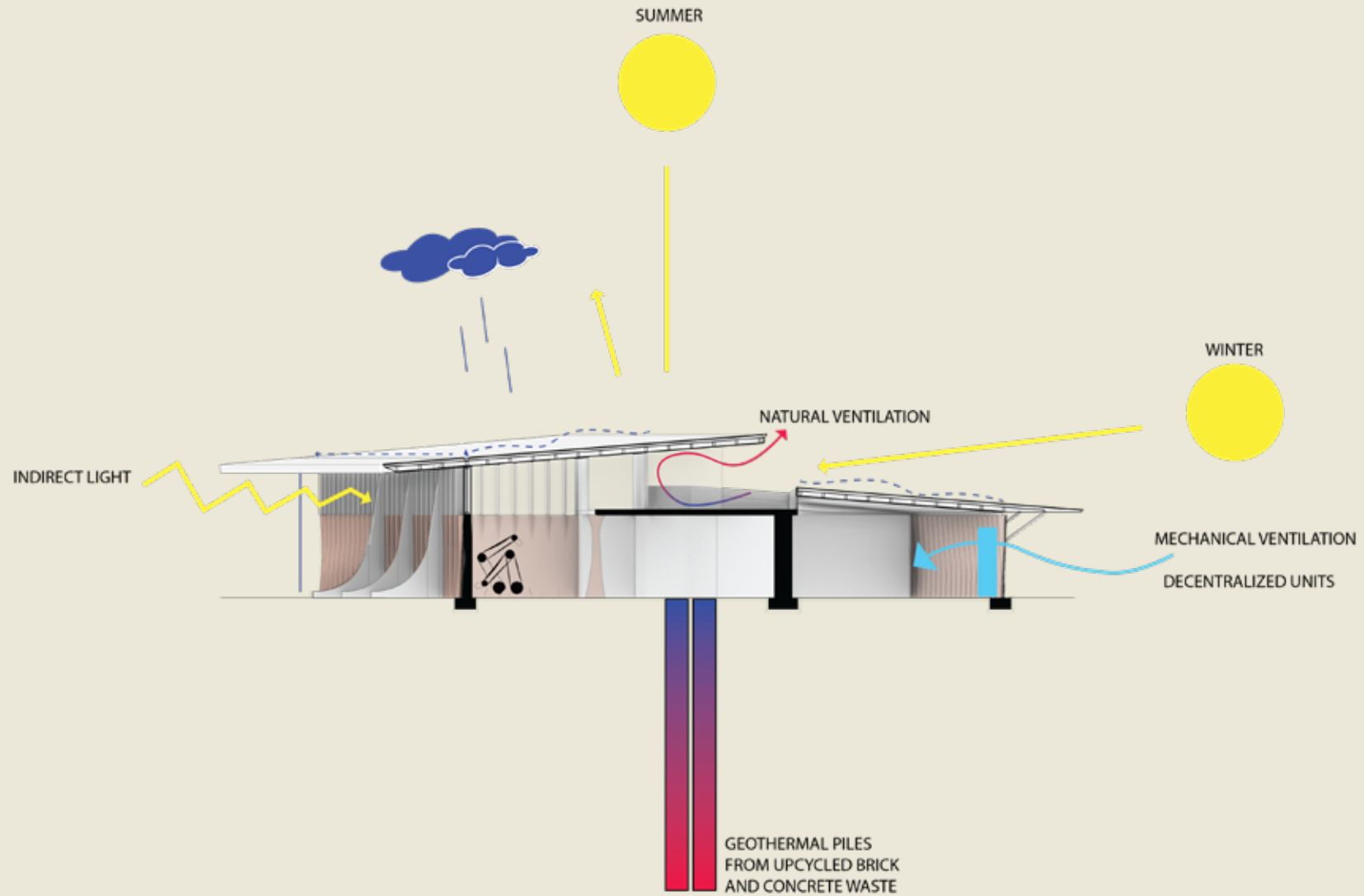
- Robotic Upcycling Lab
- Cafe
- Waste Storage
- Studio
- Kitchen
- Restrooms
- Studio/ Quality Control
- Terrace

PROGRAM



SECTION A-A'

