

P5

Structural design for
change

**Timber Top-Ups on Reinforced
Concrete structures to increase
dwellings area**

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Student:

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5426138

2023.06.26



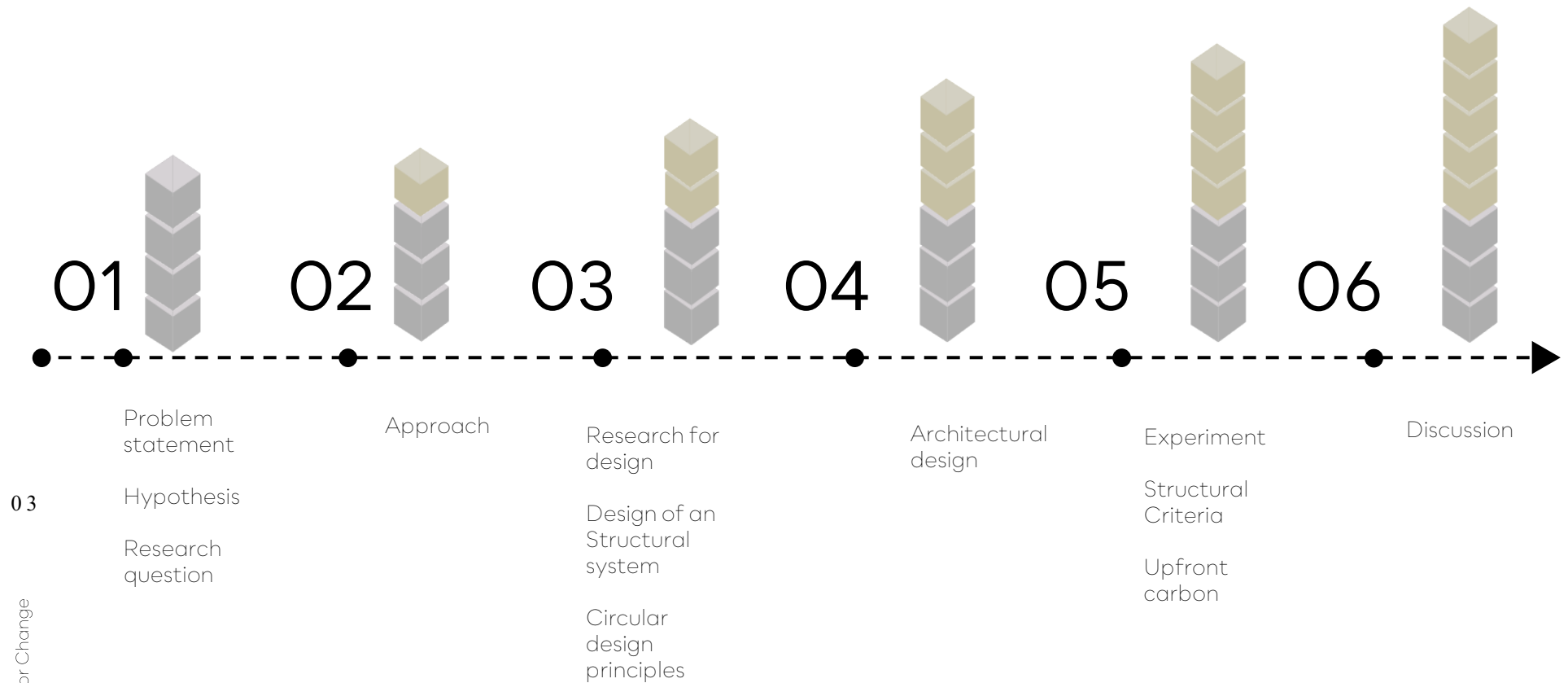
Top-Up:
Substructure

(RC)
structure

01

Introduction

Structure of the presentation



Dutch Government Created Housing Shortage, Blames Market

Far from trusting the market, politicians won't leave housing alone.

Why is there a housing shortage in the Netherlands? The Dutch housing crisis explained



Despite Housing Shortage, Dutch Universities Continue to Admit International Students

Netherlands | Europe | International Studies | Higher Education News | by [Erudera News](#) | Dec 05, 2022



The Netherlands continues to be a popular study destination for international students despite them facing struggles to find accommodation for the duration of their stay in the

Recent Articles

Supreme Court's Decision Day on Student Loan Forgiveness Plan...

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Number of International Students in Finland Is Growing, Newly Released Dat...

• Finland Jun 22, 2023

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• Australia Jun 22, 2023



▲ The Dutch Housing Shortage

Report

The Dutch Housing Shortage

Jasper Koops ■ 17 May 2021 at 17:00

The Netherlands currently has a housing shortage of 285,000 houses, according to ABF Research. The shortage is recognized by the government and is given high

Housing construction in Urk, March 2020 - Credit: [fokkebok / DepositPhotos](#) - License: [DepositPhotos](#)

BUSINESS HOUSING SHORTAGE HOUSING MARKET ATLAS RESEARCH ATLAS FOR MUNICIPALITIES HOUSING CONSTRUCTION » MORE TAGS

WEDNESDAY, 22 JUNE 2022 - 08:03

SHARE THIS:



Netherlands has 390,000 too few homes

There is a shortage of 390,000 homes in the Netherlands. That amounts to about 5 percent of the total number of homes, according to the Atlas for municipalities 2022. On average, there are 105 candidates for every 100 available homes in the Netherlands.

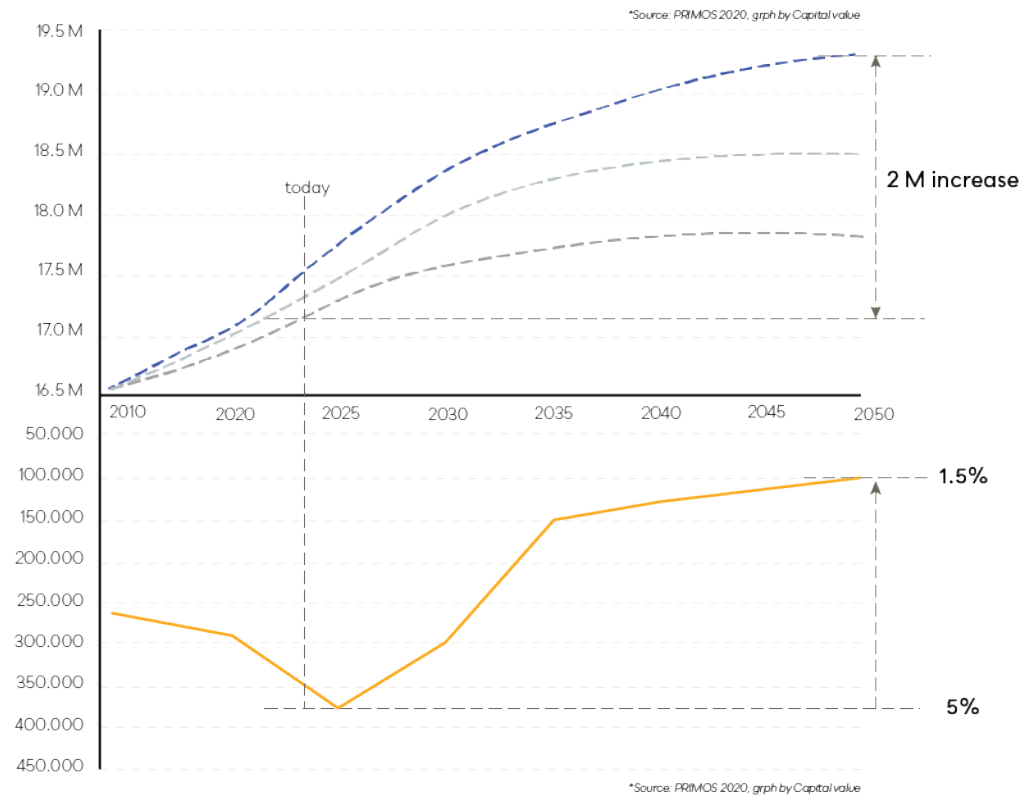
Of the largest municipalities, the shortage is highest in Amstelveen and Amsterdam. These municipalities have about 150 candidates per 100 available homes. The housing shortage is also high in Hilversum, Utrecht, and Amersfoort, with 140 candidates for every 100 available homes.

ATLAS/DEPOTPHOTOS

01 Introduction

Background

Projected increase of population in the Netherlands



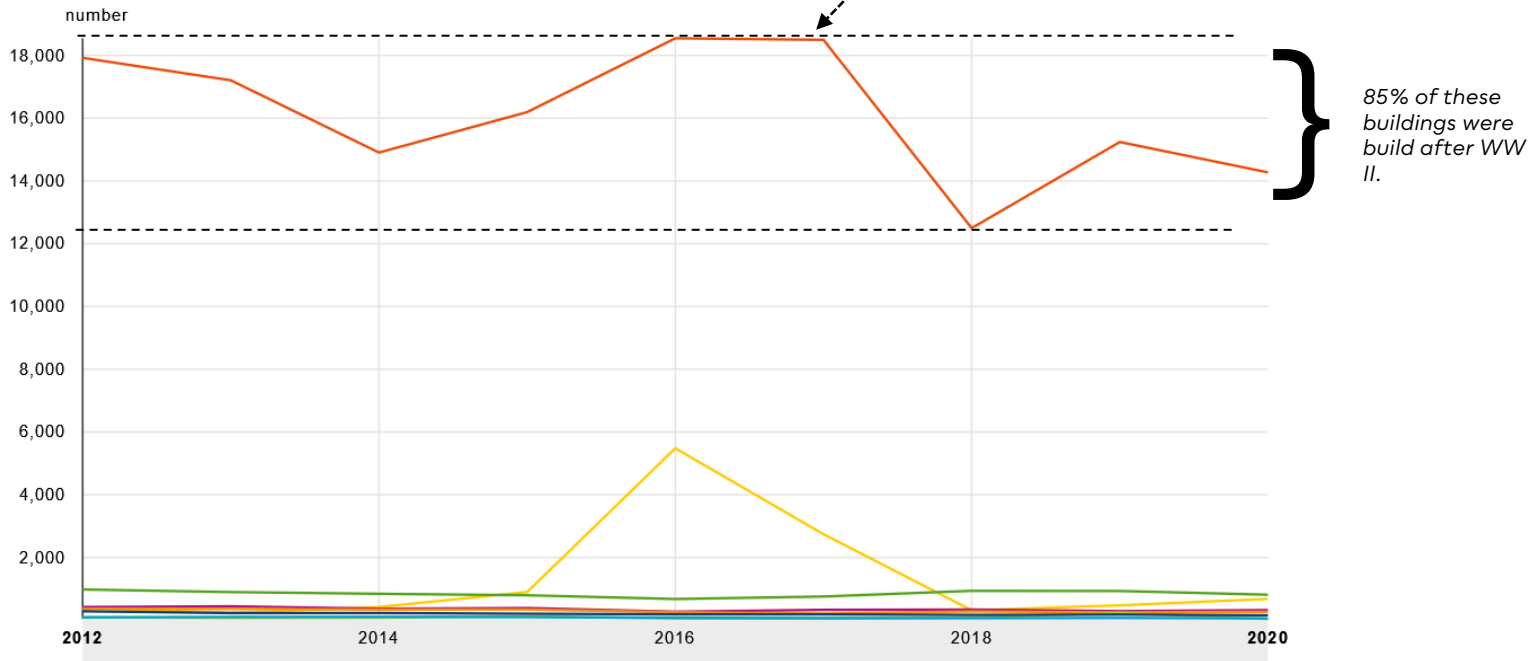
Intendend number of houses to be reduced

01 Introduction

Background

Demolition of dwellings in the Netherlands

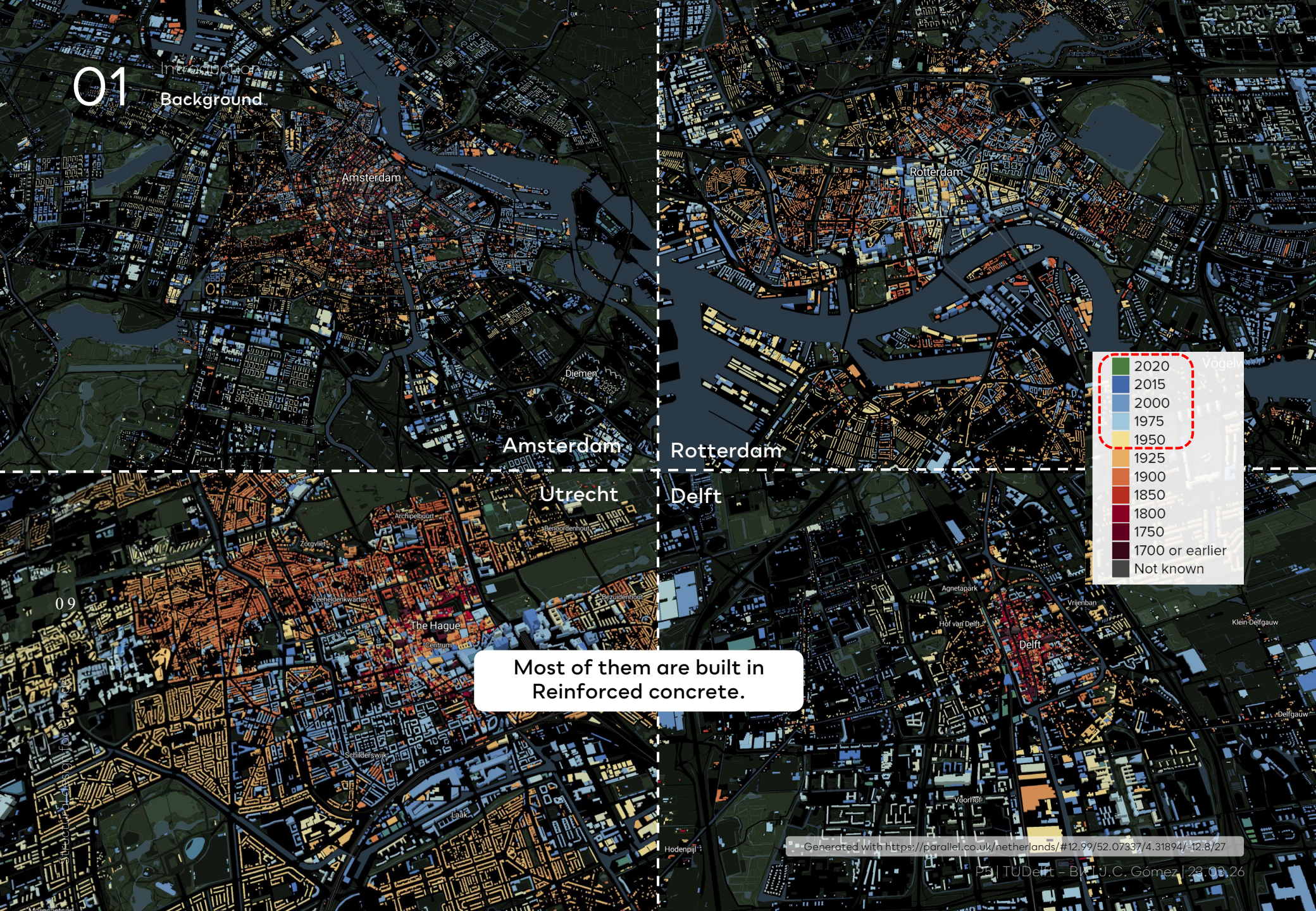
Topic: Demolition
Regions: The Netherlands



Source: (Pardo Redondo, Don't demolish restore! 2021).

01

Introduction
Background



09

Most of them are built in
Reinforced concrete.

01

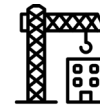
Introduction
Background



Existing building ----->

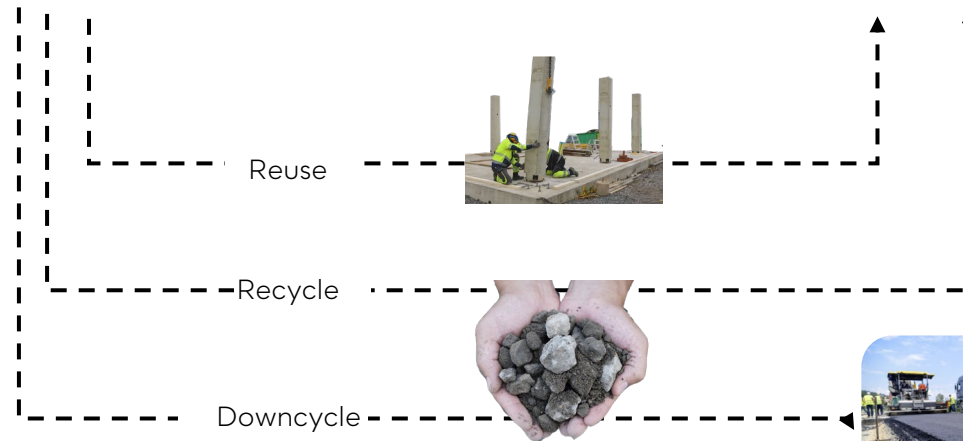


+



Build new increasing the area

08

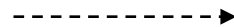


01

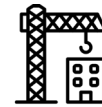
Introduction Hypothesis



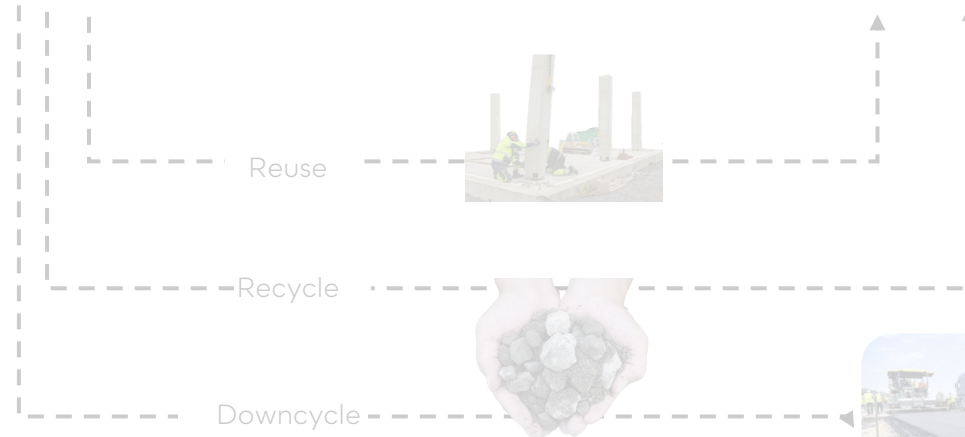
Existing building



+



Build new increasing the area



09

Structural design for Change

01

Introduction
Hypothesis



01

Introduction
Hypothesis

11

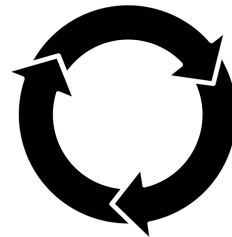
Strategic design for Change



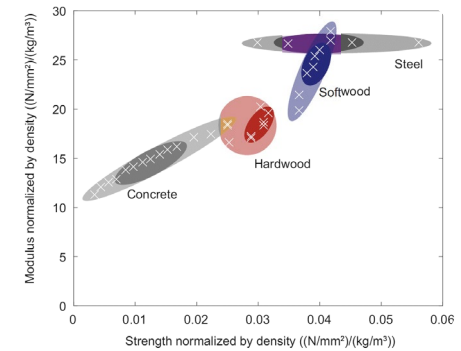
01

Introduction Hypothesis

Carbon
sequestration



Renewable material. &
It can be cascaded.



High strength-to-density
ratio compared to other
material

01

Introduction Hypothesis

choose impact category
Global Warming Potential (GWP)

choose unit
 m^3

filter by material group
no filter

filter and sort by "functional unit"
according to declared unit



How to increase the area of existing Reinforced Concrete structures to extend their lifespan by using timber top-ups?

Approach

SQ. 1 |

Which structural timber systems can be more effective when topping up existing Reinforced Concrete Structure (RCS) buildings?

Collect literature

SQ. 2 |

What opportunities and limitations have topping up an existing RC structure building?

Collect literature
& experimental.

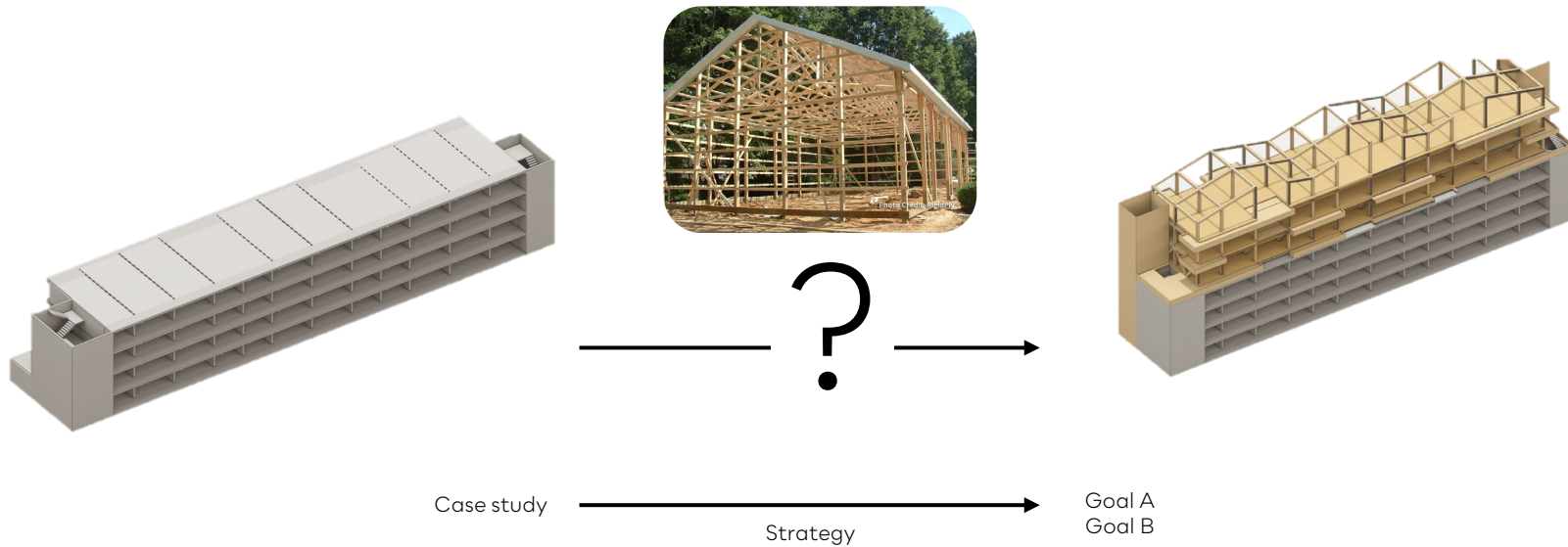
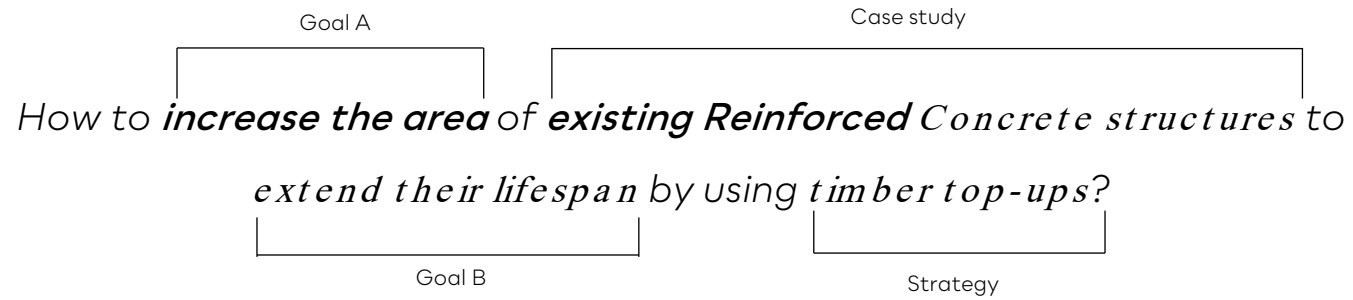
SQ. 3 |

To what extent can be increased the area of an existing RC building with timber?

