Accelerating Circularity in Built-Environment Through "Active-Procurement"

An aggregated assessment framework to make sustainable choices while using secondary material at early design phase

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TU Delft

Faculty of Architecture, Urbanism and Building sciences

Track Building Technology

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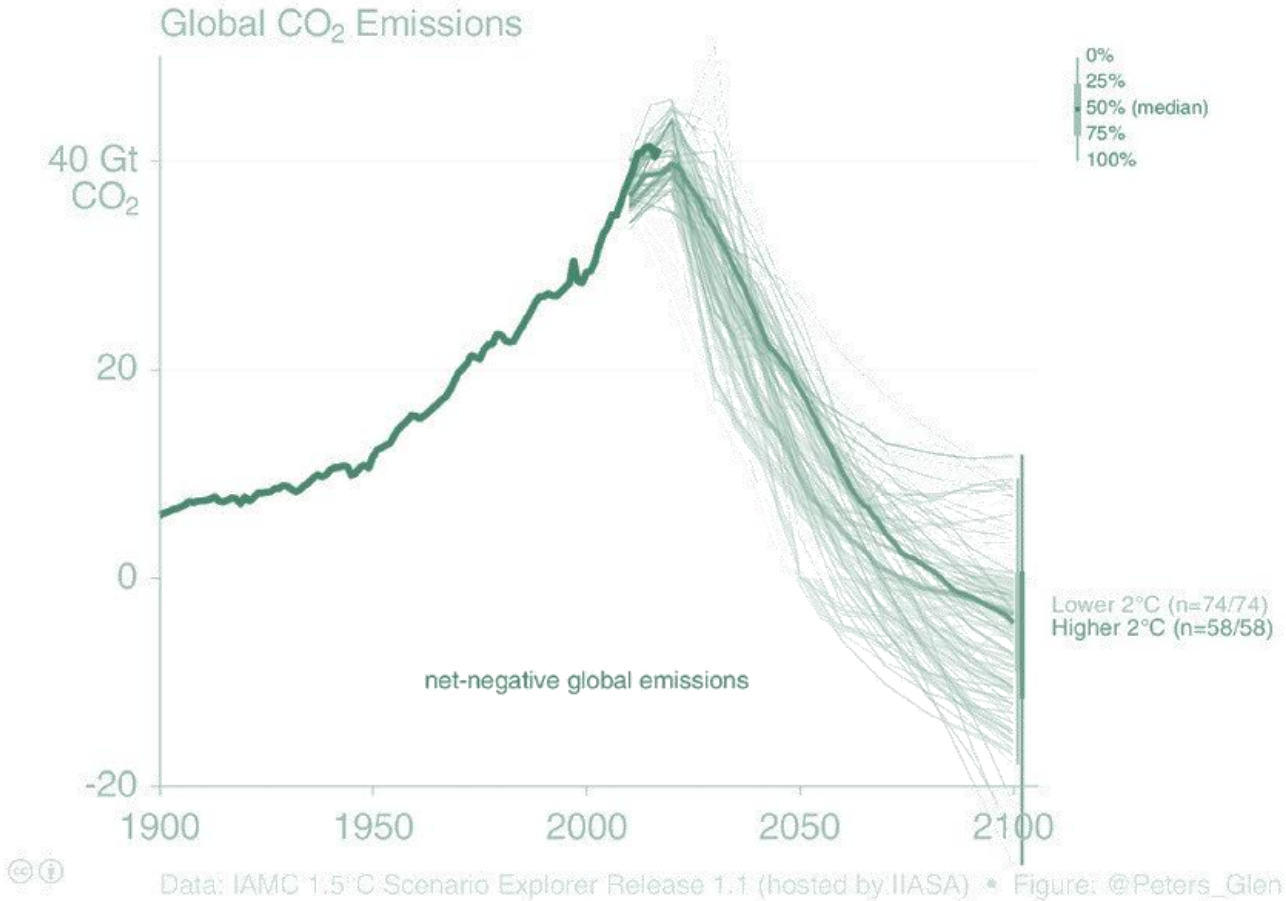
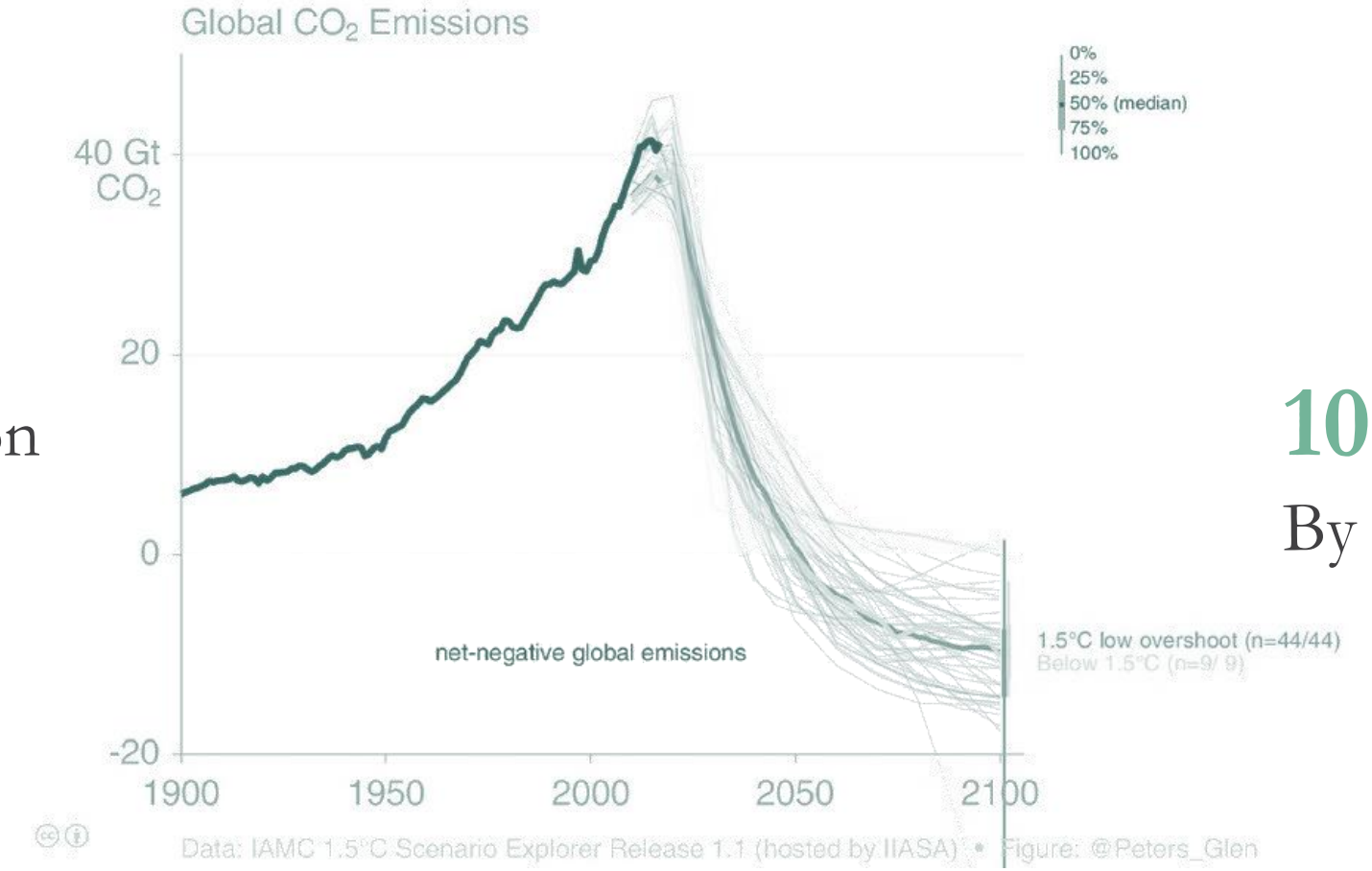
First Mentor- Tillmann Klein
Second Mentor- Peter Russel
Guest Mentors- Tom Blankendaal, Royal BAM Group n.v.
Marcel Tabak, ABT b.v.

Context


Global CO_2 Emissions
40 Gt CO_2
20
0
-20
1900
1950
2000
2050
2100
0%
25%
50% (median)
75%
100%
net-negative global emissions
Lower 2°C (n=74/74)
Higher 2°C (n=58/58)
Data: IAMC 1.5°C Scenario Explorer Release 1.1 (hosted by IIASA) • Figure: @Peters_Glen

Context

50% Reduction
By 2030



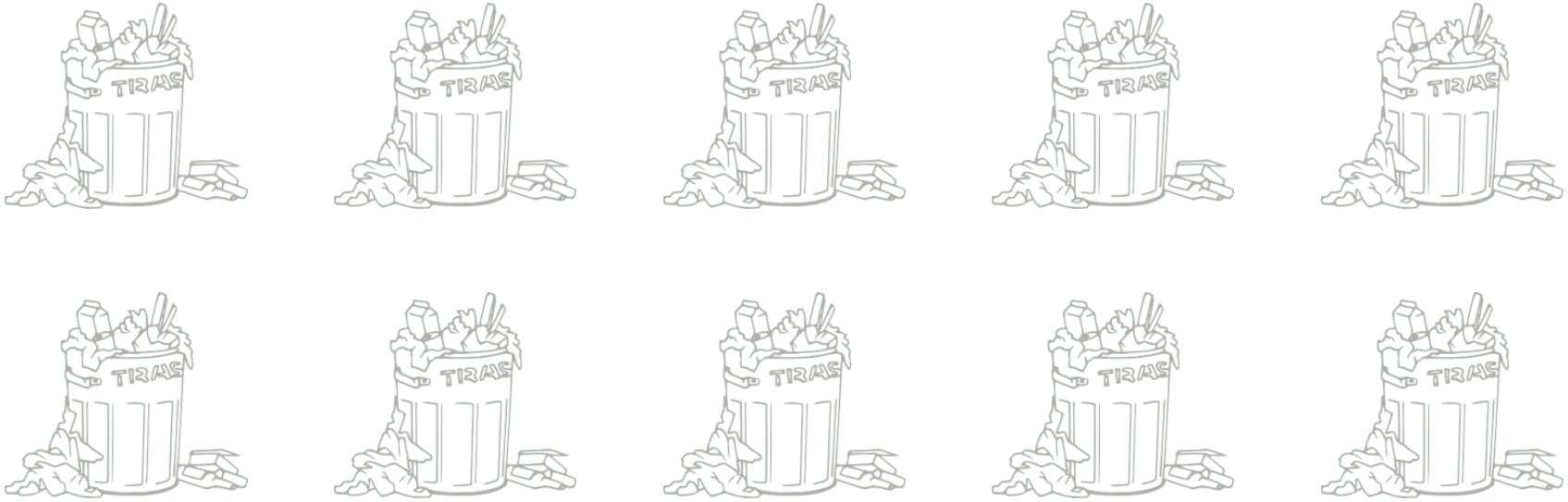
100% Reduction
By 2050

Context

Context

Context

Total waste in Europe (non-hazardous)



Context

Total waste in Europe (non-hazardous)

30% due to Construction and Demolition

Context

CDW Recovery rate

Total Construction and Demolition Waste in Europe

Context

CDW Recovery rate

Total Construction and Demolition Waste in Europe

90%

recycled reused Energy backfilling

Context

backfilling

Context

CDW Recovery rate

Total Construction and Demolition Waste in The Netherlands

100%

recycled reused Energy backfilling

Context

CDW Recovery rate

Total Construction and Demolition Waste in The Netherlands

100%

recycled

reused

Energy

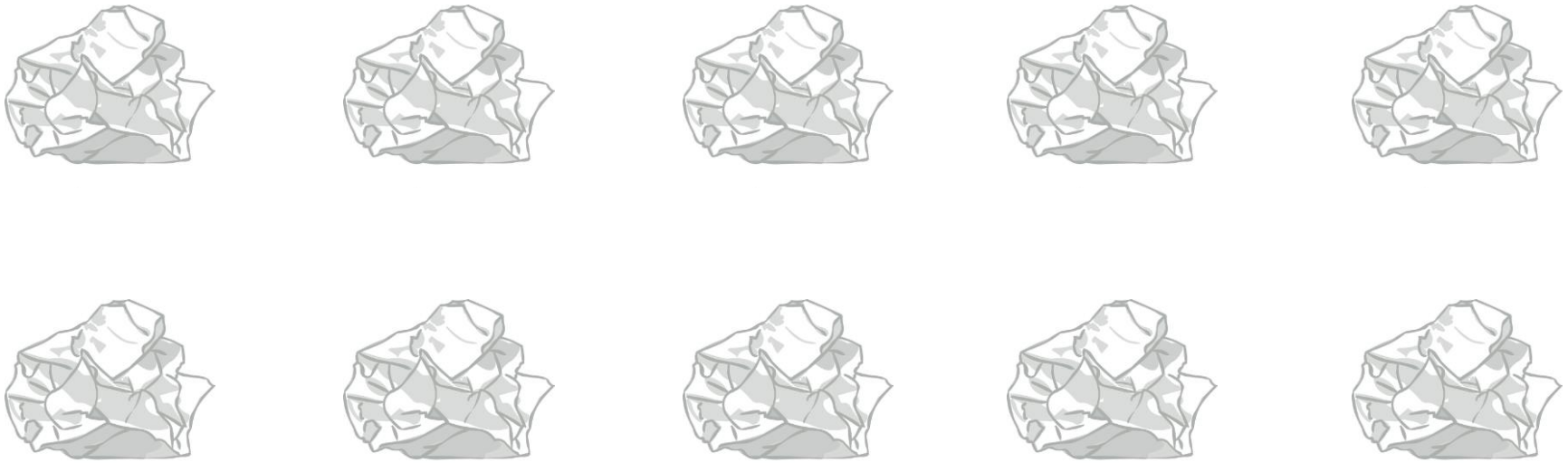
backfilling

Context

backfilling

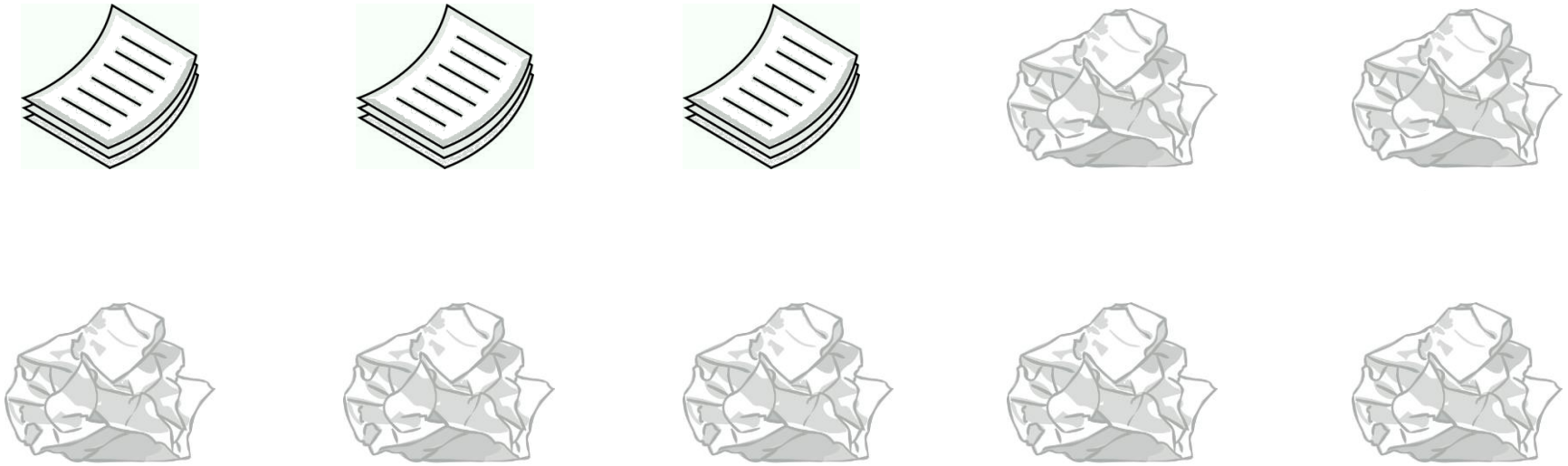
Context

Total material that goes for recycling in Europe



Context

Total material that goes for recycling in Europe

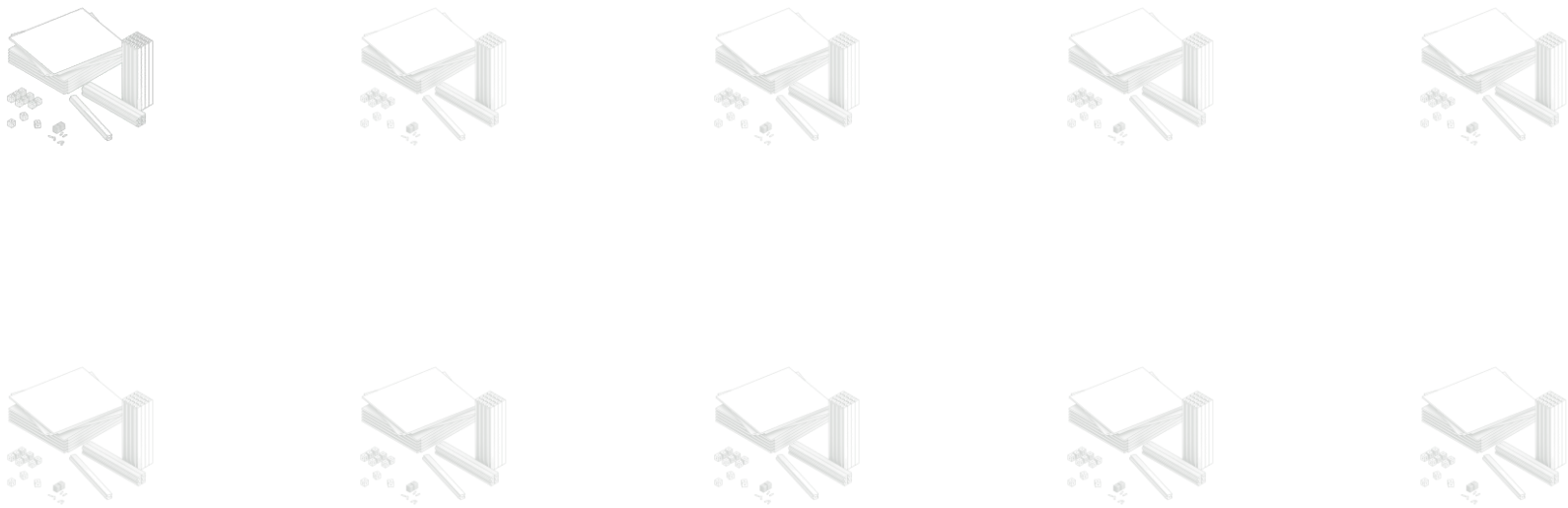


30% can be directly reused

Context

Circular Material Use rate

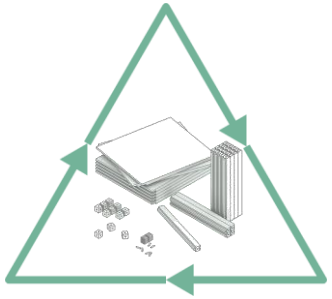
Total material demand in Europe



Context

Circular Material Use rate

Total material demand in Europe



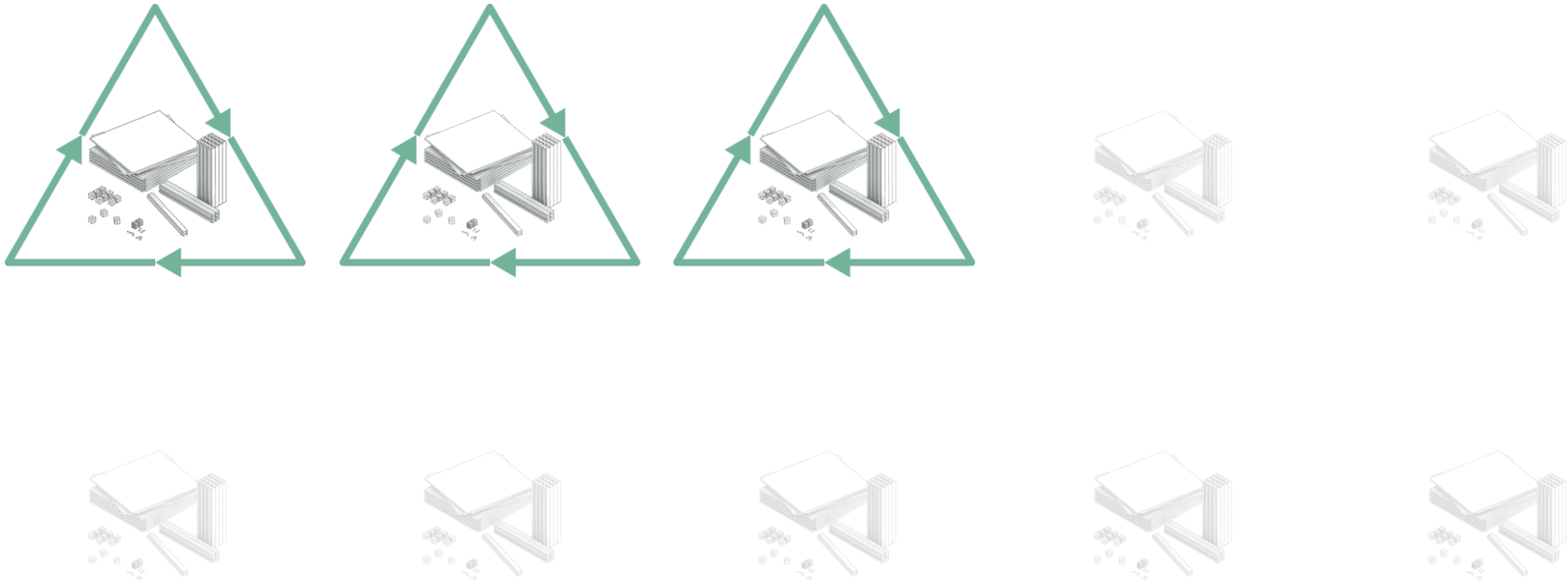
11% Secondary material in 2016

(recycled)

Context

Circular Material Use rate

Total material demand in The Netherlands



29% Secondary material by 2016

(recycled)

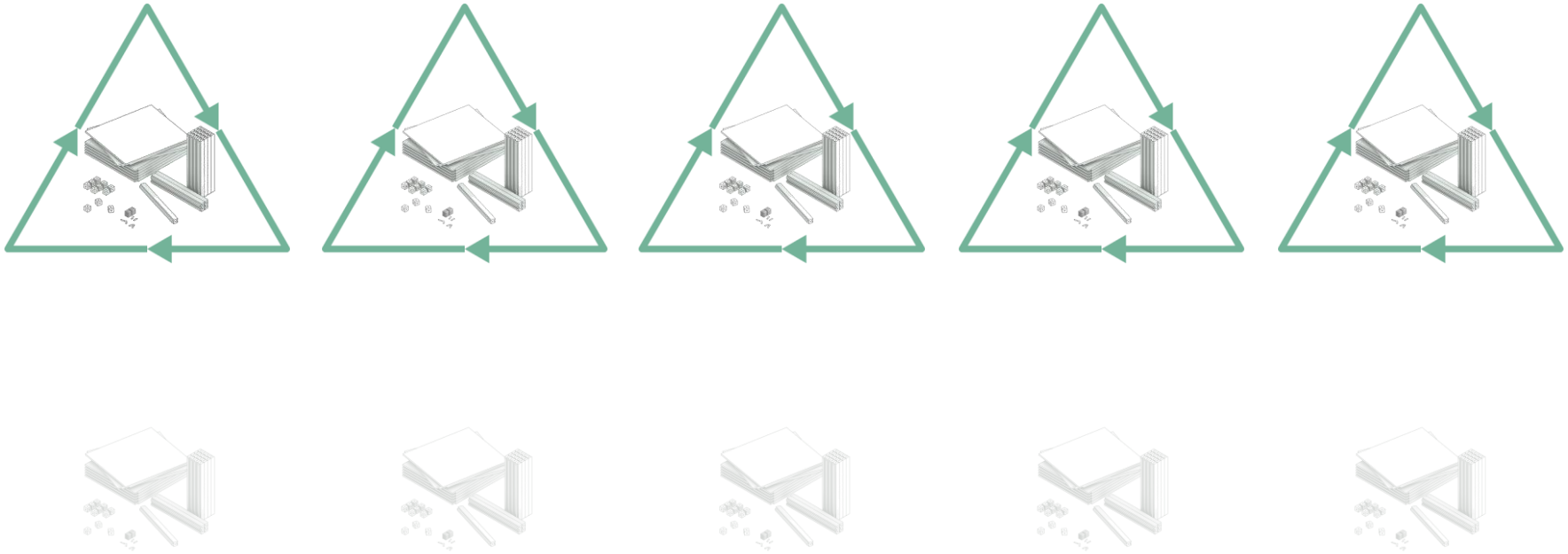
3,6% increase from 2010

0,6% increase per year

Context

Circular Material Use rate

Total material demand in The Netherlands



47% Secondary material by 2050

(recycled)

3,6% increase from 2010

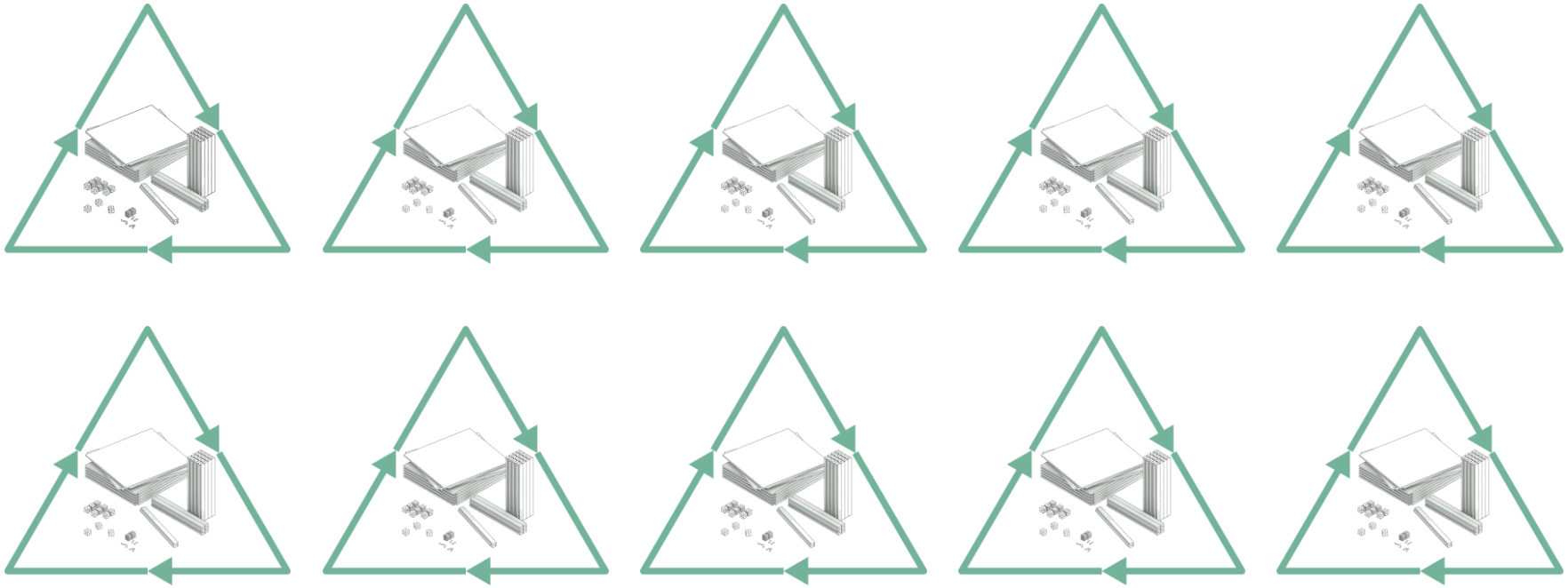
0,6% increase per year

Context

“Goal”

Circular Material Use rate

Total material demand in The Netherlands



100% Secondary material by 2050

(recycled)

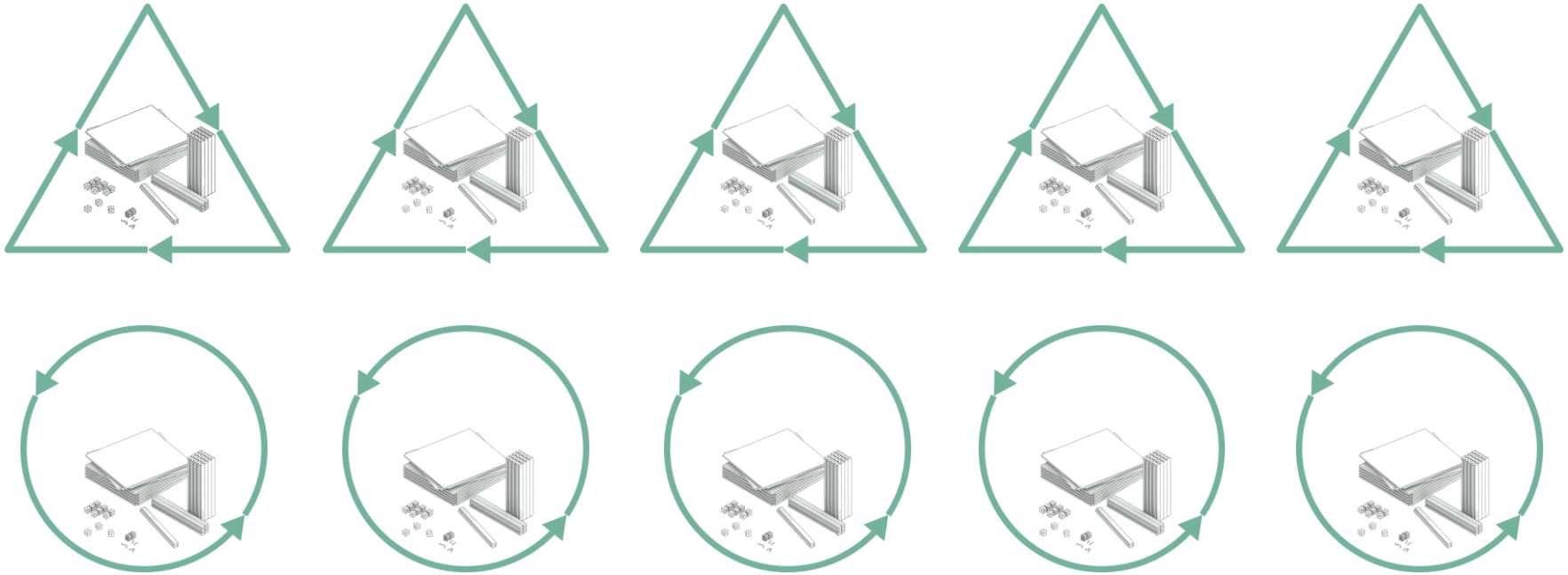
2,5% increase per year

Context

“Goal”