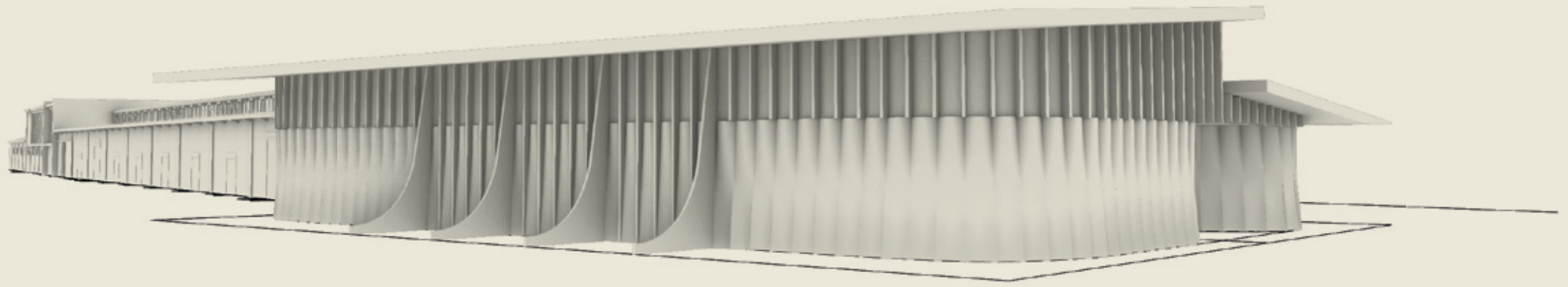
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CLIMATE DESIGN

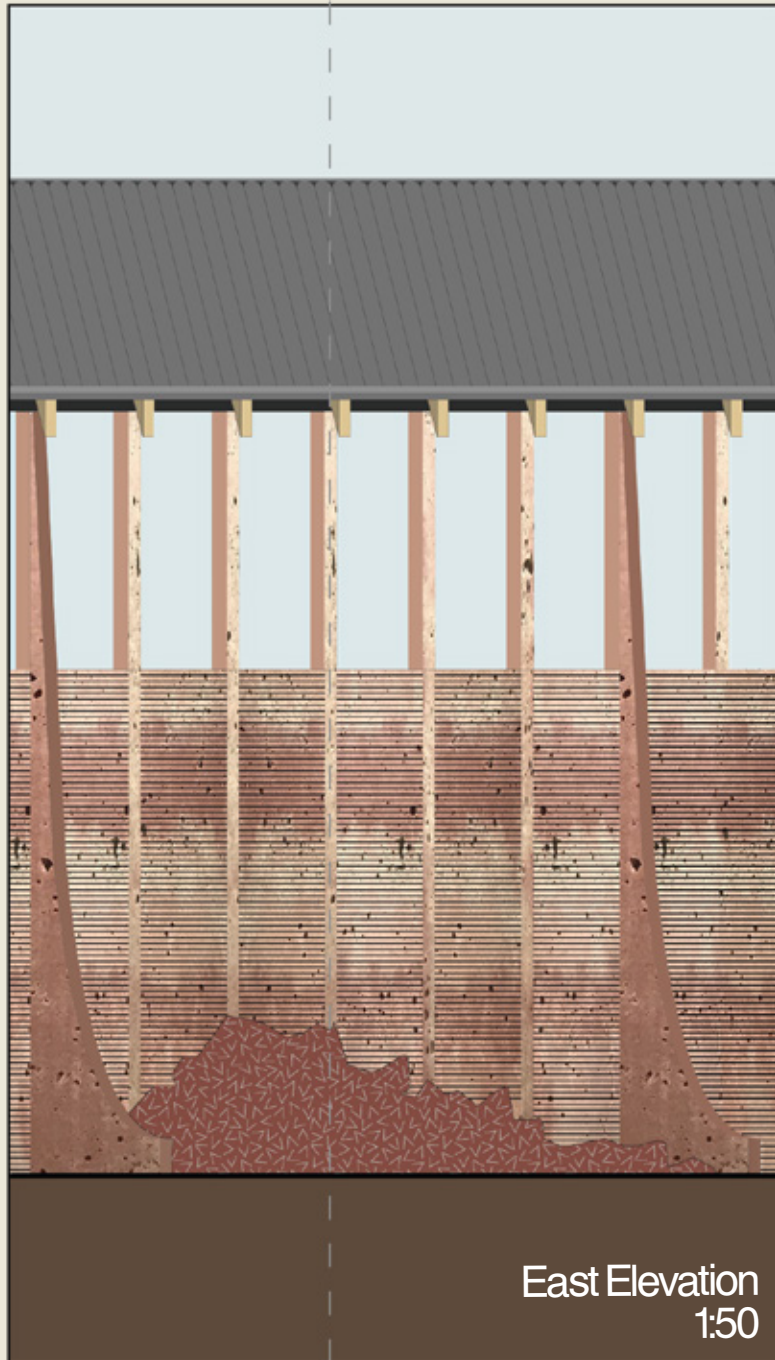
Waste deposits





NORTH - EAST VIEW

AD



East Elevation
1:50

▼ 7780

▼ 6360

▼ 5950

▼ 4000

▼ 00

AC



▼ 7780

▼ 7200

▼ 5360

▼ 5000

▼ 4000

▼ 2250

▼ 00

West Elevation
1:50