Experimental

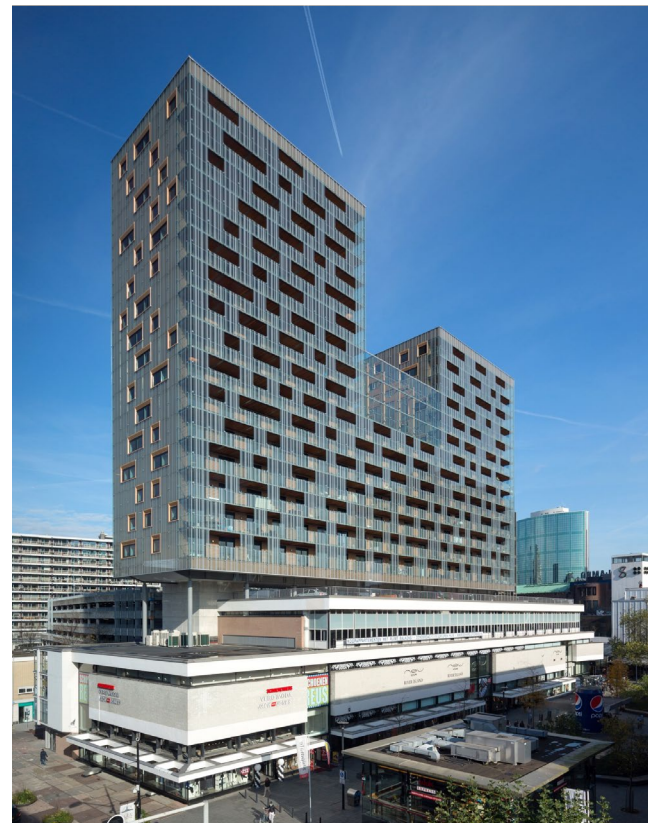
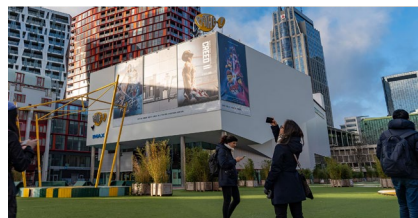
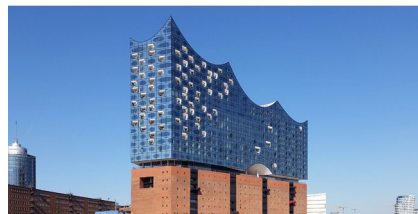
02

Introduction Problem-solving approach



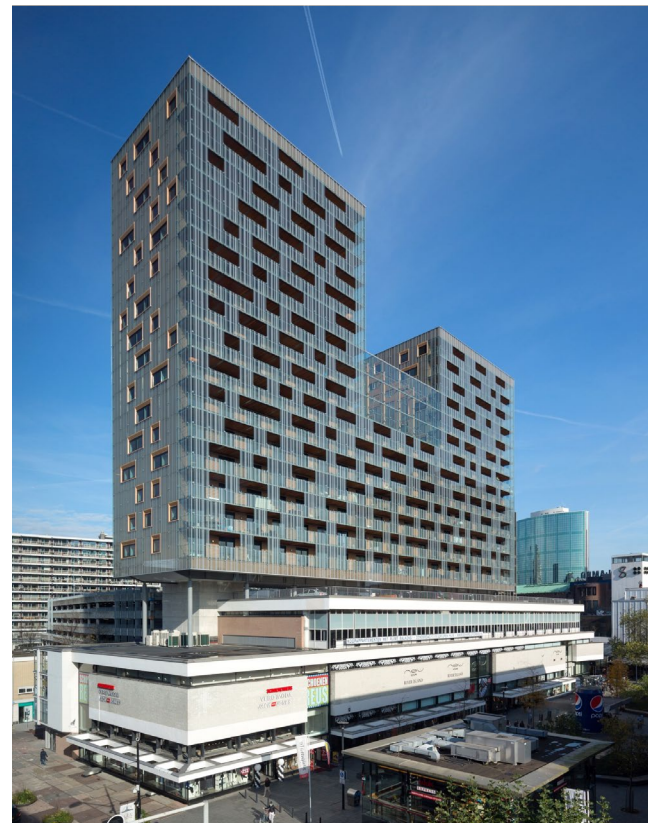
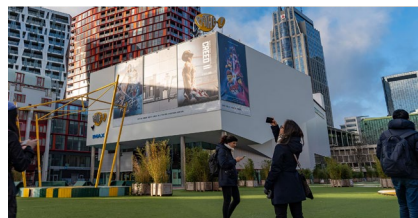
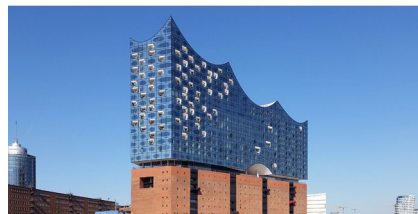
02 Case studies

Problem-solving approach



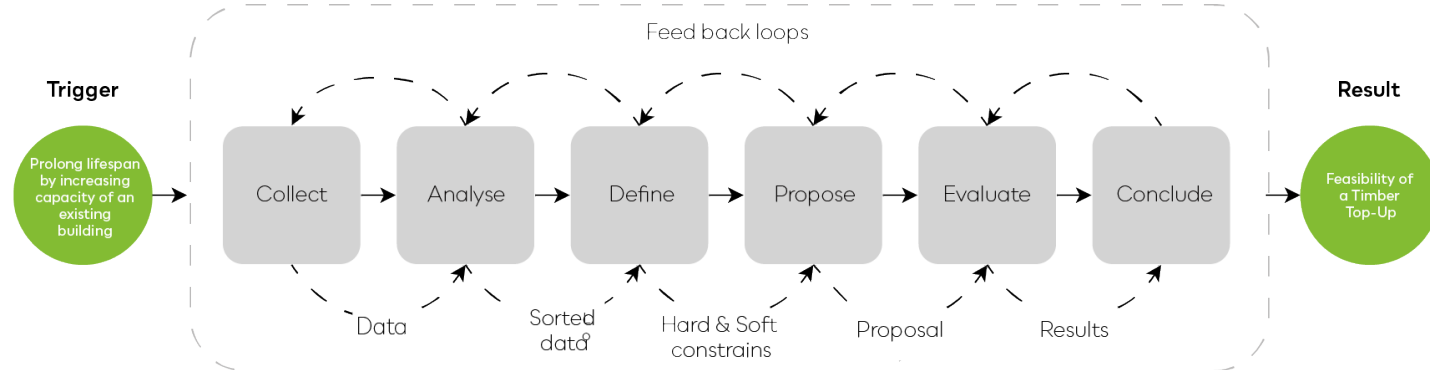
02 Case studies

Problem-solving approach



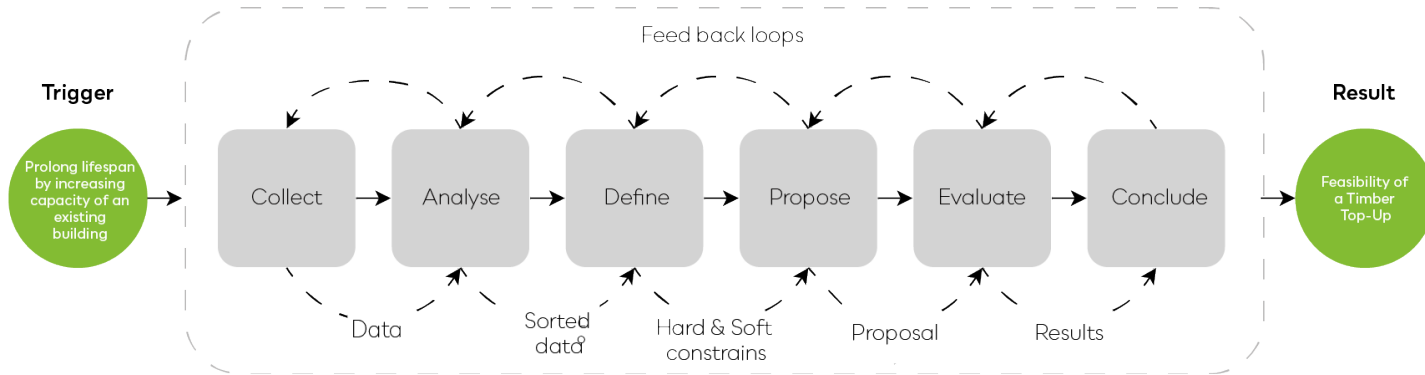
02

Research for design Problem-solving approach



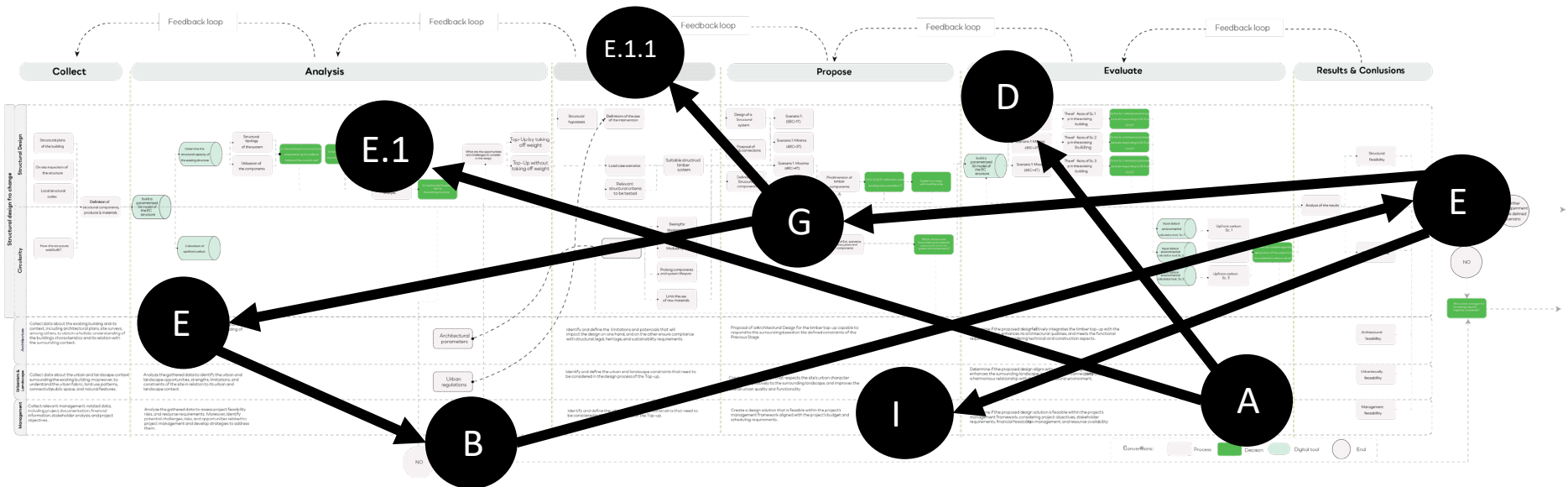
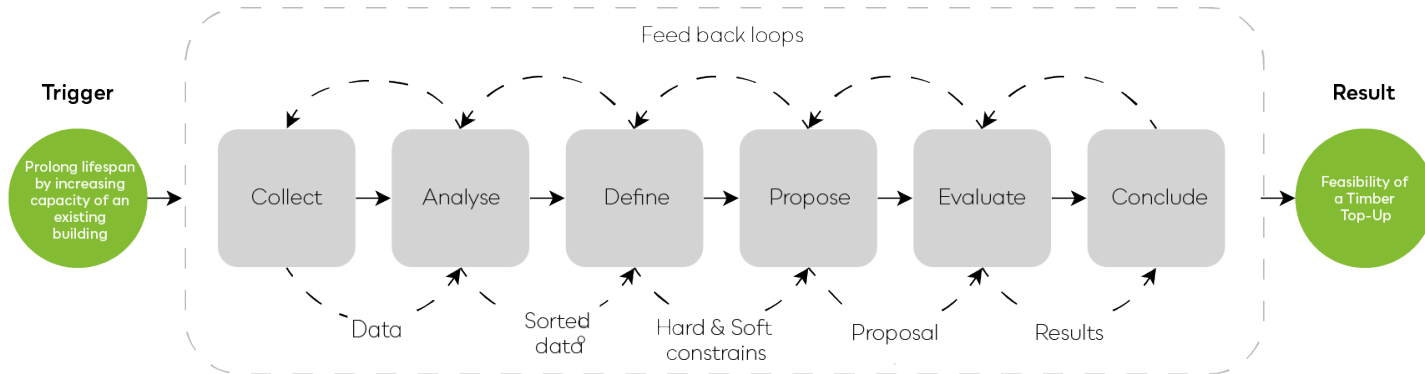
02

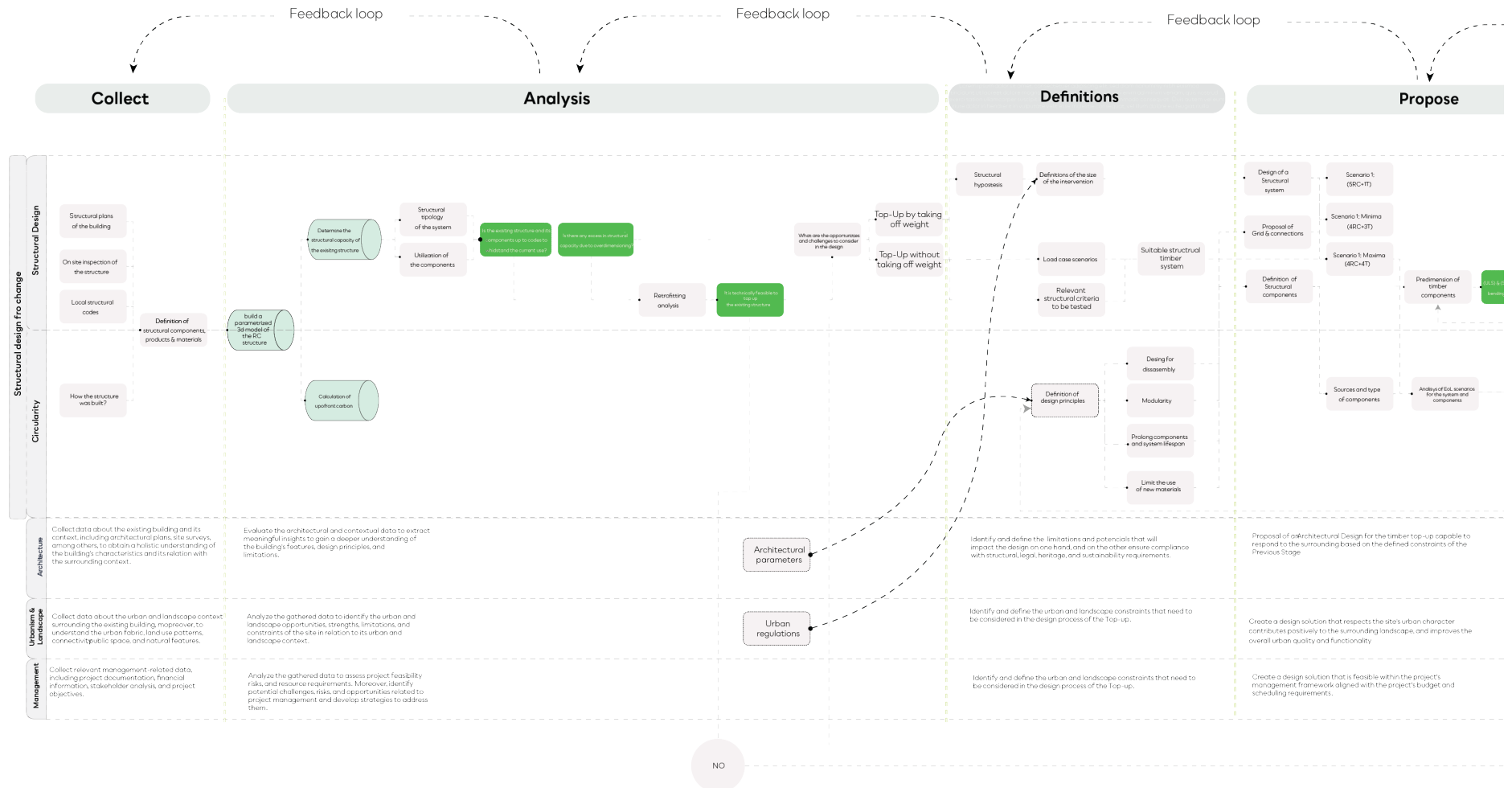
Research for design Problem-solving approach