Circular Material Use rate

Total material demand in The Netherlands

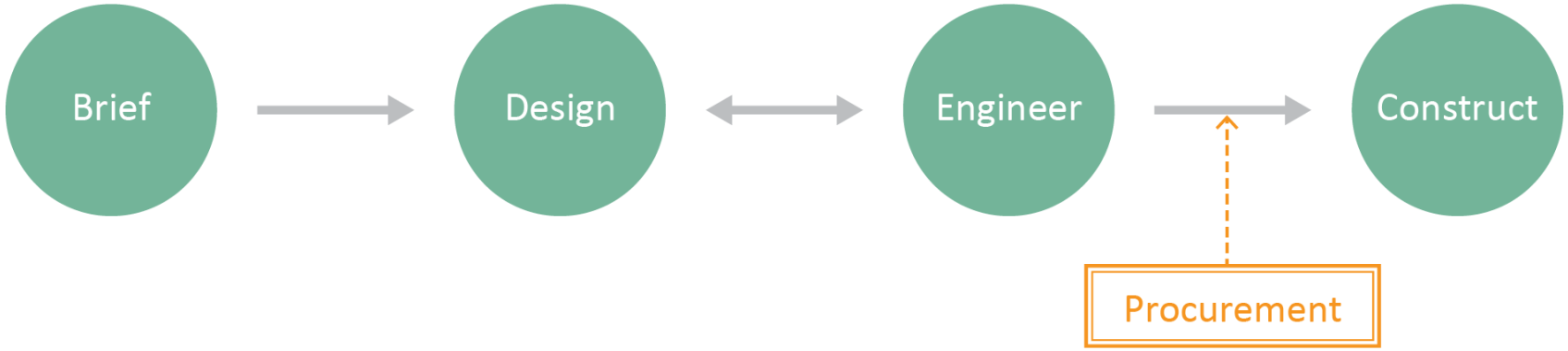


100% Secondary material by 2050

(recycled & reused)

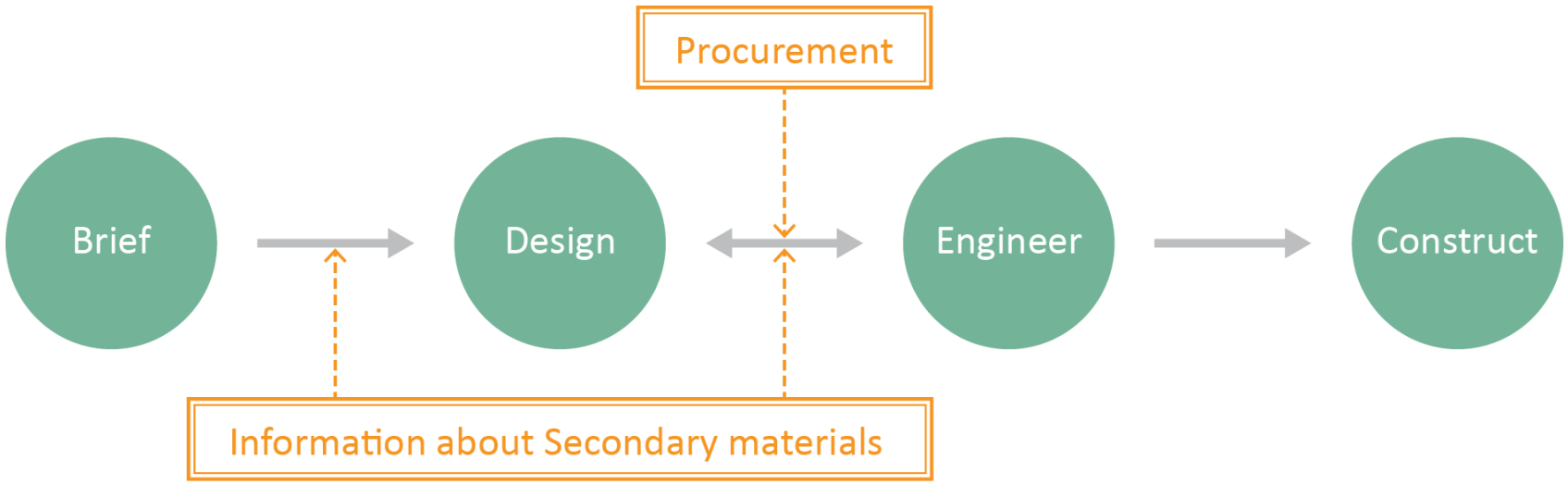
2,5% increase per year

Problem



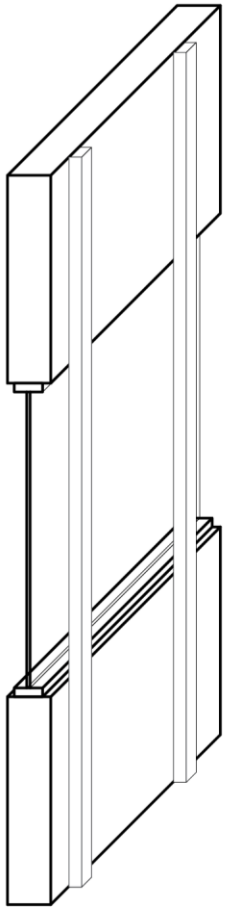
State-of-the-art practice

Objective


Procurement
Brief
Design
Engineer
Construct
Information about Secondary materials

Creative Freedom

Objective



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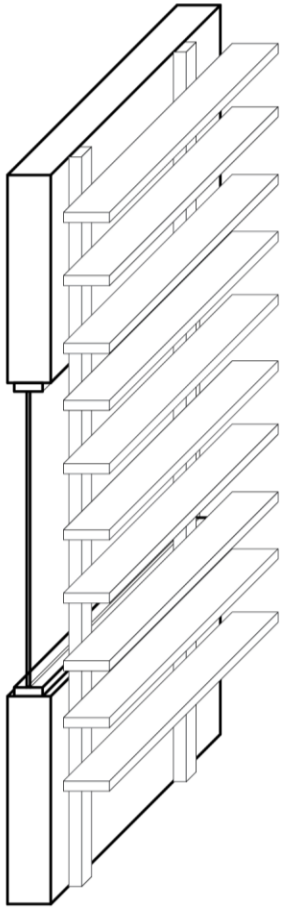

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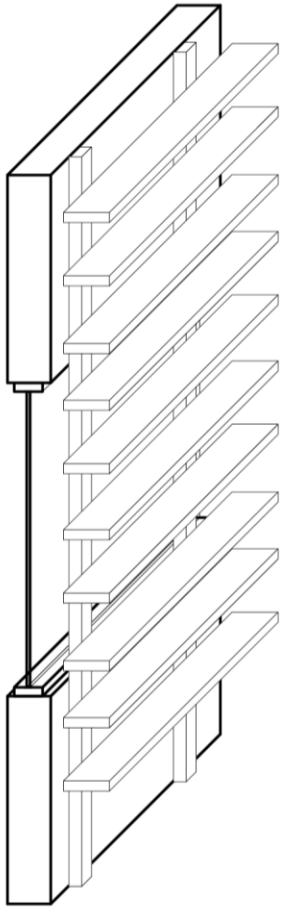

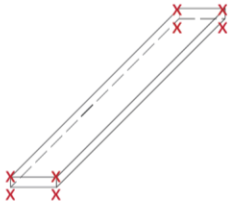

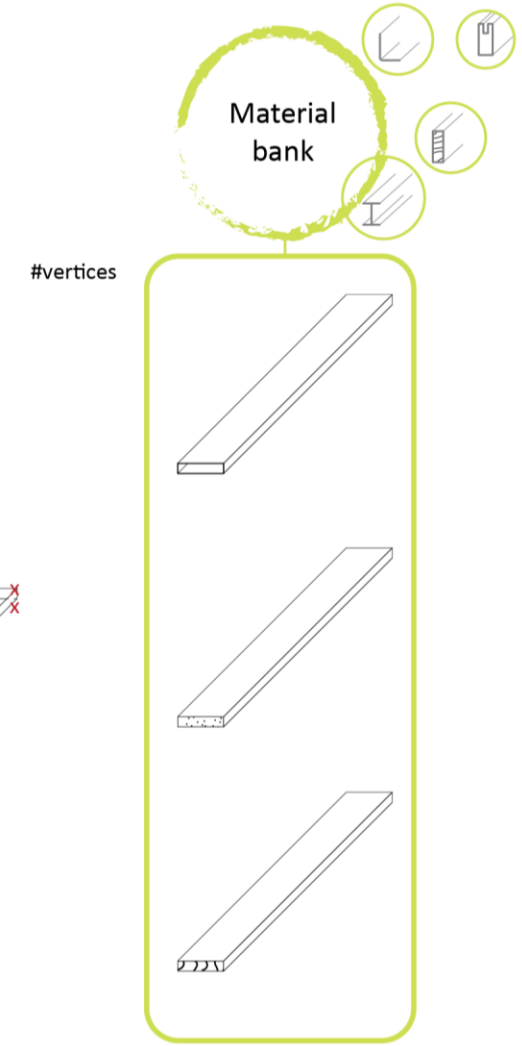

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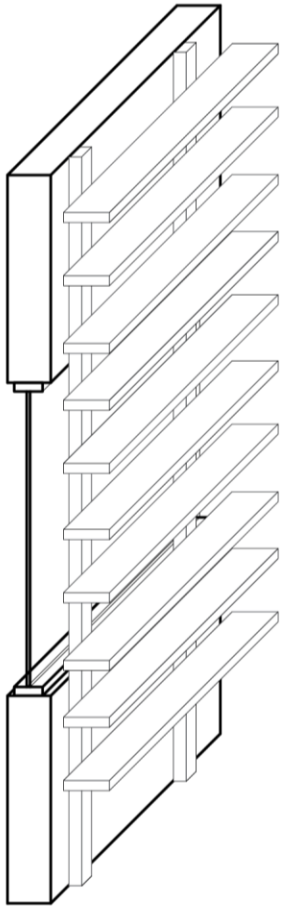

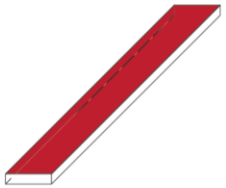

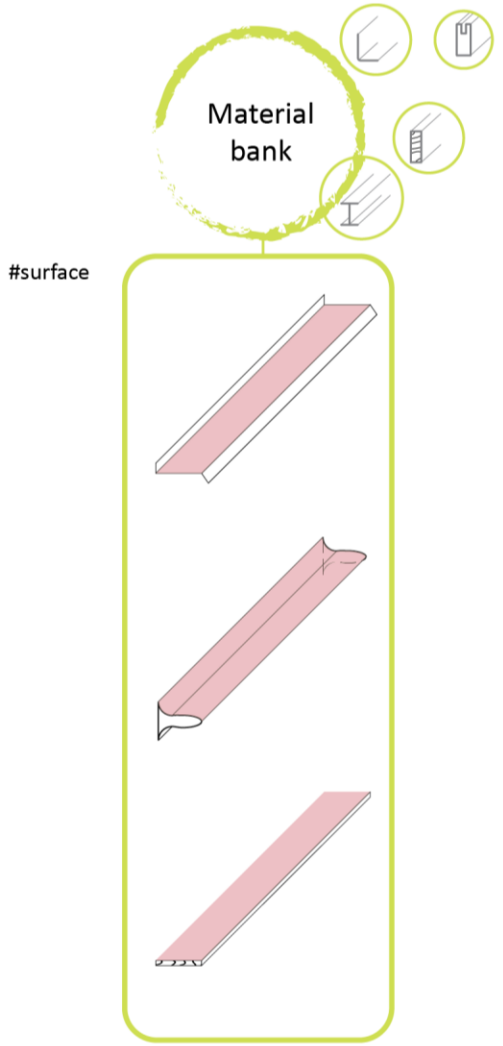

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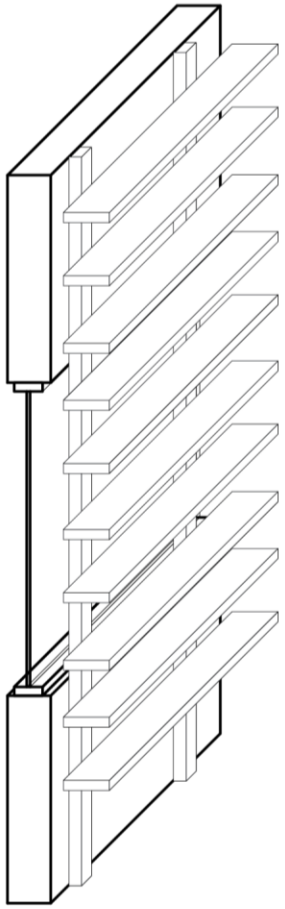

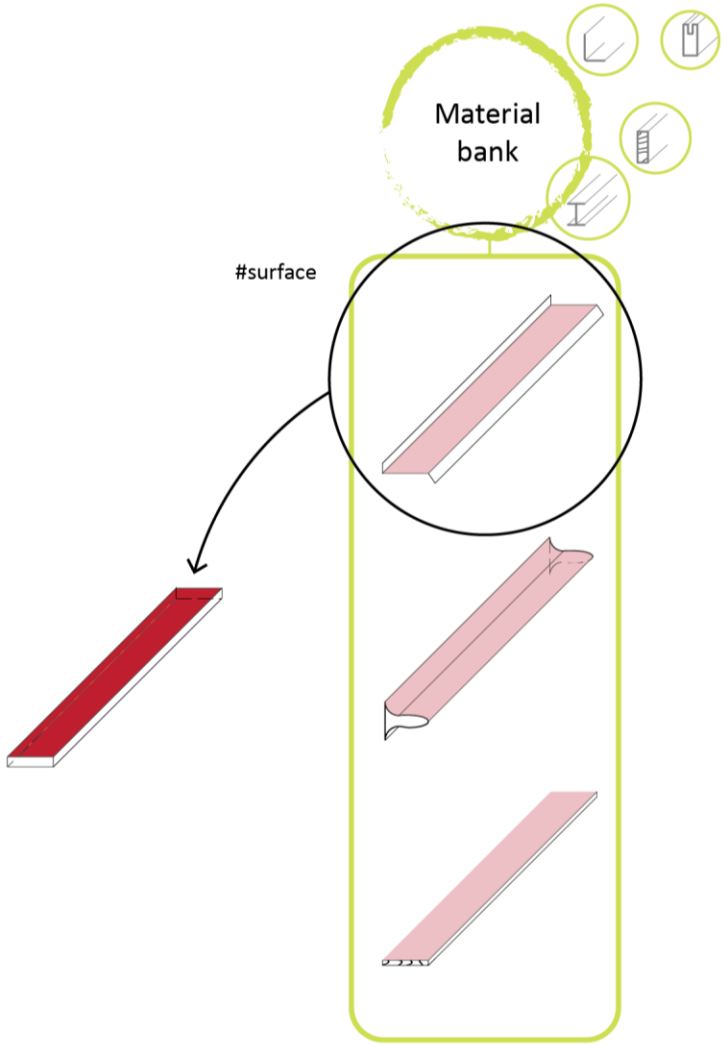

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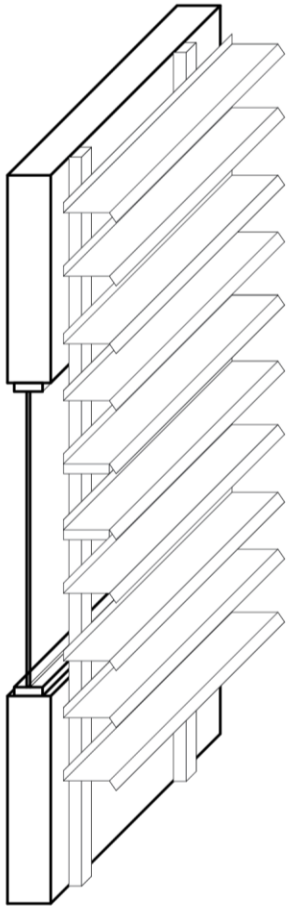

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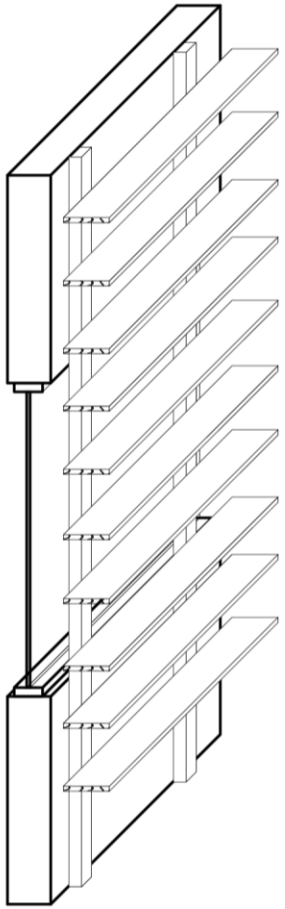

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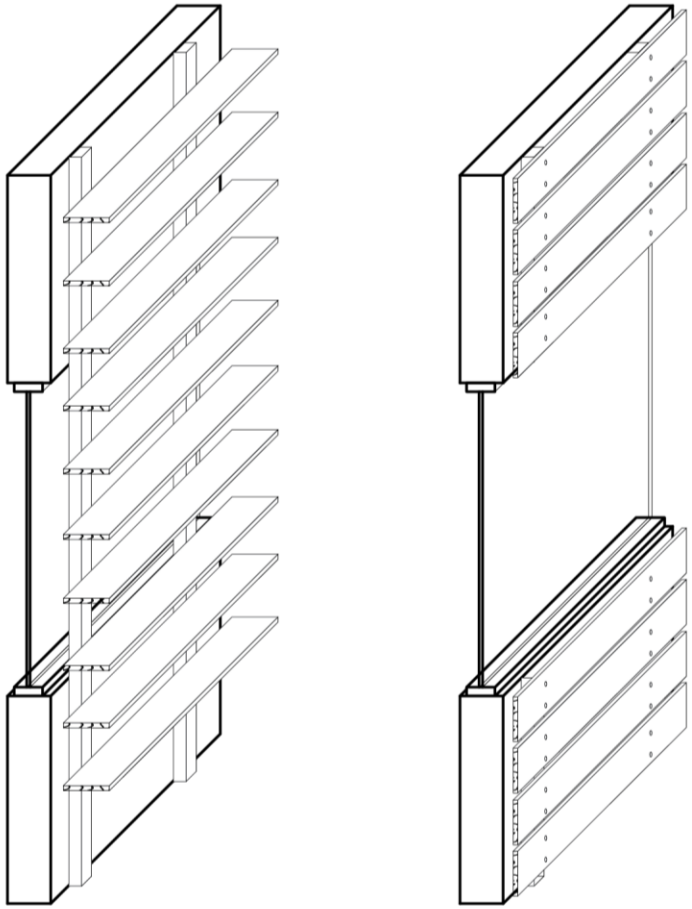

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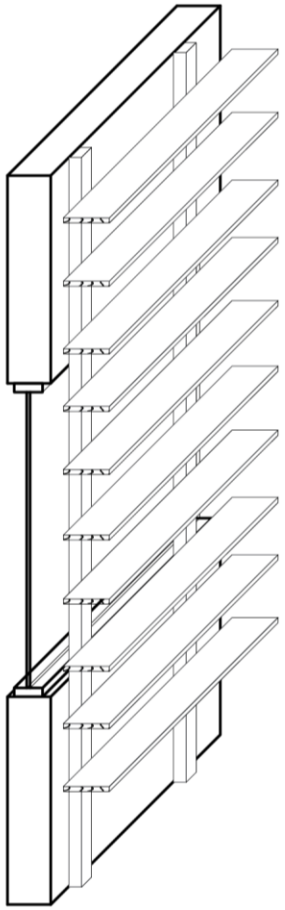
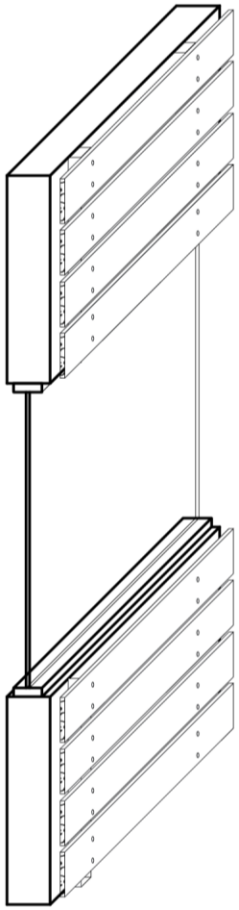
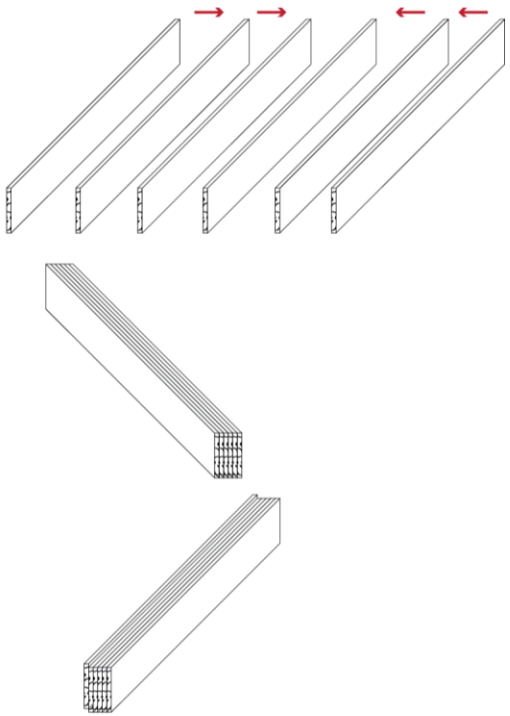






Main question

What **information** is required by a designer to use second-hand material in building design – ensuring **circular flow**, **low** environmental **impacts**, **cost** and **energy** consumption? And **when** and **how** should it be provided to them?

Research approach

Circularity Assessment

Qualitative

Transformation Capacity

Building Circularity Indicator

Building Circularity Index

Quantitative

Material Circularity Indicator (MCI)

LCA

Circularity Assessment

Qualitative

Transformation Capacity

Building Circularity Indicator

Building Circularity Index

Quantitative

Material Circularity Indicator (MCI)

LCA

Circularity Assessment

Transformation Capacity

Design for Disassembly aspects

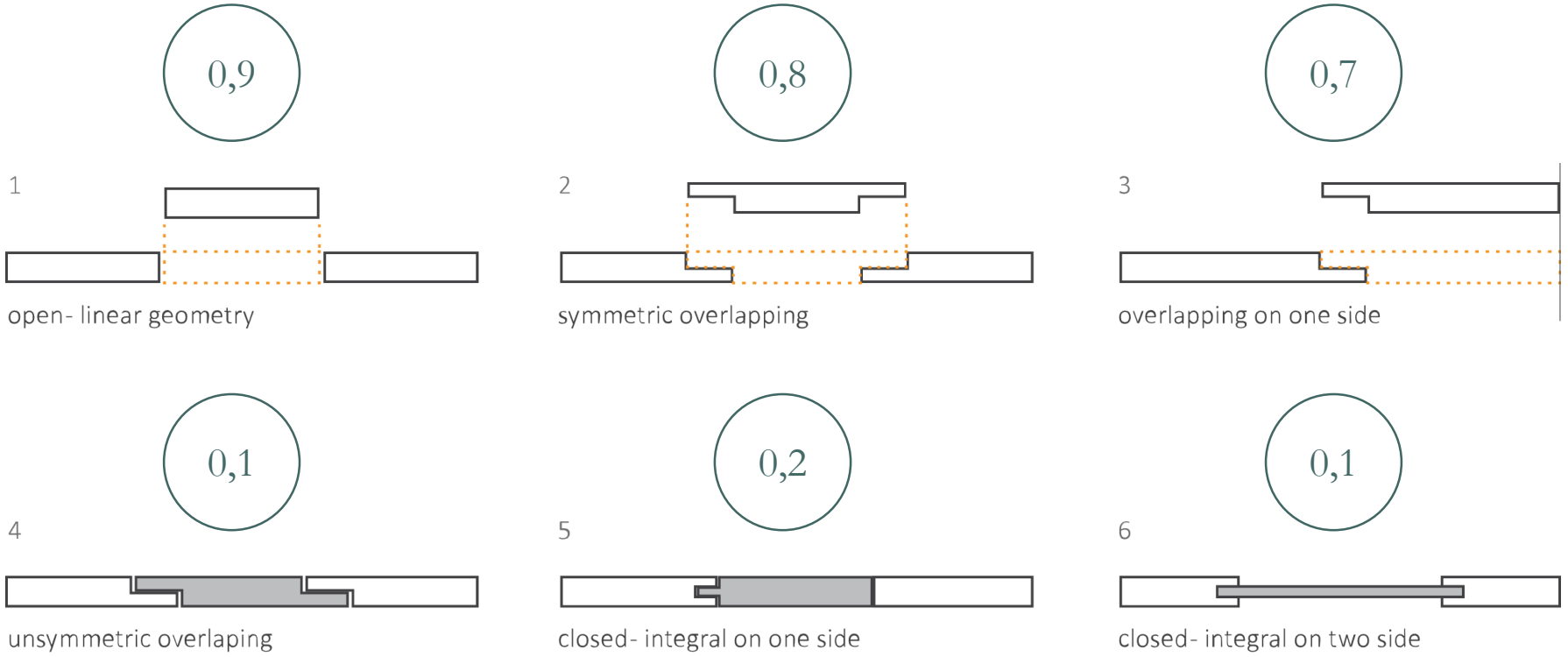
1. Functional decomposition (FD)
2. Systemization (SY)
3. Base element (BE)
4. Life cycle coordination (LCC)
5. Relational pattern (RP)
6. Assembly process (A)
7. Geometry (G)
8. Connection (C)

Circularity Assessment

Transformation Capacity

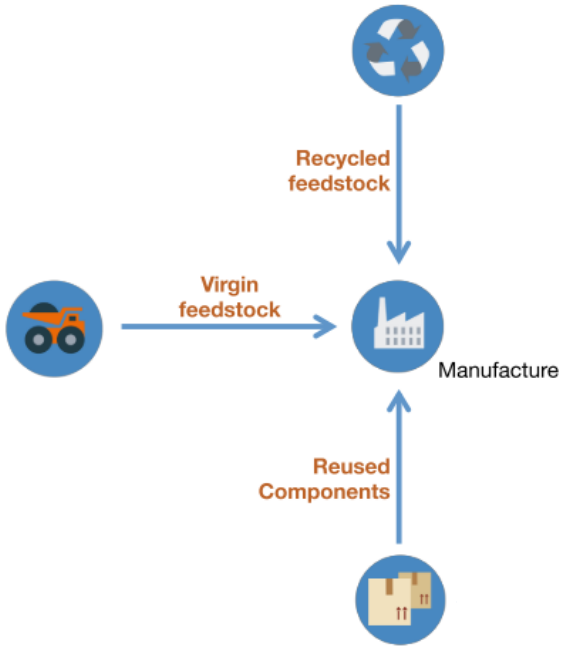
Design for Disassembly aspects

1. Functional decomposition (FD)
2. Systemization (SY)
3. Base element (BE)
4. Life cycle coordination (LCC)
5. Relational pattern (RP)
6. Assembly process (A)
7. **Geometry (G)**
8. Connection (C)



Circularity Assessment

Material Circularity Indicator (MCI)

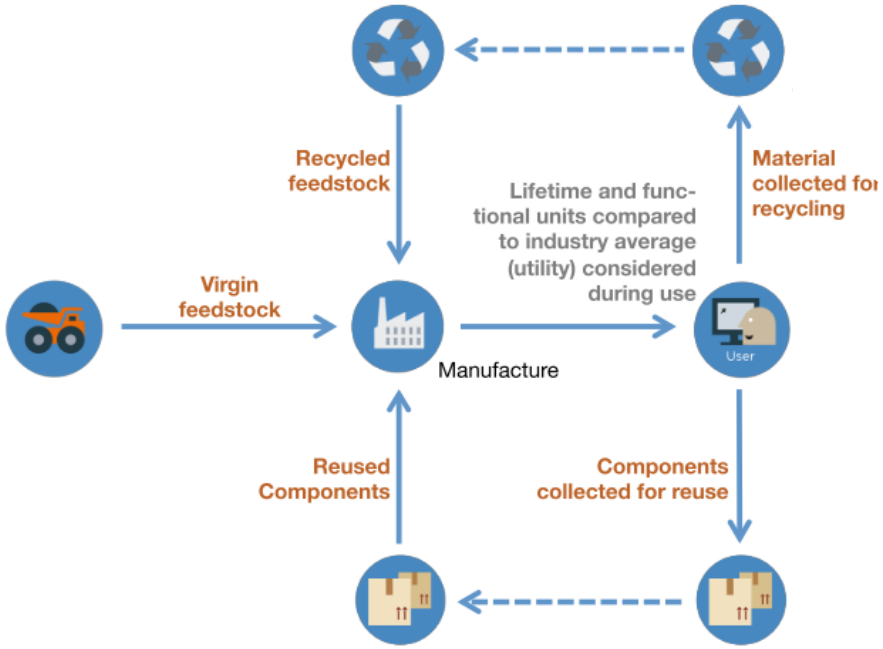


Production phase

(Ellen MacArthur Foundation & Granta Design, 2015)

Circularity Assessment

Material Circularity Indicator (MCI)

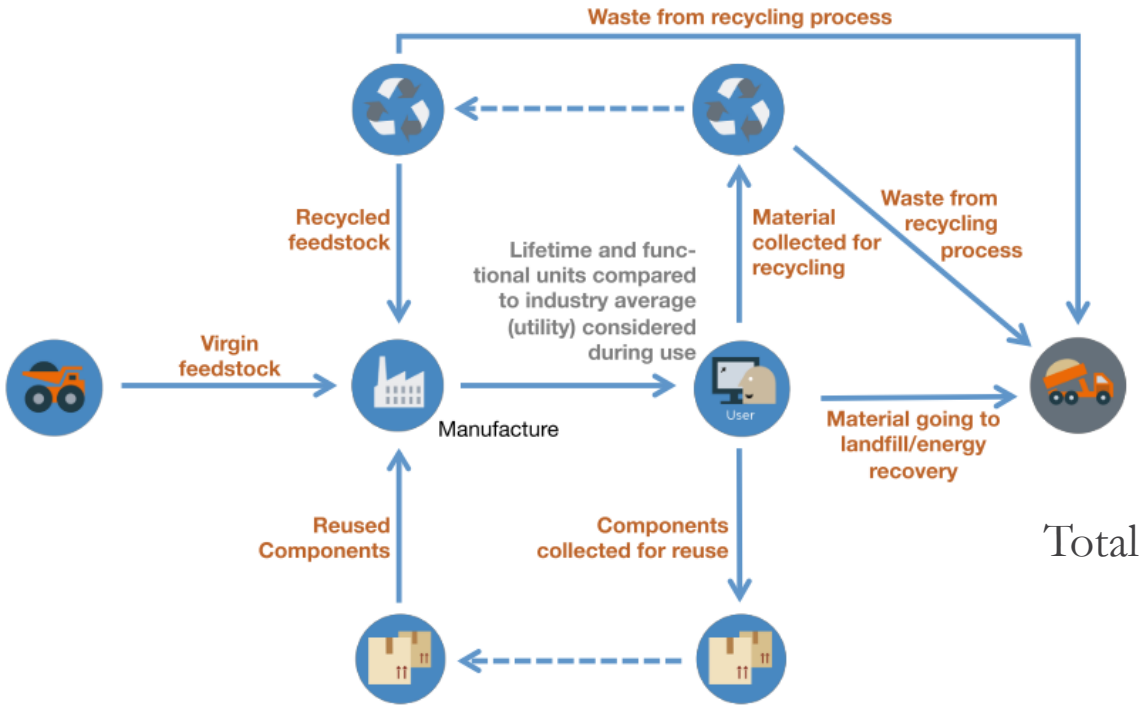


Production phase End of Life phase

(Ellen MacArthur Foundation & Granta Design, 2015)