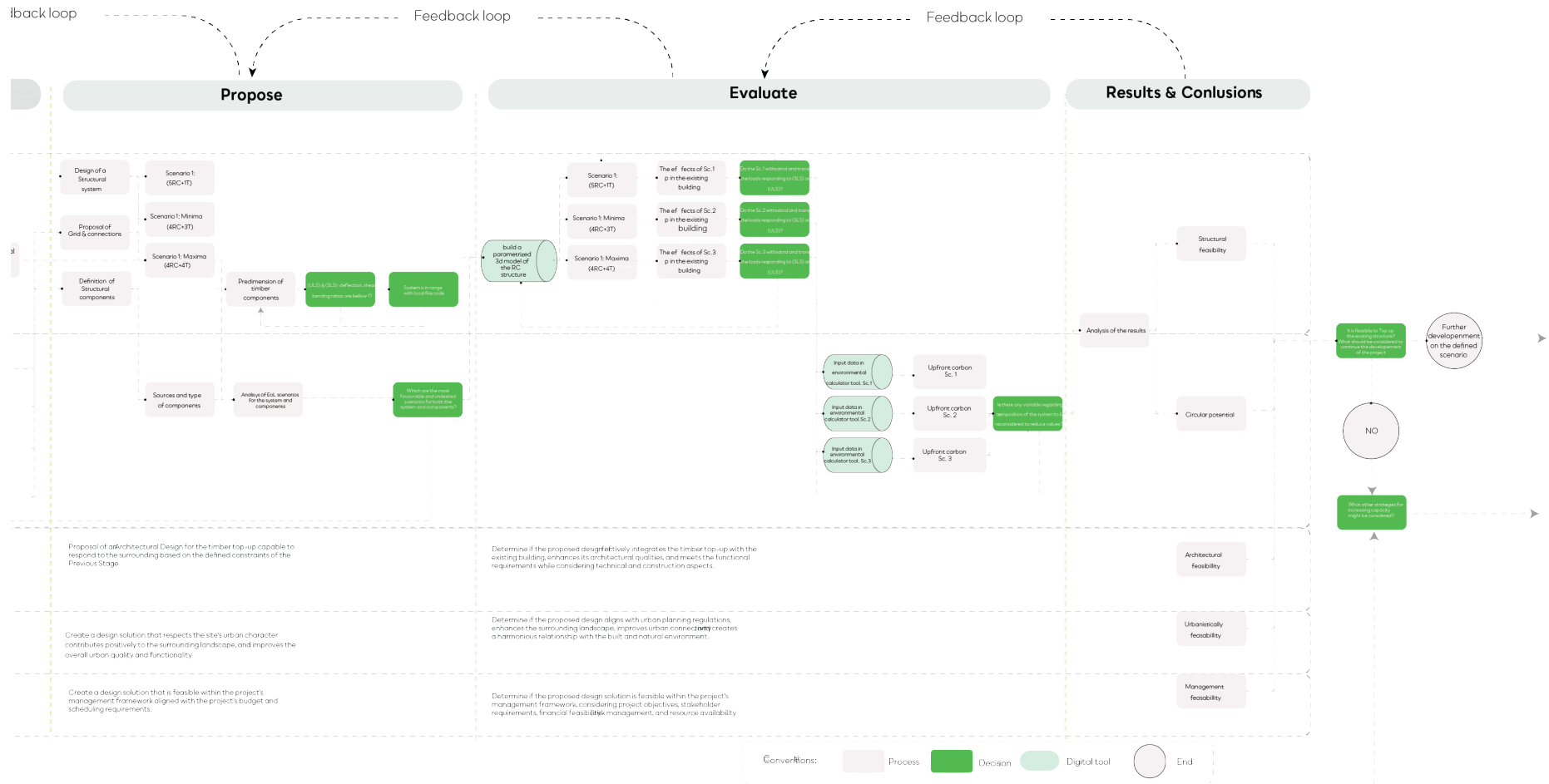


18









03

Research for design
Case study selection



15% of the
housing stock

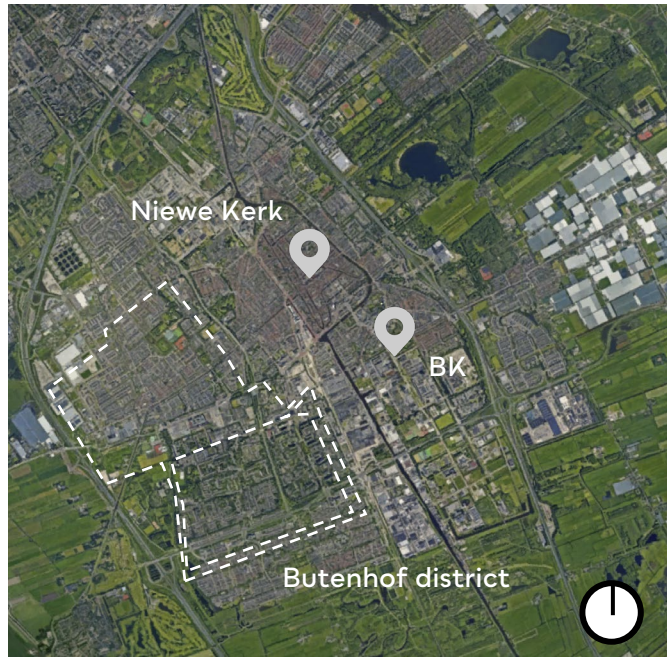
22

Structural design for Change



03

Case study selection for intervention The neighborhood of Gillisbuurt in Delft



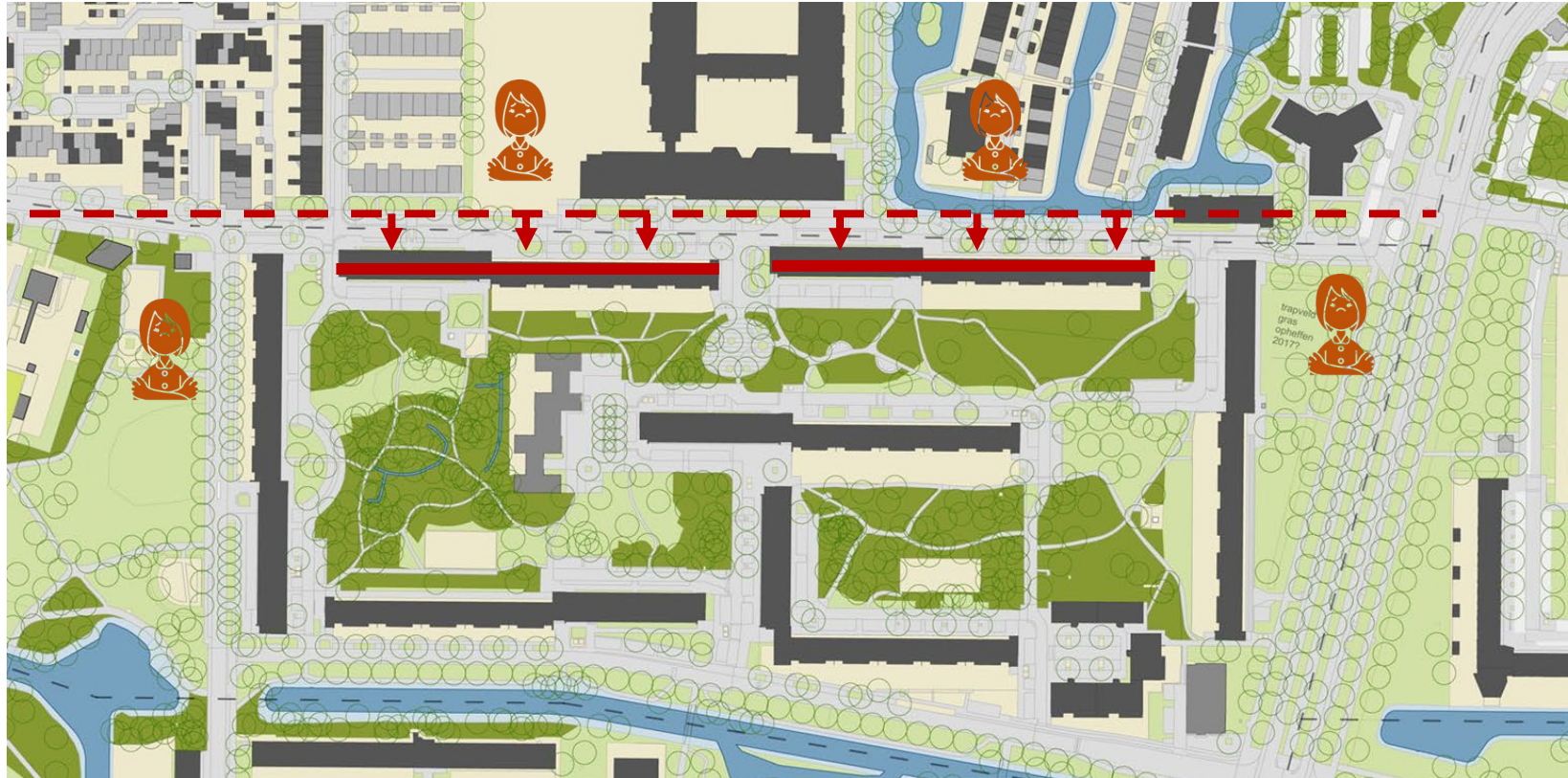
City of Delft



Gillisbuurt residential block

03

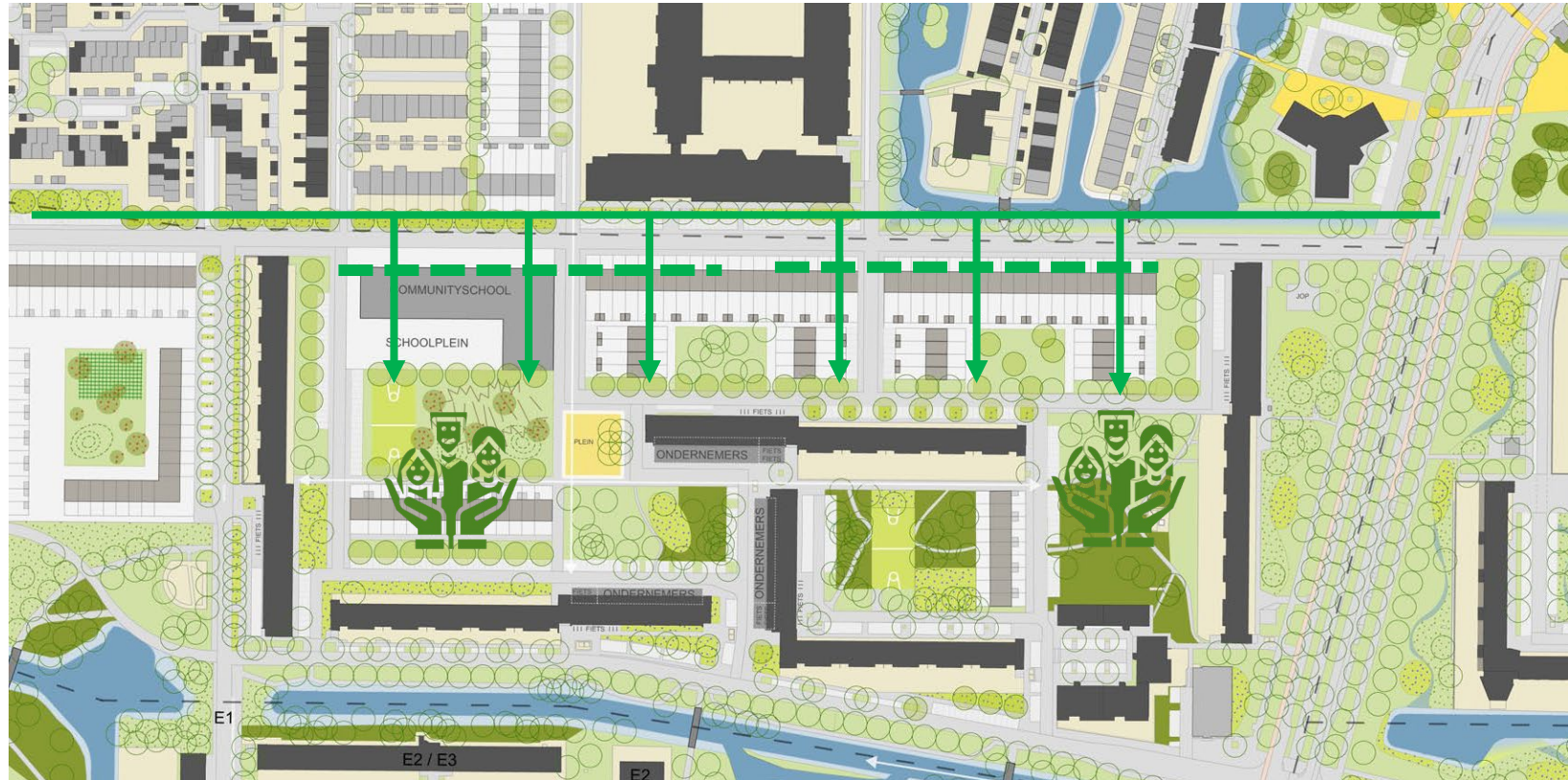
Case study selection for intervention The neighborhood of Gillisbuurt in Delft



Integral exploration of the Buitenhof area-opportunity cards by the Delfts Geemente.

03

Case study selection for intervention The neighborhood of Gillisbuurt in Delft

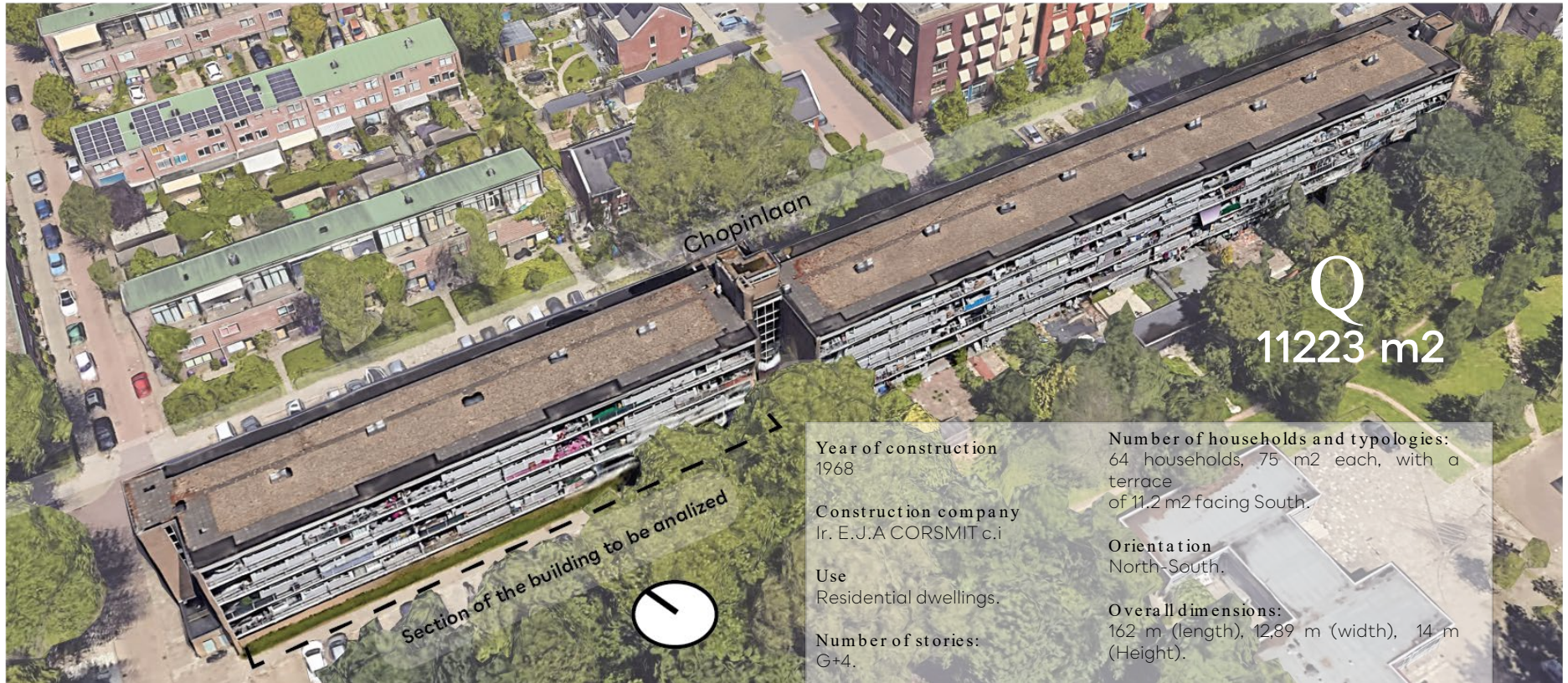


Integral exploration of the Buitenhof area-opportunity cards by the Delfts Geemente.

03

Research for design

Collect: Gathering available information about the building.

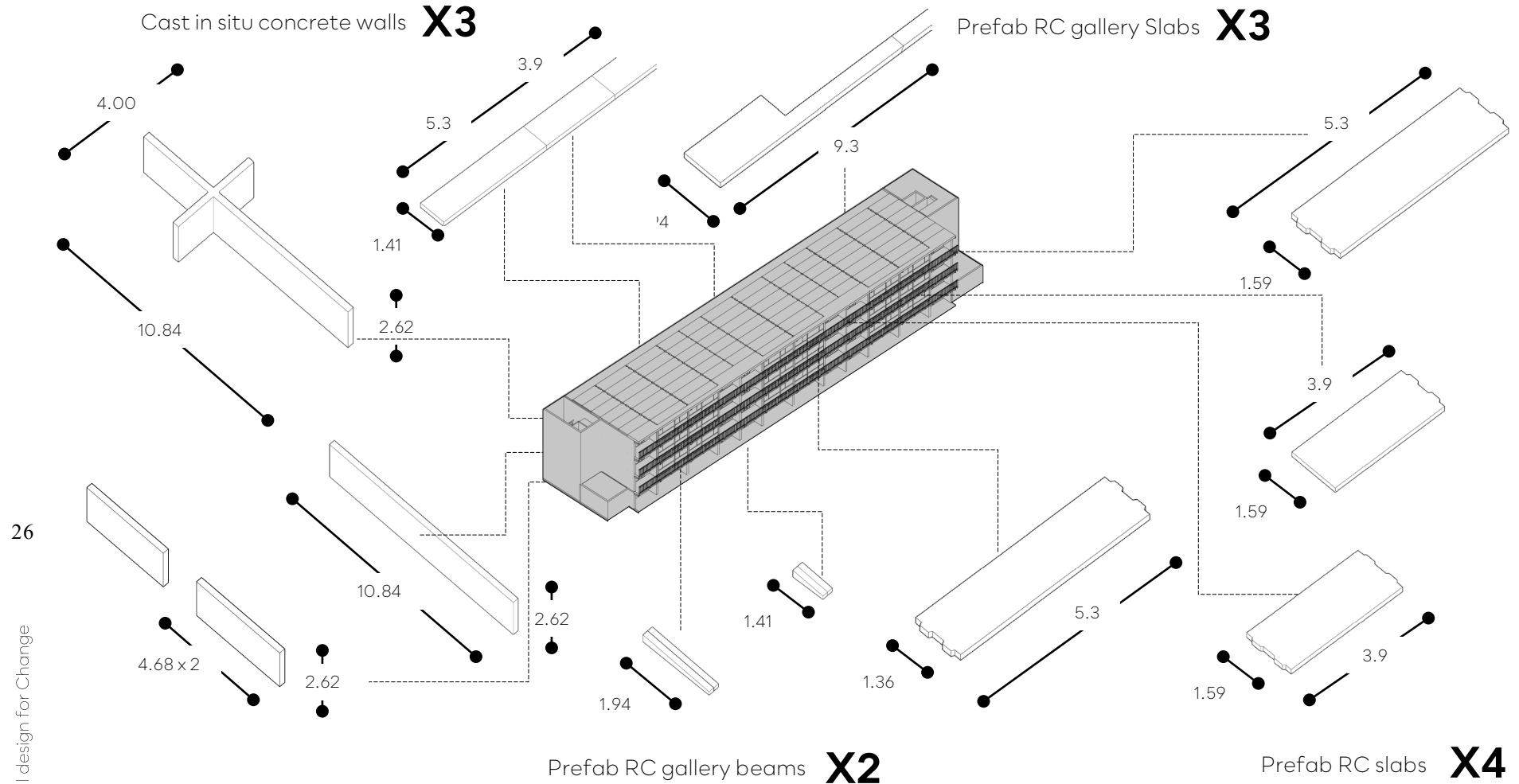


25

03

Research for design

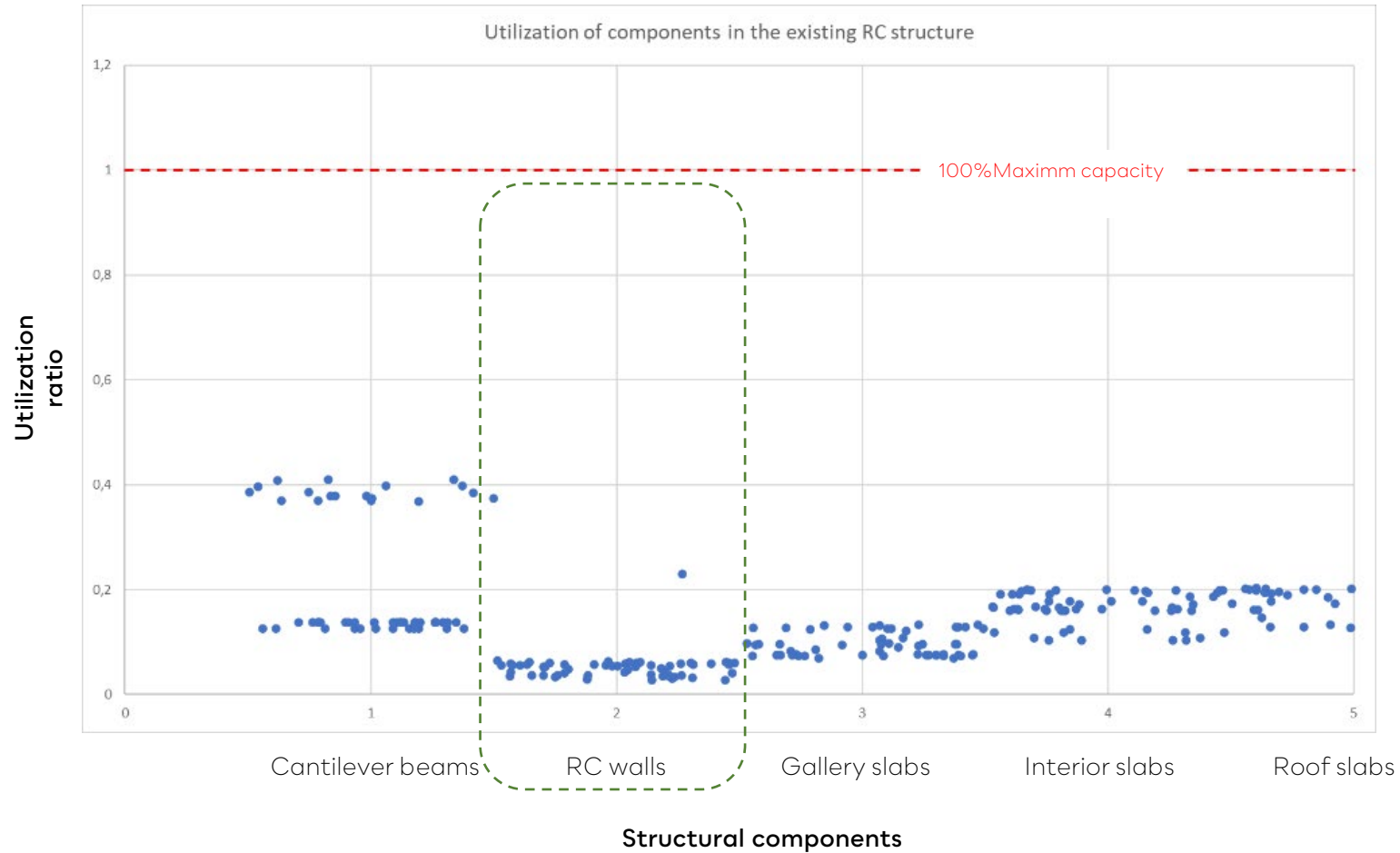
Analyze: Composition of the structure.



03

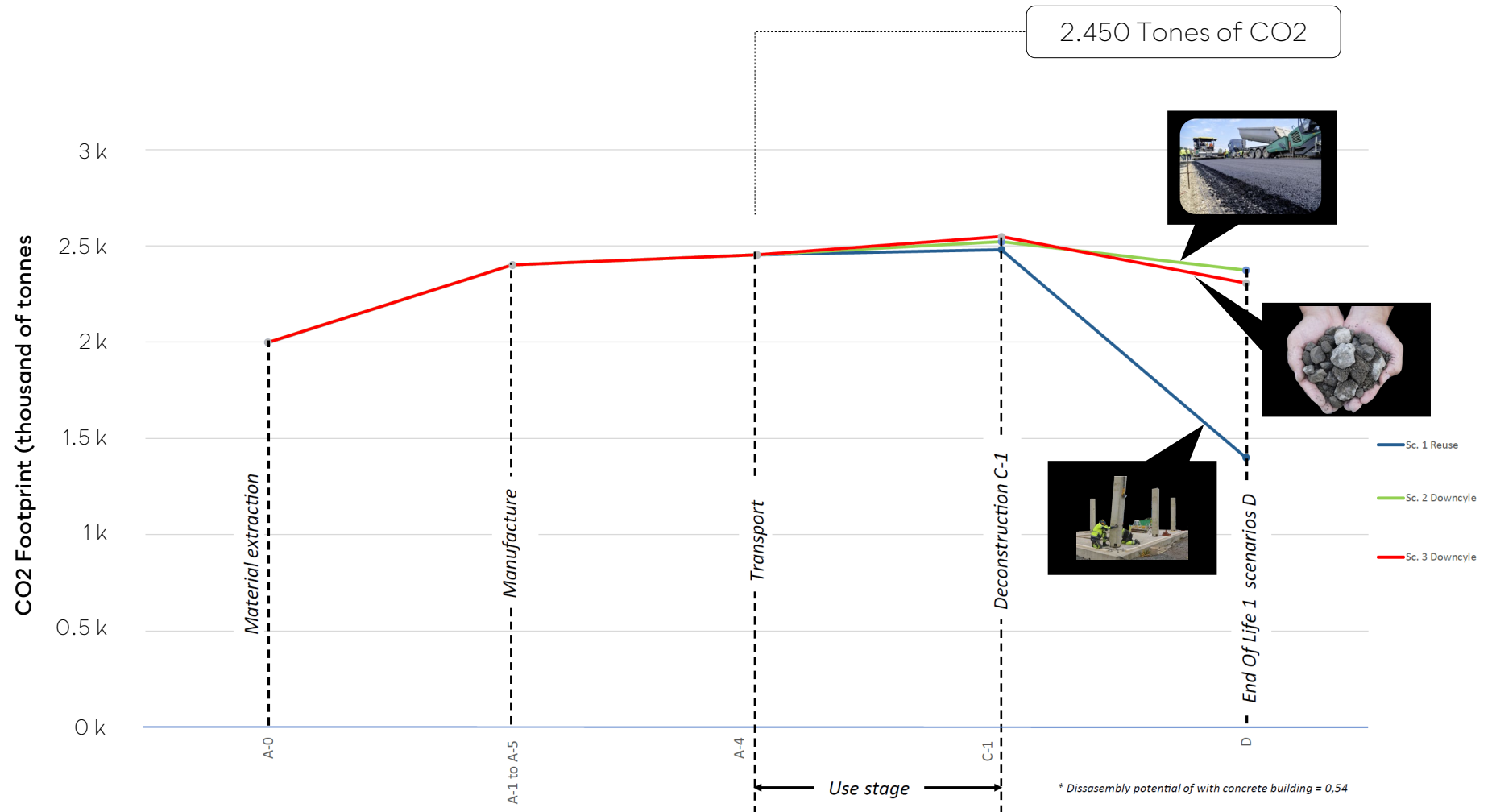
Research for design

Analyze: Utilization of existing RC components



03

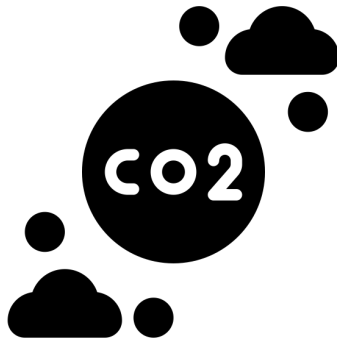
Research for design Analyze: Upfront carbon



03

Research for design

Analyze: Upfront carbon



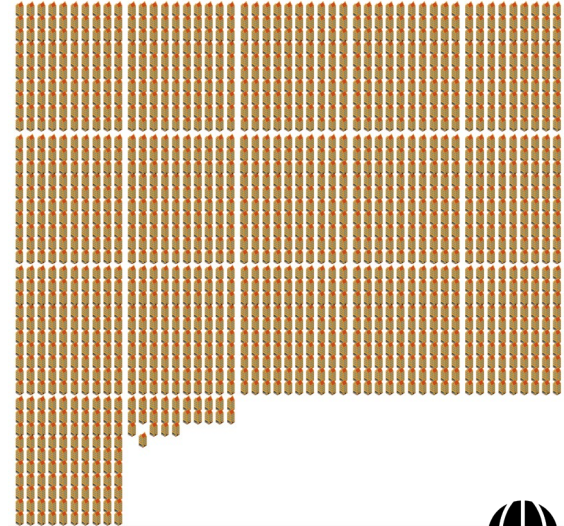
2.450 tones

*1 tone of CO2 = a 500 m³ hot air balloon

*1 tone of CO2 = Electricity consumption (grey)
by 0.65 households in one year in NL.

* Taken from: <https://www.climateneutralgroup.com/en/news/what-exactly-is-1-tonne-of-co2/>

Electricity consumption (grey) by 1625 households in one year in NL.



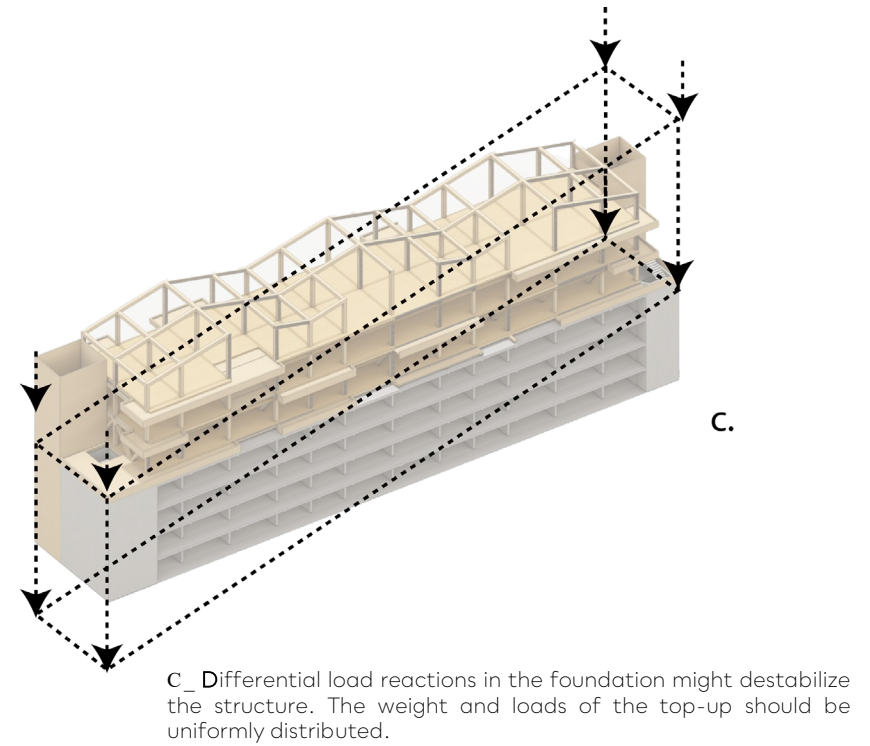
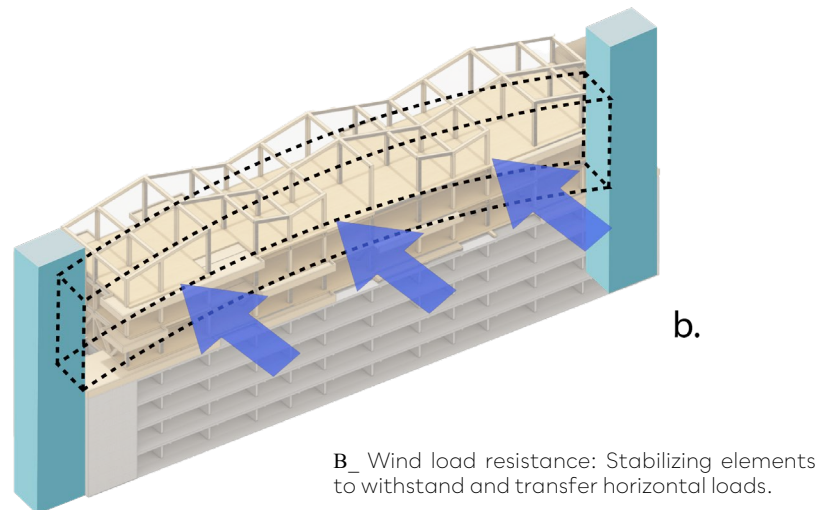
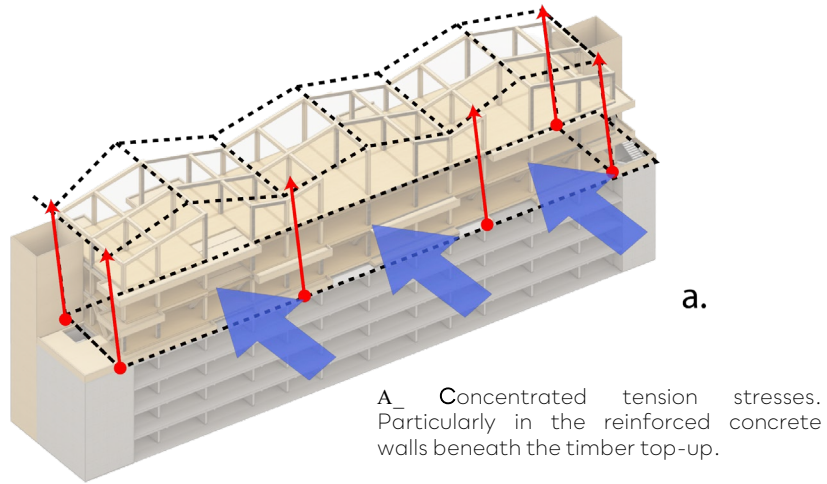
2.450 hot air balloons of 500 m³



03

Research for design

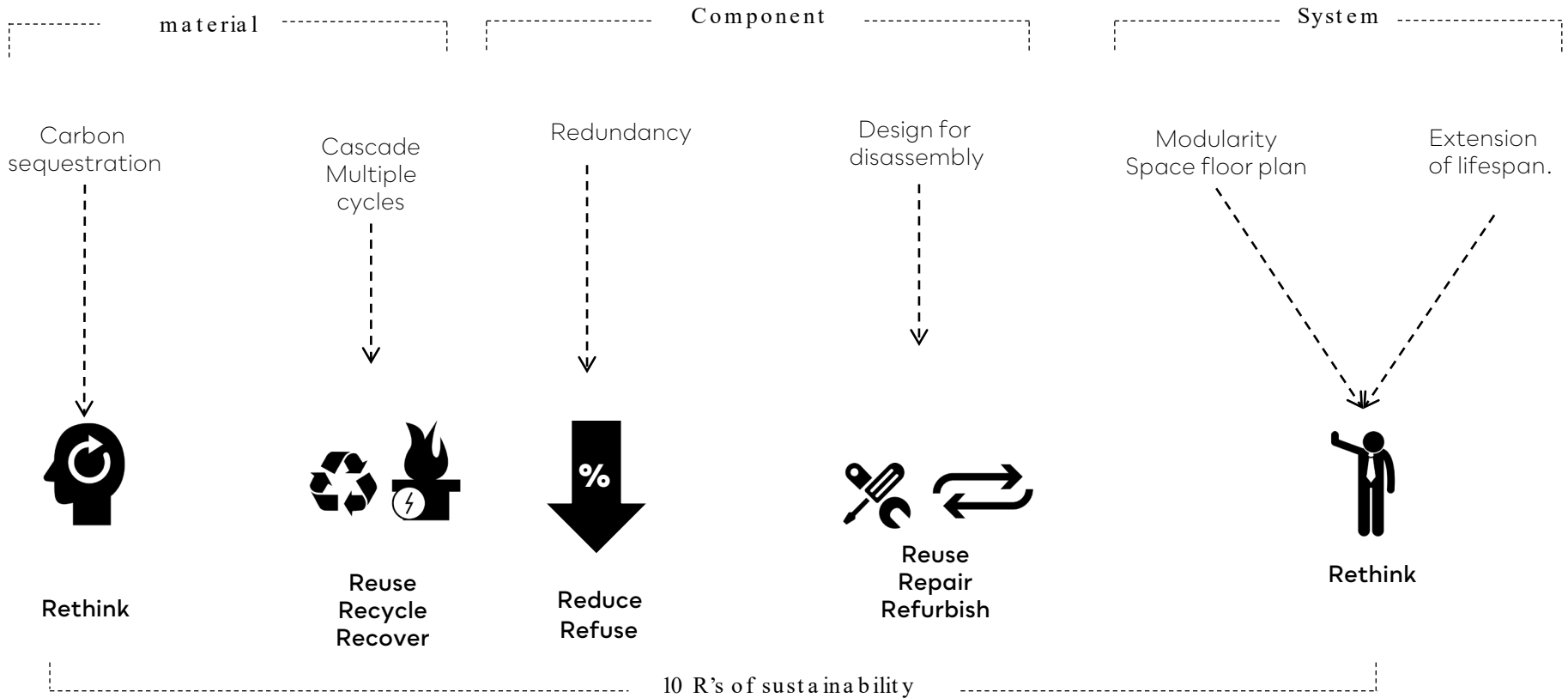
Define: Structural hypothesis



03

Research for design

Define: Circular design principles

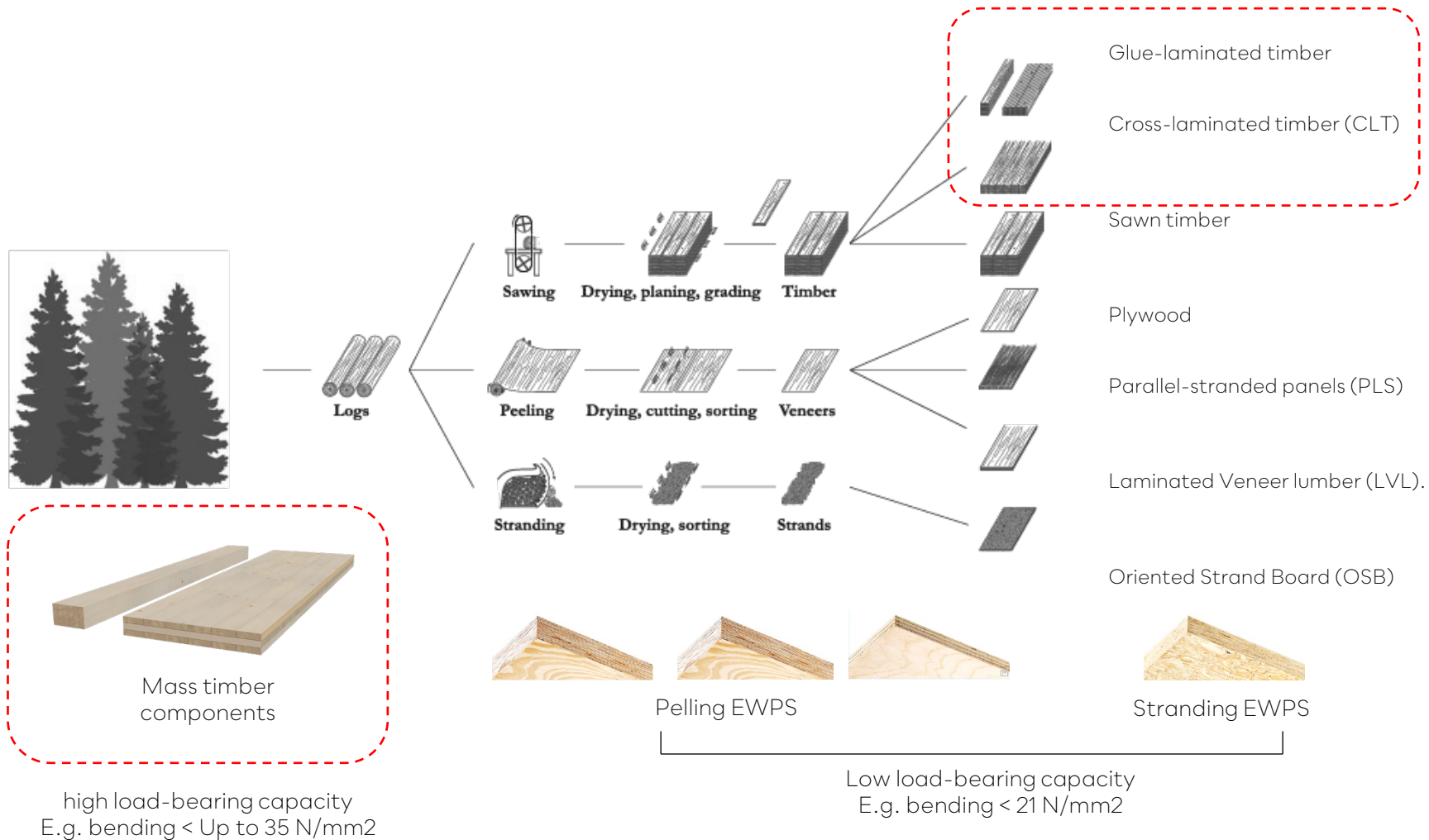


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03

Research for design

Propose: Selection of timber products



32

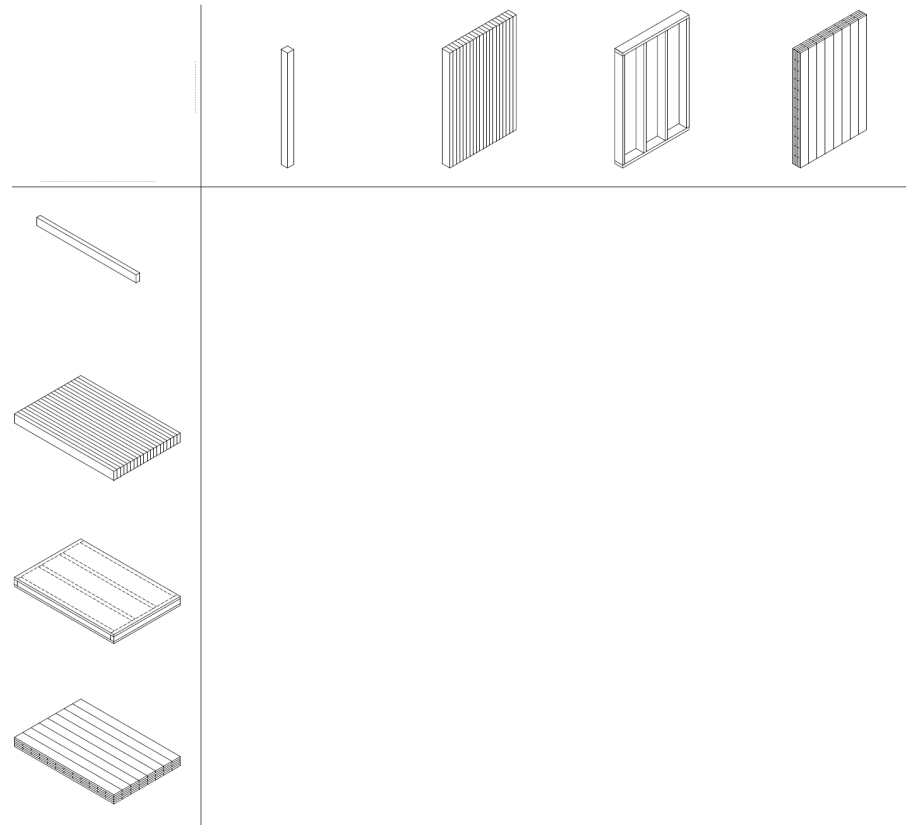
03

Research for design

Propose: Selection of systems

Vertical structural components

Horizontal structural components



03

Research for design

Propose: Selection of components

- A. Fire resistance.
+ Horizontal loads.

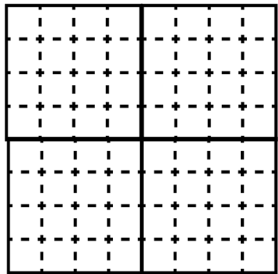
Charring layer 120 min =
65 mm (each side).

$H > 13$ m.

*Charring layer 90 min =
50 mm (each side).

$H > 13$ m.

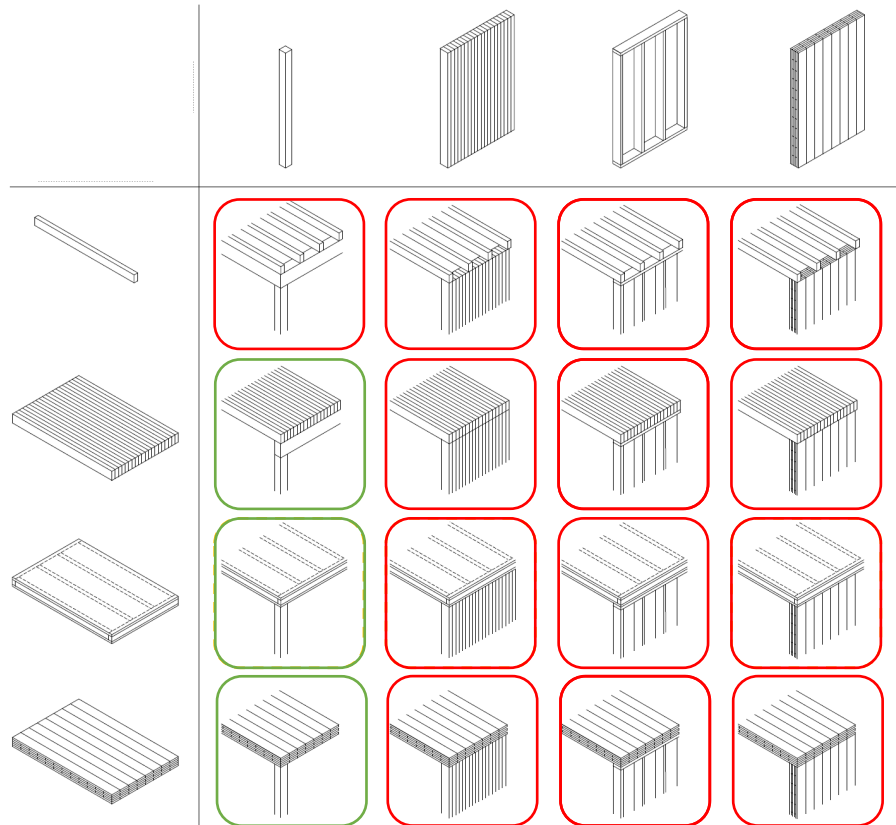
- B. Open space flexibility.



Vertical structural components

C. Optioned components

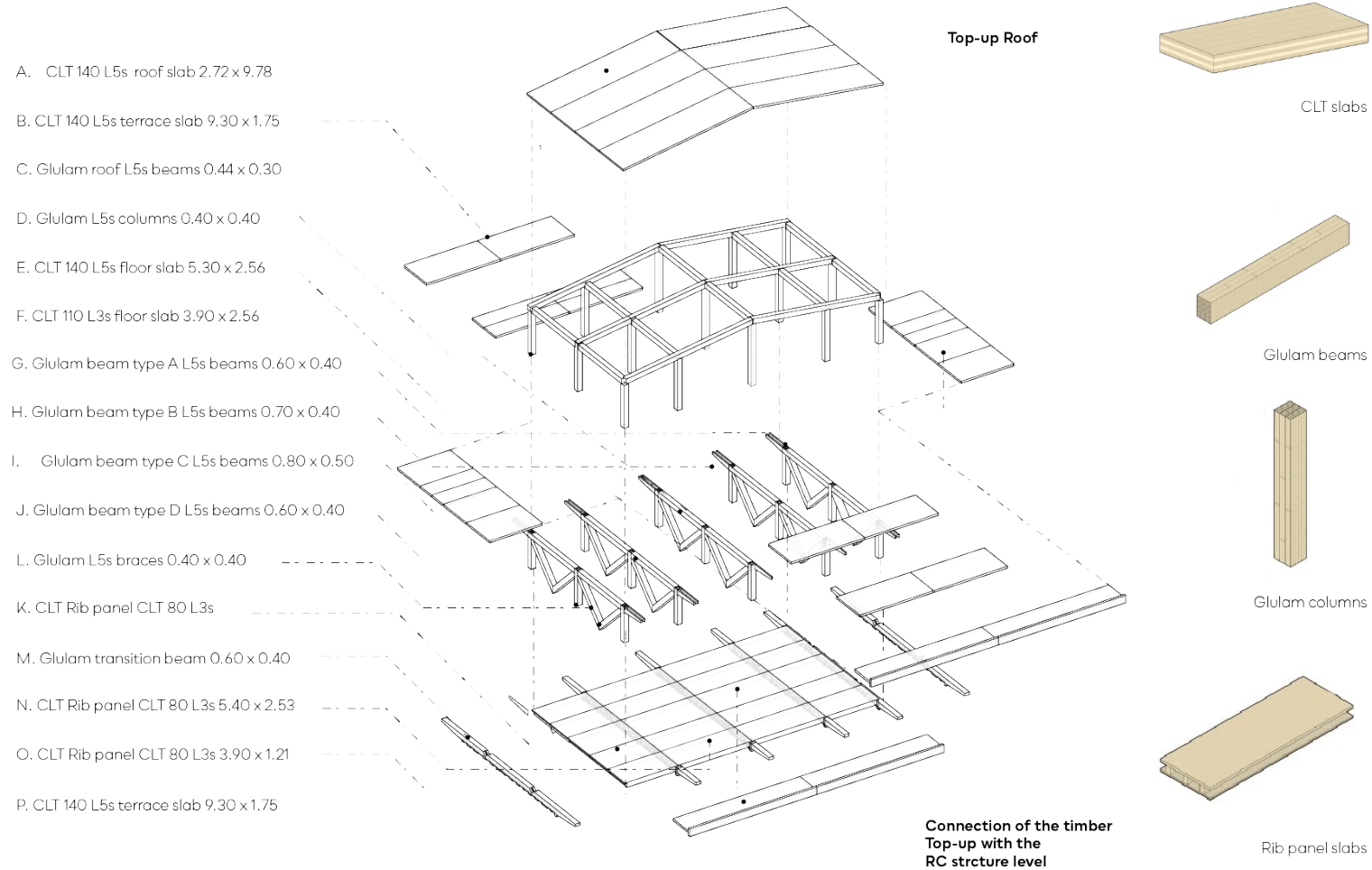
Horizontal structural components



03

Research for design

Propose: Design of the structural system



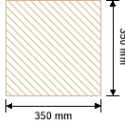
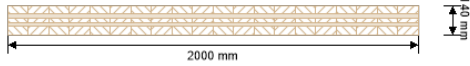
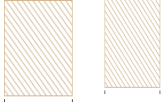
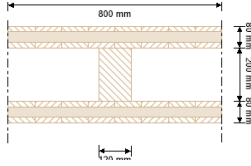
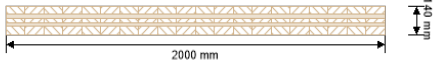
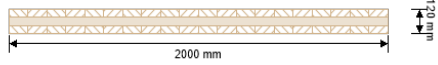
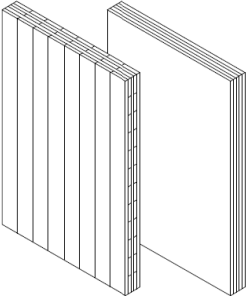
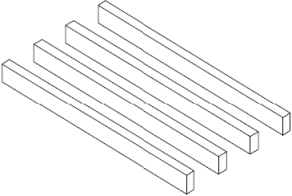
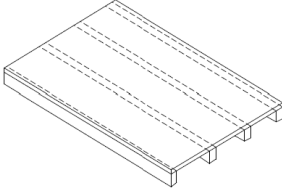
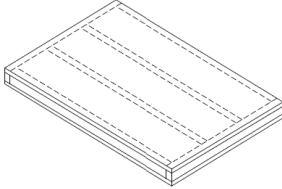
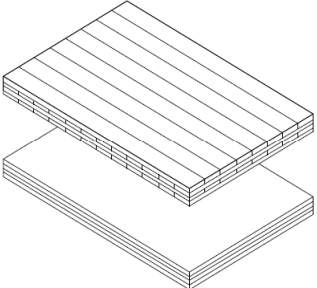
03