Circularity Assessment

Material Circularity Indicator (MCI)



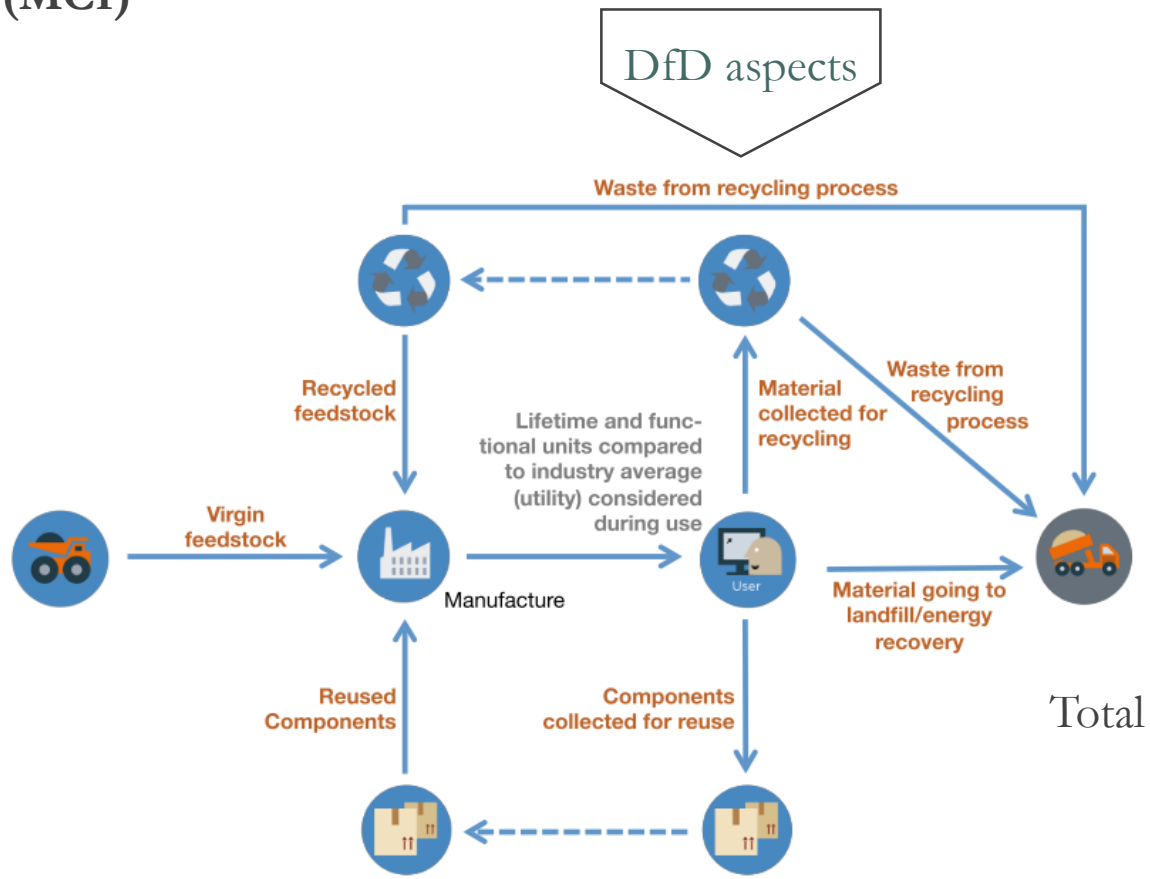
Total waste generated

Production phase End of Life phase

(Ellen MacArthur Foundation & Granta Design, 2015)

Circularity Assessment

Material Circularity Indicator (MCI)



Total waste generated

Production phase

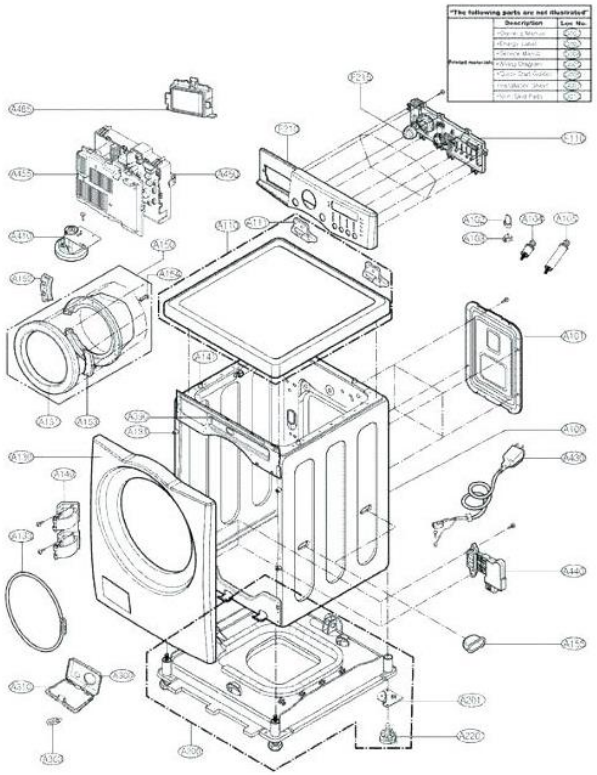
End of Life phase

(Ellen MacArthur Foundation & Granta Design, 2015)

Circularity Assessment

Material Circularity Indicator (MCI)

MCI = 0,8



Production phase

=

MCI = 0,8

In use phase

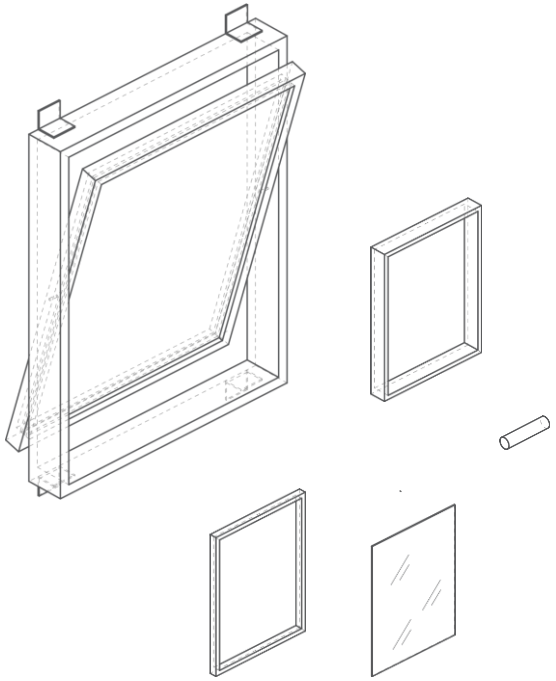
http:// www.designboom.com

http://wallcar.me/set/

Circularity Assessment

Material Circularity Indicator (MCI)

MCI = 0,9



Production phase

≠

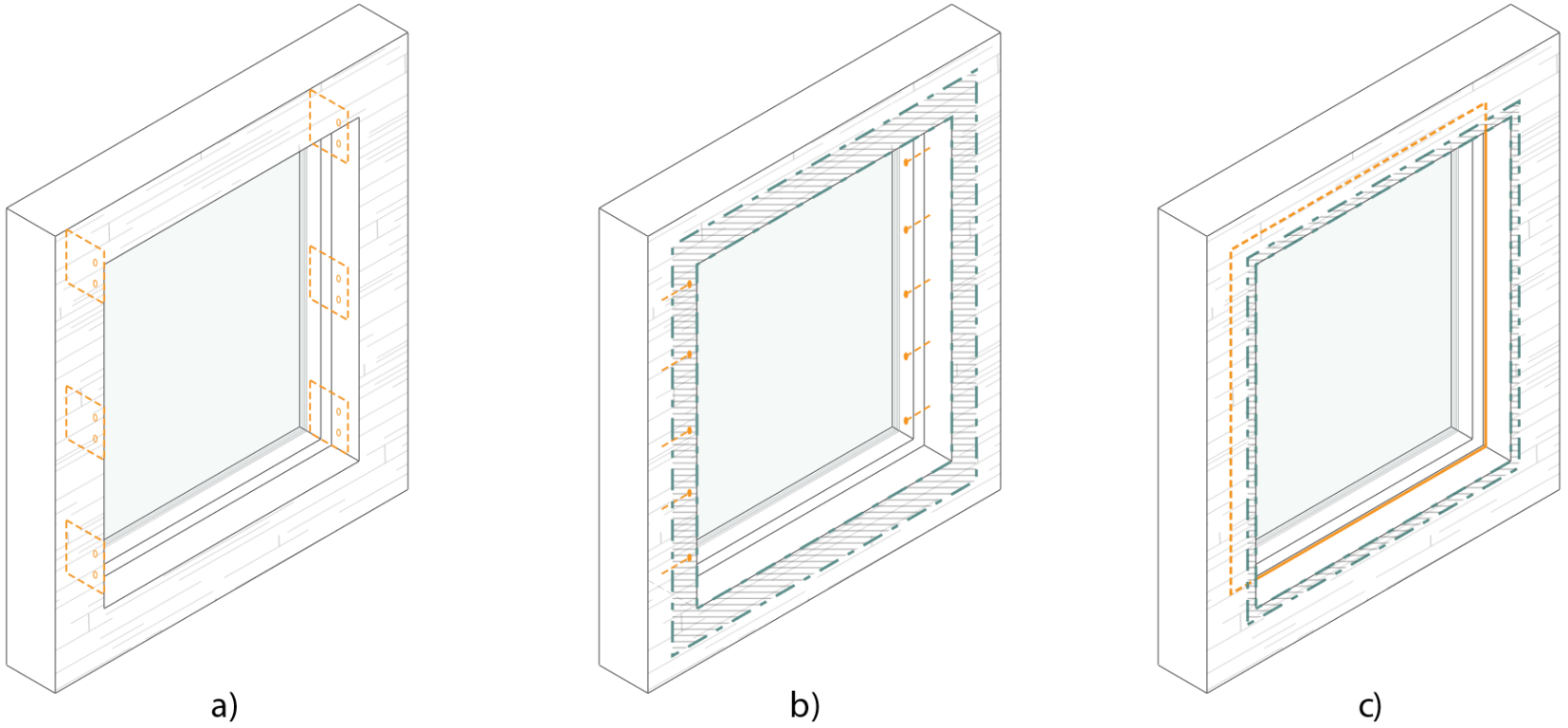
MCI = ?

End of Life phase

https://www.milgard.com

Circularity Assessment

Material Circularity Indicator (MCI)



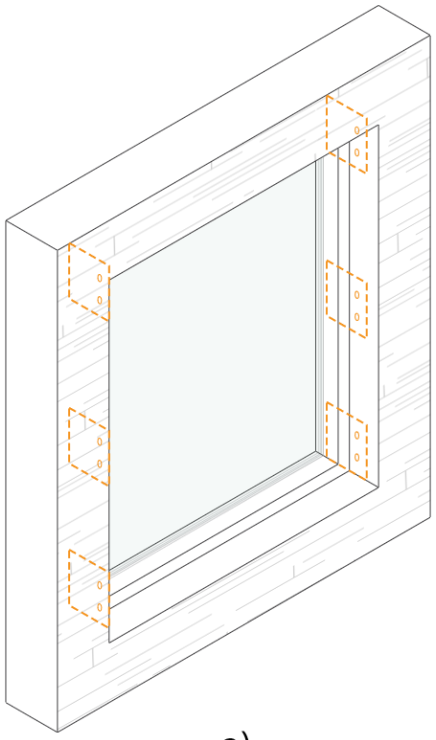
Demountable

Fixed with nails

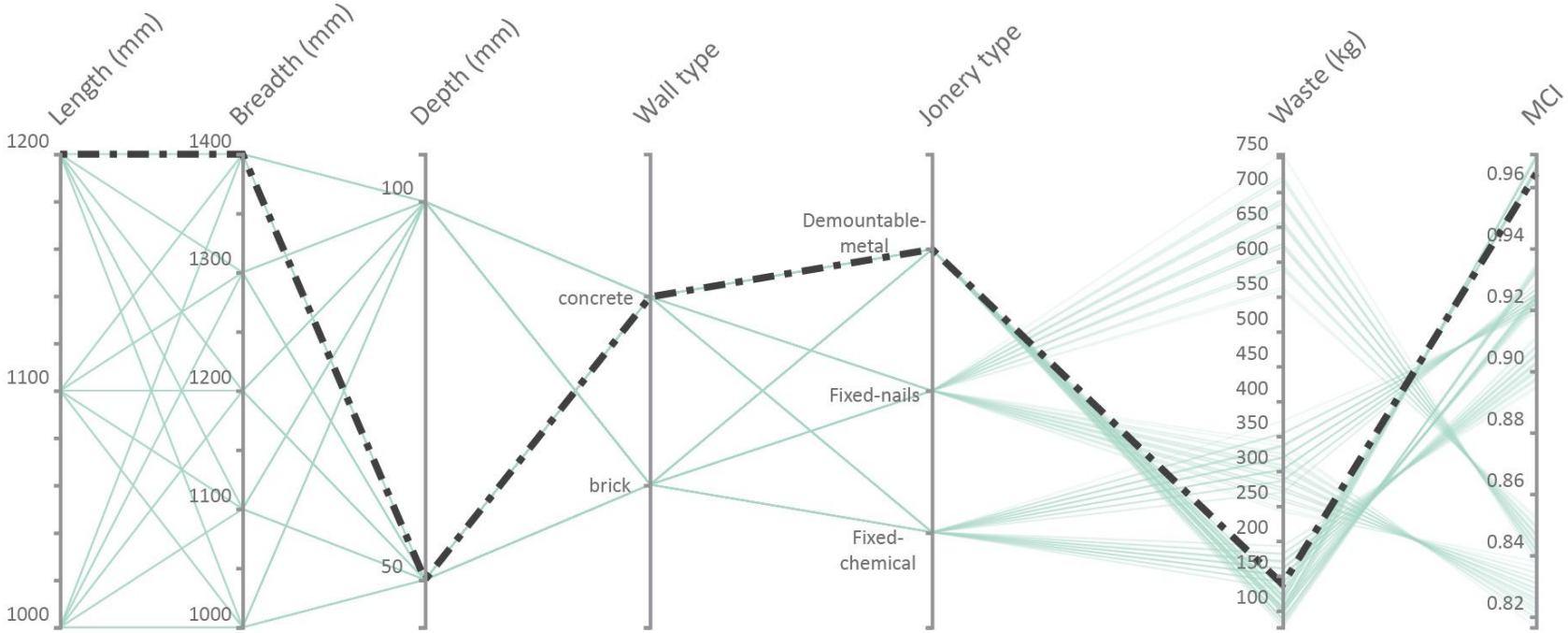
Fixed with chemical

Circularity Assessment

Material Circularity Indicator (MCI)

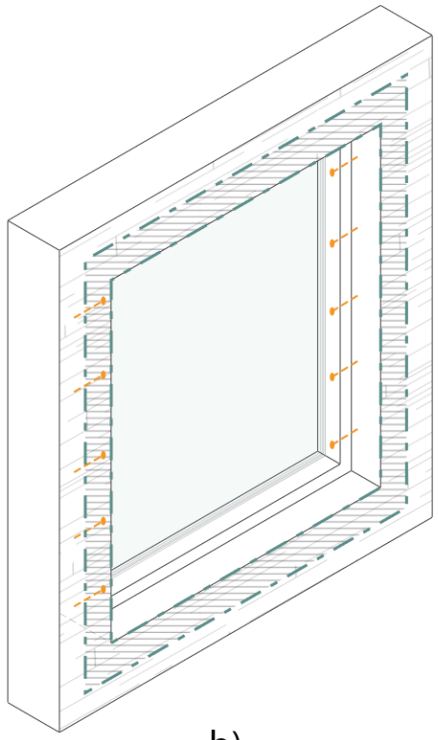


a)

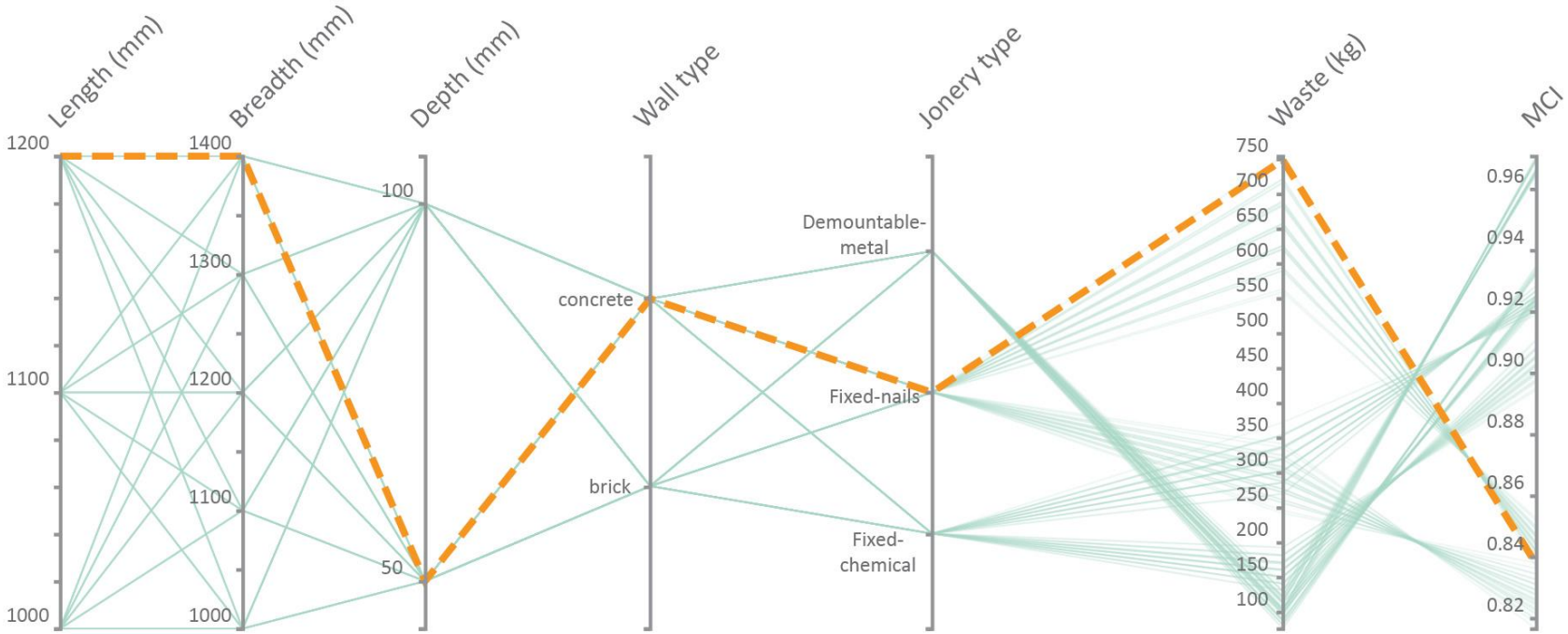


Circularity Assessment

Material Circularity Indicator (MCI)

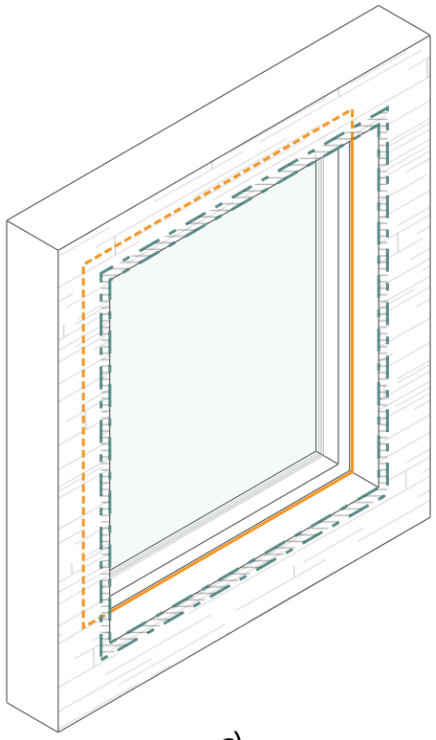


b)



Circularity Assessment

Material Circularity Indicator (MCI)



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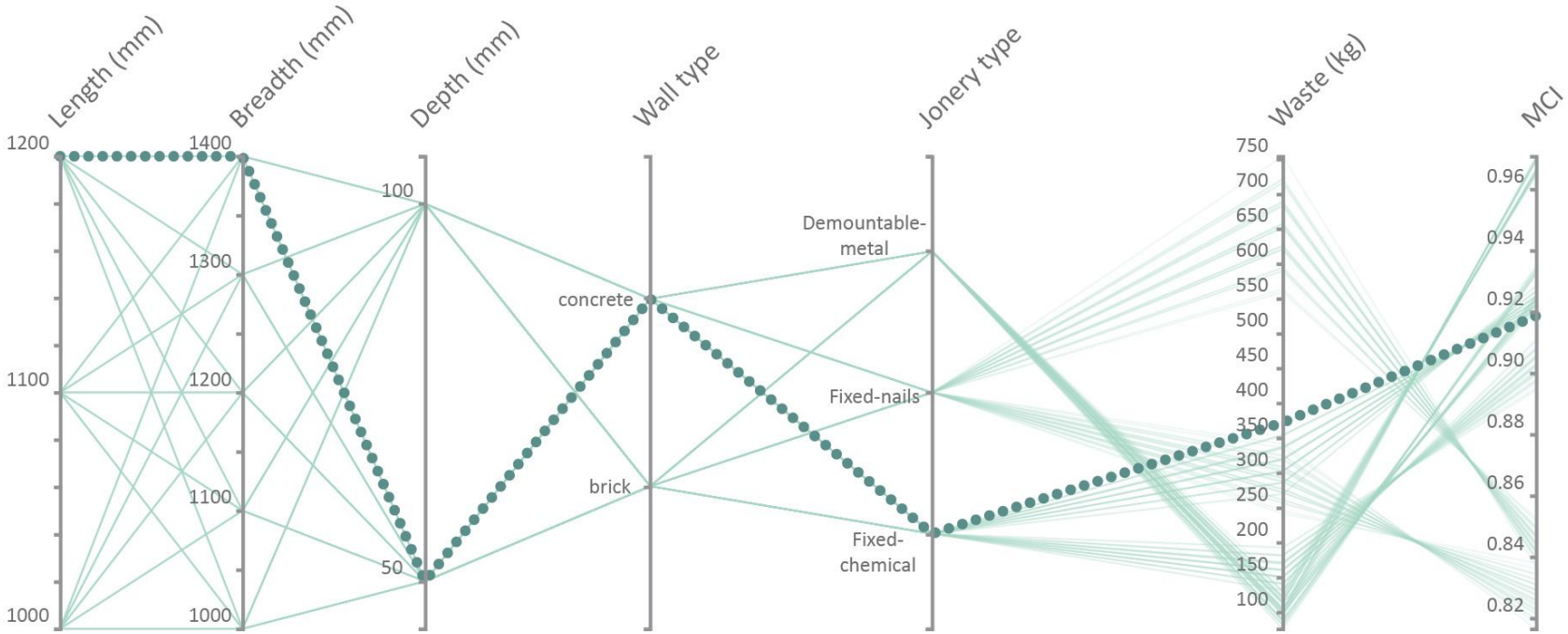
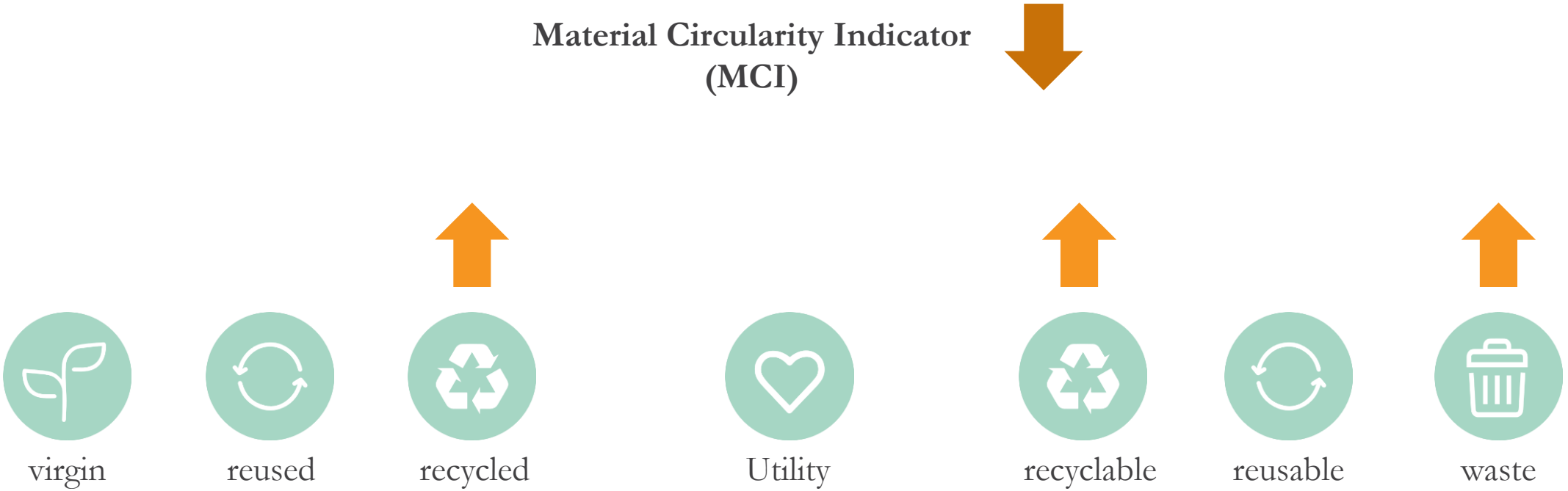


Circularity Assessment

Material Circularity Indicator (MCI)

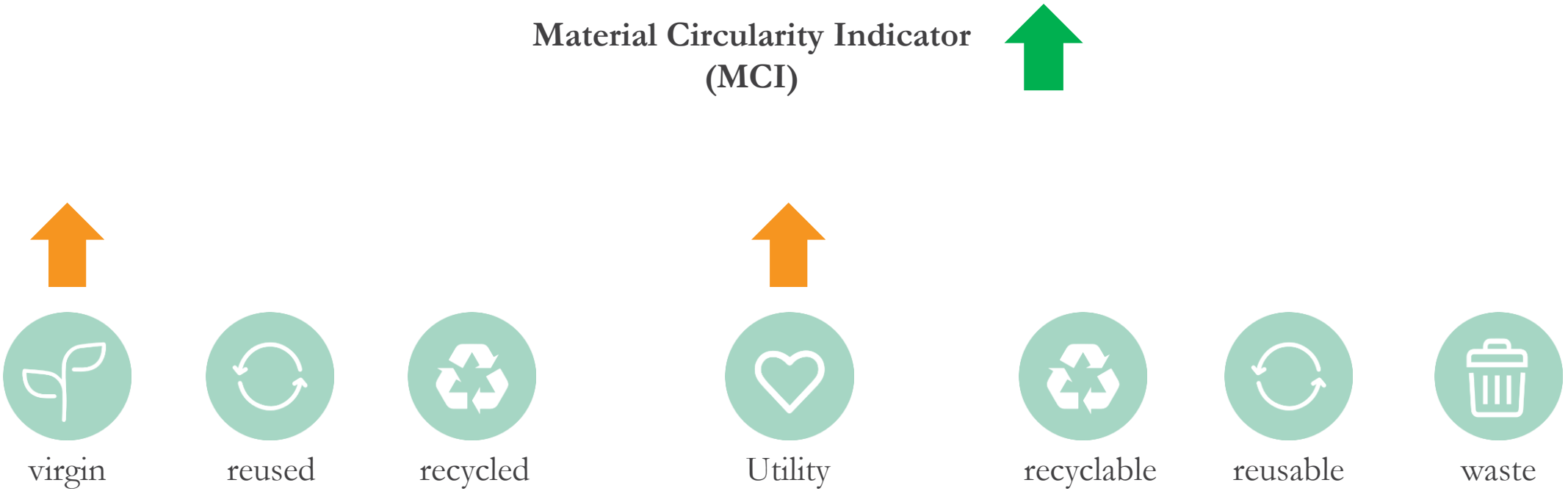
Circularity Assessment

Material Circularity Indicator (MCI)



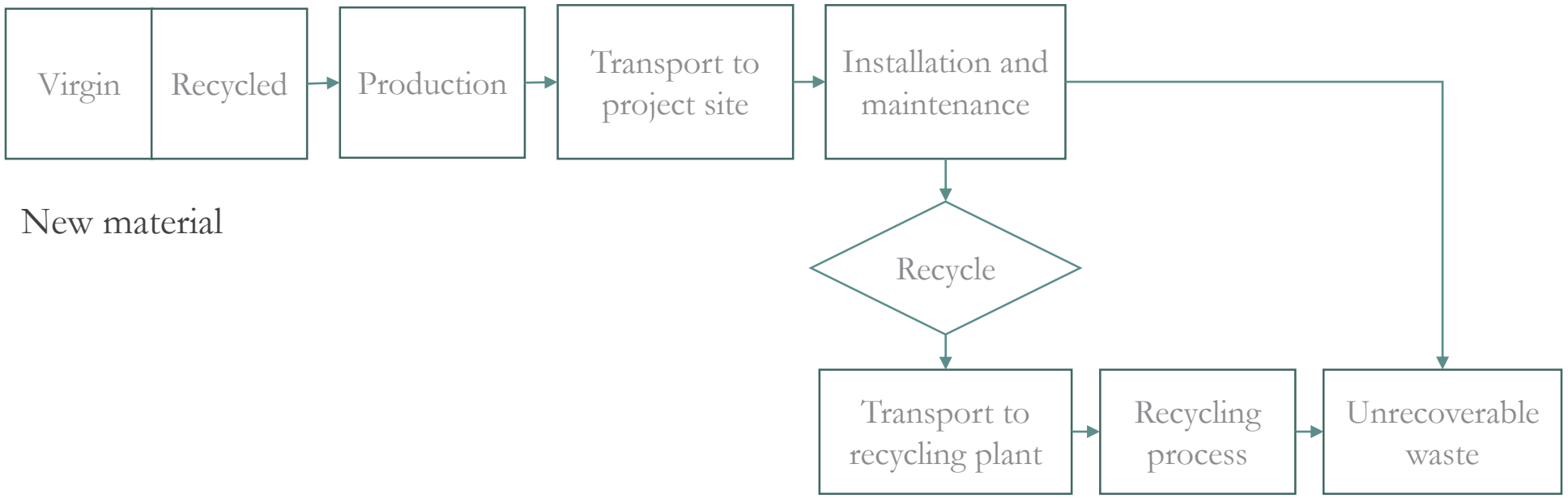
Circularity Assessment

Material Circularity Indicator (MCI)