Research for design

Propose: definition of connections

	Connection	Type	Dimensions	R[ax,k]	Producer	Reference
	A_Slab-to-beam connection.	Carbon steel plate	50 x 1200 mm x 10 nails per 1.2 mts	2200 kN*m2		Sharp metal hooked plate
	Rothoblas					
	B_Beam to column connection.	Concealed connectors for high-capacity standard connections	340*160 mm	190 kN	Knapp	RICON® S
	C_Bracing to beam	Concealed connectors for high-capacity standard connections	340*160 mm * 2	190 kN	Knapp	RICON® S 390/80 VS+ZP
36	D_Column-to-column connection.	Column to column connection system	280*280 mm	2350 kN	Rothoblas	PIL80S160
	E_Bracing to column connection.	Concealed bracket with and without holes	146 * 480 mm with 60 nails	146,6 kN	Rothoblas	Concealed s

Structural pre-dimension calculations

	Columns	Cores	Beams	Slabs
	Glulam beams Glulam Columns b = 350*350 mm CLT Spruce 24C	CLT panels CLT 5L 140 mm Spruce 24C	Glulam beams Glulam beam, Variable Dimensions.	Ribbed box panels CLT 80 3L 80 mm (36 cms) Spruce 24C CLT panels CLT 5L 140 mm CLT 3L 120 mm Spruce 24C
Section			 	  
Axonomic		 		  

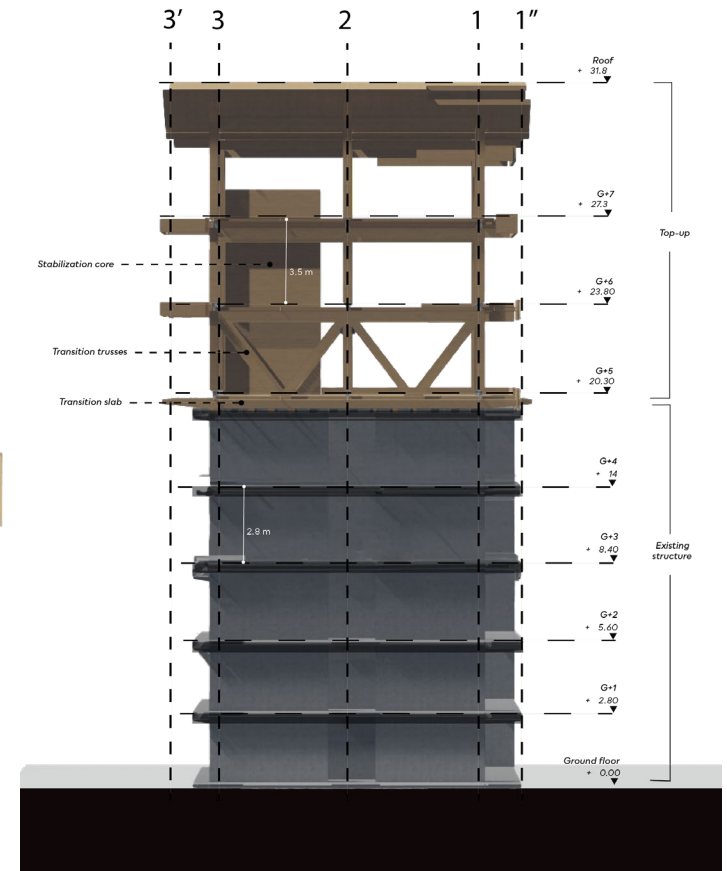
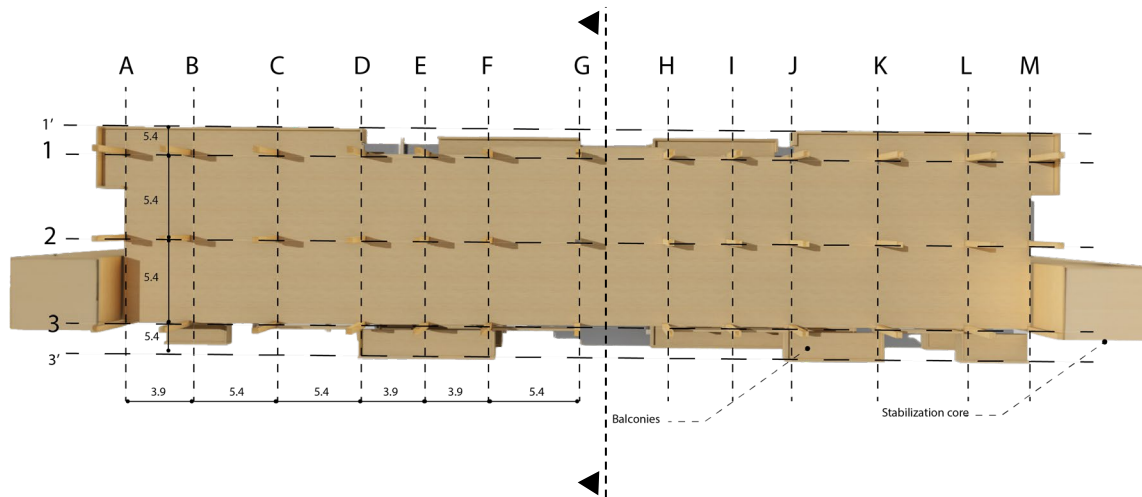
03

Research for design

Propose: Design of the structural system

38

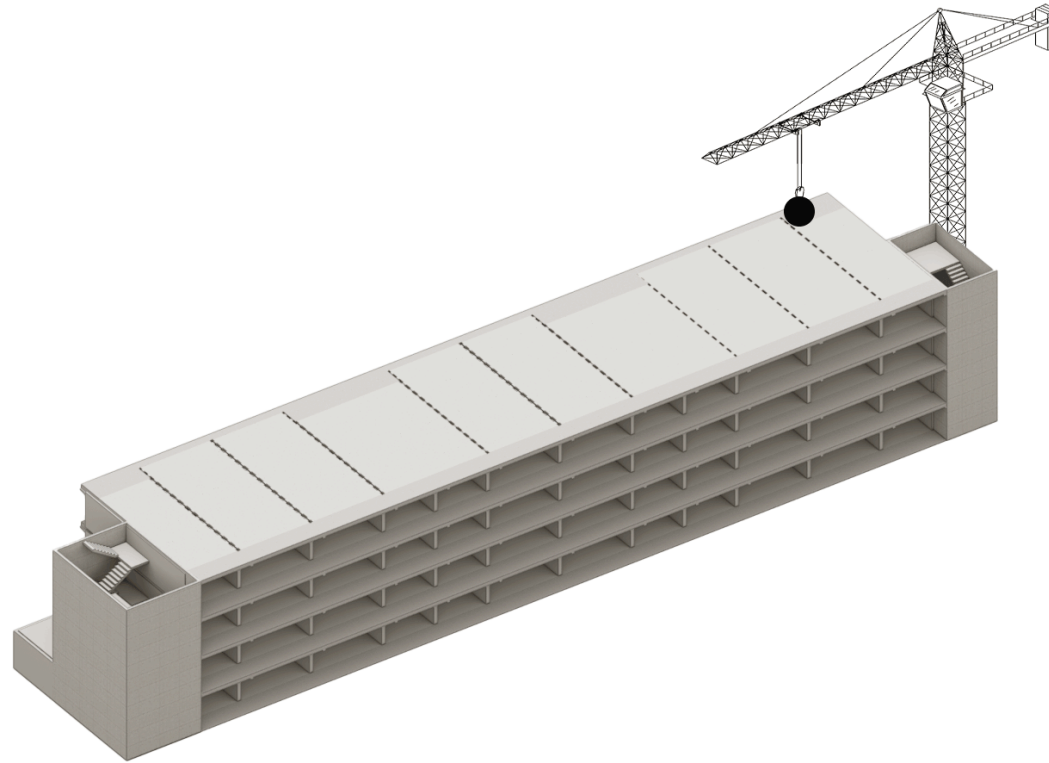
Structural design for Change



03

Research for design

Propose: Assembly



04

Research for design

Propose: Architectural design



04

Research for design

Propose: Architectural design

41

Structural design for Change



04

Research for design

Propose: Architectural design

42

Structural design for Change



04

Research for design

Propose: Architectural design

43

Structural design for Change



04

Research for design

Propose: Layout flexibility

44

Structural design for Change



04

Research for design

Propose: Layout flexibility

45

Structural design for Change



04

Research for design

Propose: Layout flexibility



04

Research for design

Propose: Layout flexibility



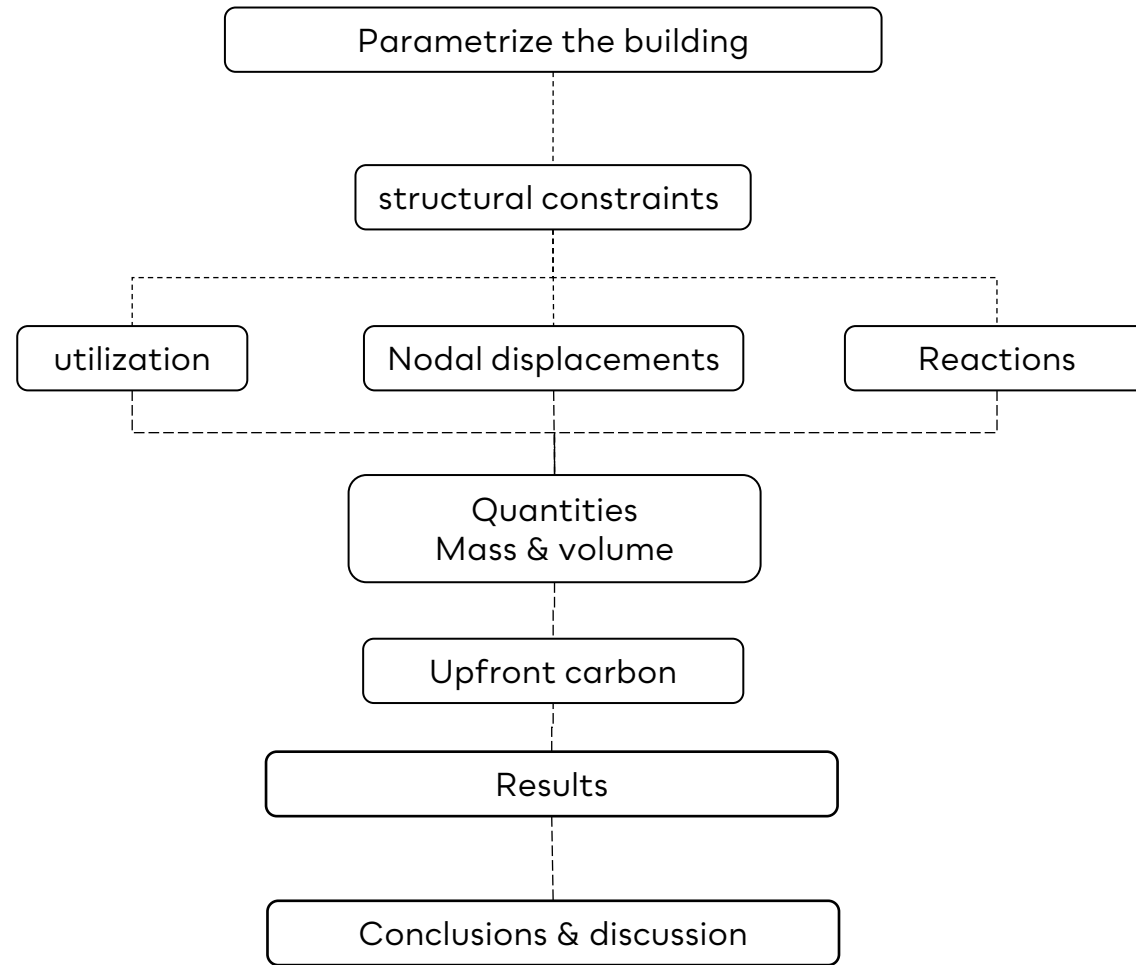
05

Experiment

Evaluate: methodology



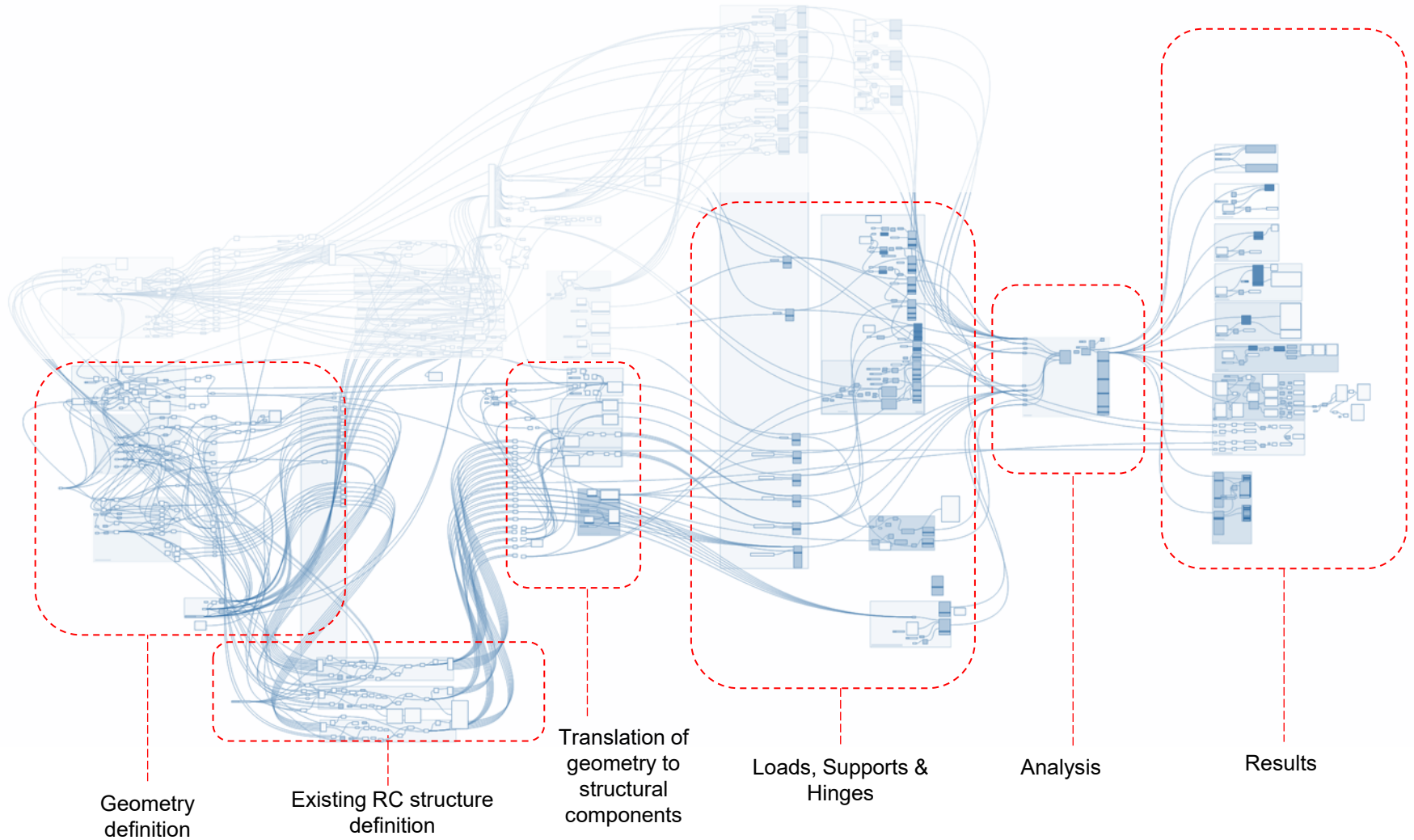
Karamba 3D
parametric engineering



05

Experiment

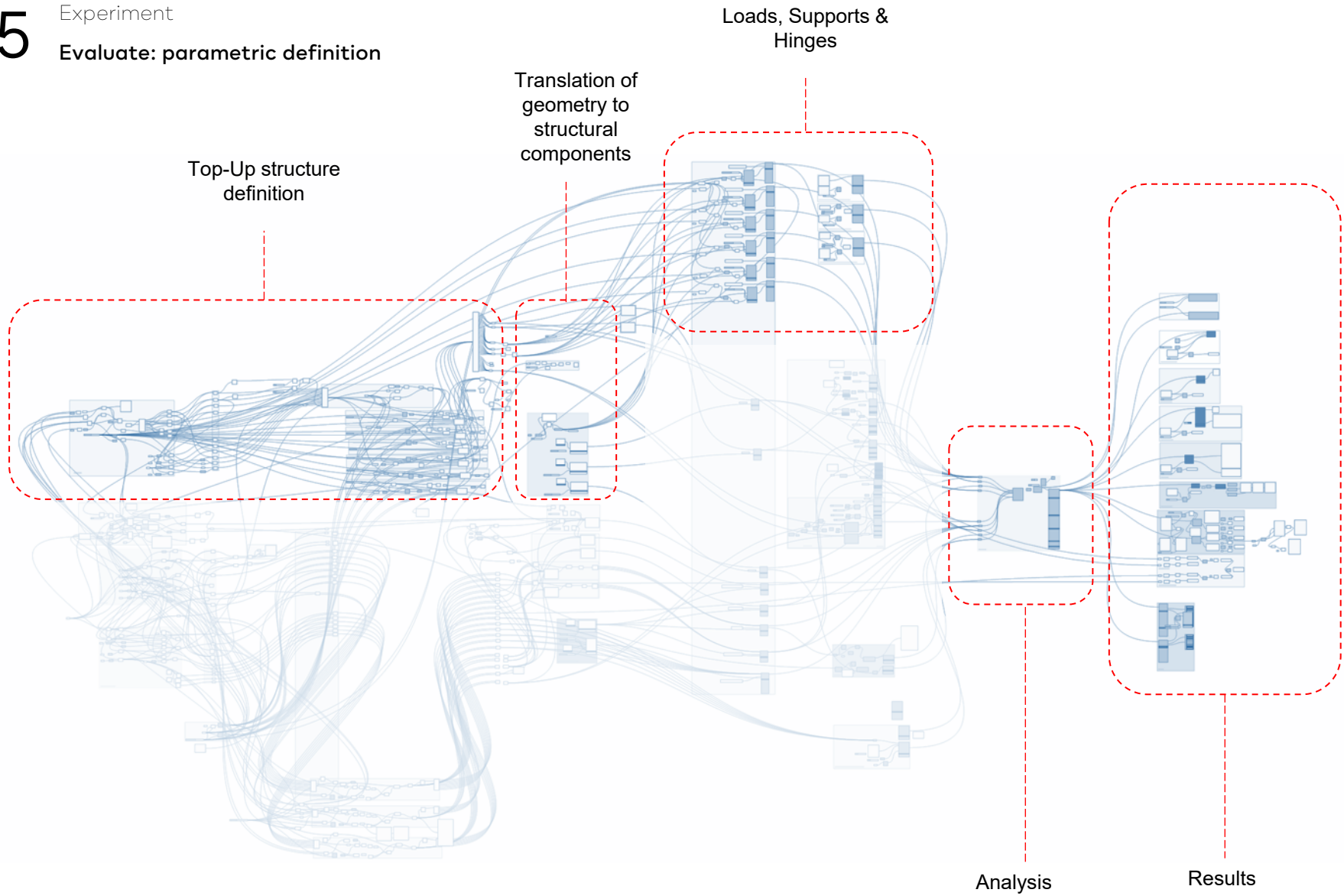
Evaluate: parametric definition



05

Experiment

Evaluate: parametric definition



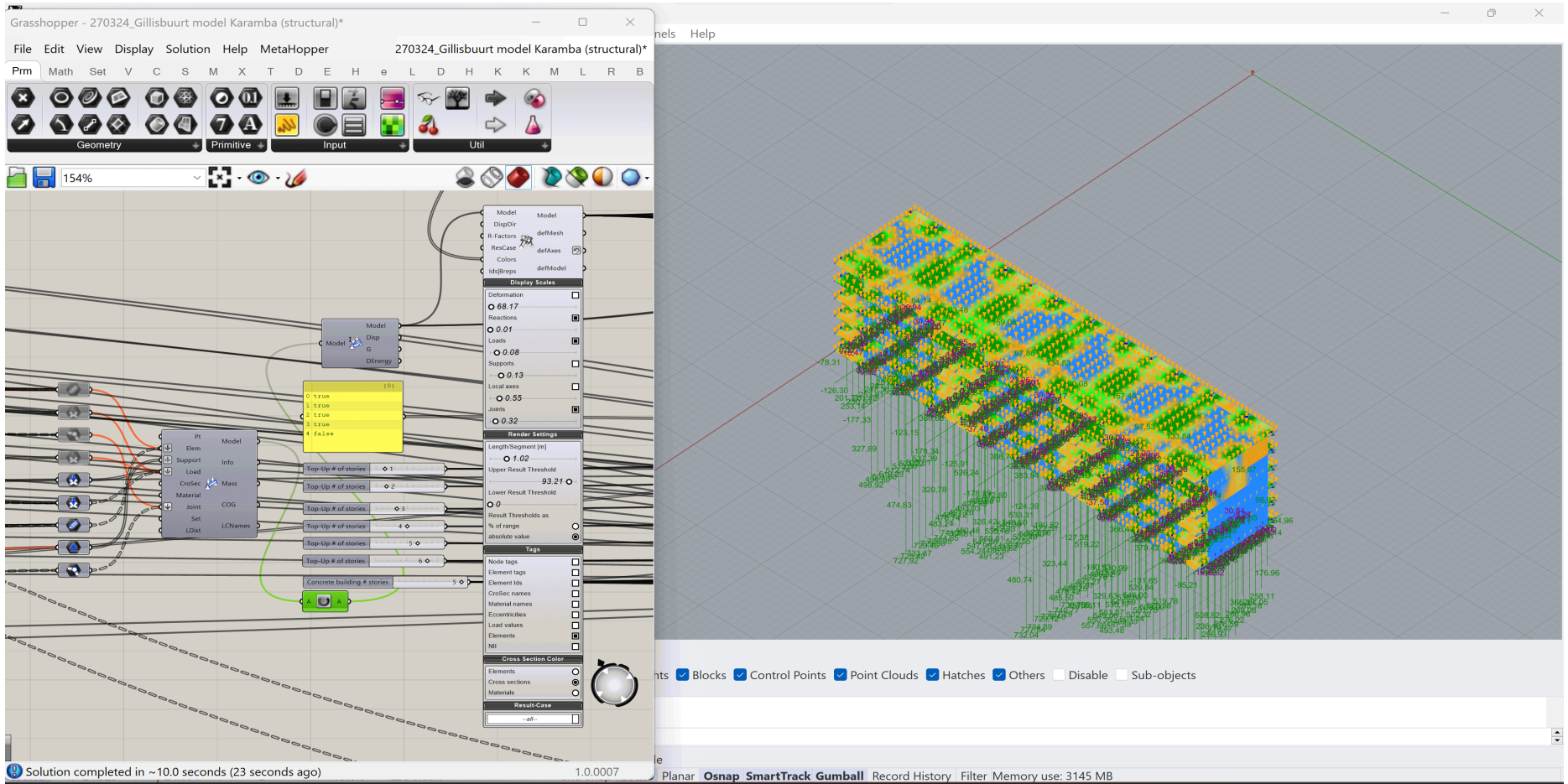
05

Experiment

Evaluate: Structural iterations

51

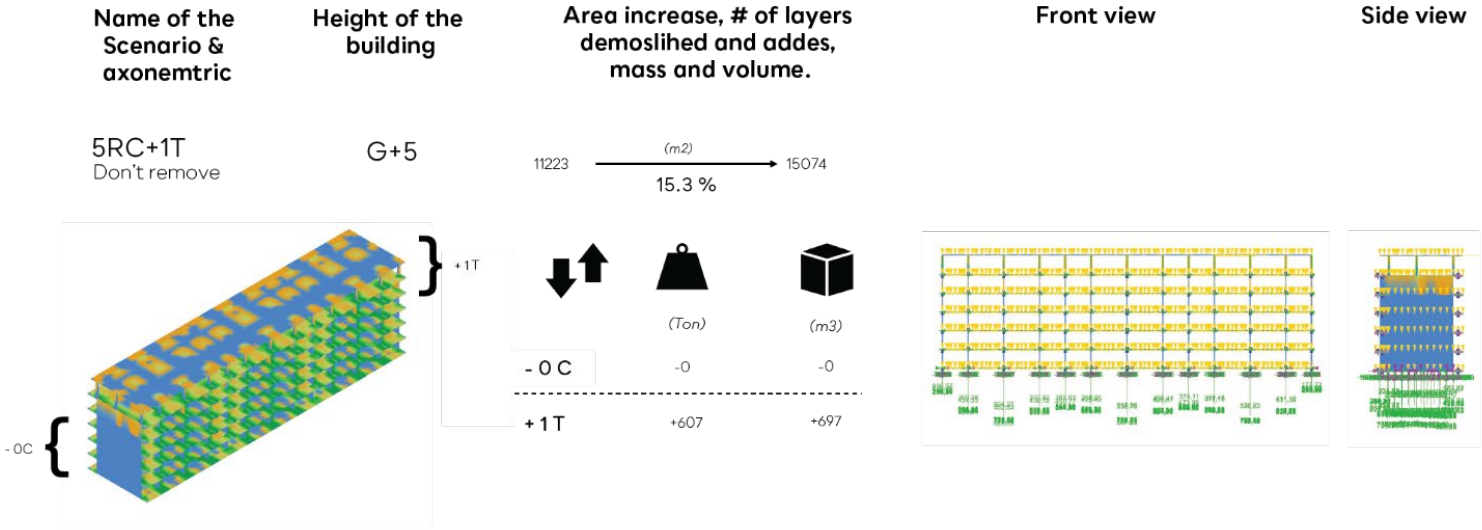
Structural design for Change



05

Experiment

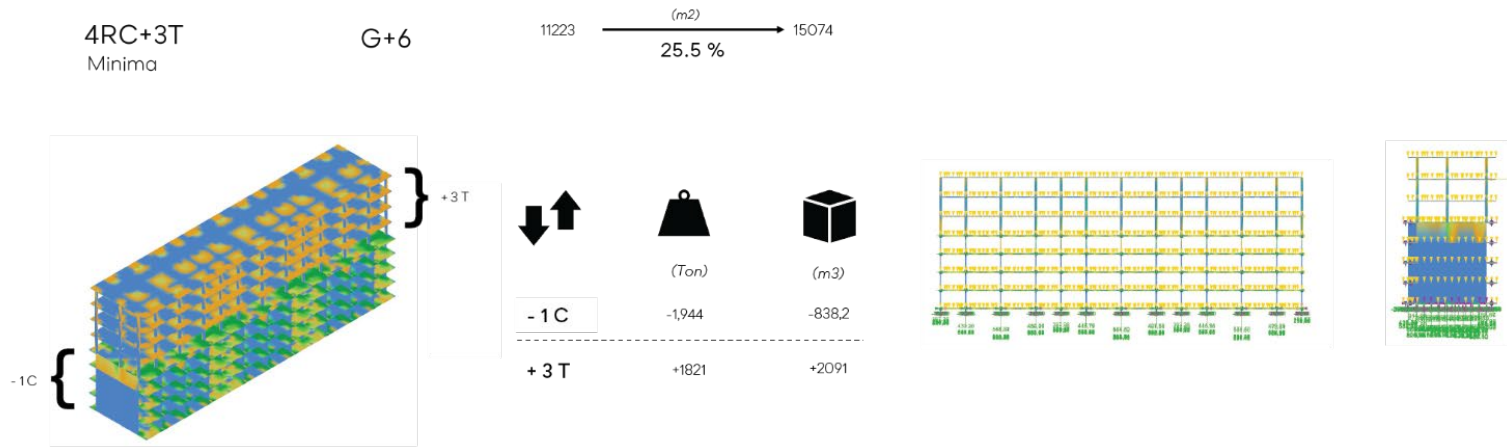
Evaluate: Scenarios



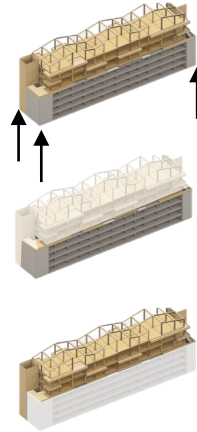
05

Experiment

Evaluate: Scenarios



Ultimate Limit state (ULS)

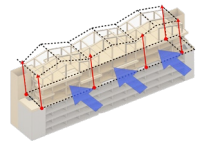


1. Reaction in the foundations after Topping-up.

2. Utilization of the RC main elements in the existing structure.

3. Utilization of the Timber top-up components

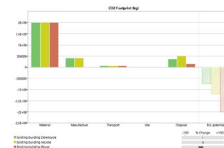
Service Limit State (SLS)



4. Comparison of displacements on the RC walls. (M a x i m a).

5. Deflection limit (Nodal displacements). (M a x i m a).

Environmental impacts



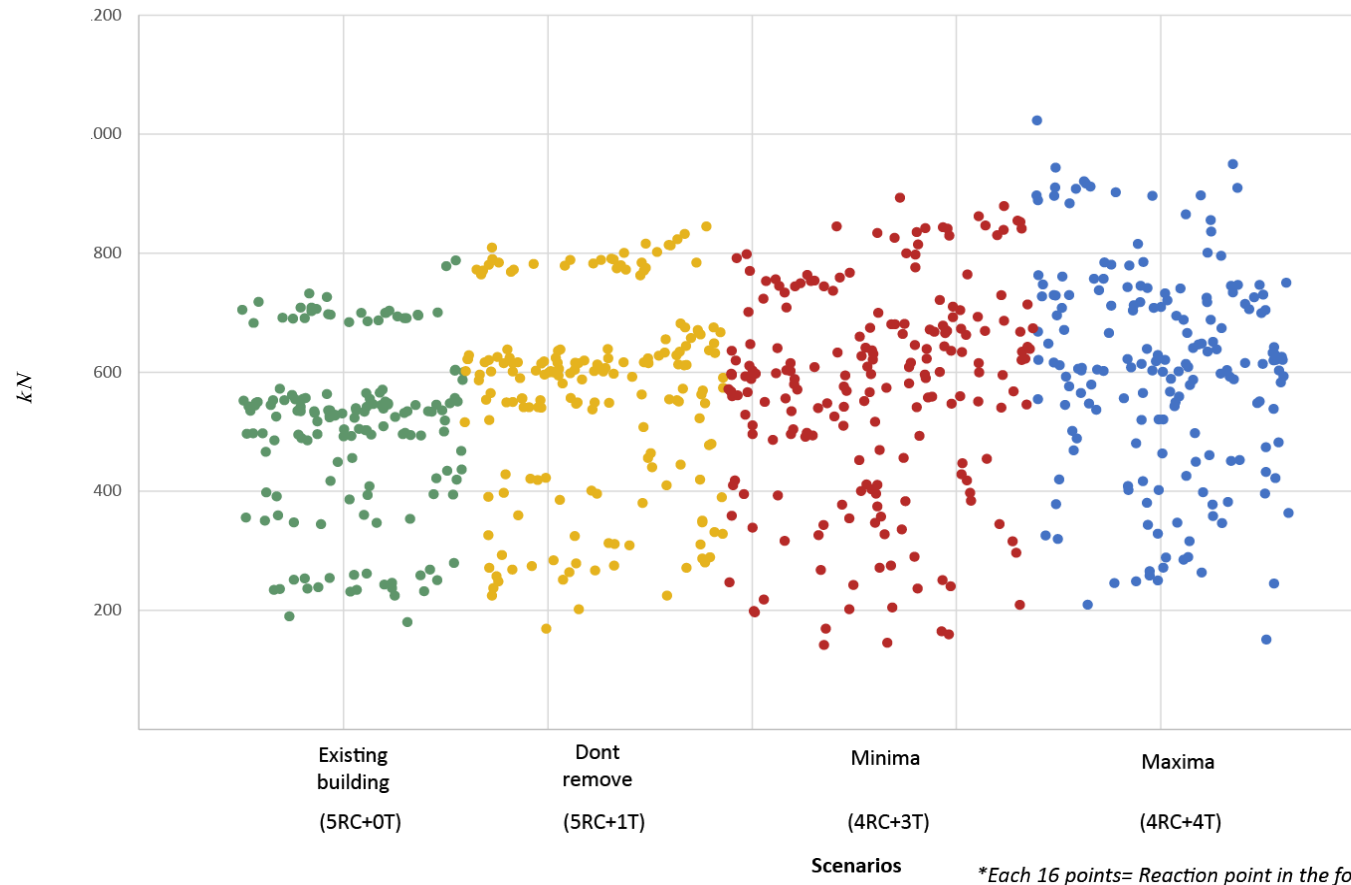
6. Upfront carbon in two lifecycles for the structure.

05

Experiment

Evaluate: Reaction in the foundations after Topping-up.

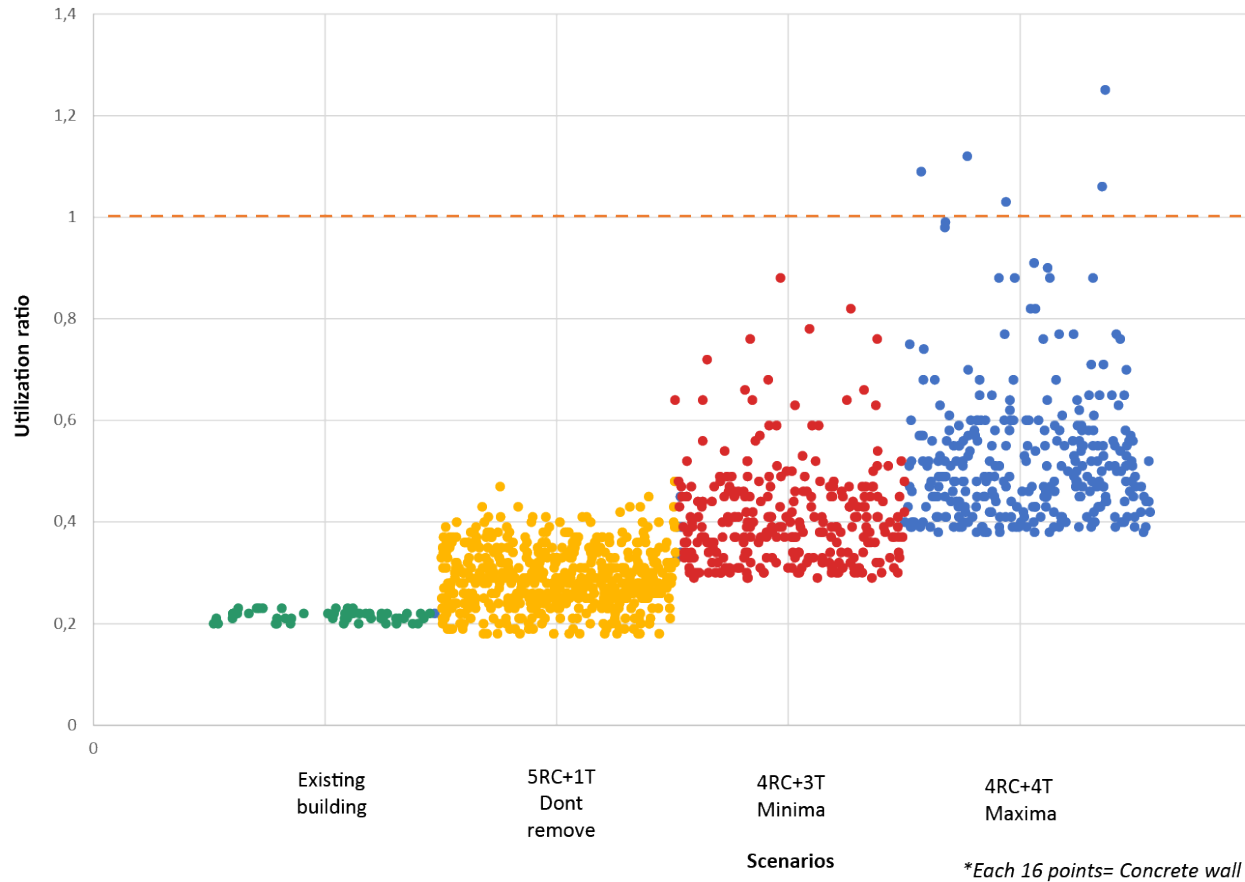
*Each points= is one reaction point.



05

Experiment

Evaluate: Utilization of RC walls in the RC structure after topping up.

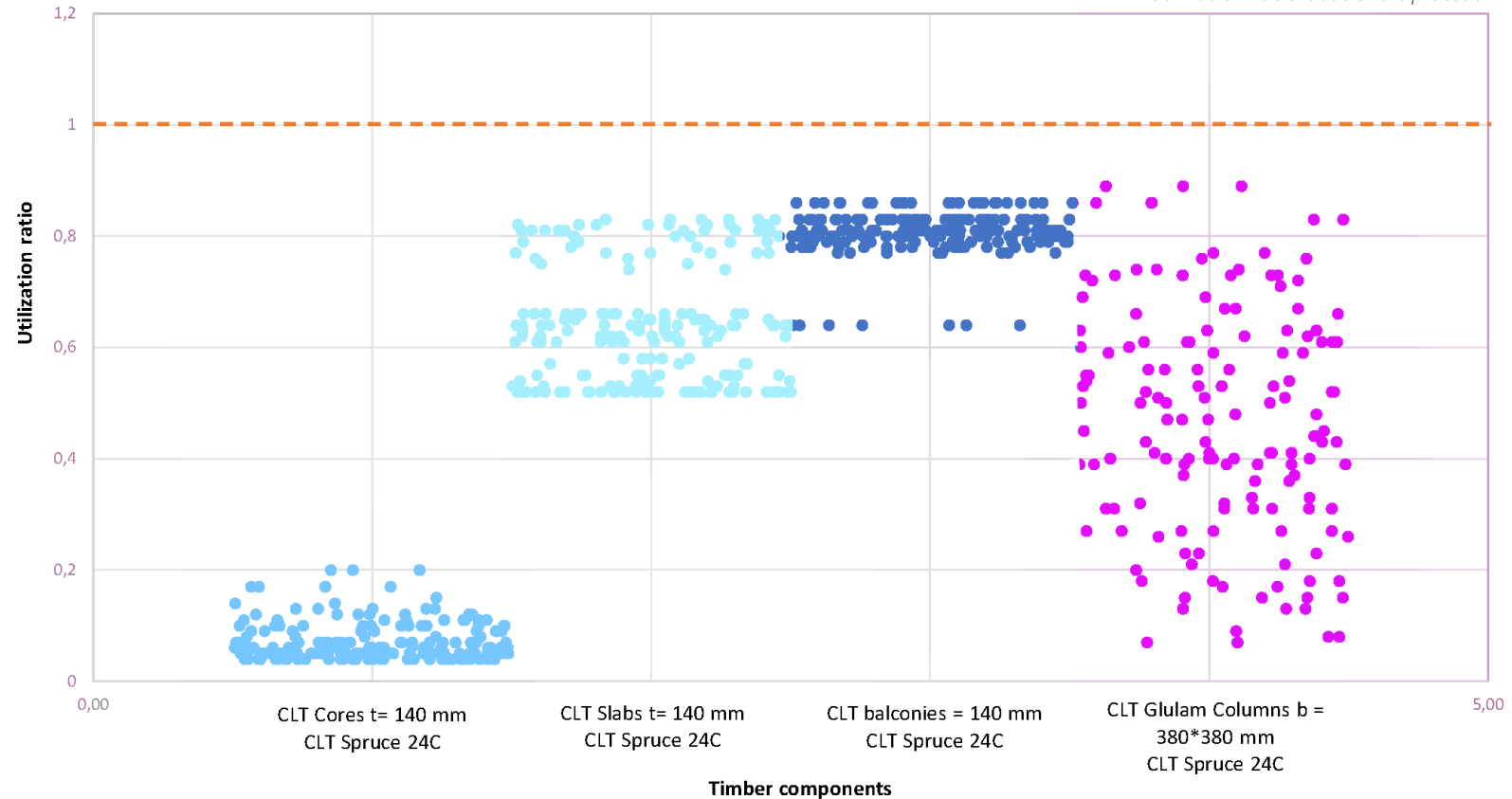


05

Experiment

Evaluate: Utilization of the timber components (maximum area)

*For cores and slabs, every 16 points = Timber slab.
 ** For Slabs and balconies: A sample of 200 of the highest utilization ratio sections is plotted



*For cores and slabs, each 16 points = Timber slab.
 ** For Slabs and balconies : A sample of 200 of the highest utilization ratio sections are plotted

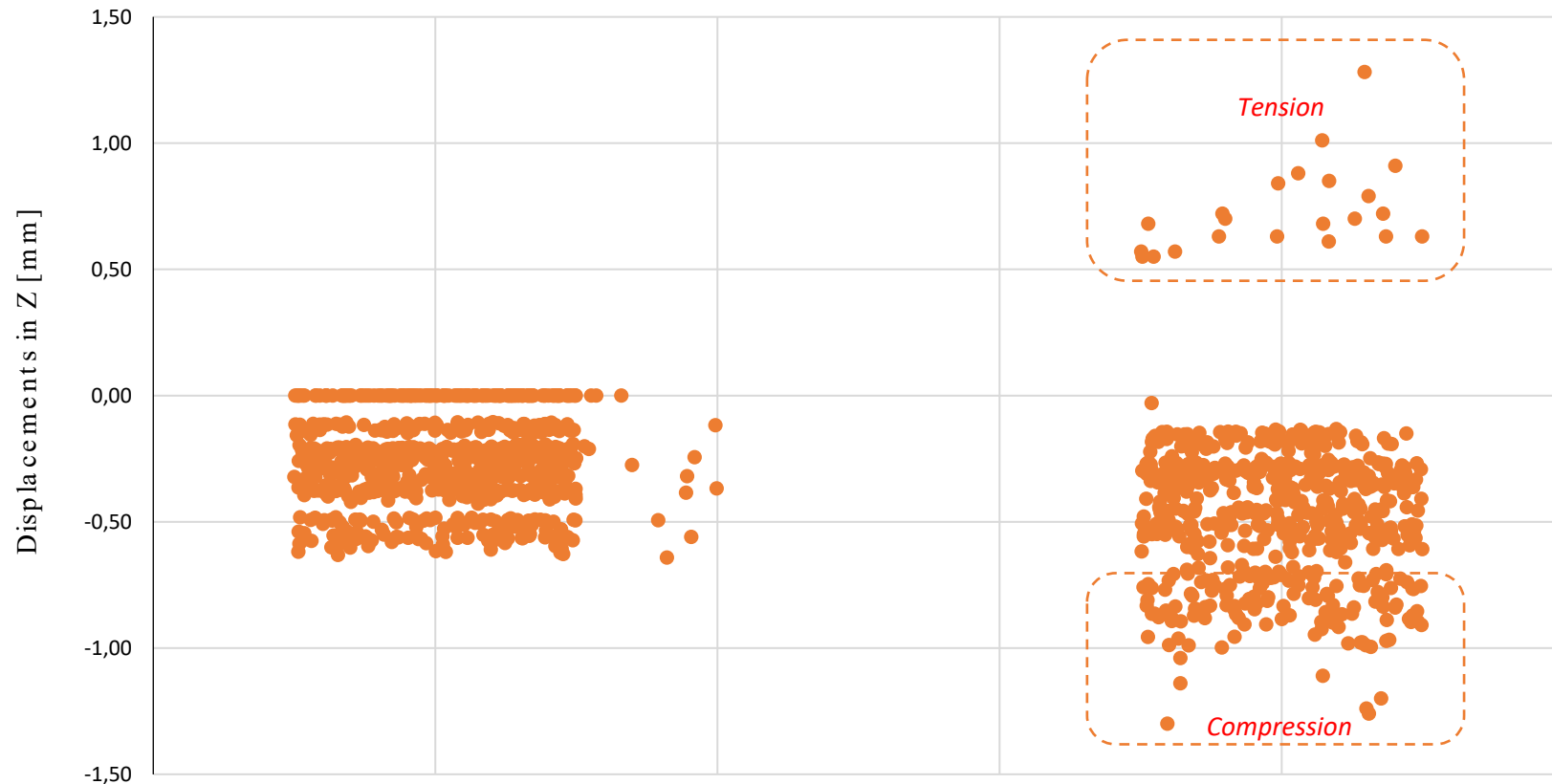
05

Experiment

Evaluate: Reactions of the concrete structure (Nodal displacements).