Circularity Assessment

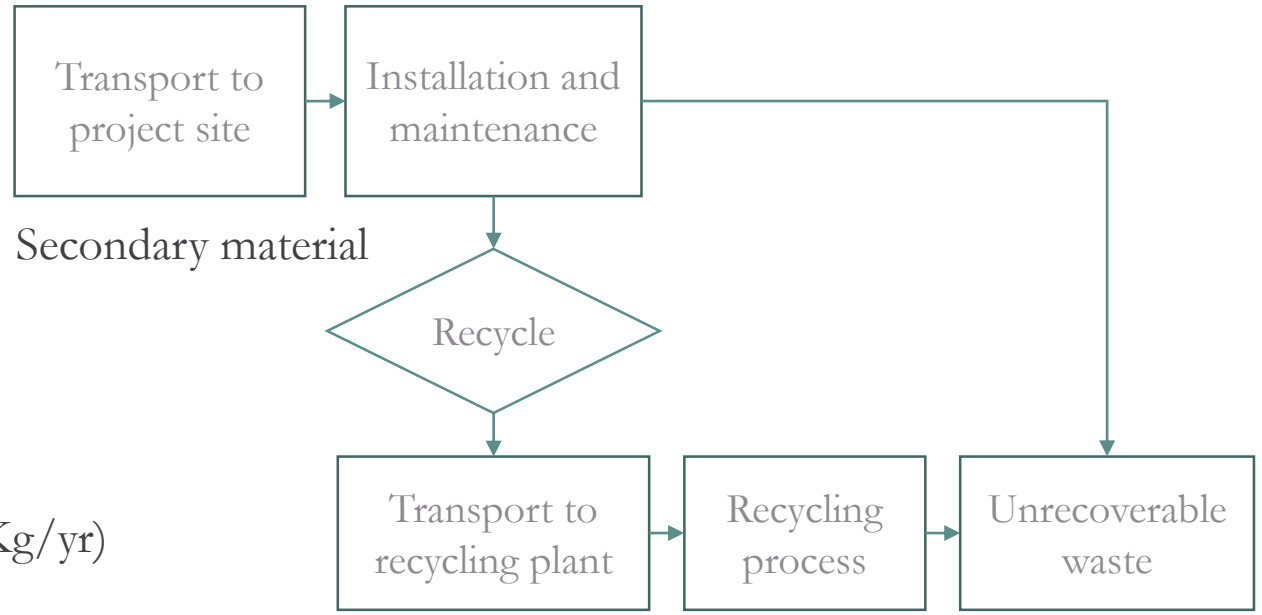
Embodied CO_2



Circularity Assessment

Embodied CO_2

$$\frac{\text{Total embodied } CO_2}{\text{Life expectancy of the building}} \text{ (Kg/yr)}$$



Case studies

Circl Pavilion (**2017**)
Use life - **30yrs**

- Reusable facade
- Reusable wooden structure
- Virgin sources for structure and skin
- Reused internal partition walls, flooring, finishes

ABT office, Delft (**2001**)
Use life - **20yrs**

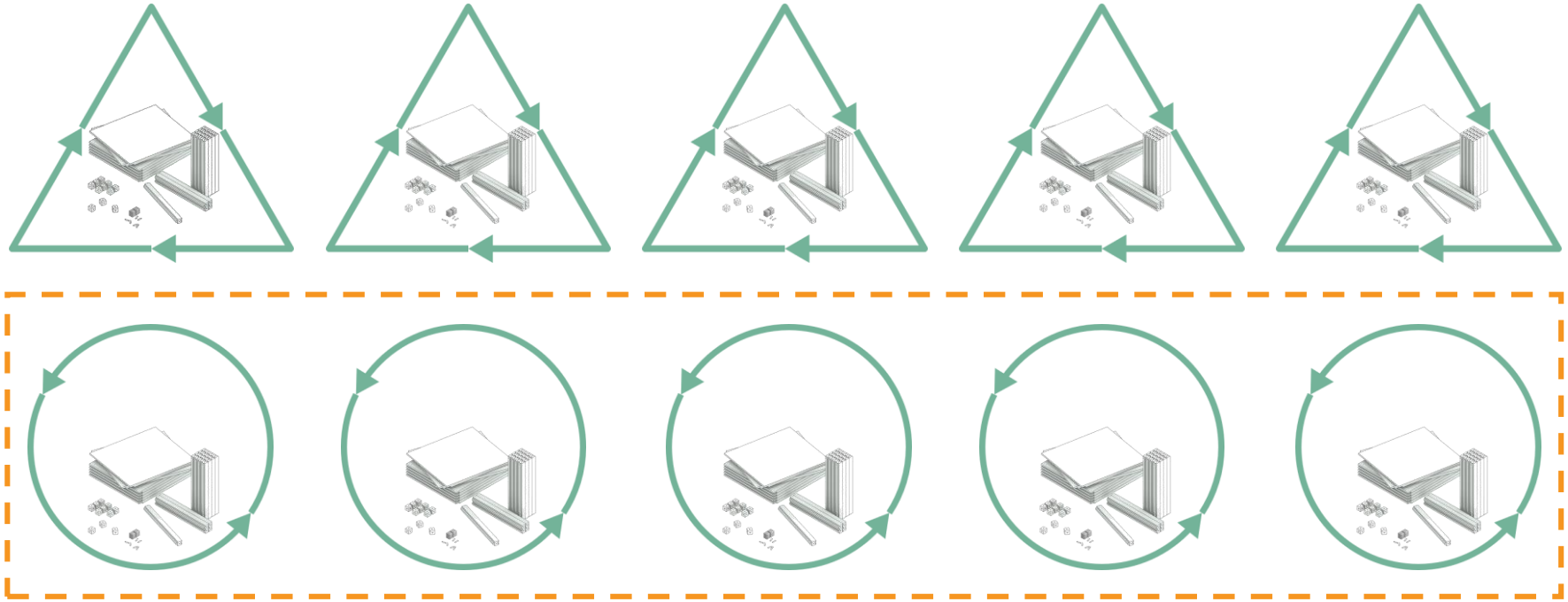
- Reusable facade
- Reusable steel structure
- Virgin building materials

Brummen Townhall (**2013**)
Use life - **20yrs**

- Reusable facade
- Reusable steel structure
- Virgin building materials

“Goal”

Total material demand in The Netherlands



100% Secondary material by 2050

(recycled & reused)

2,5% increase per year

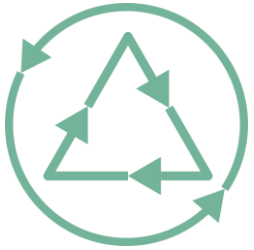
Expert interviews

Information about **available material**

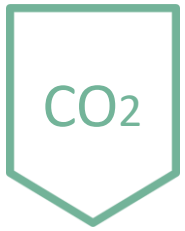
No clear **methodology** to assess **benefits** of using **secondary material**

Assessment Framework

Circular flow



Embodied CO_2



Technical performance

Life expectancy

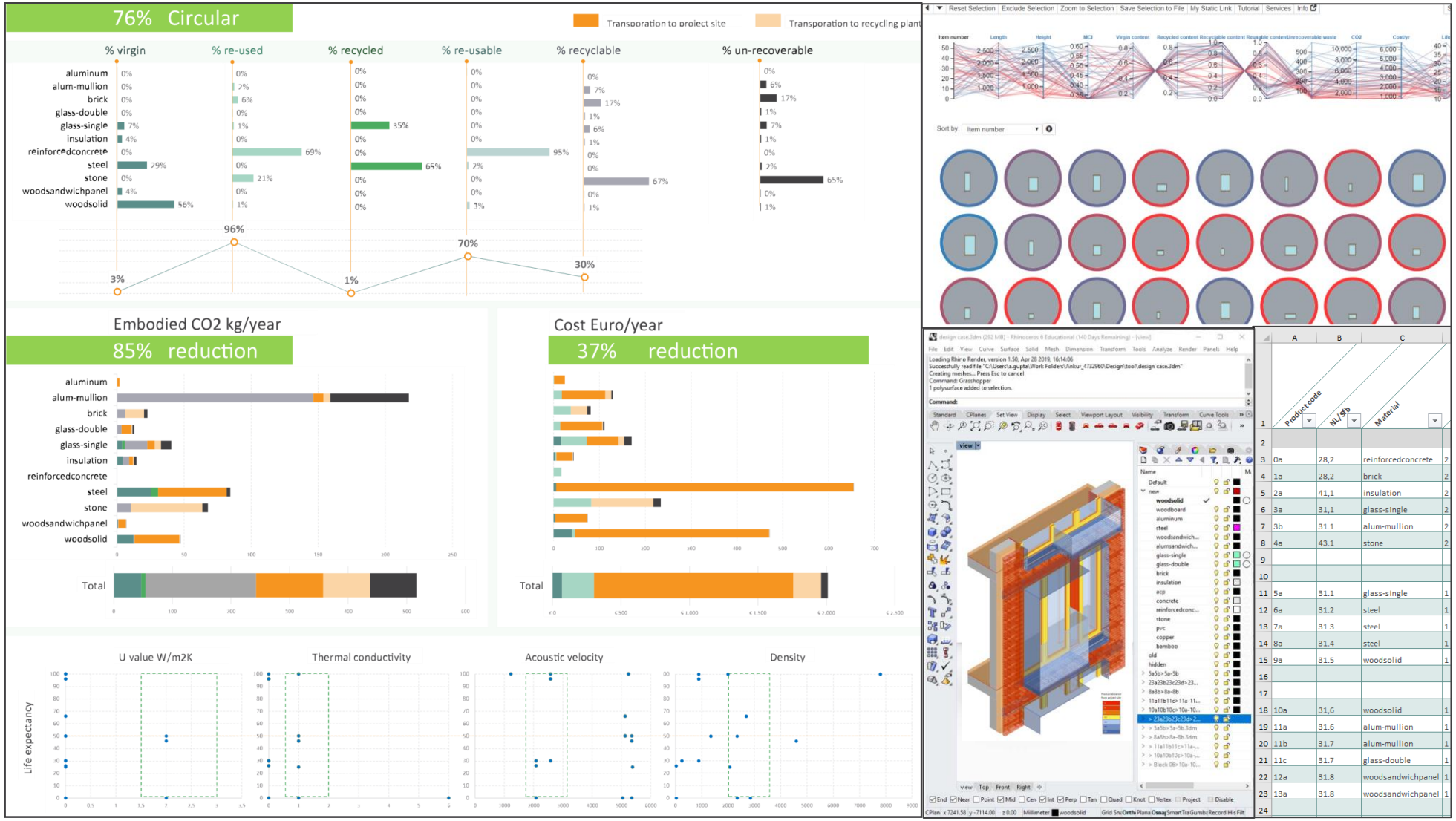
How?

- Active Procurement

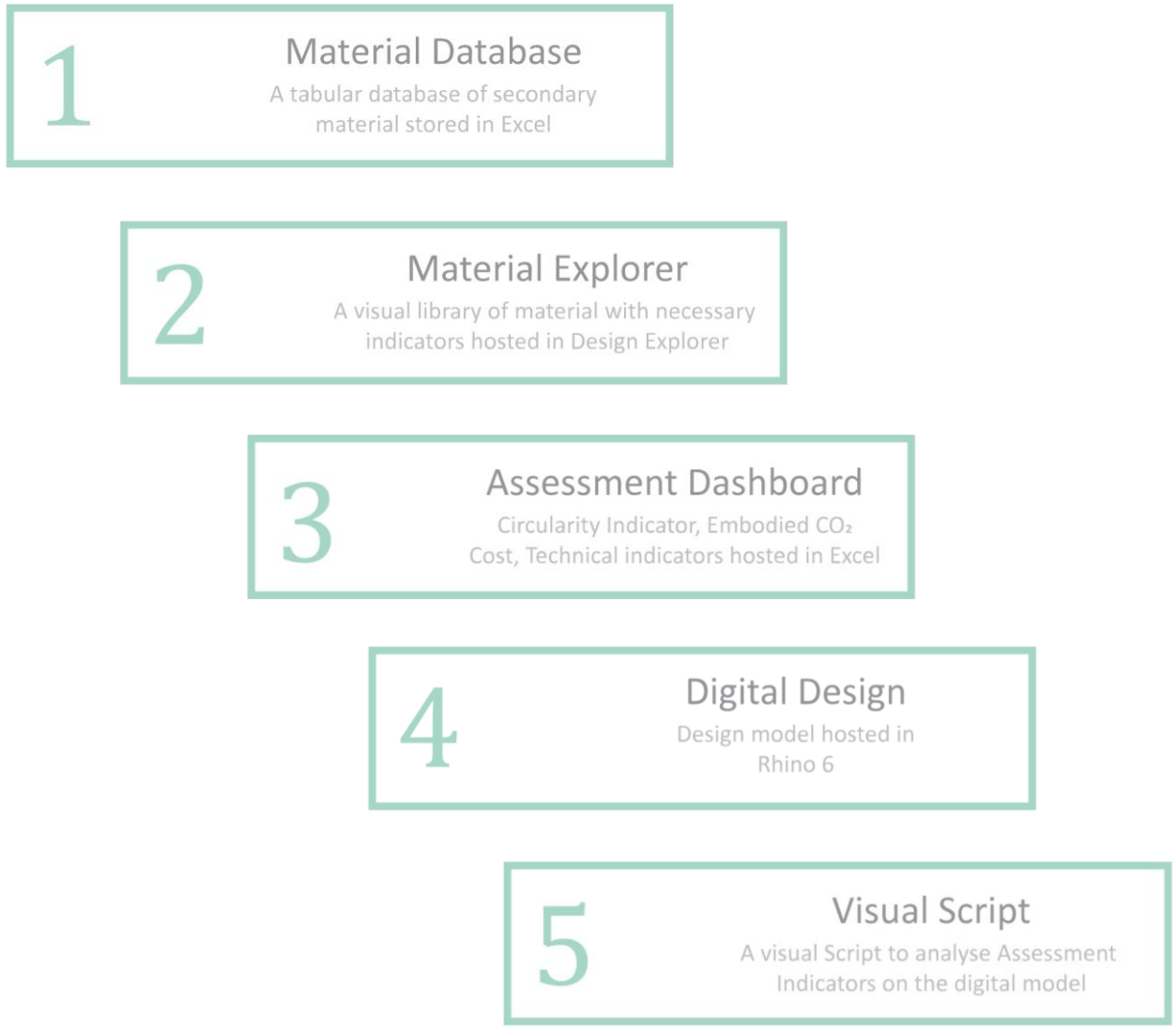
When?

- Initial design phase

Assessment Framework



Assessment Framework



Assessment Framework

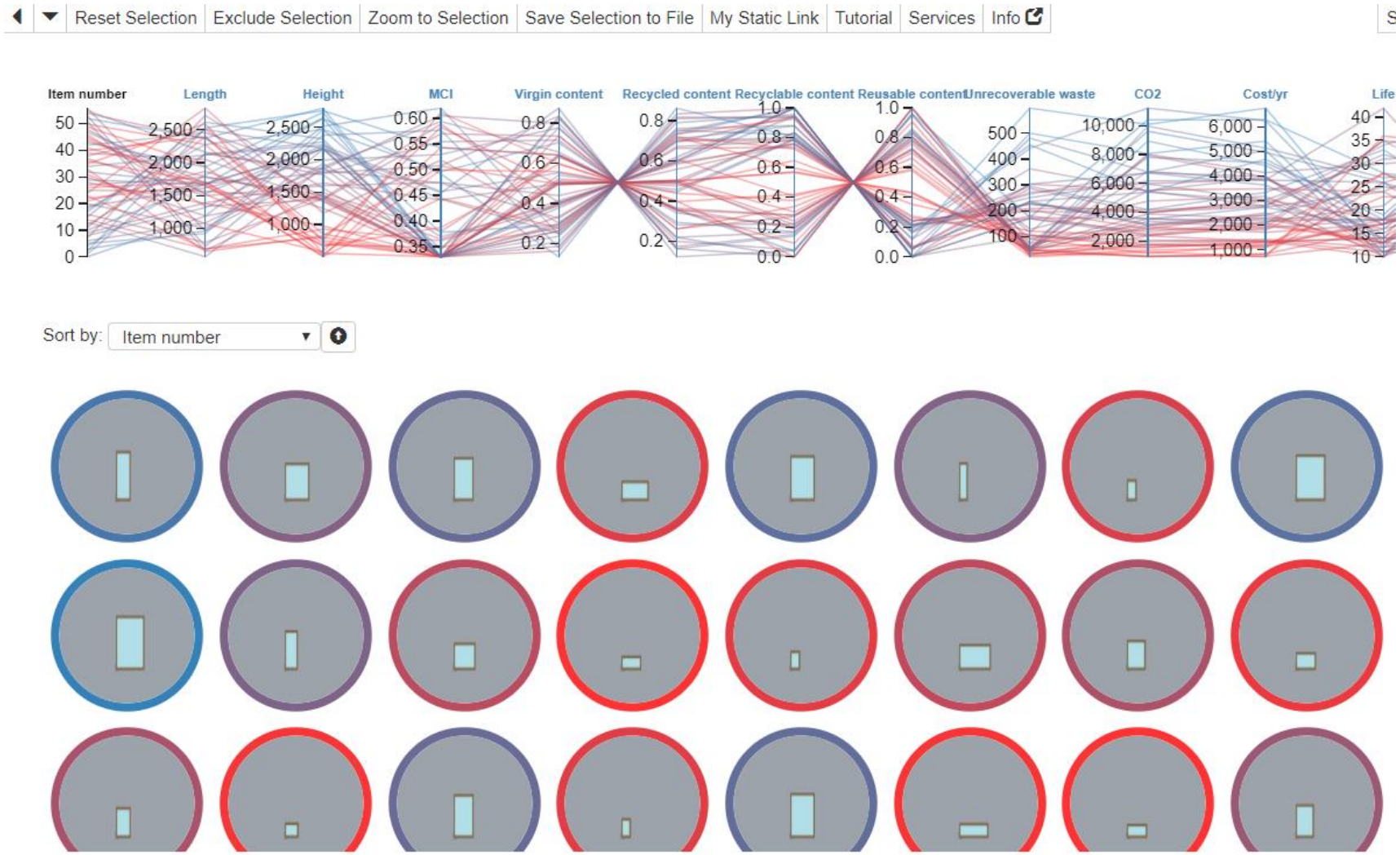
2 Material Explorer

A visual library of material with necessary indicators hosted in Design Explorer

Assessment Framework

2 **Material Explorer**

A visual library of material with necessary indicators hosted in Design Explorer



3 **Assessment Dashboard**

Circularity indicator, Embodied CO_2, Cost, Technical indicators hosted in Excel

4 **Digital Design**

Design model hosted in Rhino 6

5 **Visual Script**

A visual Script to analyse Assessment indicators on the digital model

Assessment Framework

3 Assessment Dashboard

Circularity Indicator, Embodied CO_2
Cost, Technical indicators hosted in Excel

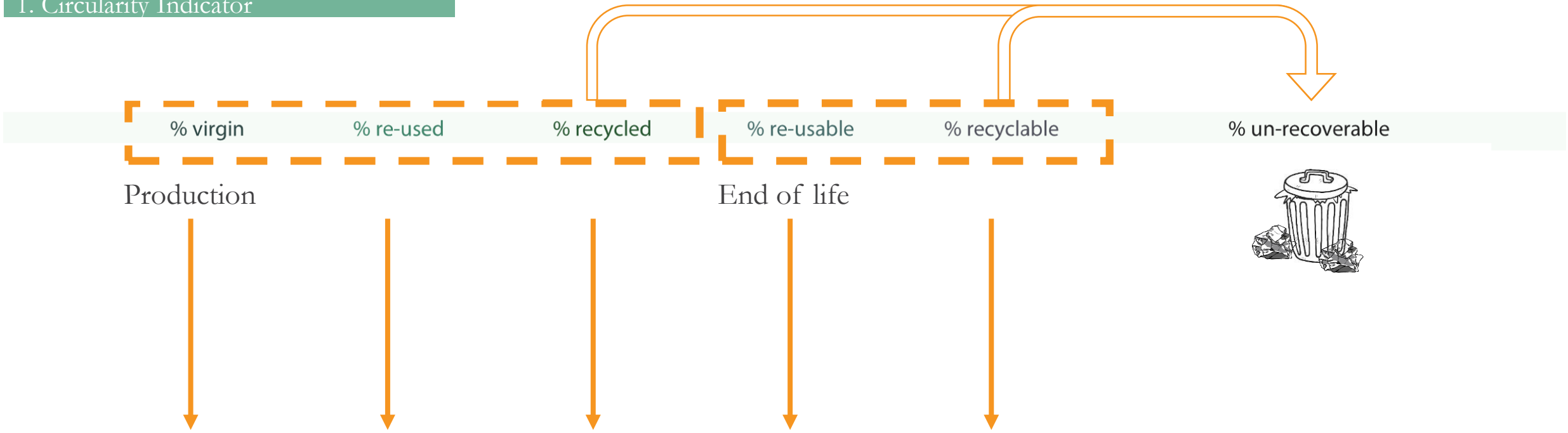
1. Circularity Indicator
2. Embodied CO_2
3. Cost
4. Technical Performance
5. Life expectancy

Assessment Framework

3 Assessment Dashboard

Circularity Indicator, Embodied CO_2 Cost, Technical indicators hosted in Excel

1. Circularity Indicator

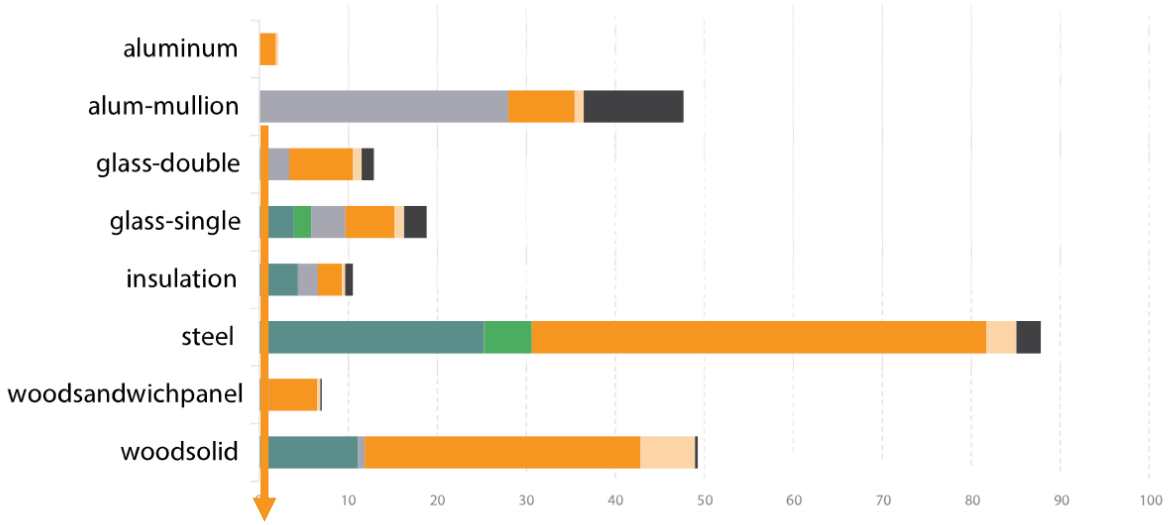


Assessment Framework

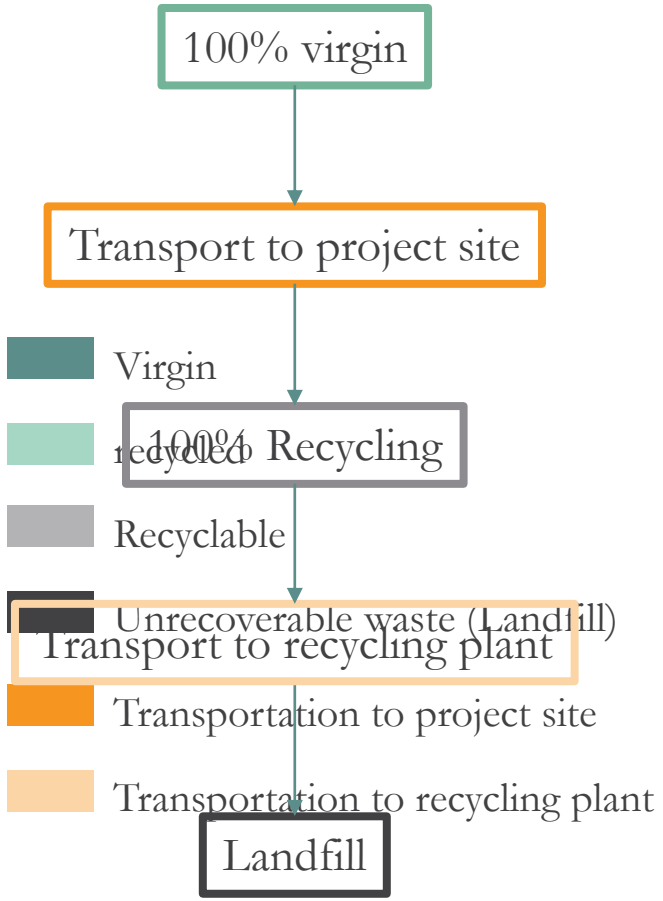
3 Assessment Dashboard

Circularity Indicator, Embodied CO_2 Cost, Technical indicators hosted in Excel

2. Embodied CO2 kg/yr



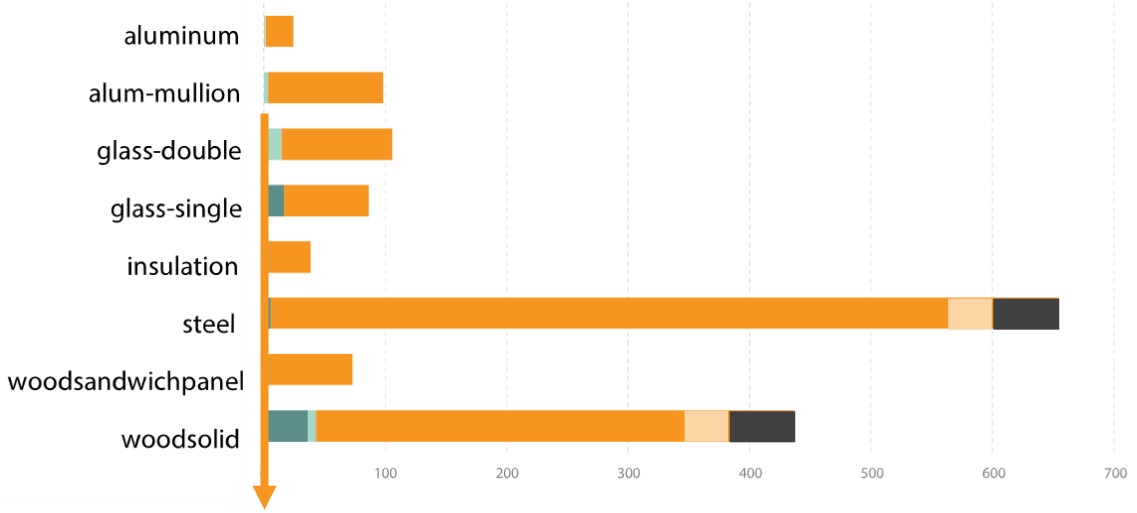
Compared Boundary condition



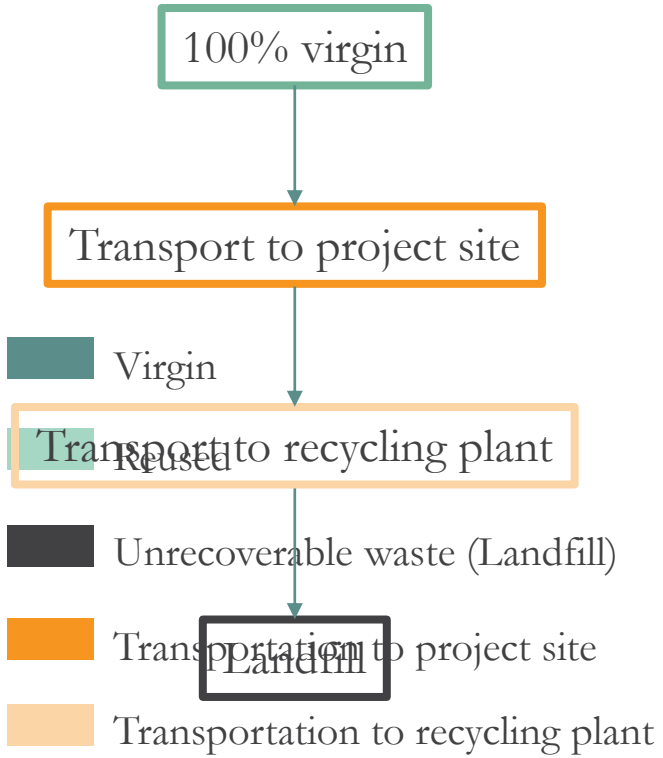
Assessment Framework

3 Assessment Dashboard
Circularity Indicator, Embodied CO_2
Cost, Technical indicators hosted in Excel

3. Cost



Compared Boundary condition

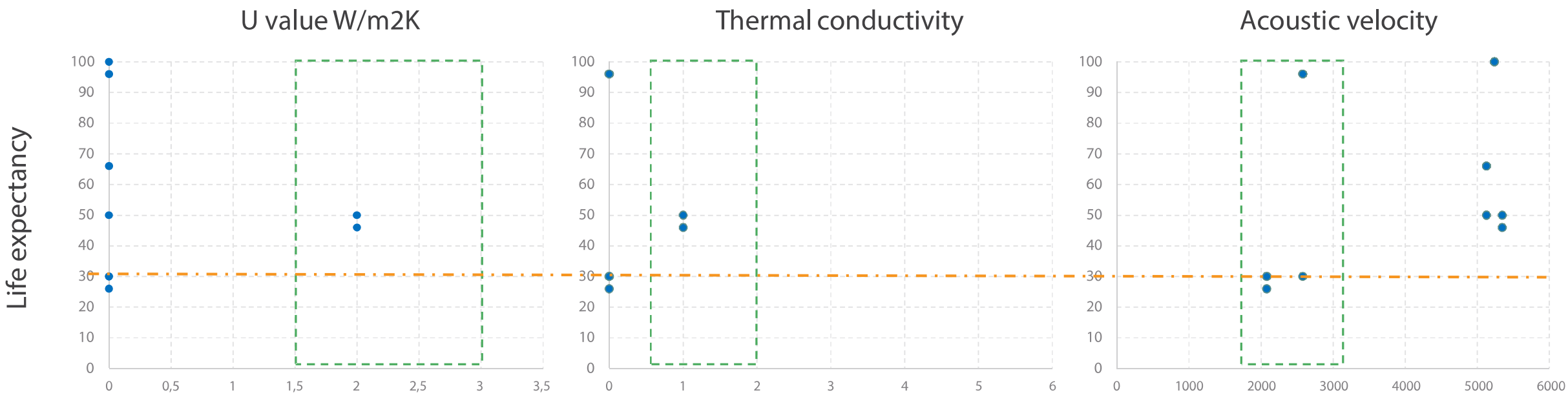


Assessment Framework

3 Assessment Dashboard

Circularity Indicator, Embodied CO_2 Cost, Technical indicators hosted in Excel

4. Technical Performance

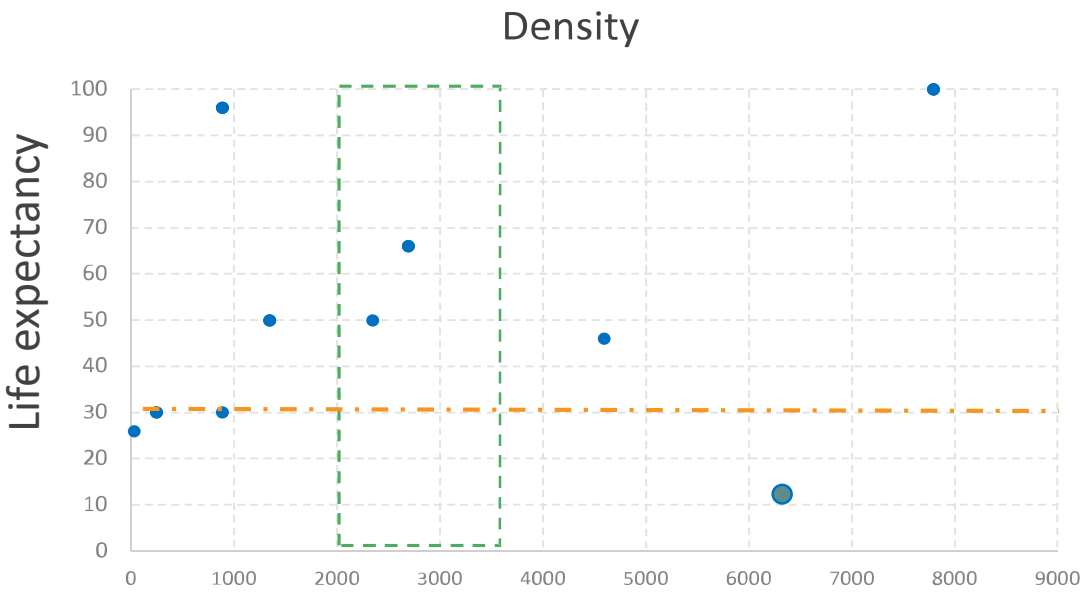


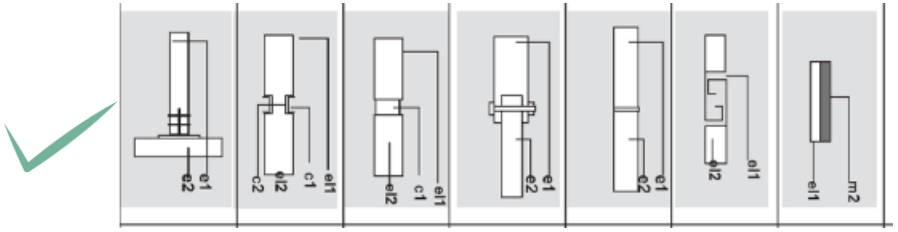
Assessment Framework

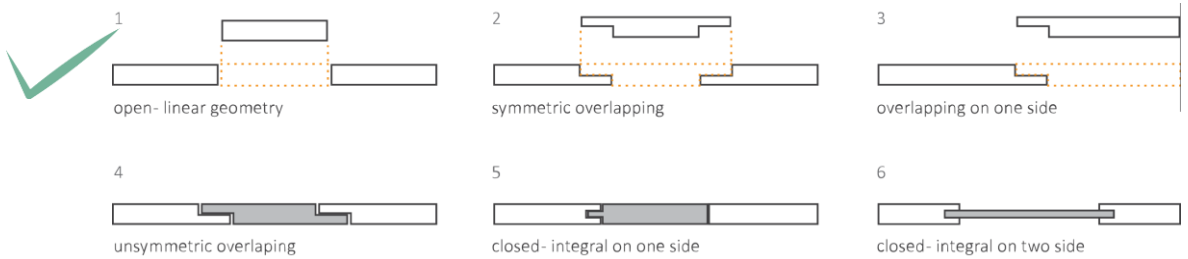
3 Assessment Dashboard

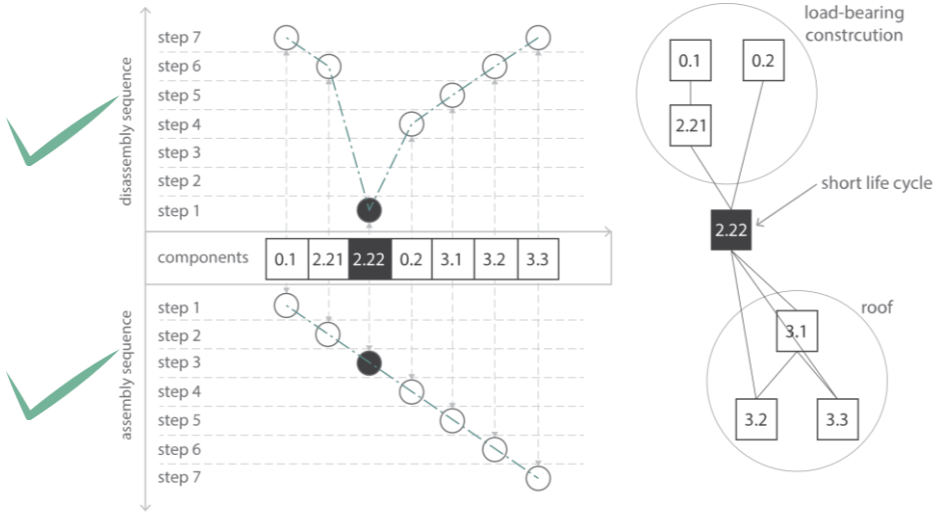
Circularity Indicator, Embodied CO_2
Cost, Technical indicators hosted in Excel

5. Life expectancy









Assessment Framework

3 Assessment Dashboard

Circularity Indicator, Embodied CO_2
Cost, Technical indicators hosted in Excel

Proposed aggregated layout

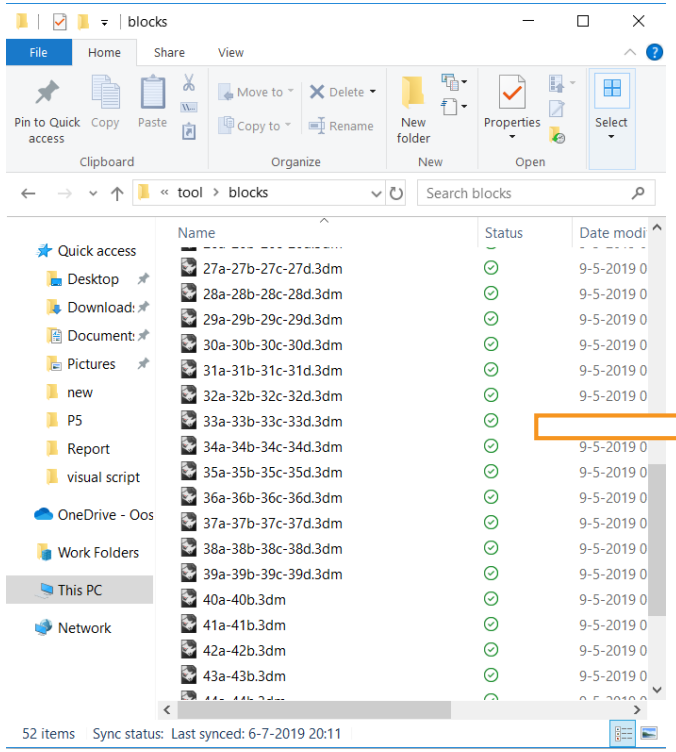
1. Circularity Indicator
2. Embodied CO2
3. Cost
4. Technical performance
5. Life expectancy

Assessment Framework

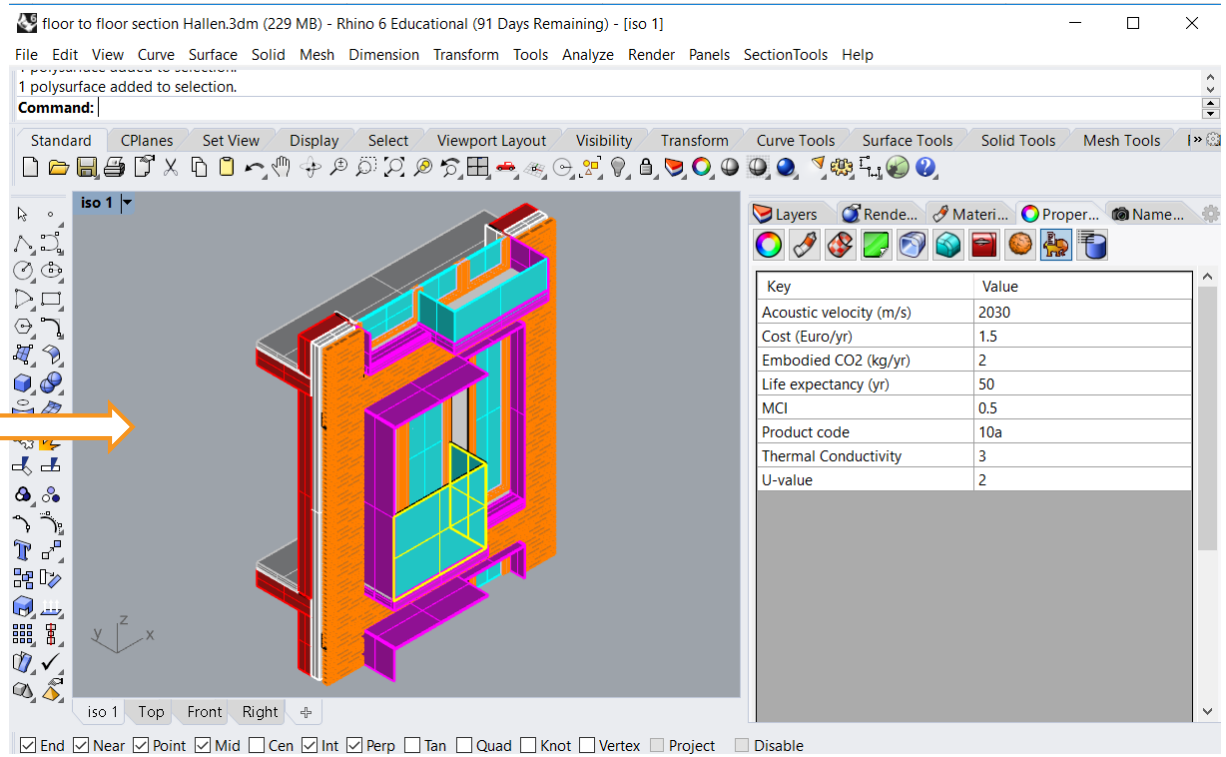
4

Digital Design

Design model hosted in Rhino 6



3D models of material



Hosted in Rhino with necessary labels

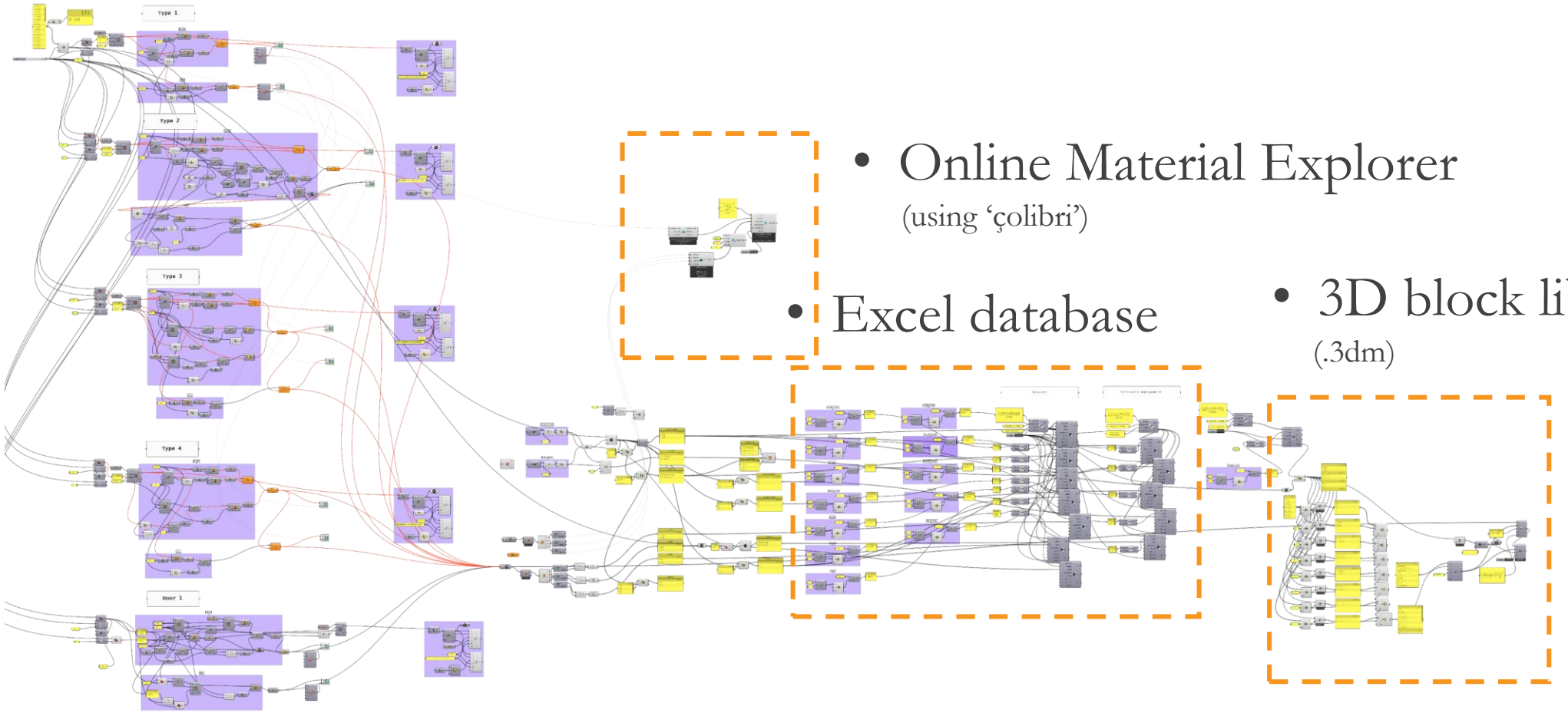
Assessment Framework

5

Visual Script

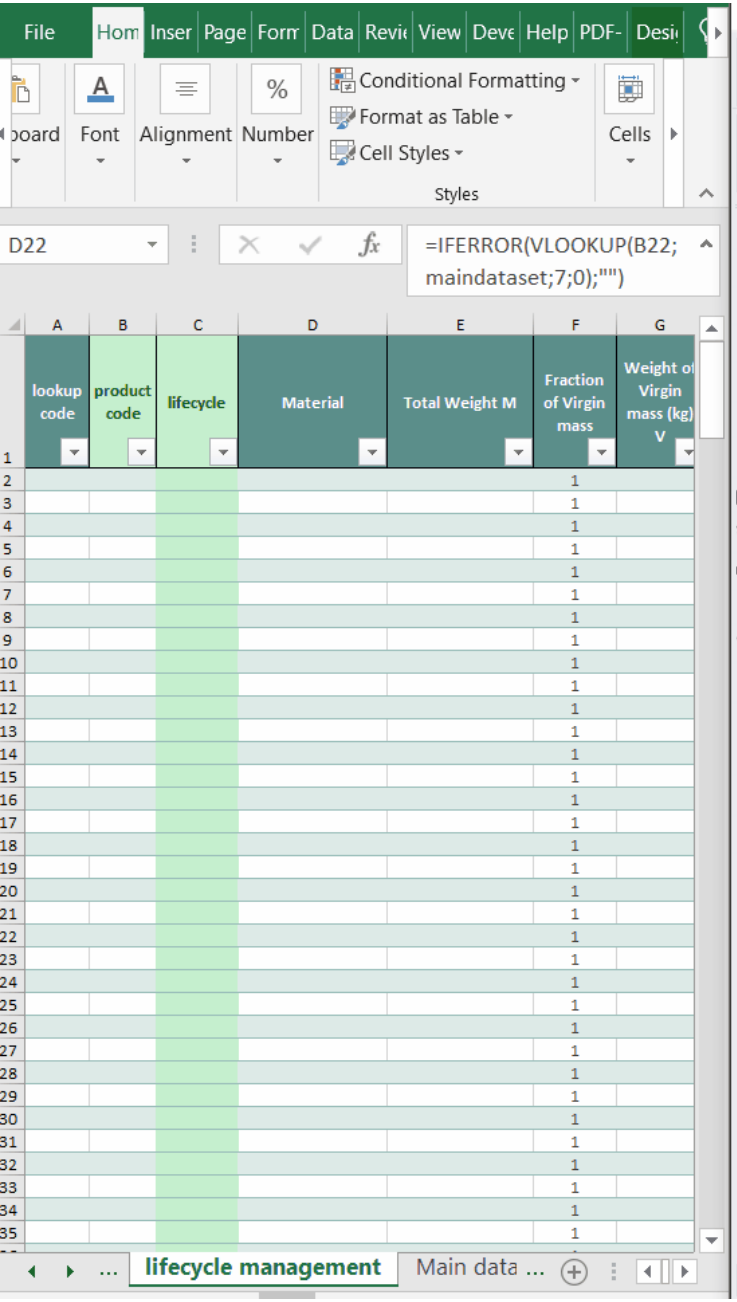
A visual Script to analyse Assessment Indicators on the digital model

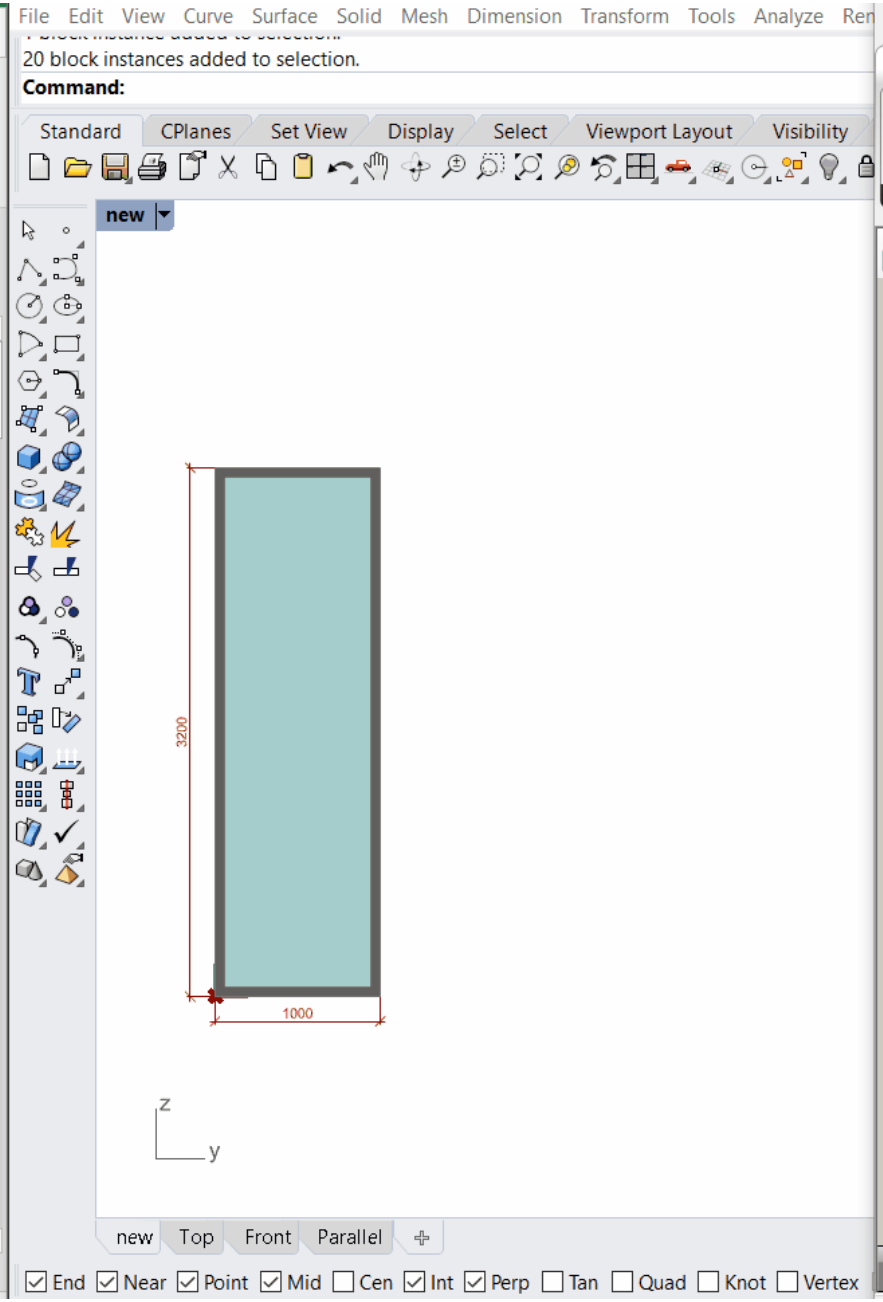
1. To create a quick online library of materials

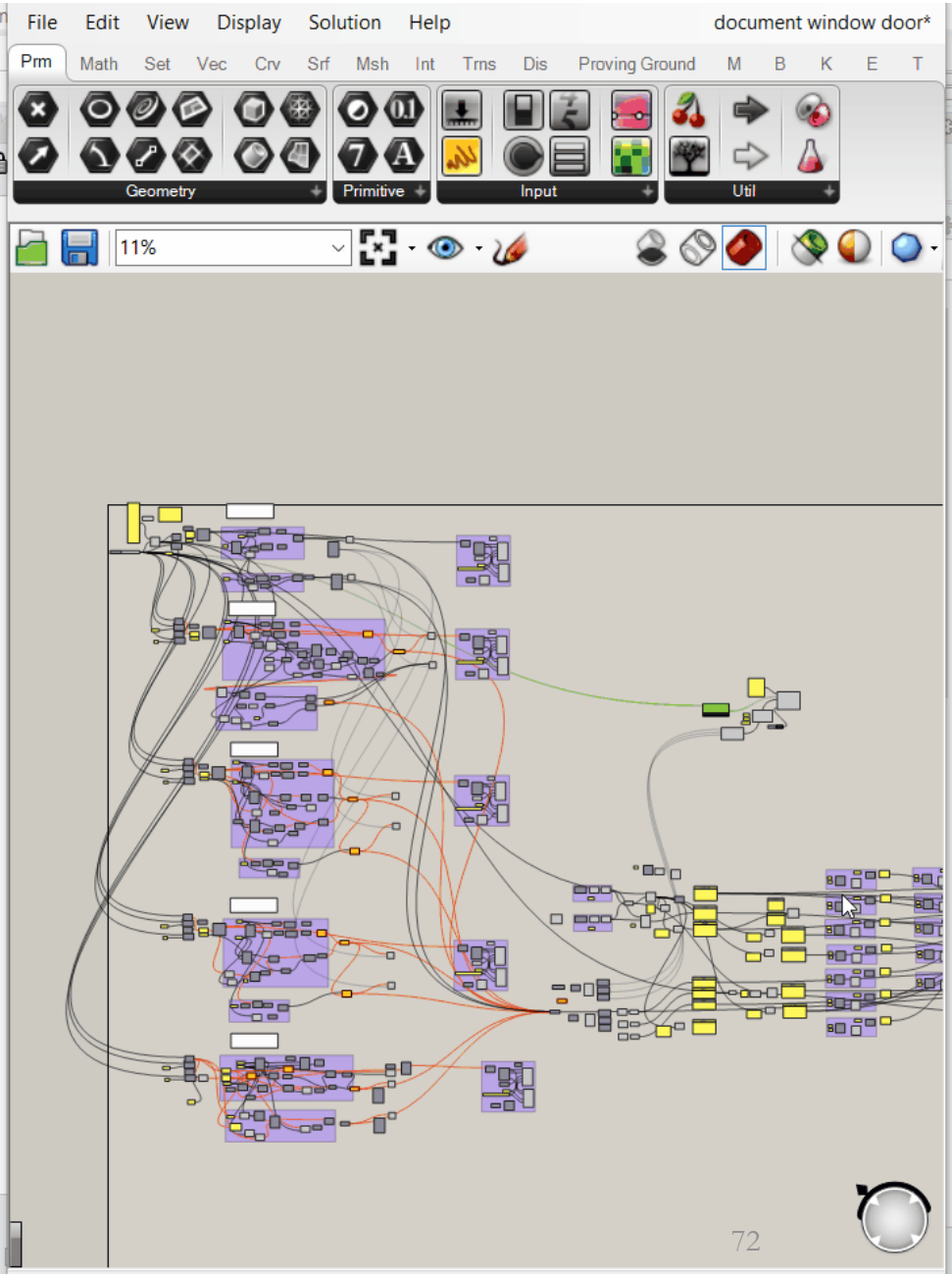


- Online Material Explorer
  (using 'çolibri')
- Excel database
- 3D block library
  (.3dm)