2.

*Each 11 points= Concrete wall vertices



Existing building
(5RC+0T)

(4RC+4T)

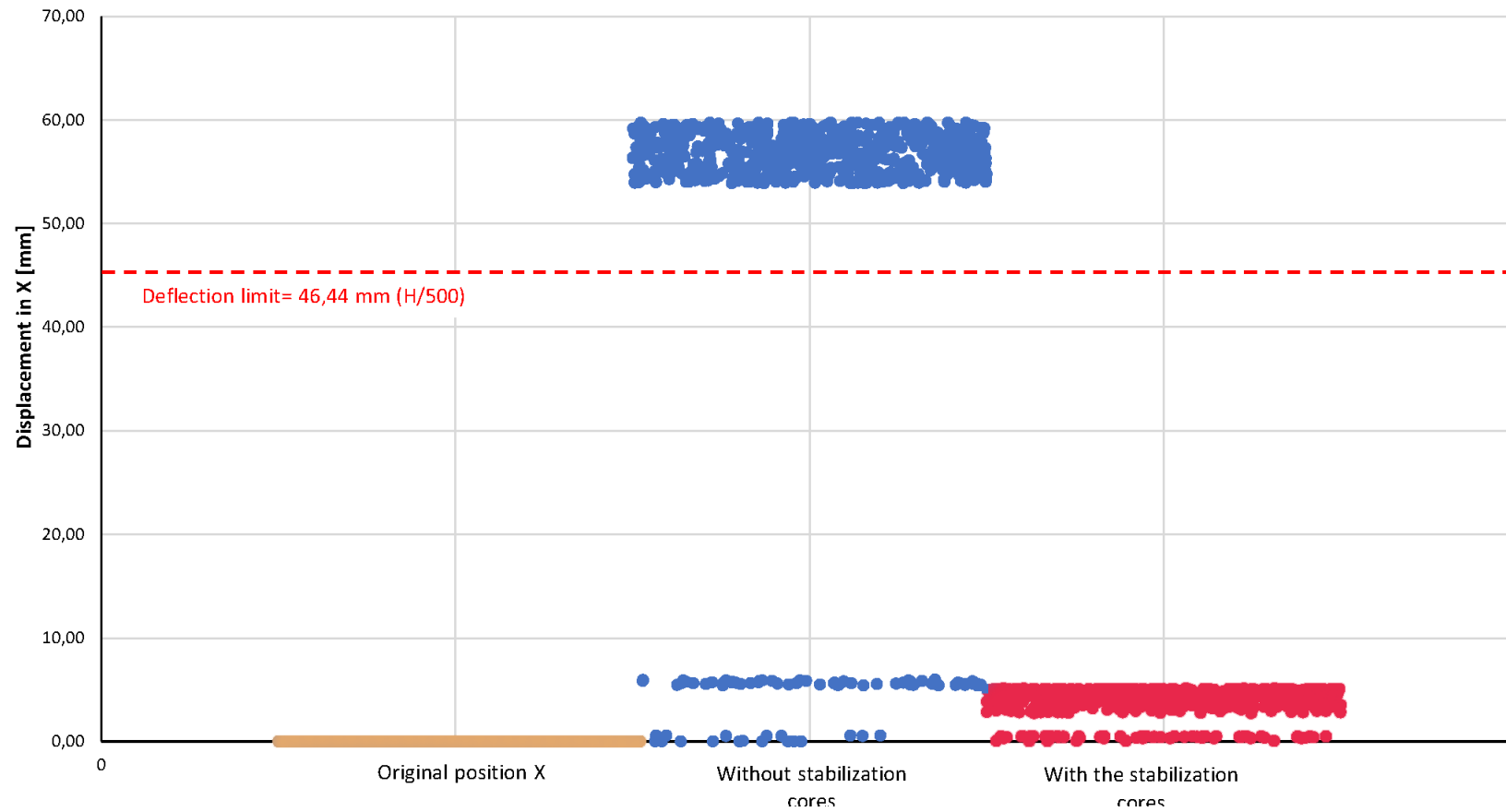
Scenarios

05

Experiment

Evaluate: SLS - Deflection limit (Nodal displacements).

*Each eight points= Roof CLT timber slab



05

Experiment

Evaluate: Upfront embodied carbon.

Parameter

Prefab existing
RC Slabs

In cast existing
RC walls

Timber Top up
components

A_	Environmental Cost indicator	ECI	16,59	16,59	16,59
B_	Connection type	CT	0,60	0,10	1,00
C_	Connection accessibility	CA	0,80	1,00	1,00
D_	Disassembly potential of the connection	DPc	0,69	0,18	1,00
E_	Independency	ID	1,00	0,40	1,00
F_	Geometry of product edge	GPE	1,00	1,00	1,00
G_	Disassembly potential of the composition	DPcp	1,00	0,57	1,00
H_	Disassembly potential of the product or element	DPp	0,81	0,28	1,00
I_	Disassembly potential of building	DPb		0,54	1,00

A_ Impact the product in the shearing layer

B_ Dry, Soft & hard chemical, bolted...

C_ Freely accessible, damage in the surrounding.

D_ How easily can the connection be detached?

E_ elements are intermingled or even integrated with each other?

F_ Overlapped, Closed, open?

I_ How easily can the building be detached?

G_ How easily can the element be detached?

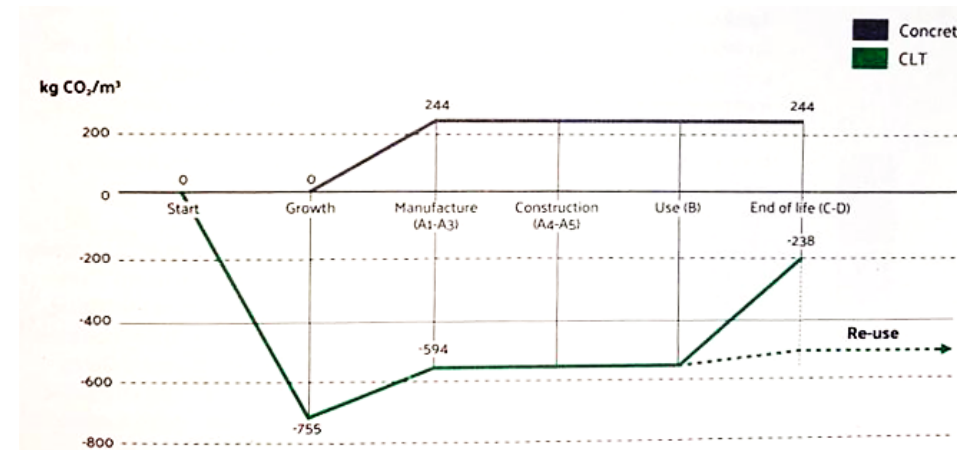
H_ How easily can the component be detached?



2_ Sequestration carbon of timber.

Parameter	Value	Unit
Density of spruce C24	420,0	kg/m ³
Ratio of molecular weight Co2	3,7	
Moisture content of timber	12	%
Sequestered carbon of Spruce C24	-0,69	kg*m3

$$\begin{aligned}
 \text{captured CO}_2 \text{ (in kg/m}^3\text{)} &= \frac{\text{quantity of wood in m}^3 \times \text{density of wood (at 12\% wood moist content per kg/m}^3\text{)}}{1 + (12 / 100)} \times \frac{3.67}{2}
 \end{aligned}$$

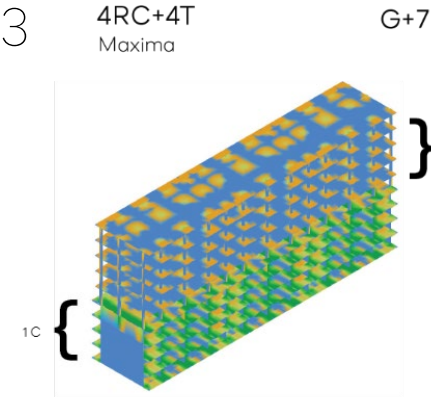
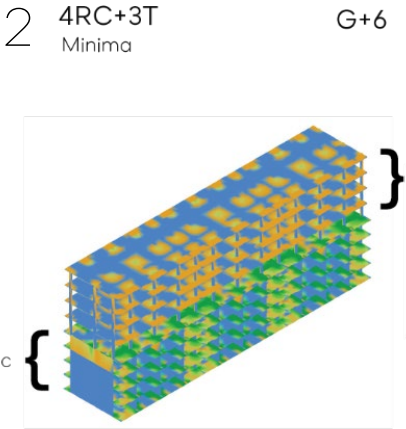
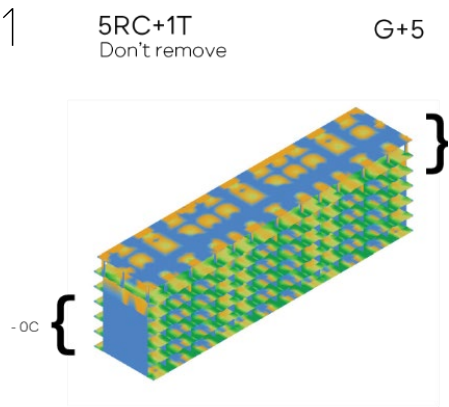


05

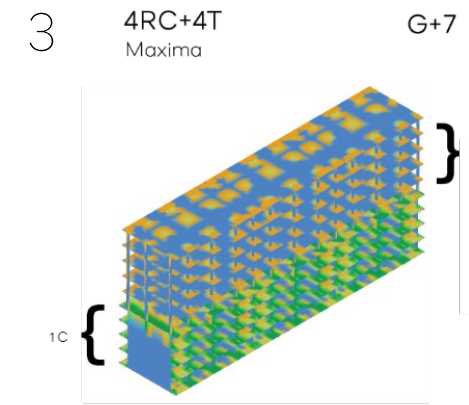
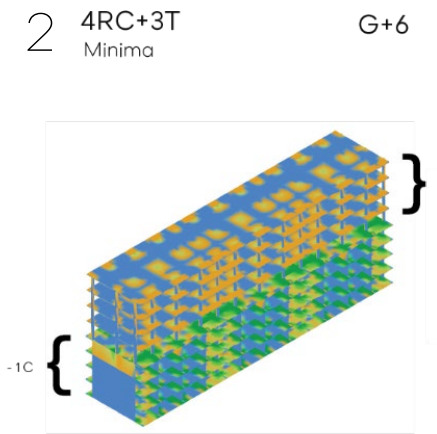
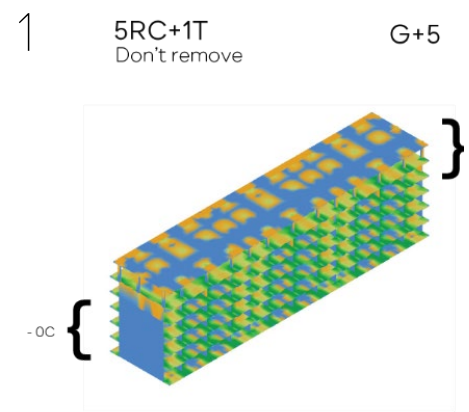
Experiment
Evaluate: Upfront embodied carbon RC structure.

		Existing building (1st. cycle)												
		Upfront carbon - Existing RC structure				End of life Scenarios								
		Material	manufacture	Transport	Total	Downcycle		Recycle		Reuse		Total Upfront C. first cycle EoL scenario		
		A-0	A-1 to A-5 (whiout A-4)	A-4	A-0 to A-5	C-1 (Preparation)	D (Downcyle)	C-1 (Process)	D (Recycle)	C-1 (Preparation)	D (Reuse)*	D (Downcyle)	D (Recycle)	D (Reuse)
Scenario		Kg	Kg	Kg	kg	Kg	Kg	Kg	Kg	Kg	Kg	Ton	Ton	Ton
0	Structure today	2,00E+06	0,00E+00	5,25E+04	2,05E+06	0	0	0	0	0	0,00E+00	2450	2450	2450
1	(5RC+1T)	2,00E+06	0,00E+00	5,25E+04	2,05E+06	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	2450	2450	2450
2	(5RC+3T)	2,00E+06	0,00E+00	5,25E+04	2,05E+06	6,88E+04	-1,49E+05	9,53E+04	-2,41E+05	2,72E+04	-1,08E+06	1972	1907	1000
3	(5RC+4T)	2,00E+06	0,00E+00	5,25E+04	2,05E+06	6,88E+04	-1,49E+05	9,53E+04	-2,41E+05	2,72E+04	-1,08E+06	1972	1907	1000

* Includes a Disassembly potential of building of 0,54



Top-Up (2nd. Cycle)										
Upfront carbon Top-Up				End of life Scenarios						
Seq. carbon**	Manufacture/ material	Transport	Total	Combustion		Reuse		Total Upfront C second cycle timber		
NA	A-1 to A-5 (whitout A-4)	A-4	A-0 to A-5	C-1 (Preparation)	D (Combustion)	C-1 (Process)	D (Reuse)*	D (Energy recovery)	D (reuse)	
Kg	Kg	Kg	kg	Kg	Kg	Kg	Kg	Ton	Ton	
0 Structure today	0	0	0	0	0	0	0	0	0	0
1 (5RC+1T)	-4,80E+04	2,21E+05	6,37E+04	2,37E+05	2,12E+04	4,80E+04	3,01E+04	-2,21E+05	306	46
2 (5RC+3T)	-4,32E+05	6,64E+05	1,91E+05	4,23E+05	6,37E+04	4,32E+05	9,04E+04	-6,64E+05	919	-150
3 (5RC+4T)	-7,67E+05	8,85E+05	2,55E+05	3,72E+05	8,50E+04	7,67E+05	1,21E+05	-8,85E+05	1225	-392

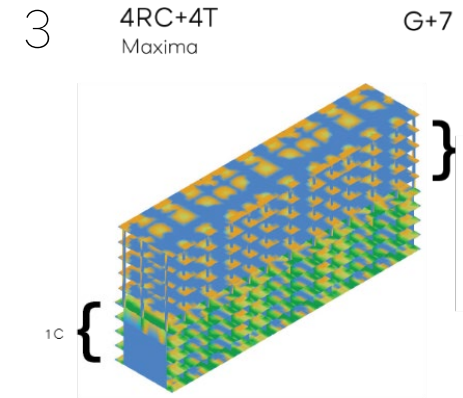
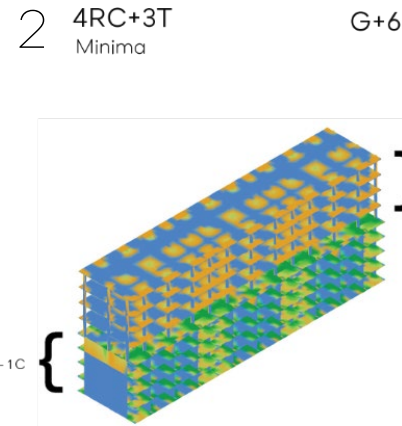
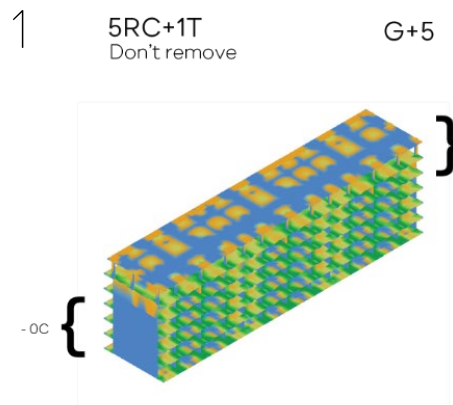


05

Experiment

Evaluate: Upfront embodied carbon and area

	Upfront Embodied carbon in all of the scenarios						
	Downcycle+ Energy recovery	Recyle+ Energy recovery	Reuse+ Energy recovery	Downcycle+ Reuse	Recyle+ Reuse	Reuse+ Reuse	Increase in area
Structure today	2450						0 %
(5RC+1T)	2358	2358	2358	2098			15 %
(4RC+3T)	2891	2825	1918	1822	1756	849	26 %
(4RC+4T)	3197	3132	2224	1580	1514	607	34 %



How to increase the area of existing Reinforced Concrete structures to extend their lifespan by using timber top-ups?

How to increase the area of existing Reinforced Concrete structures to extend their lifespan by using timber top-ups?

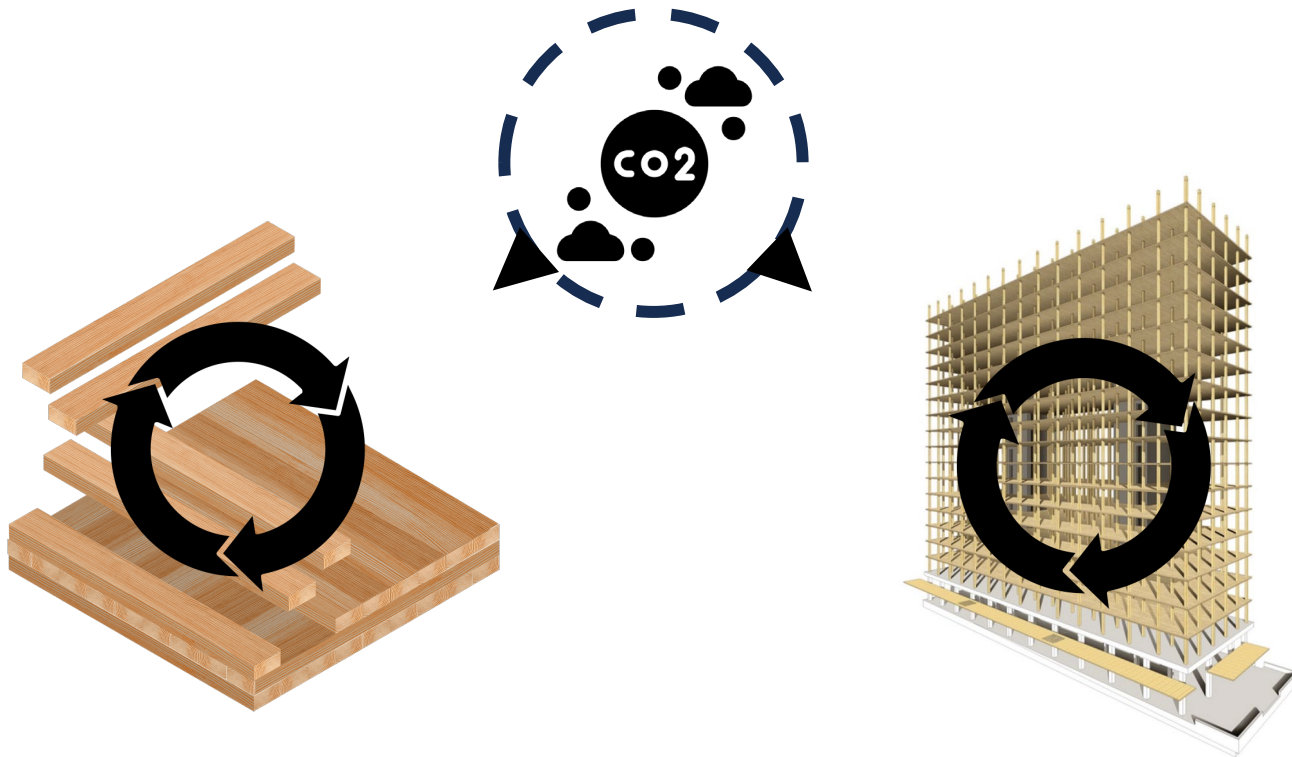
SQ. 1 |

Which structural timber systems can be more effective when topping up existing Reinforced Concrete Structure (RCS) buildings?



SQ. 2 |

What opportunities and limitations have topping up an existing RC structure building?

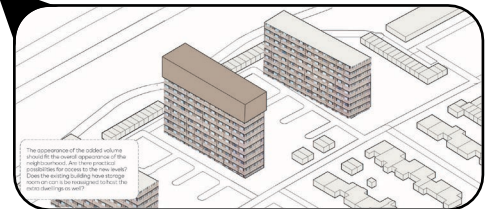
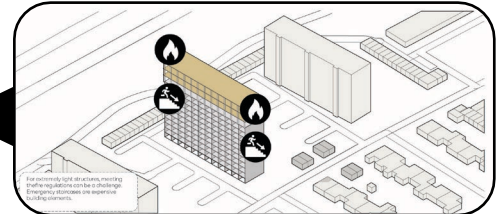
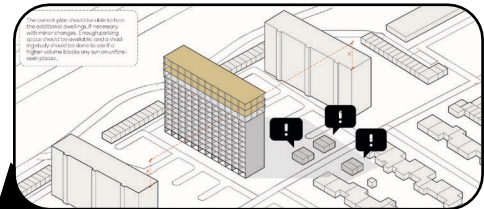
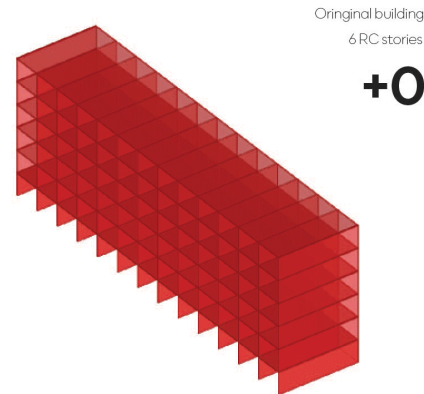
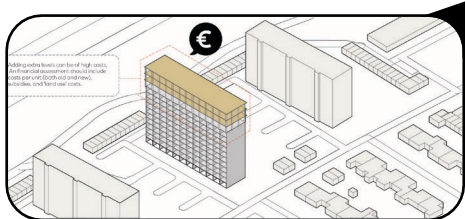
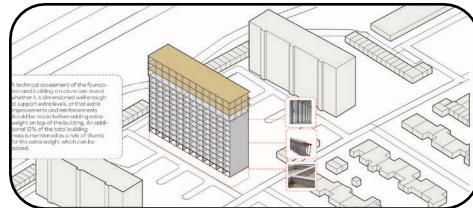
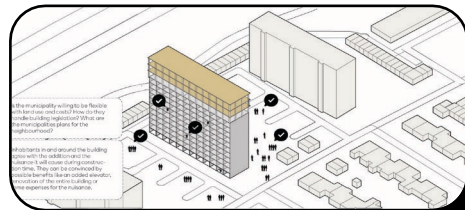


Discussion

Research questions

SQ. 3 |

To what extent can be increased the area of an existing RC building with timber?