Assessment Framework





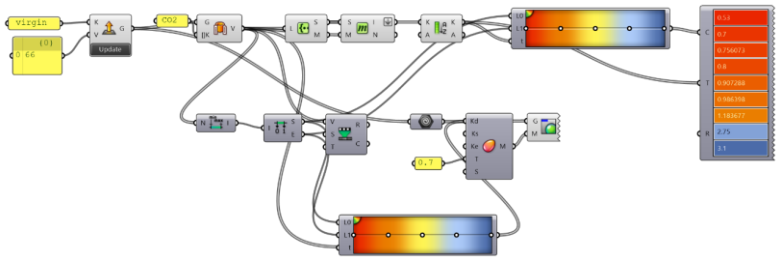


Assessment Framework

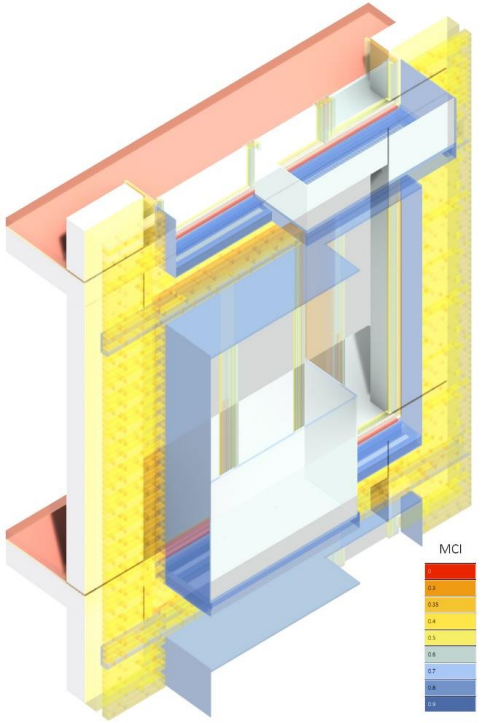
5 Visual Script

A visual Script to analyse Assessment Indicators on the digital model

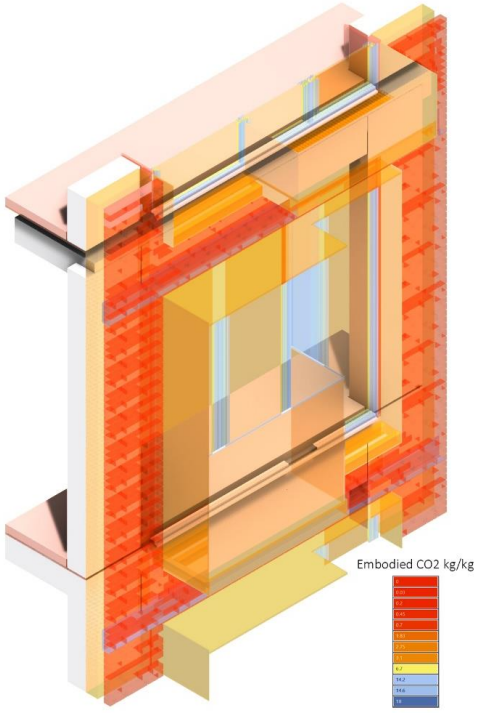
2. To analyze various labels



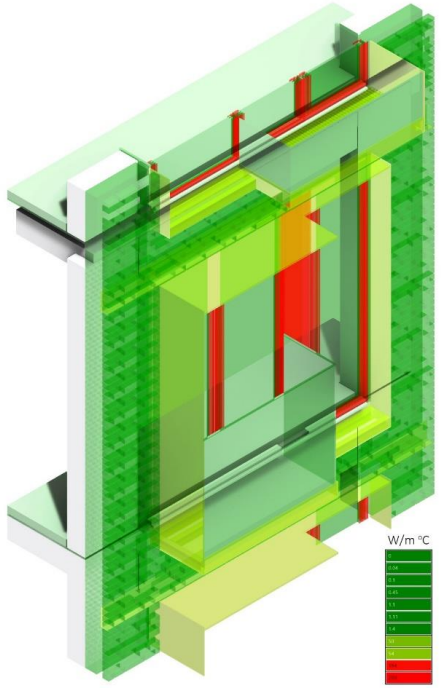
Circularity



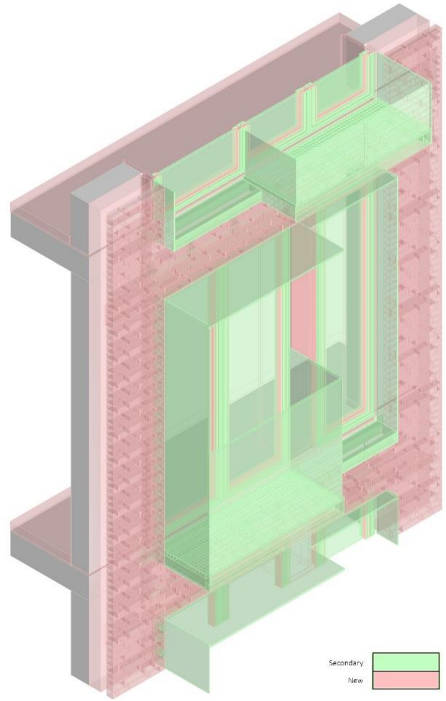
Embodied CO2



Thermal Conductivity

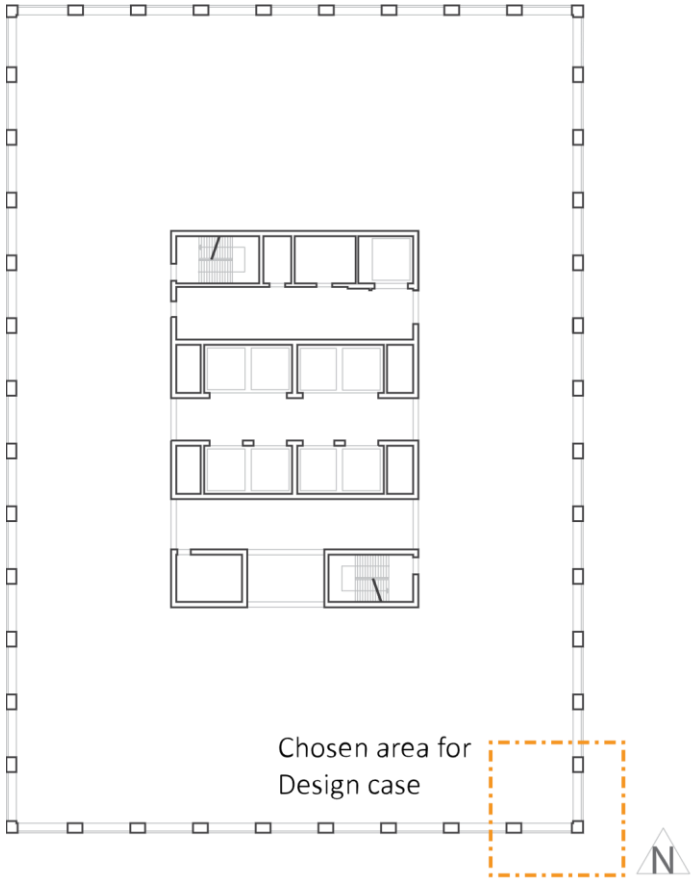


Secondary/virgin



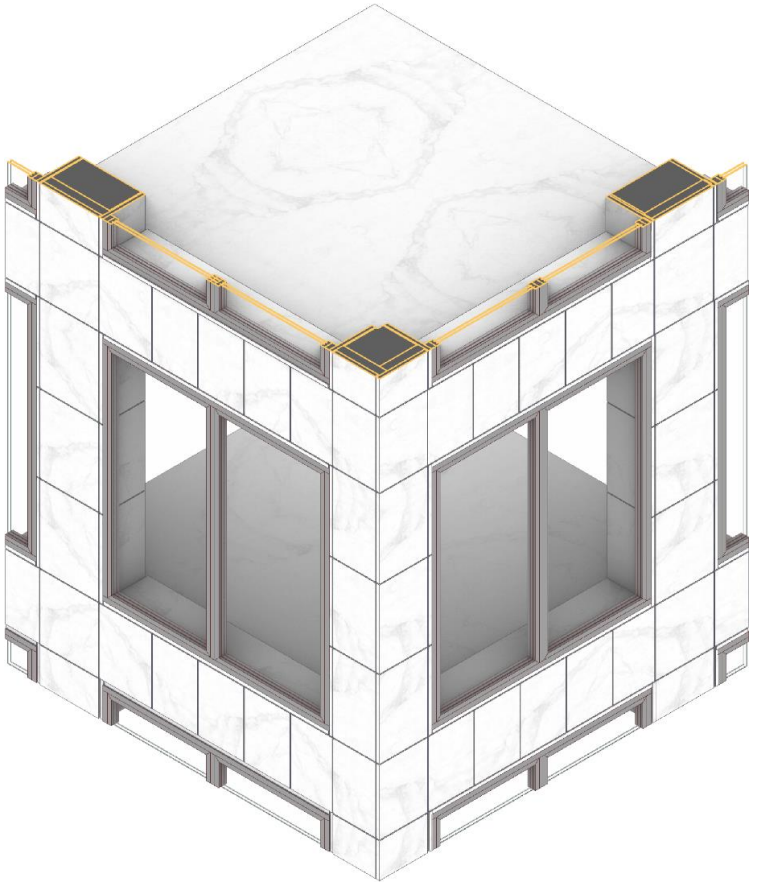
Design Case

Typical office building



3,6m gride size

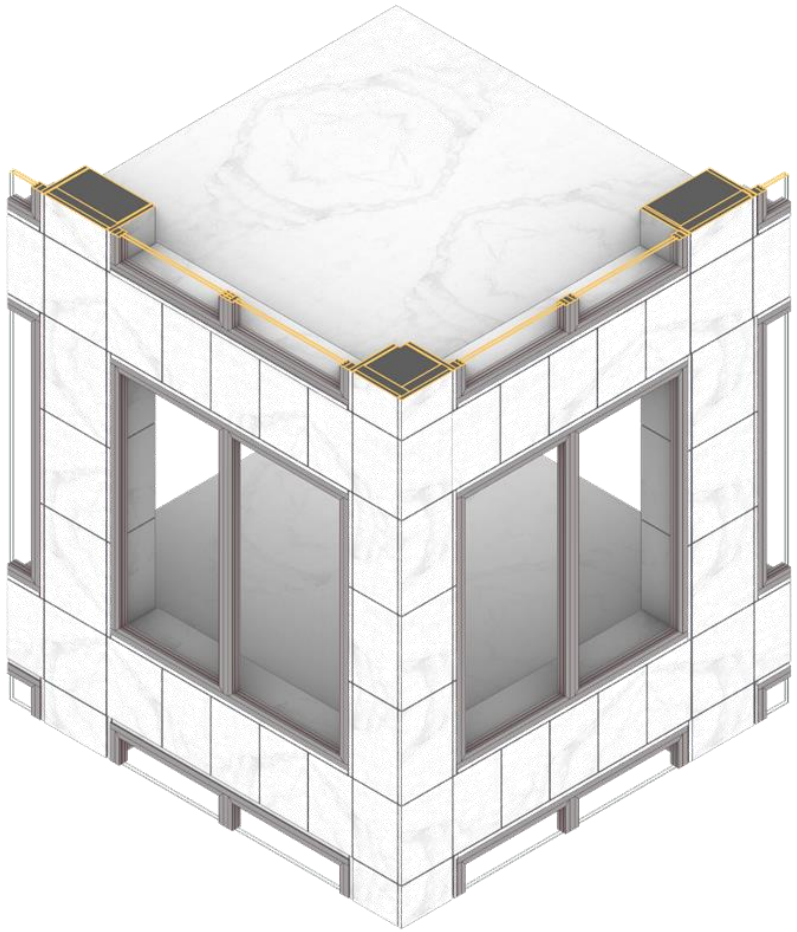
3,6m floor-floor height



Typical SE corner

Design Case

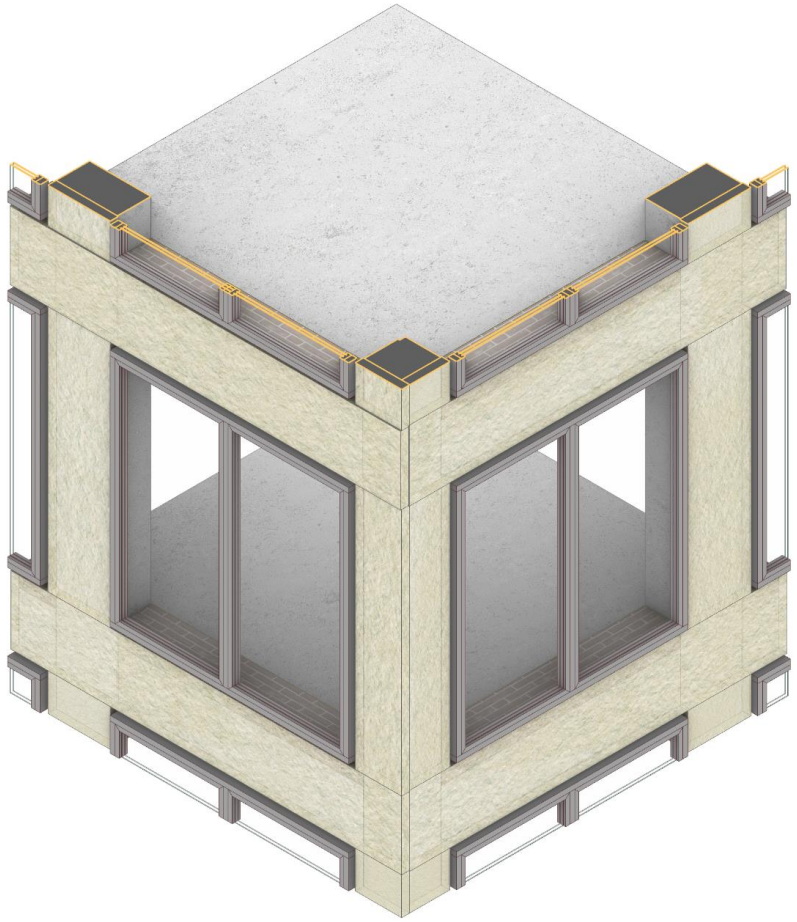
Location: Hague Expected Lifetime: 20yrs



Ankur Gupta | 4732960

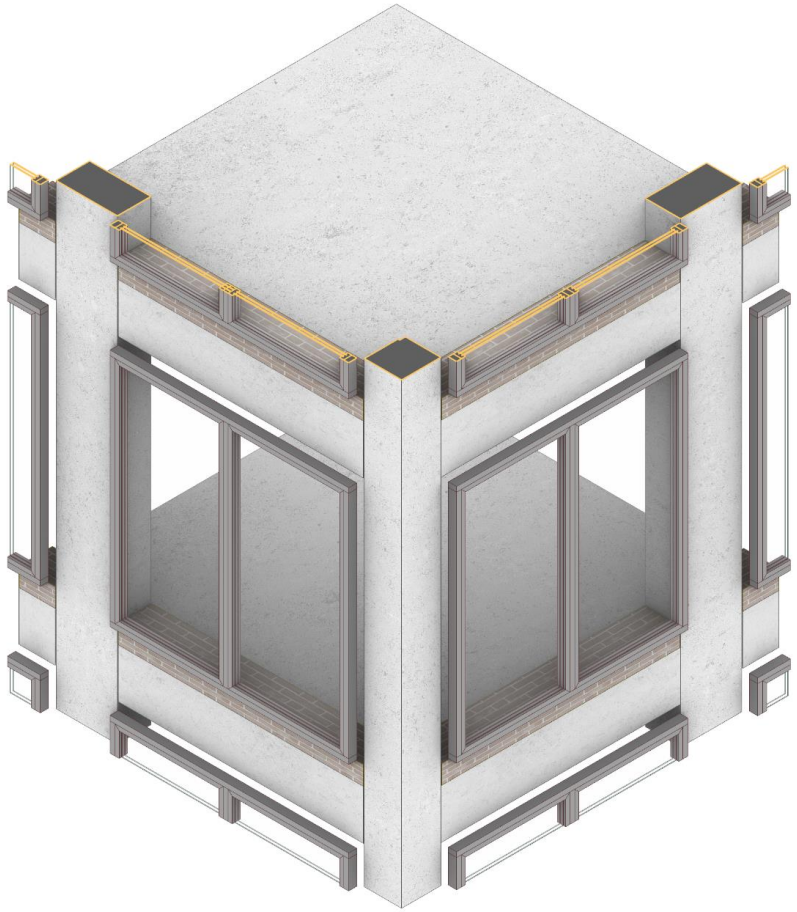
Design Case

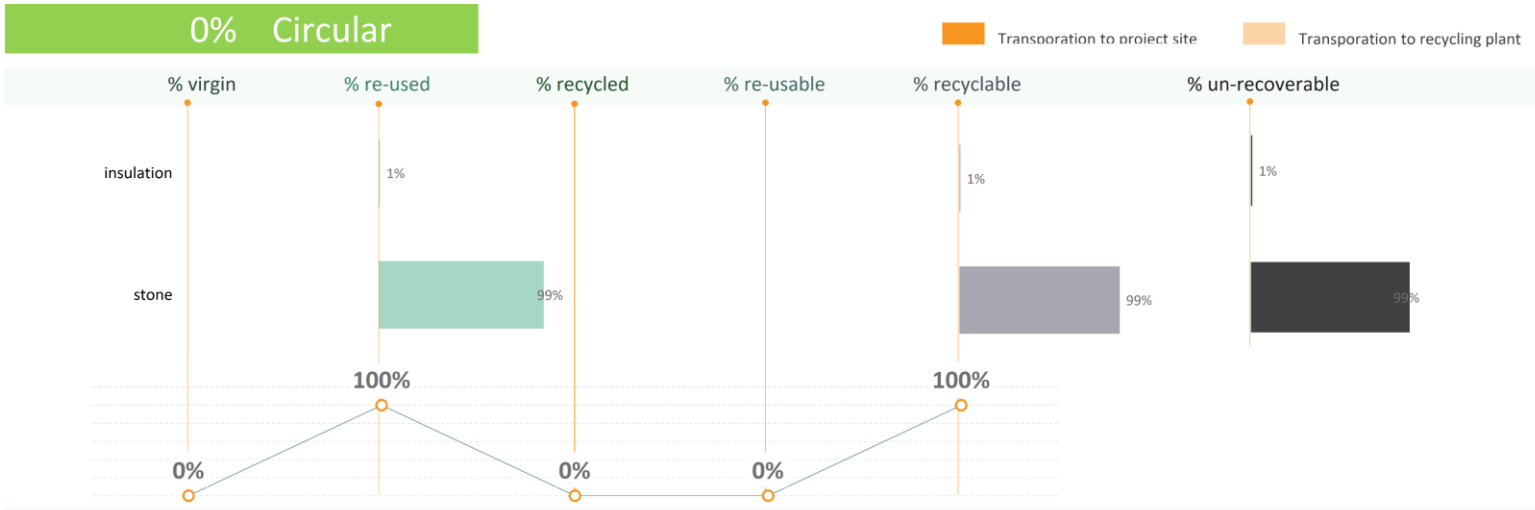
Location: Hague Expected Lifetime: 20yrs

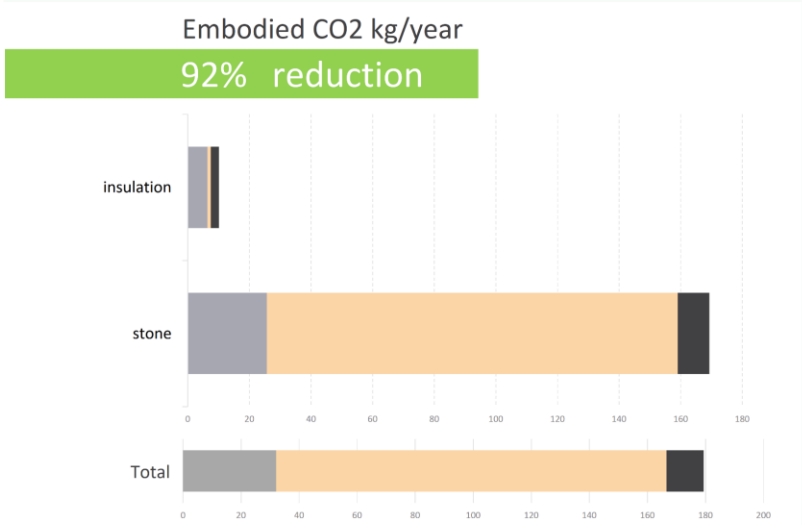


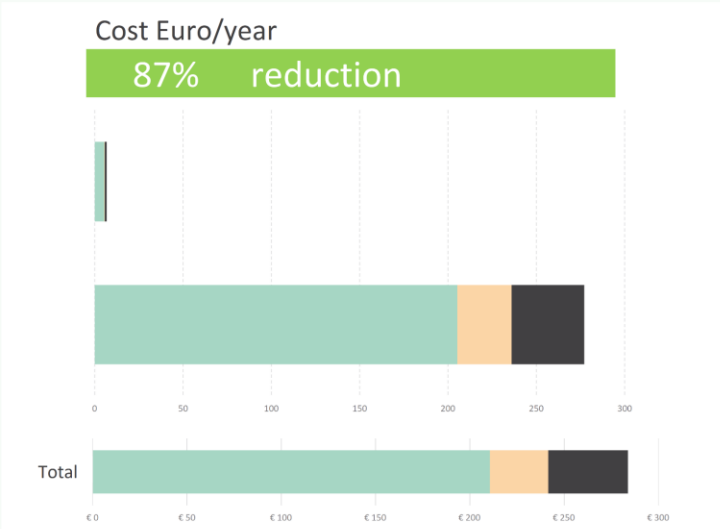
Design Case

Location: Hague Expected Lifetime: 20yrs



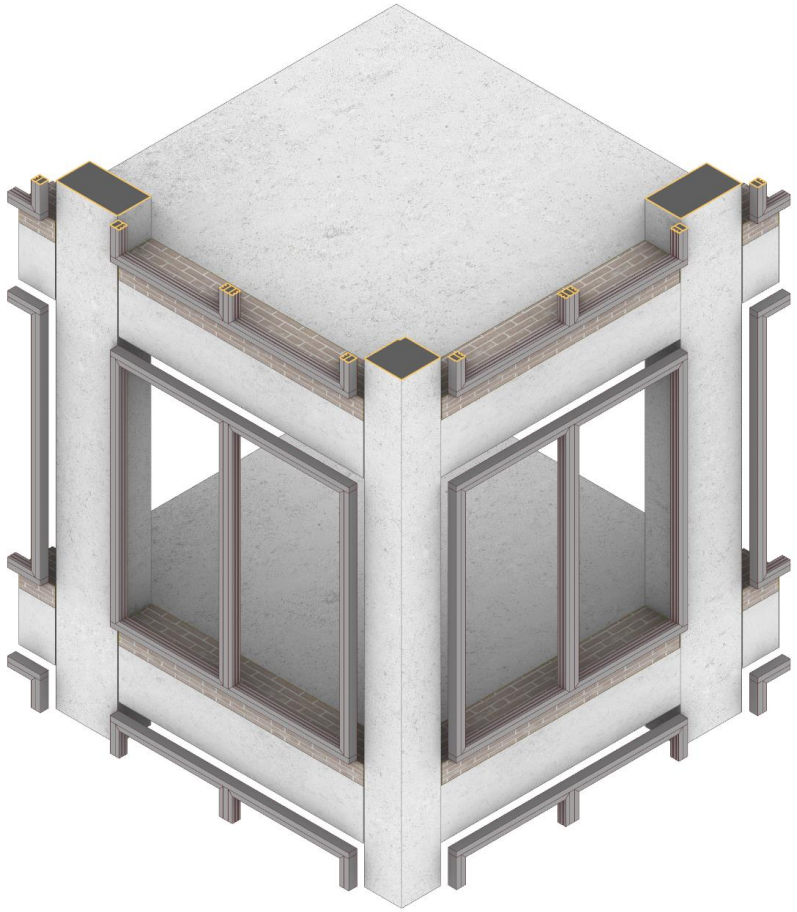


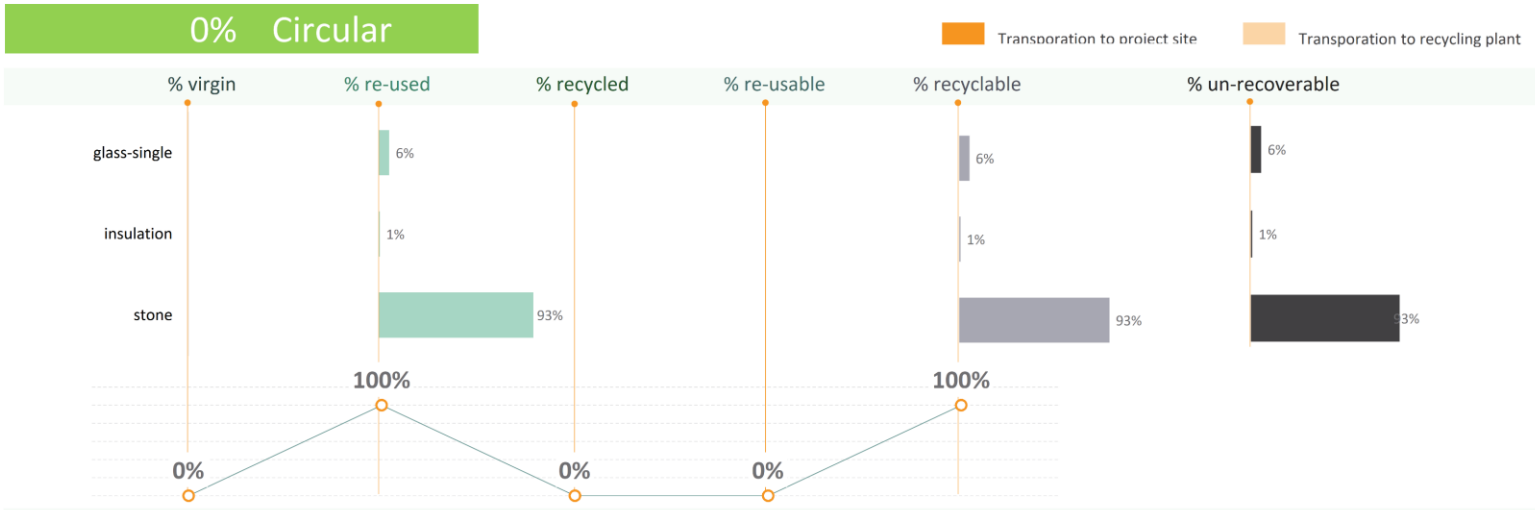


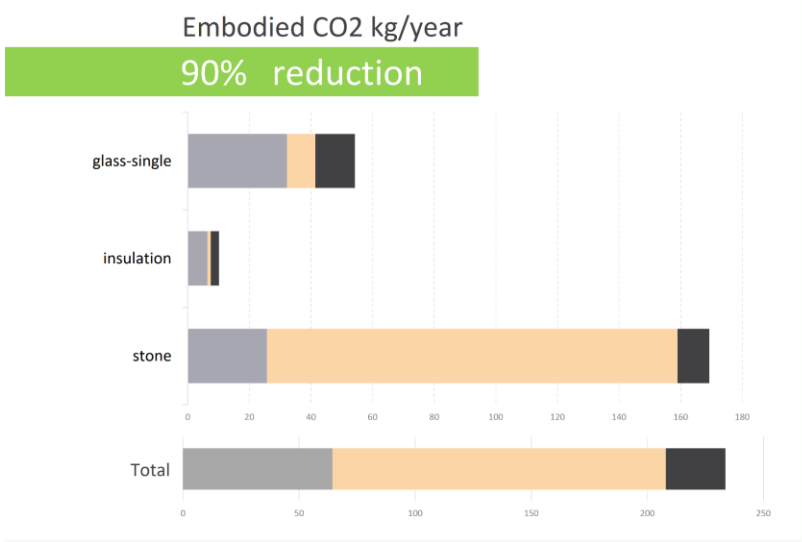


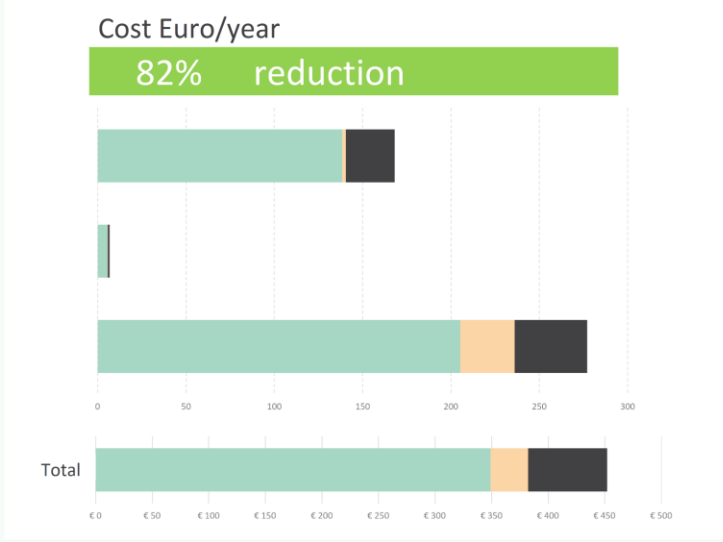
Design Case

Location: Hague Expected Lifetime: 20yrs



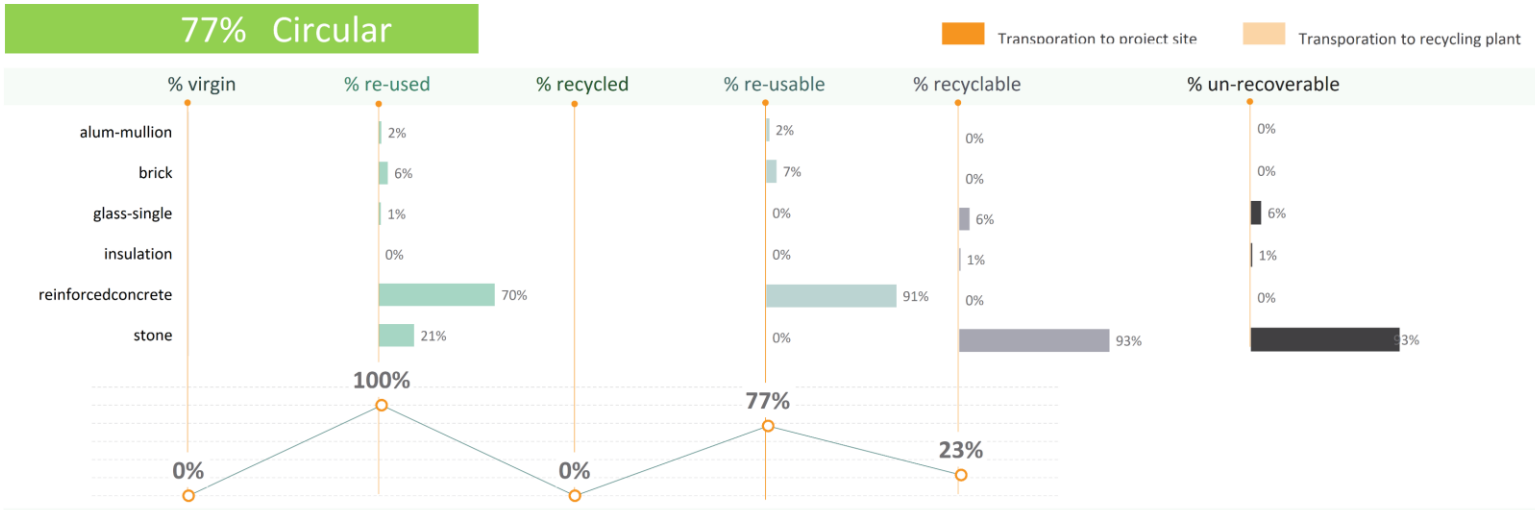


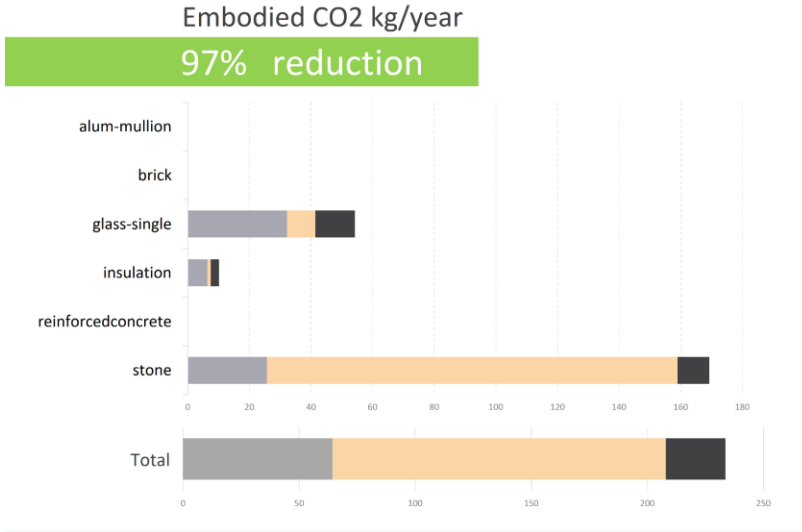


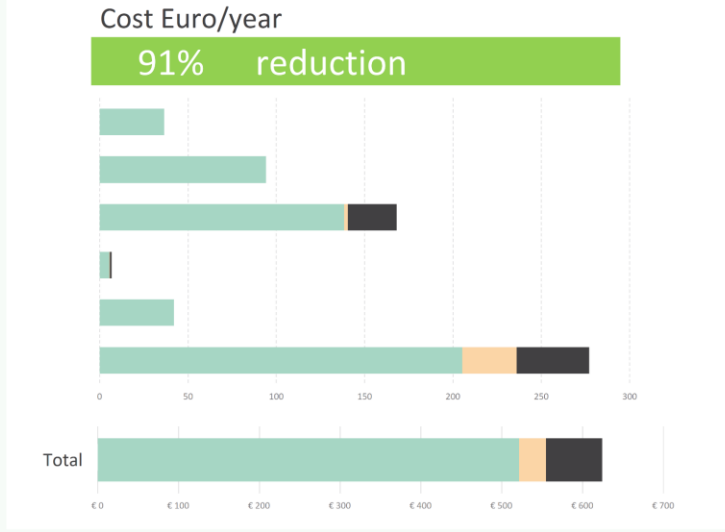


Design Case

Location: Hague Expected Lifetime: 20yrs

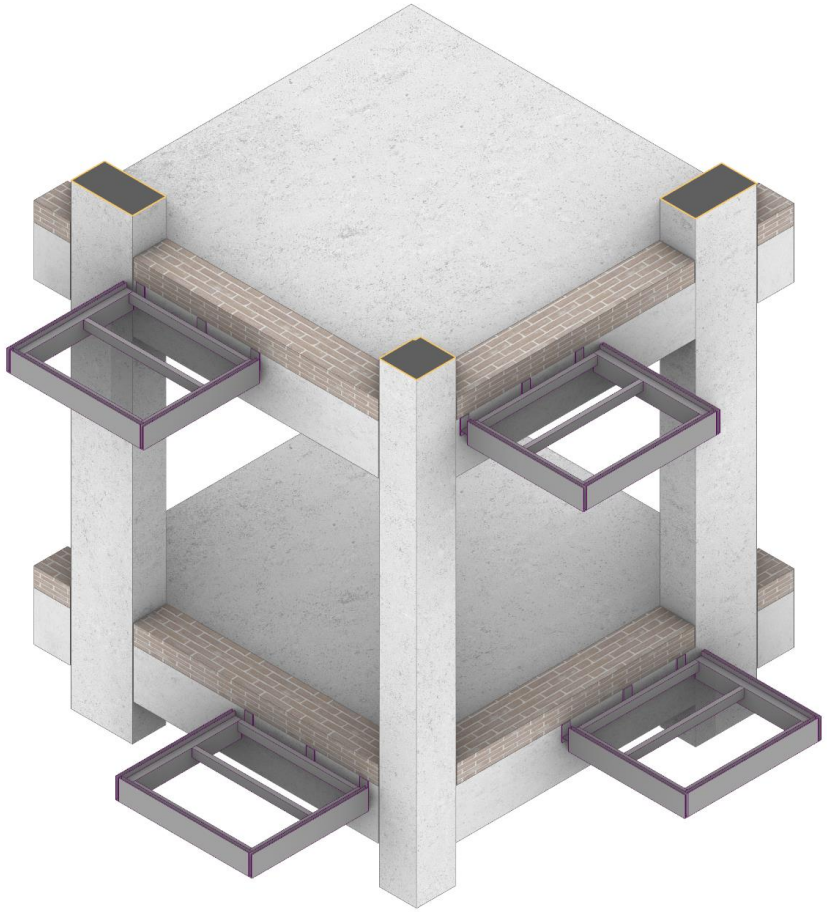


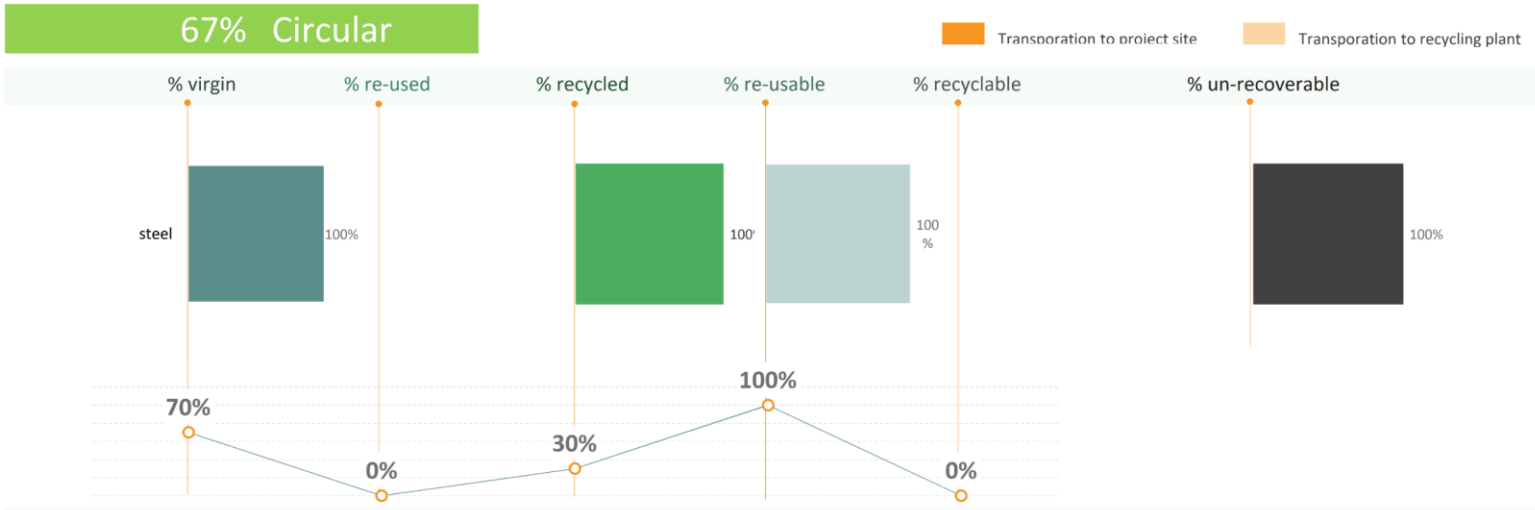


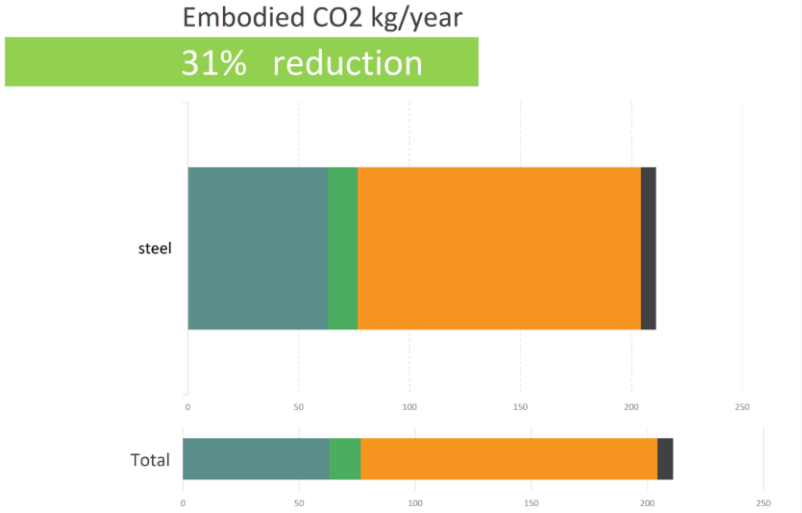


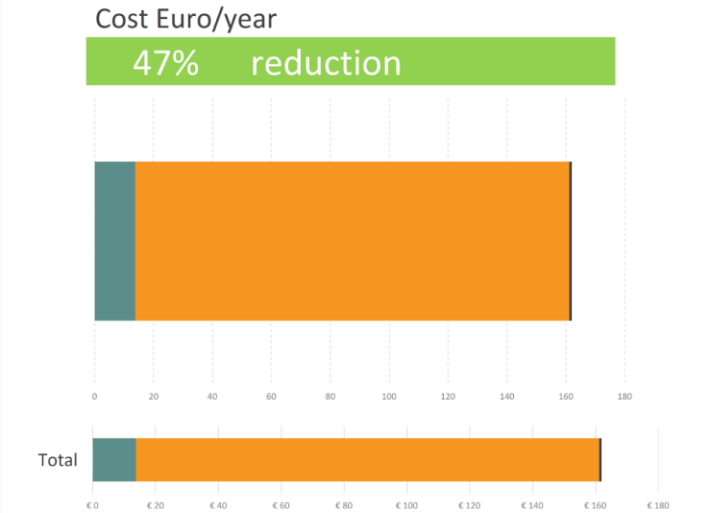
Design Case

Location: Hague Expected Lifetime: 20yrs



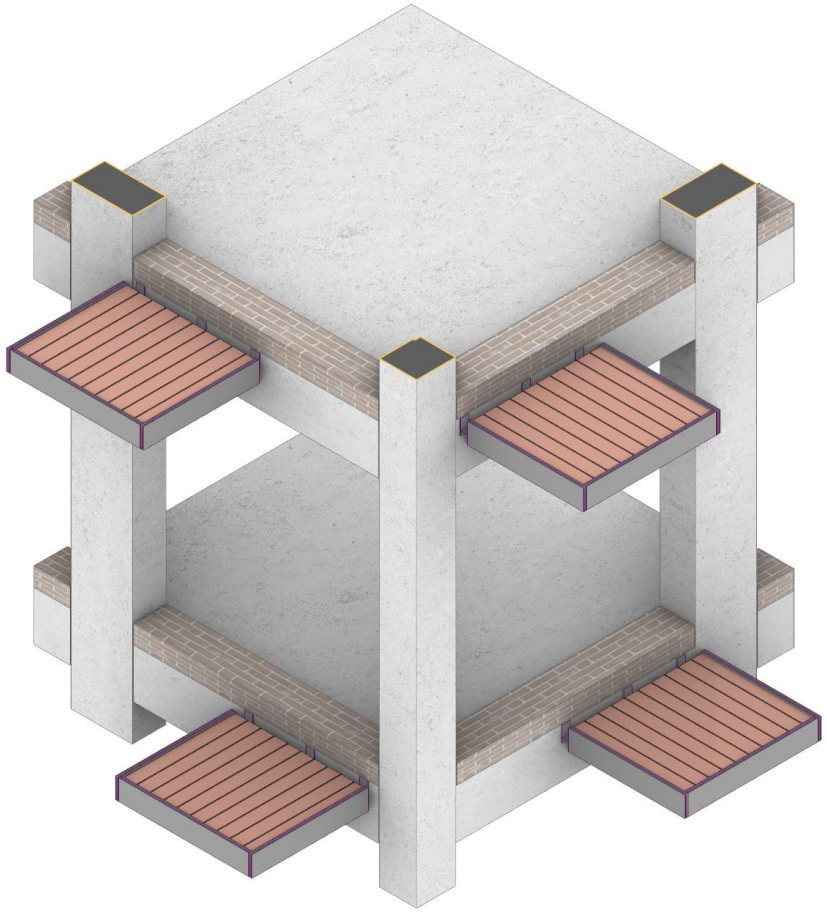


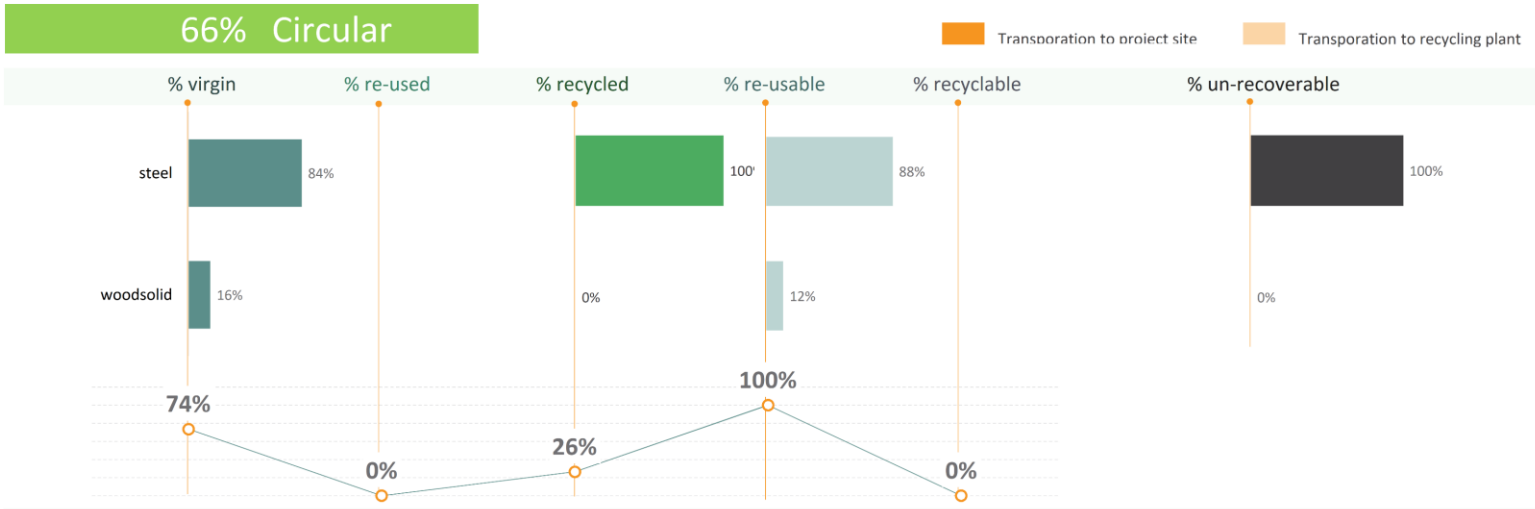


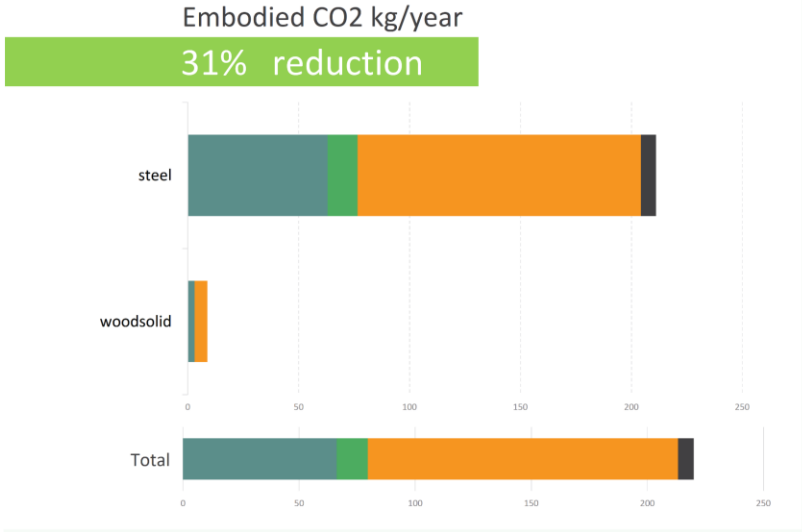


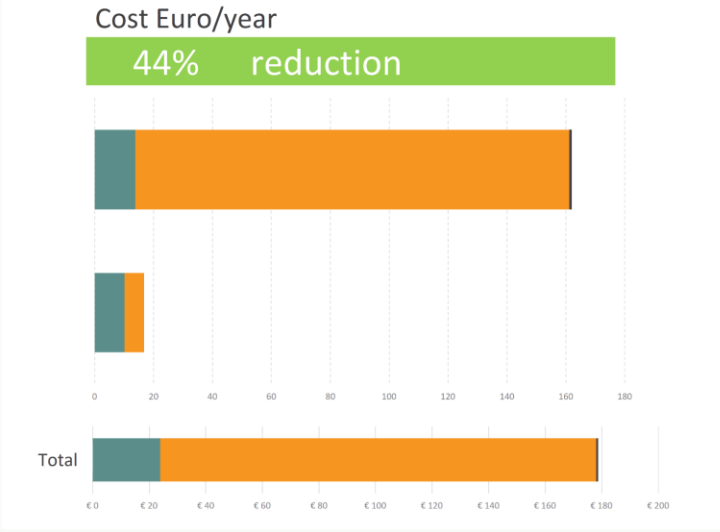
Design Case

Location: Hague Expected Lifetime: 20yrs



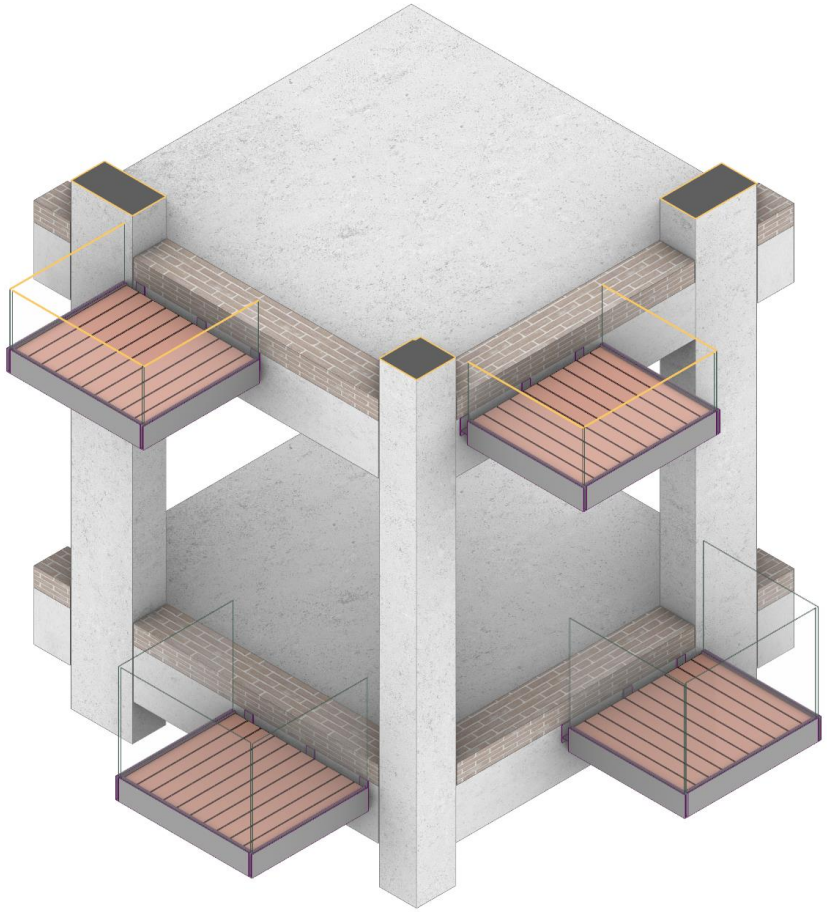


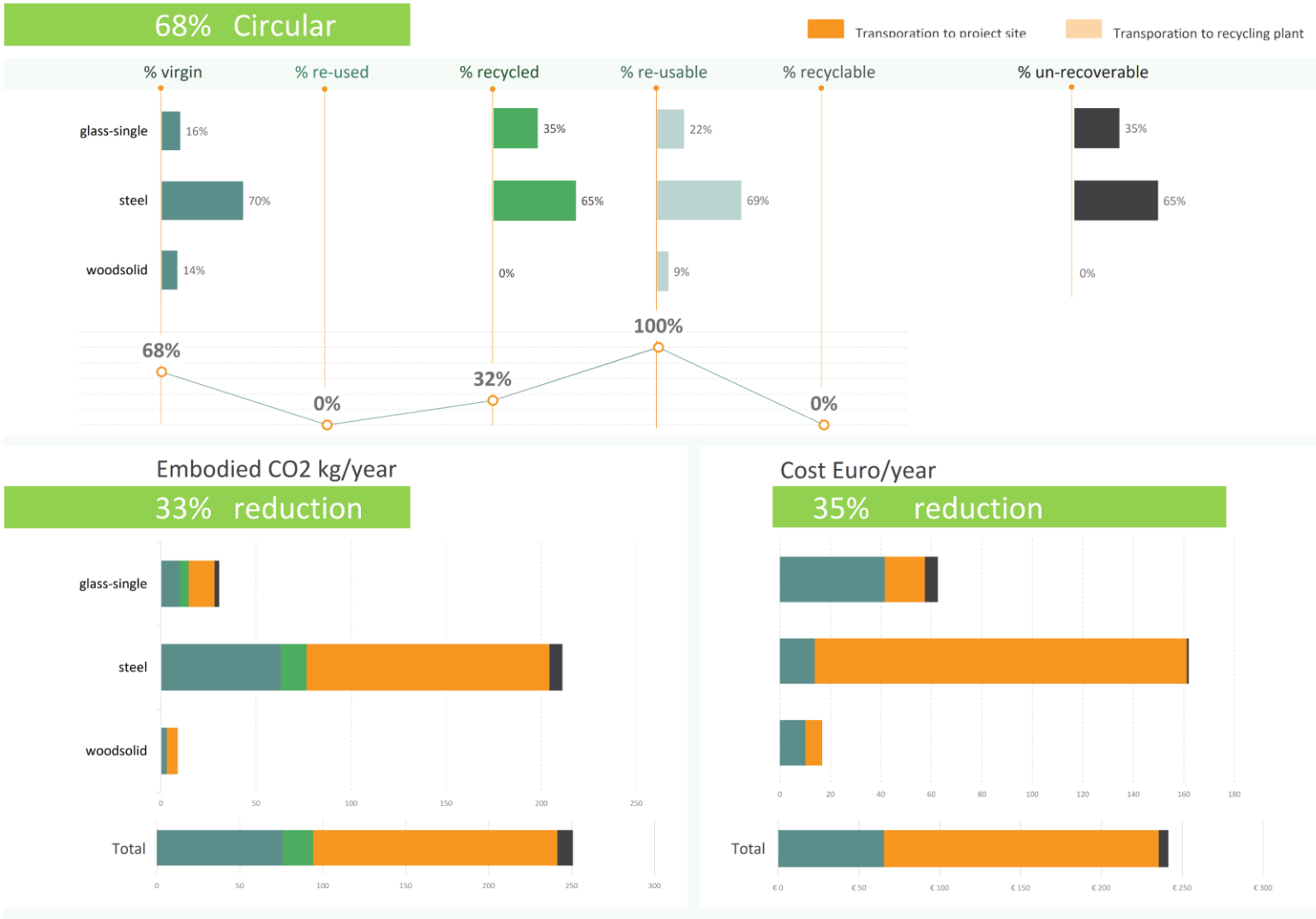




Design Case

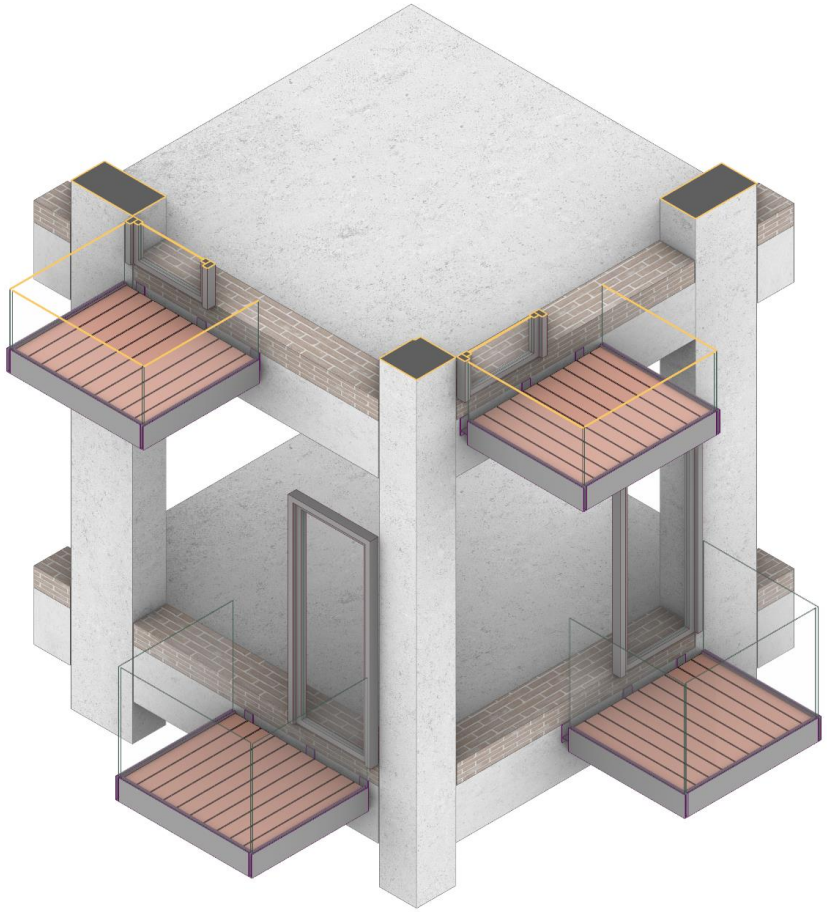
Location: Hague Expected Lifetime: 20yrs





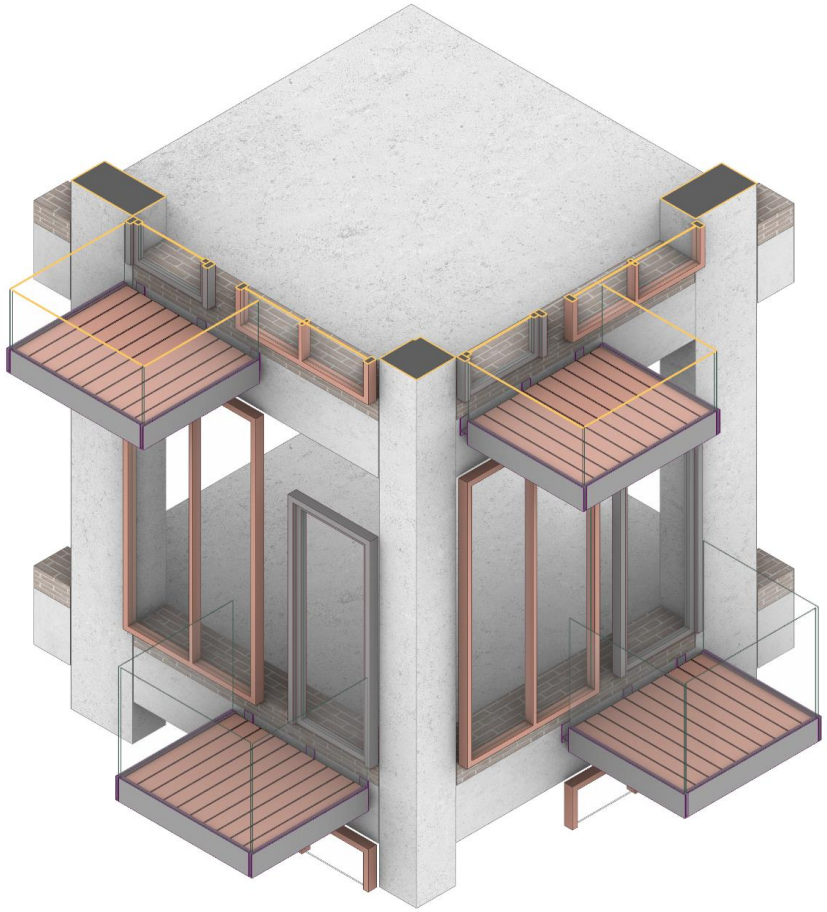
Design Case

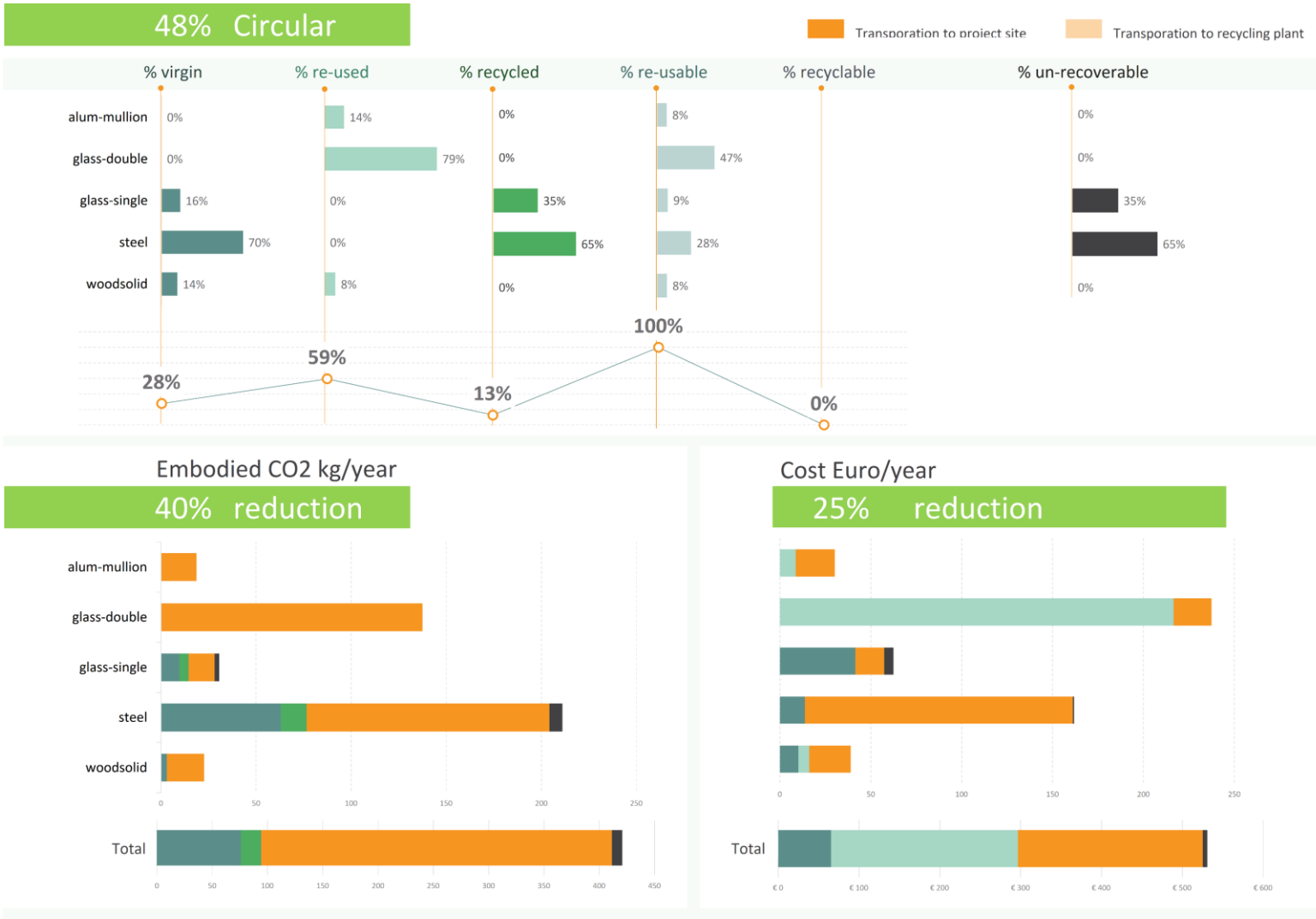
Location: Hague Expected Lifetime: 20yrs



Design Case

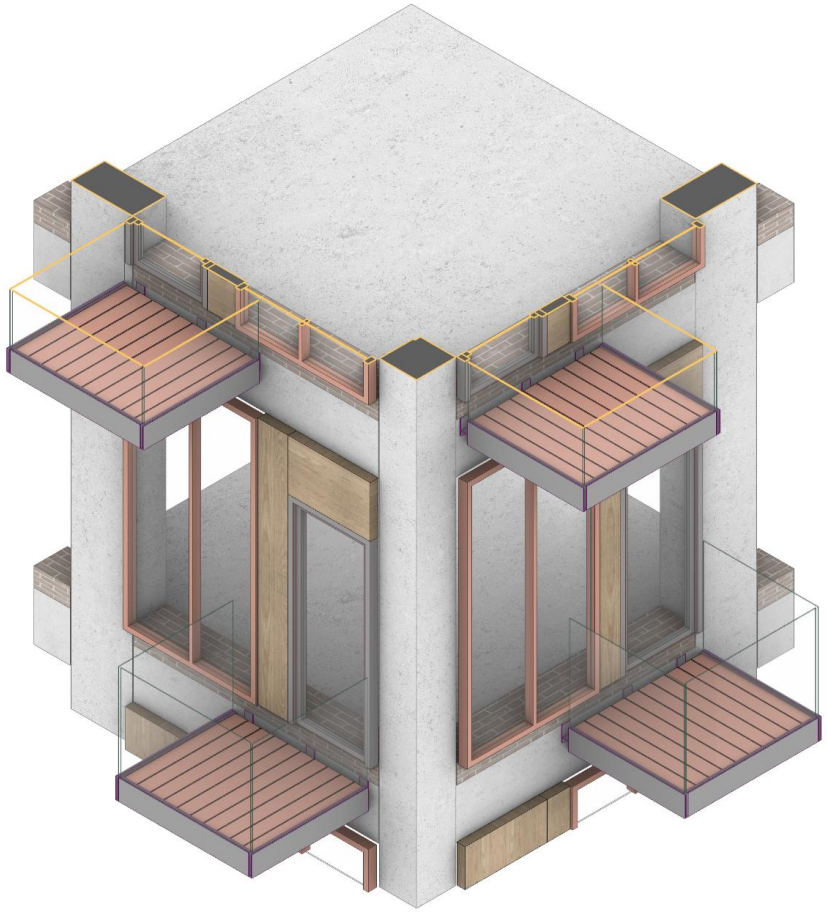
Location: Hague Expected Lifetime: 20yrs