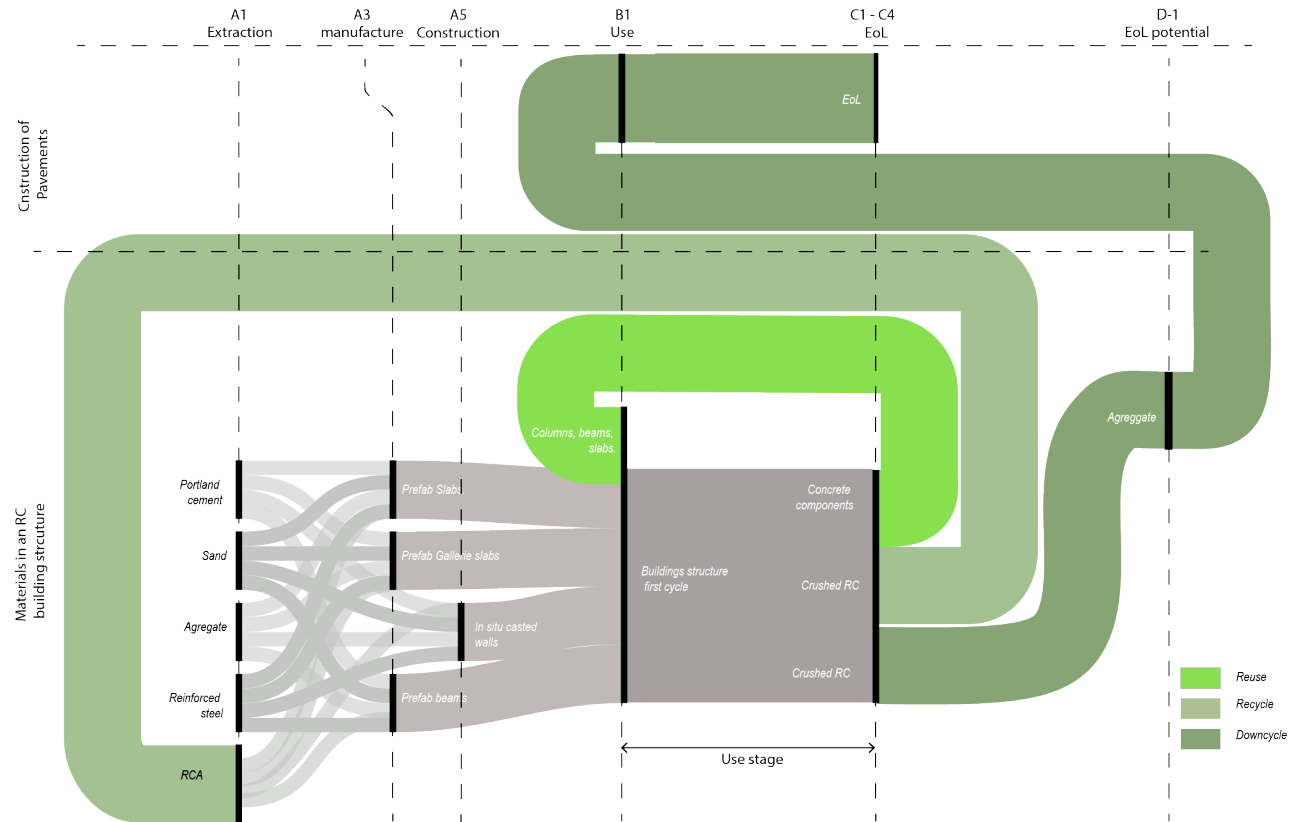


Thank you

Questions?

01

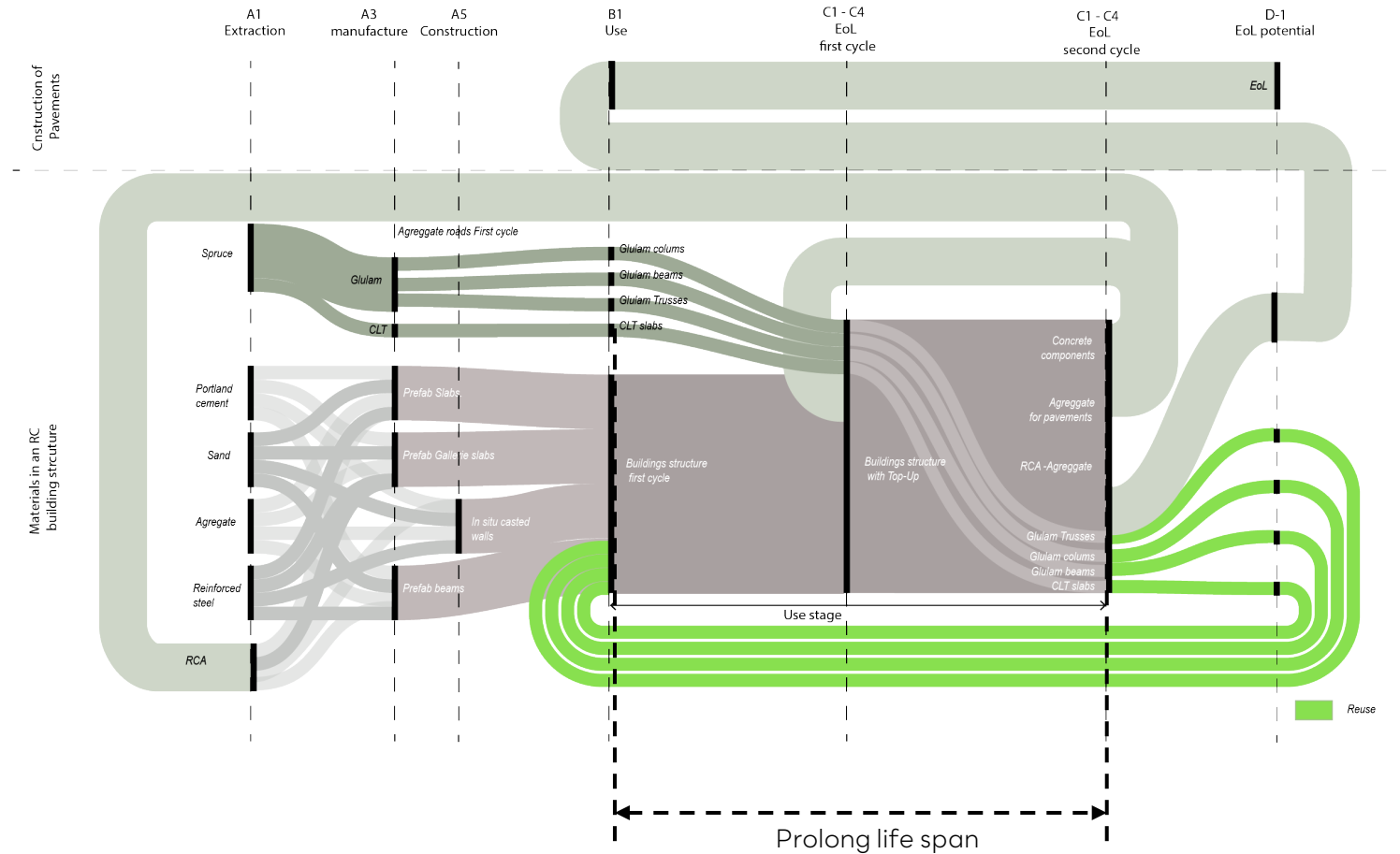
Introduction Hypothesis



01

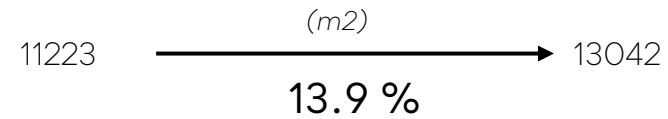
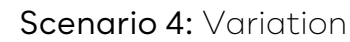
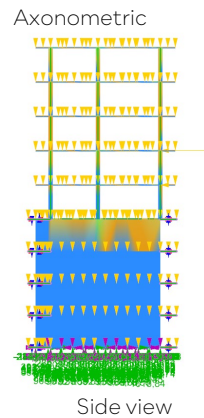
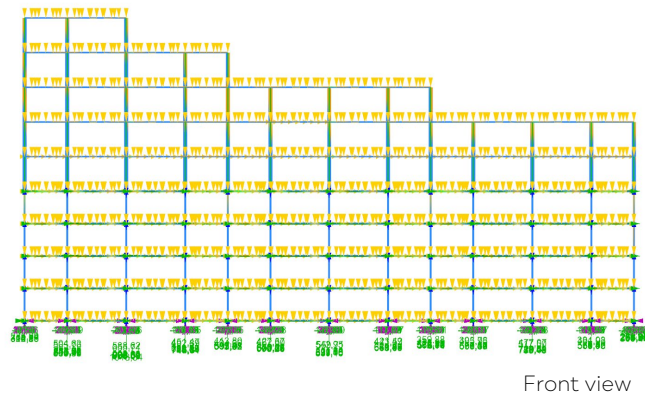
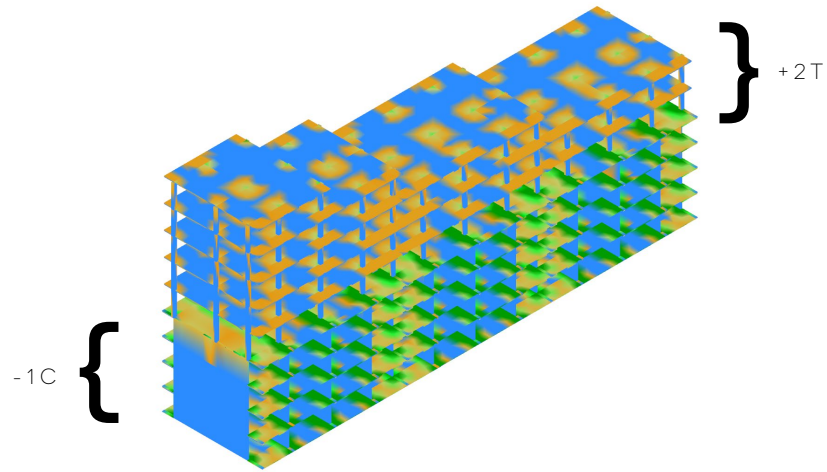
Introduction Hypothesis

Topping up



Research for design

Propose: Design of the structural system



(m3)

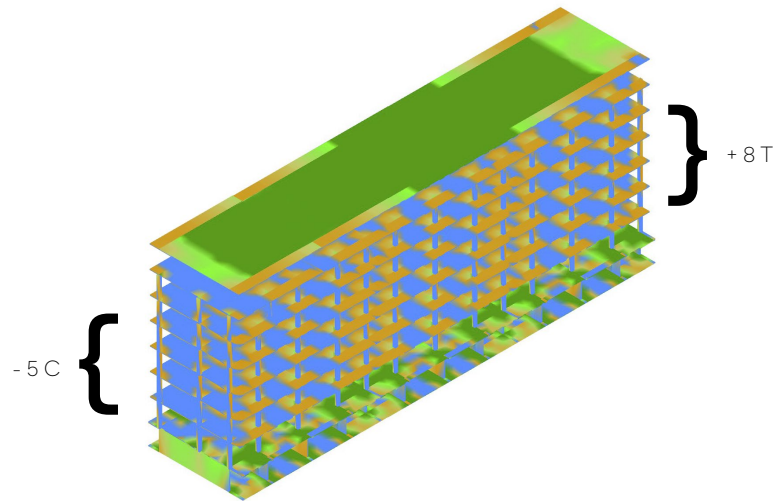
-838,2

+1394

03

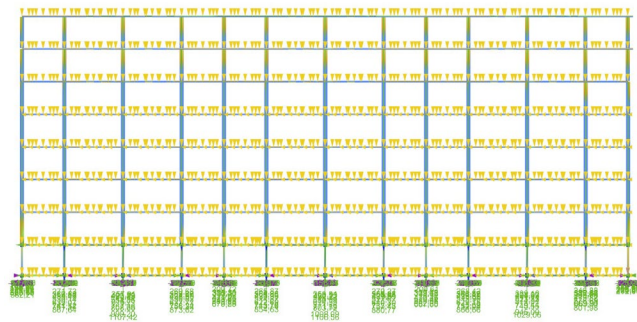
Research for design

Propose: Design of the structural system



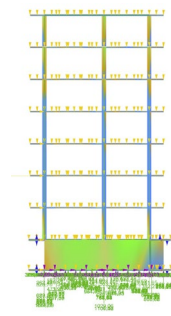
3

Structural design for Change



Front view

Axonometric



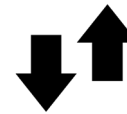
Side view

G+7

Scenario 5: Remove all

$$11223 \xrightarrow{(m^2)} 11223$$

34.4 %



(Ton)

(m3)

- 5 C

-9721

-4191

+ 8 T (dist.)

+4249

+4879

03

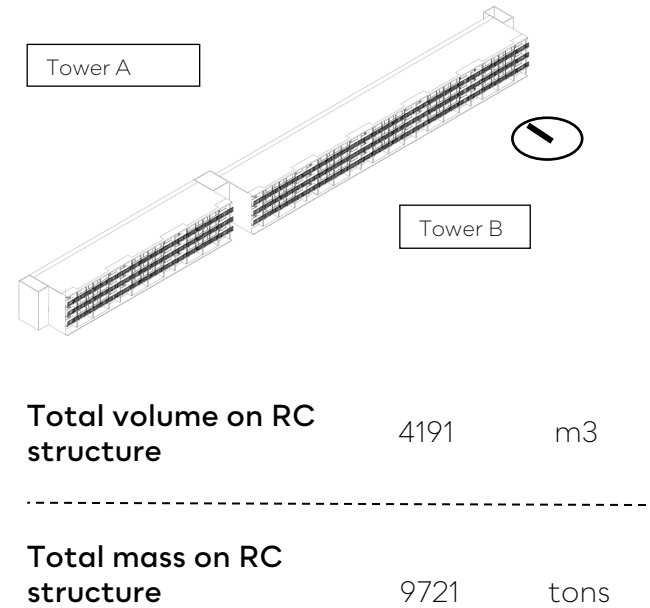
Research for design

Analyze: Volume and mass of the materials

Image	#	Component	Qty.	Composition	Raw materials	Volume (m3)*	Volume per element (m3)	Materials	Amount of material per element (in kg or lt)	Total amount of materials in the building (Tonnes) (water in m3)
	1.	Concrete prefab "L" Shape gallery.	40	Concrete matrix	Concrete (K300)(C19/22)	1,99	1,93	Portland cement	627,3	25,1
				Steel bars	Corr. steel bar (QRn48)(480 Mp)		0,06	Sand	1254,7	50,2
								Agregate	1882,0	75,3
								Water	313,7	12,5
								Reinforced steel	453,7	18,1
	2.	Concrete prefab 3.9 m Shape gallery.	40	Concrete matrix	Concrete (K300)(C19/22)	0,98	0,95	Portland cement	308,9	12,4
				Steel bars	Corr. steel bar (QRn48)(480 Mp)		0,03	Sand	617,9	24,7
								Agregate	926,8	37,1
								Water	154,5	6,1
								Reinforced steel	223,4	8,9
	3.	Concrete prefab 5.3 m Shape gallery.	40	Concrete matrix	Concrete (K300)(C19/22)	1,37	1,33	Portland cement	431,9	17,2
				Steel bars	Corr. steel bar (QRn48)(480 Mp)		0,04	Sand	863,8	34,4
								Agregate	1295,7	51,6
								Water	215,9	8,4
								Reinforced steel	312,4	12,5
	4.	Concrete prefab cantilever beam back balconies	150	Concrete matrix	Concrete (K300)(C19/22)	0,0096	0,01	Portland cement	3,0	0,1
				Steel bars	Corr. steel bar (QRn48)(480 Mp)		0,00	Sand	6,1	0,2
								Agregate	9,1	0,4
								Water	1,5	0,1
								Reinforced steel	2,2	0,1
	5.	Concrete cantilever beam Galleries	150	Concrete matrix	Concrete (K300)(C19/22)	0,02115	0,02	Portland cement	6,7	0,2
				Steel bars	Corr. steel bar (QRn48)(480 Mp)		0,00	Sand	13,3	0,5
								Agregate	20,0	0,8
								Water	3,3	0,1
								Reinforced steel	4,8	0,2
	6.	Existing casted concrete wall (Type D-C)	70	Concrete matrix	Concrete (K300)(C19/22)	5,11	4,96	Portland cement	1610,9	64,4
				Steel bars	Corr. steel bar (QRn48)(480 Mp)		0,15	Sand	3221,9	128,1
								Agregate	4832,8	193,1
								Water	805,5	32,1
								Reinforced steel	1165,1	46,4
	7.	Existing casted concrete wall (Type A)	20	Concrete matrix	Concrete (K300)(C19/22)	6,99	6,78	Portland cement	2203,6	88,1
				Steel bars	Corr. steel bar (QRn48)(480 Mp)		0,21	Sand	4407,2	176,1
								Agregate	6610,8	264,4
								Water	1101,8	44,1
								Reinforced steel	1593,7	63,7
	8.	Existing casted concrete wall (Type B)	80	Concrete matrix	Concrete (K300)(C19/22)	4,23	4,10	Portland cement	1333,5	53,3
				Steel bars	Corr. steel bar (QRn48)(480 Mp)		0,13	Sand	2667,0	106,7
								Agregate	4000,5	160,0
								Water	666,8	26,7
								Reinforced steel	964,4	38,6
	9.	Existing precast concrete slab on ground floor tower A	5	Concrete matrix	Concrete (K300)(C19/22)	103,4	100,30	Portland cement	32596,9	1303,9
				Steel bars	Corr. steel bar (QRn48)(480 Mp)		3,10	Sand	65193,7	2607,7
								Agregate	97790,6	3911,6
								Water	16298,4	651,9
								Reinforced steel	23575,2	943,0
	10.	Existing precast concrete slab on ground floor tower B	5	Concrete matrix	Concrete (K300)(C19/22)	172,4	167,23	Portland cement	54349,1	2174,0
				Steel bars	Corr. steel bar (QRn48)(480 Mp)		5,17	Sand	108698,2	4347,9
								Agregate	163047,3	6521,9
								Water	27174,6	1087,0
								Reinforced steel	39307,2	1572,3
TOTALS									Portland cement	3738,9 Ton
									Sand	7477,7 Ton
									Agregate	11216,6 Ton
									Water	1869,4 Ton
									Reinforced steel	2704,1 Ton

*Value taken from the main Grasshopper model

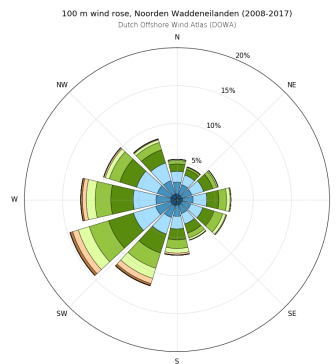
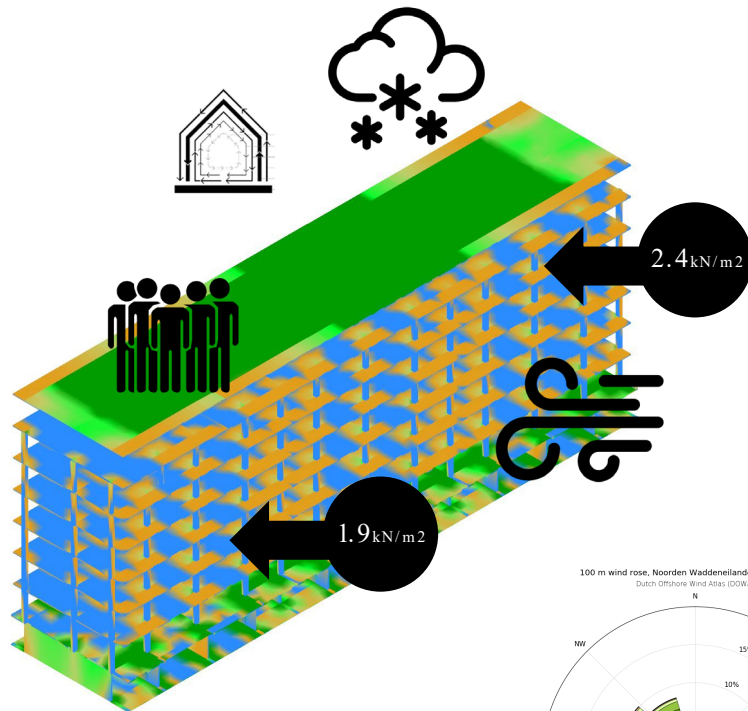
Amount of materials (kg) in one m3 of Concrete C19	
Portland cement	325 kg
Sand	650 kg
Agregate	975 kg
Water	163 lt
Density of steel	7600 Kg/m3



03

Research for design Define: Load cases

Load case scenarios



Live load	g_k	2,00 kN/m ²
2	kN/m ²	Internal: Class A Residential EC 0
3	kN/m ²	Balconies: Class A: Residential EC 0
Dead load	q_k	6,00 kN/m ²
3	kN/m ²	Partitions in lightweight CLT walls.
1,5	kN/m ²	Mechanical services (HVAC, plumbing, etc.).
1,5	kN/m ²	Facade system (windows, doors, etc.)
Snow load	s_k	0,85 kN/m ²
0,85	kN/m ²	Zone 1 of the Netherlands
Wind load	w_k (h existing)	1,90 kN/m ²
1,9	kN/m ²	Wind pressure calculation method
Wind load	w_k (h Top up)	2,45 kN/m ²
2,4	kN/m ²	Wind pressure calculation method

Load case	Load
LC1	1.35 g_k 2,7 kN/m ²
LC2	1.35 g_k + 1.5 q_k 11,7 kN/m ²
LC3	1.35 g_k + 1.5 s_k 4,0 kN/m ²
LC4	1.0 g_k + 1.5 w_k 4,9 kN/m ²
LC5	1.35 g_k + 1.5 w_k 5,6 kN/m ²
LC6	1.35 g_k + 1.5 q_k + 1.5 * 0.6 * s_k 12,5 kN/m ²
LC7	1.35 g_k + 1.5 q_k + 1.5 * 0.5 * w_k 13,1 kN/m ²
LC8	1.35 g_k + 1.5 * 0.0 * q_k + 1.5 * s_k 4,2 kN/m ²
LC9	1.35 g_k + 1.5 * 0.0 * q_k + 1.5 * w_k 5,6 kN/m ²
LC10	1.35 g_k + 1.5 * 0.6 * s_k + 1.5 * w_k 6,3 kN/m ²
LC11	1.35 g_k + 1.5 * 0.5 * w_k + 1.5 * s_k 5,4 kN/m ²
LC12	1.35 g_k + 1.5 * 0.0 * q_k + 1.5 * s_k + 1.5 * 0.5 * w_k 5,4 kN/m ²
LC13	1.35 g_k + 1.5 * q_k + 1.5 * 0.6 * s_k + 1.5 * 0.5 * w_k 13,9 kN/m ²
LC14	1.35 g_k + 1.5 * 0.0 * q_k + 1.5 * 0.6 * s_k + 1.5 * w_k 6,3 kN/m ²