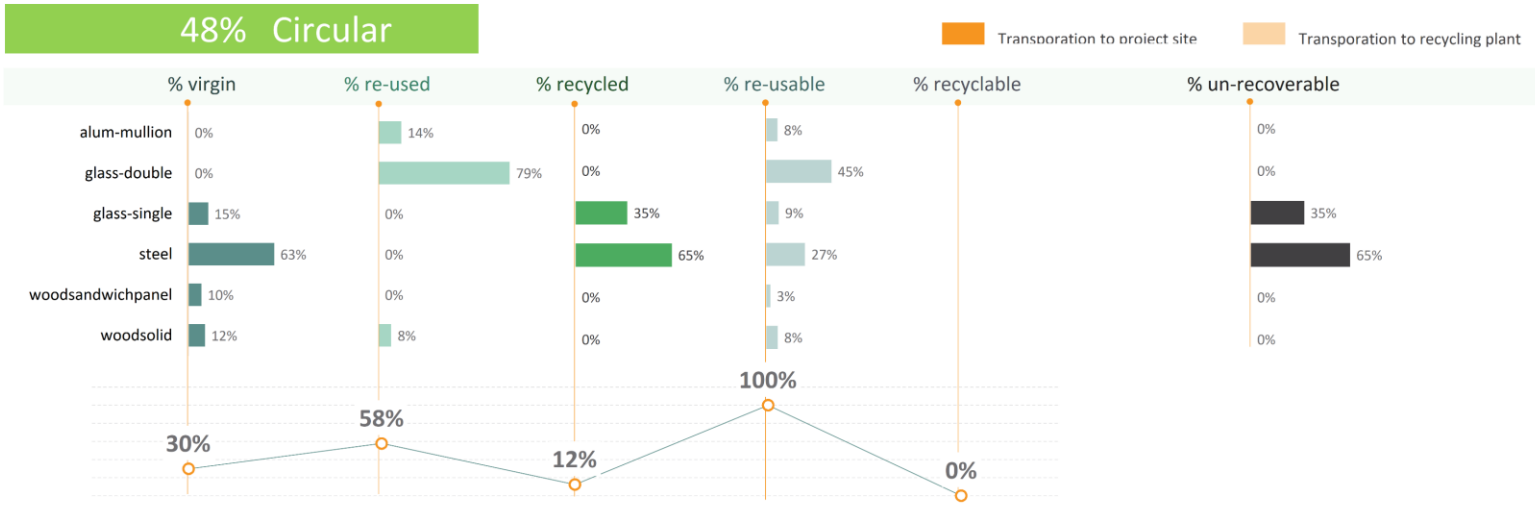


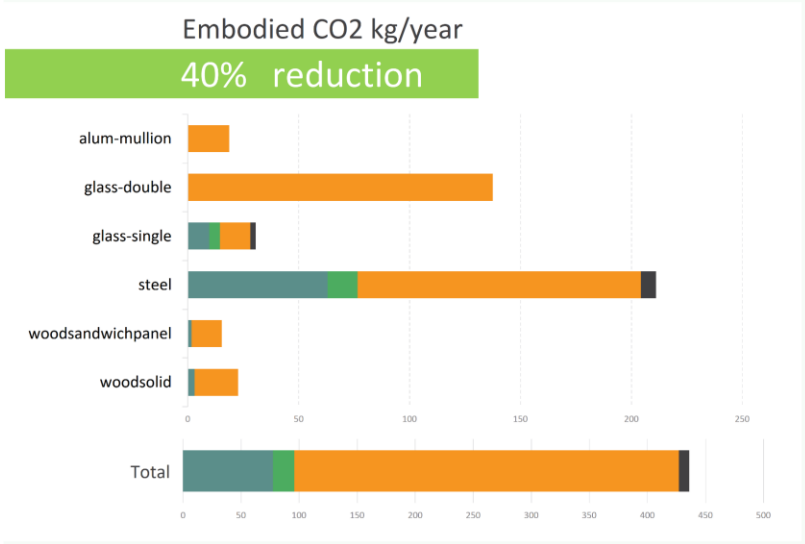


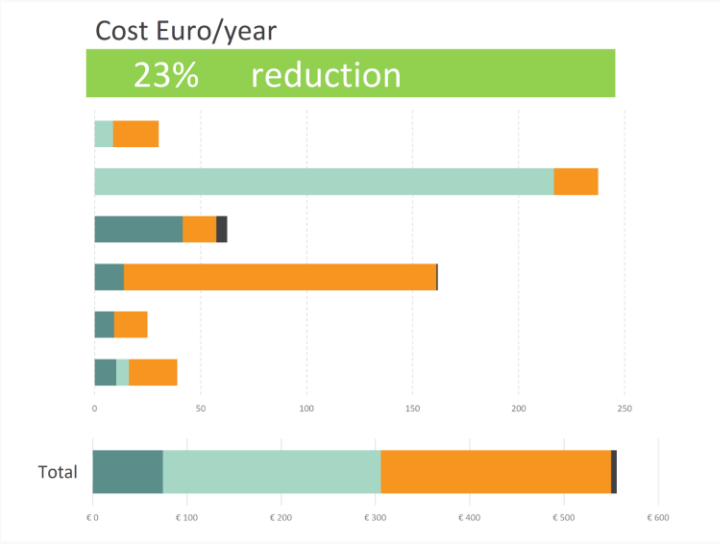
Design Case

Location: Hague Expected Lifetime: 20yrs



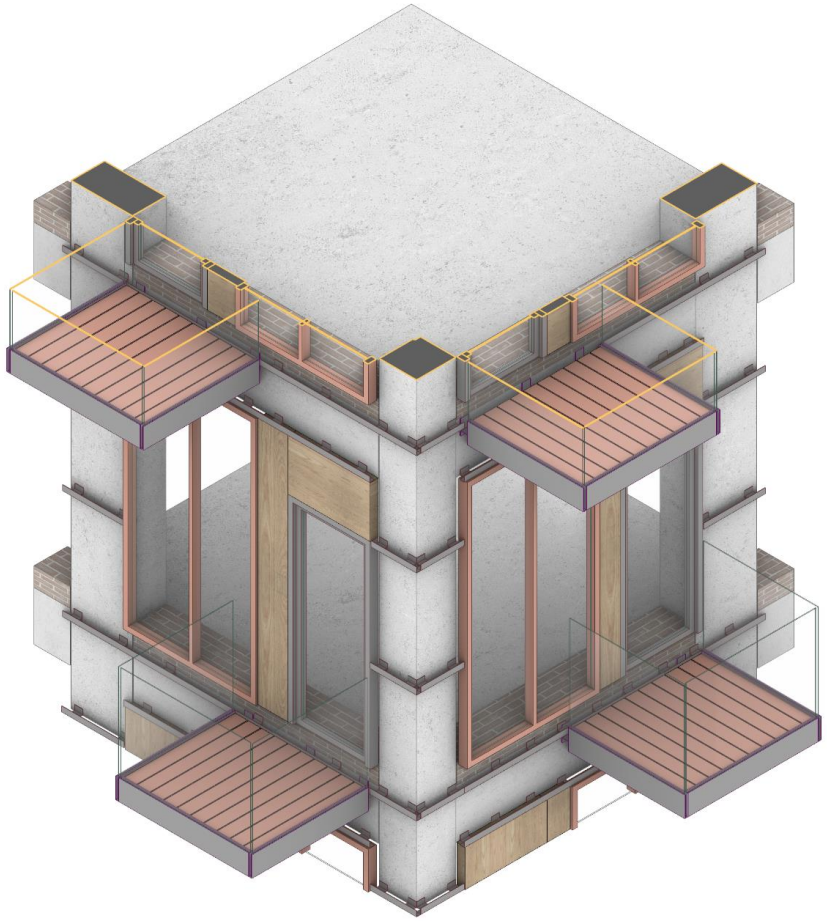


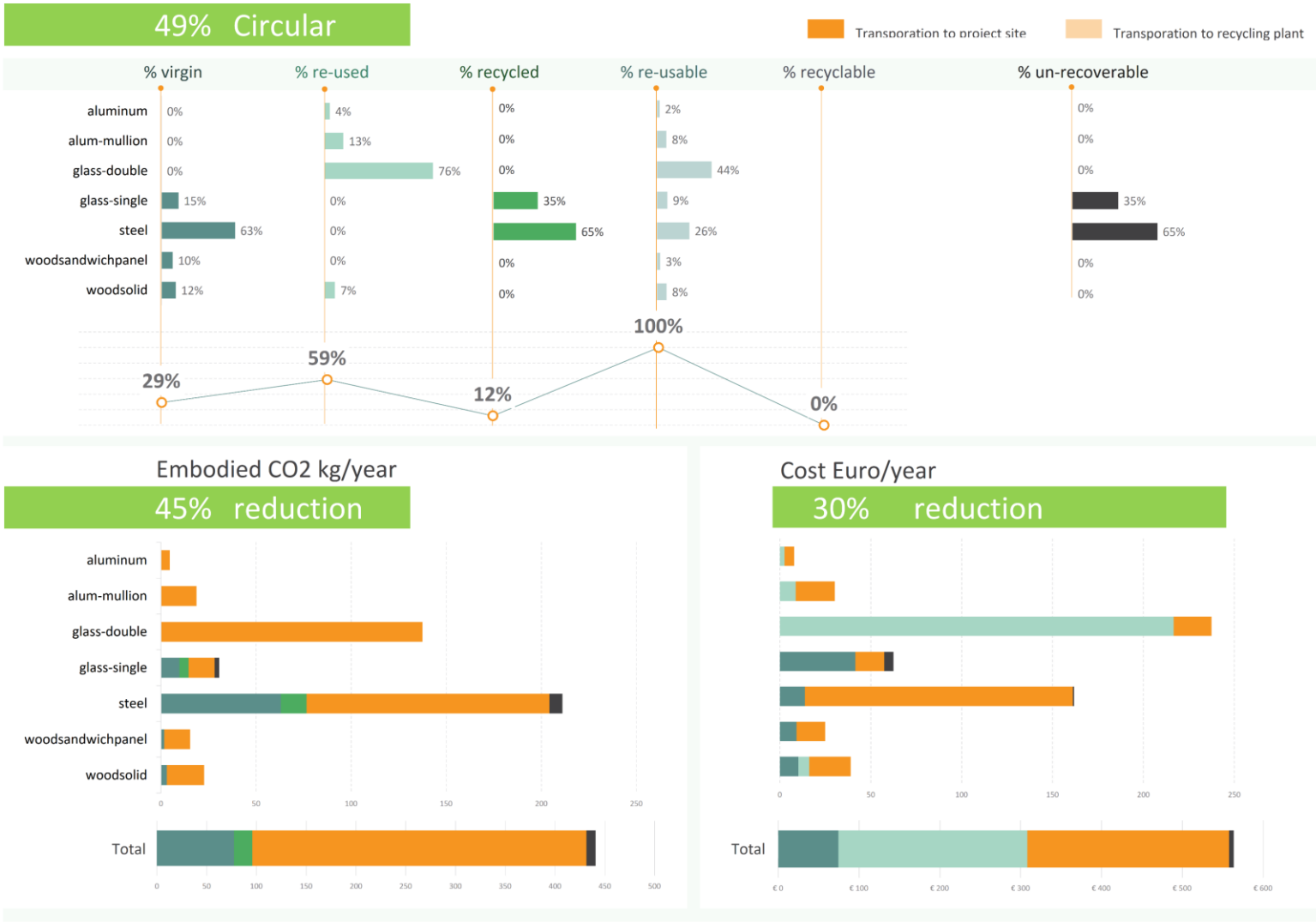




Design Case

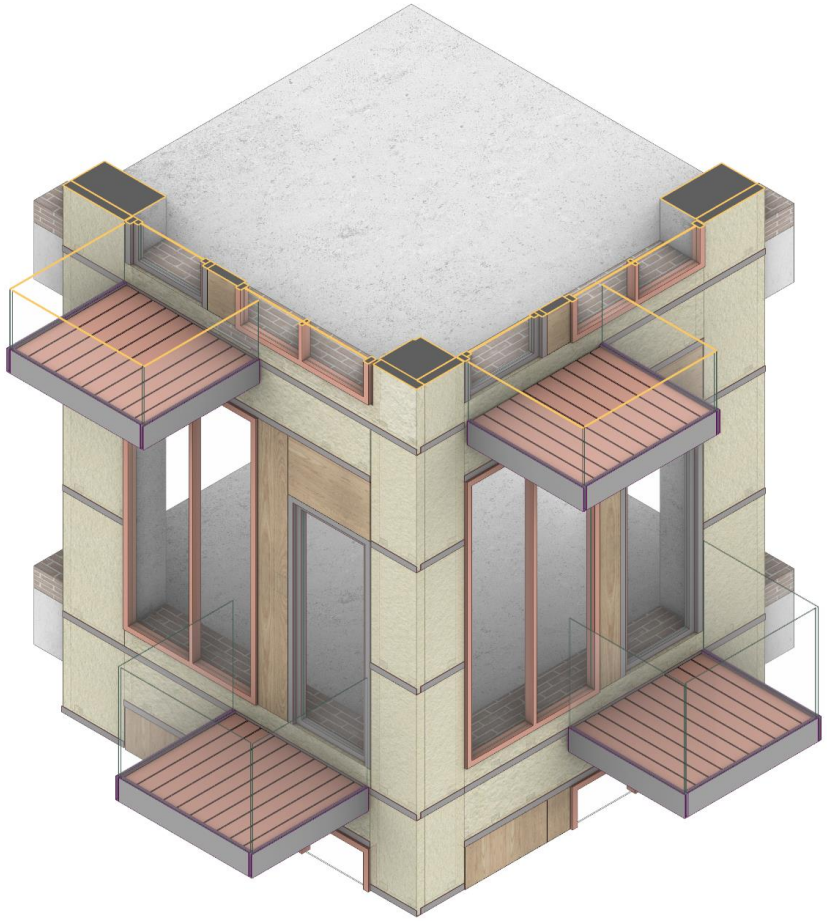
Location: Hague Expected Lifetime: 20yrs

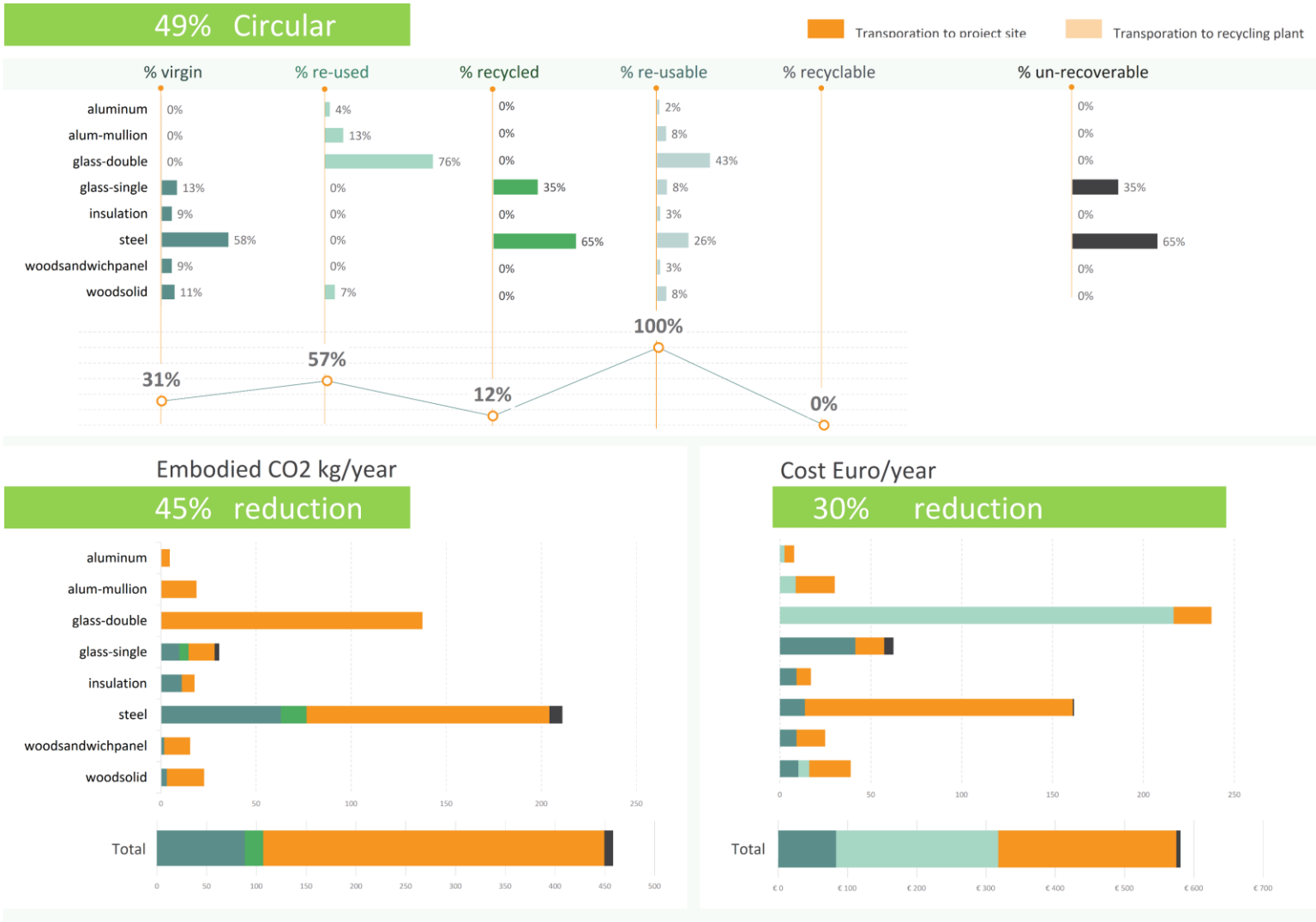




Design Case

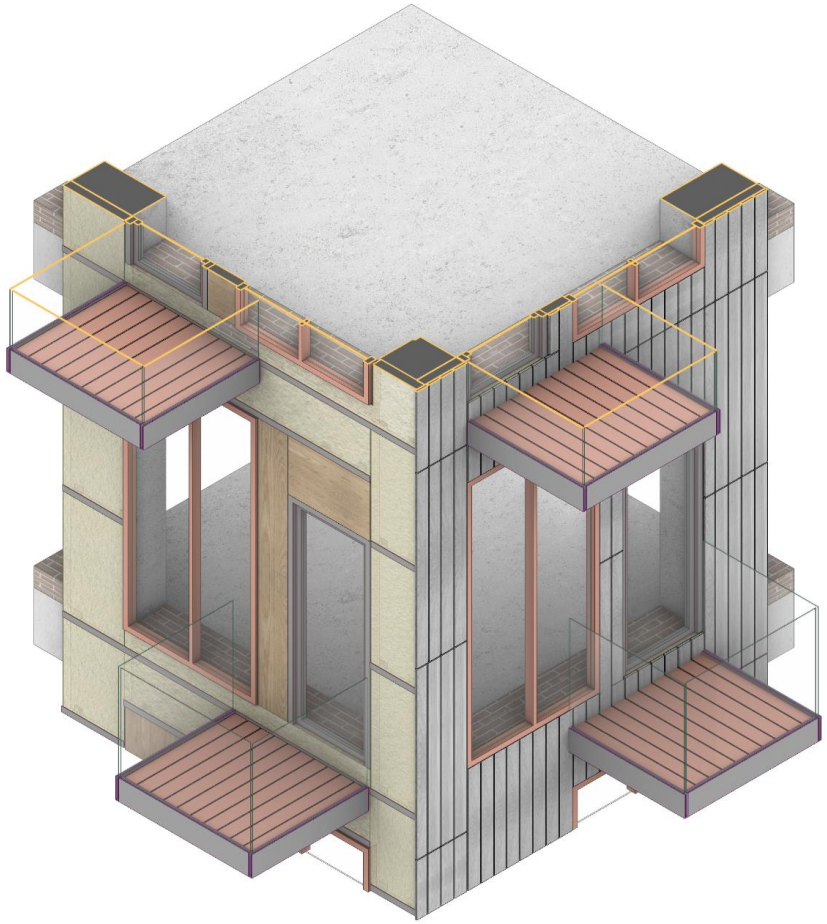
Location: Hague Expected Lifetime: 20yrs

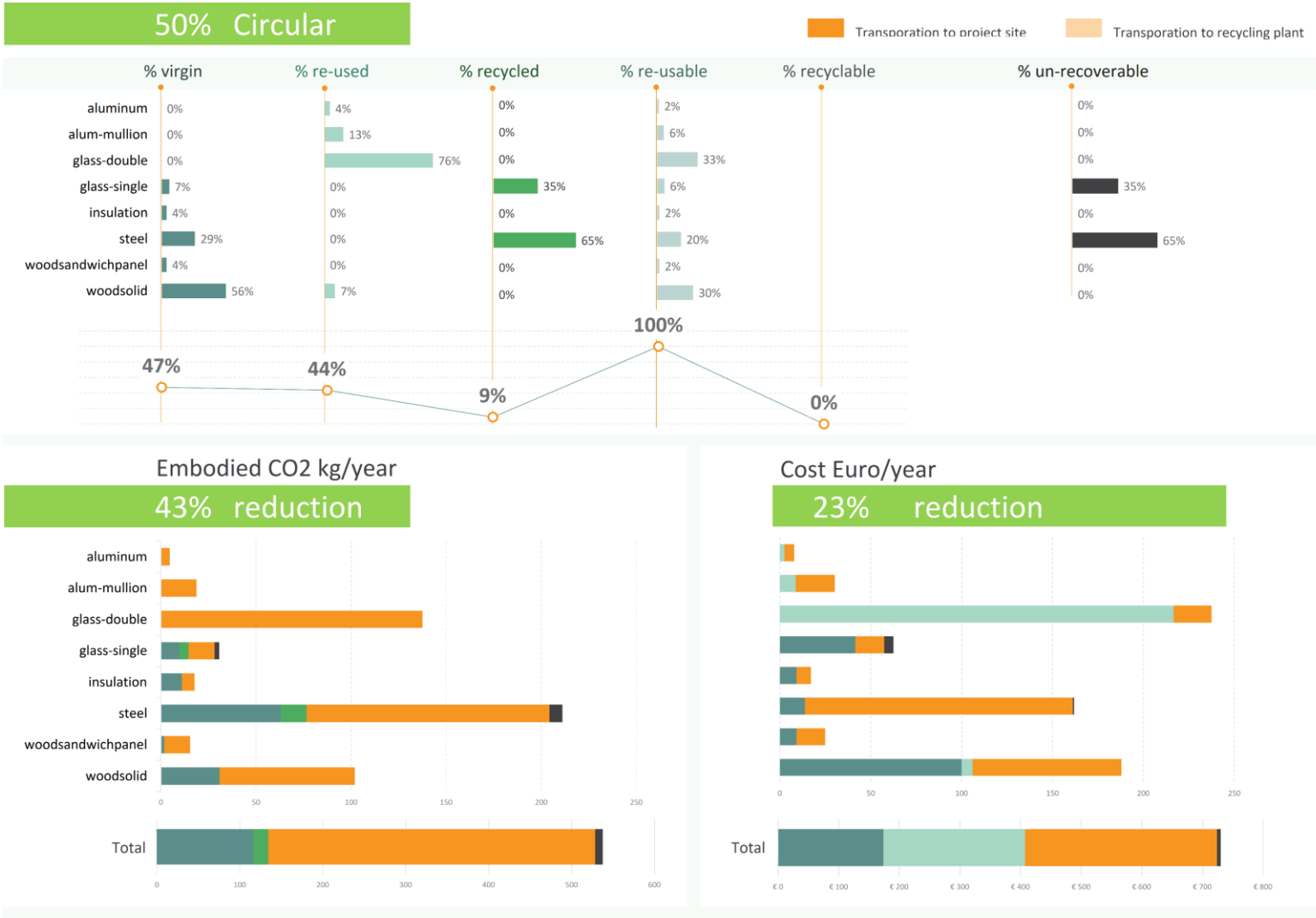




Design Case

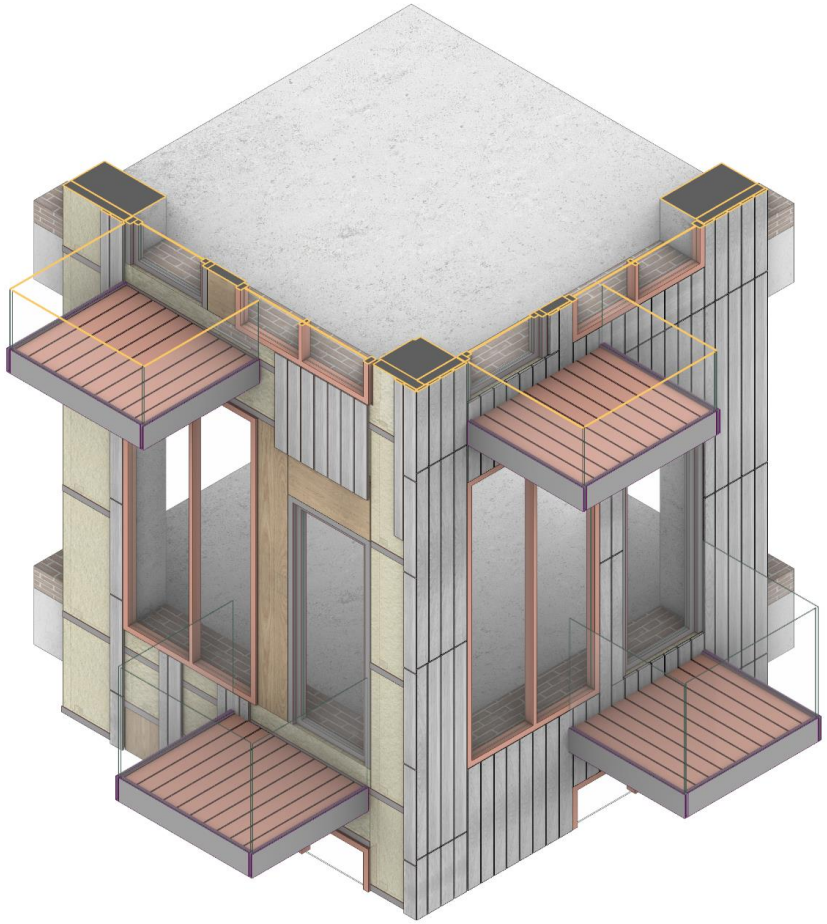
Location: Hague Expected Lifetime: 20yrs

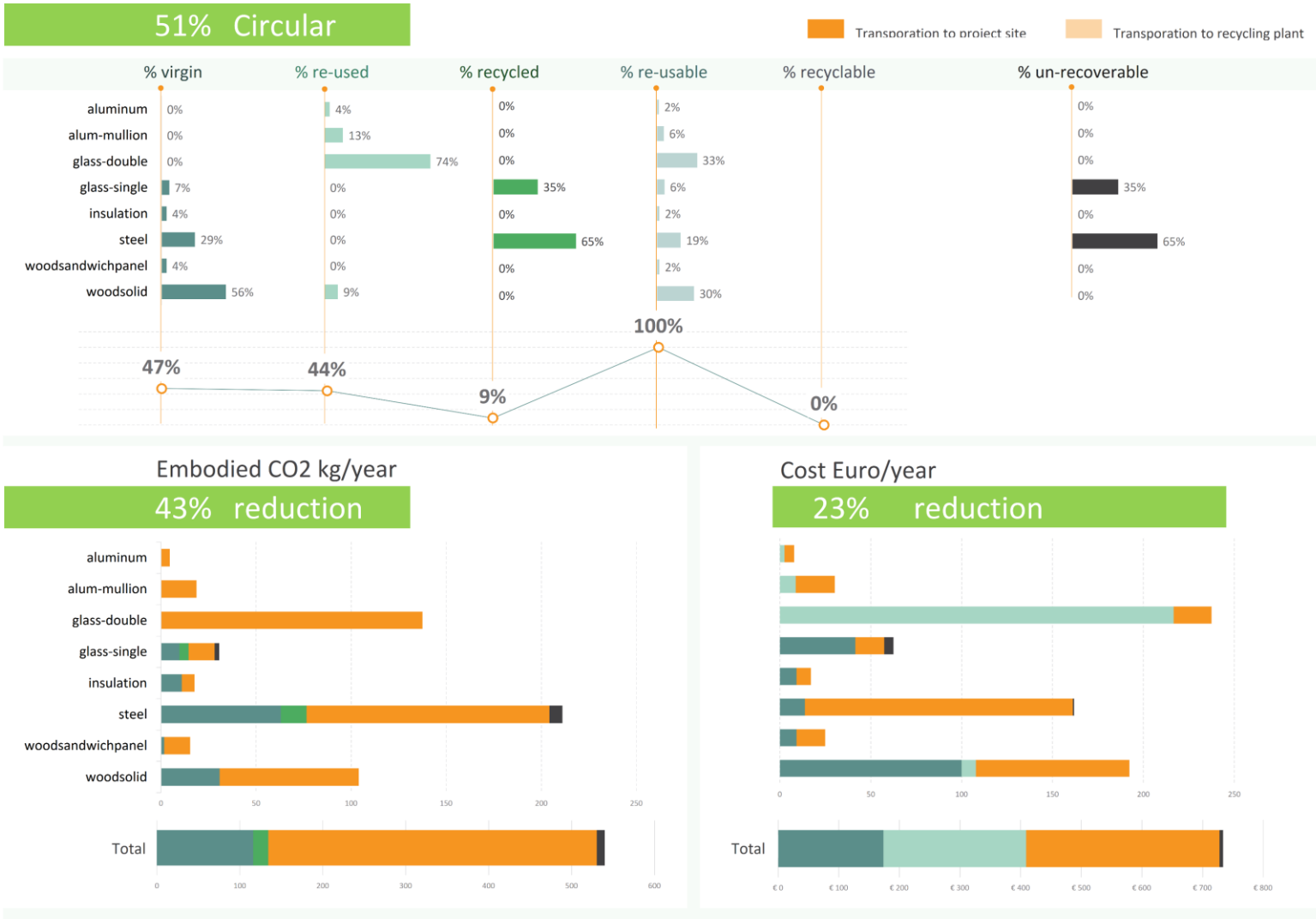




Design Case

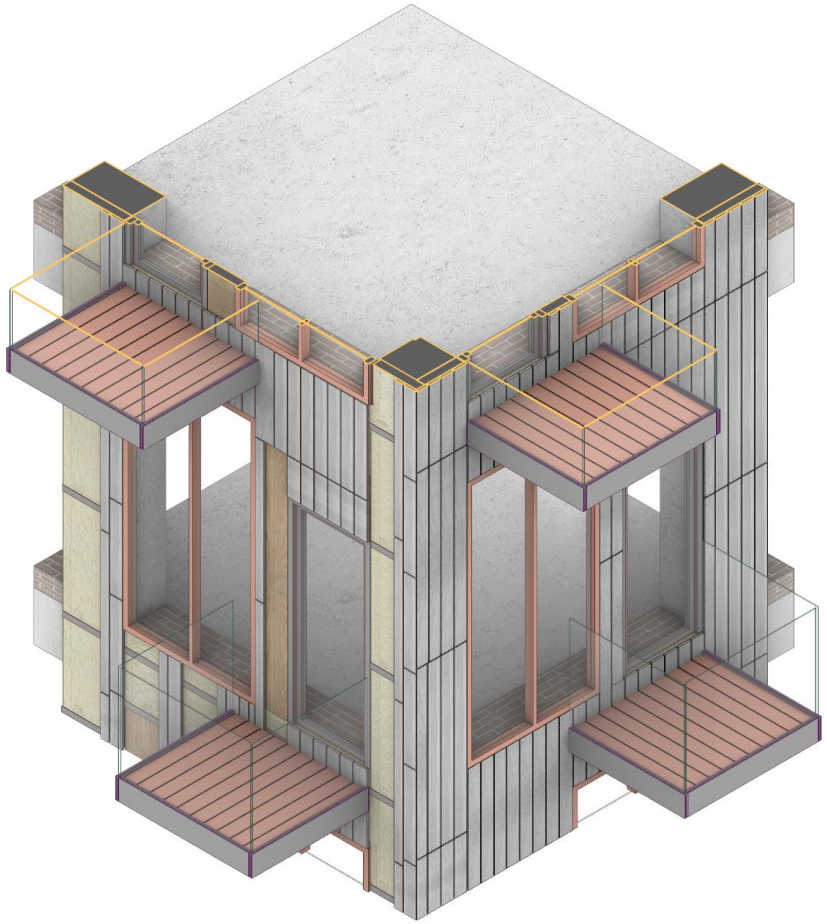
Location: Hague Expected Lifetime: 20yrs

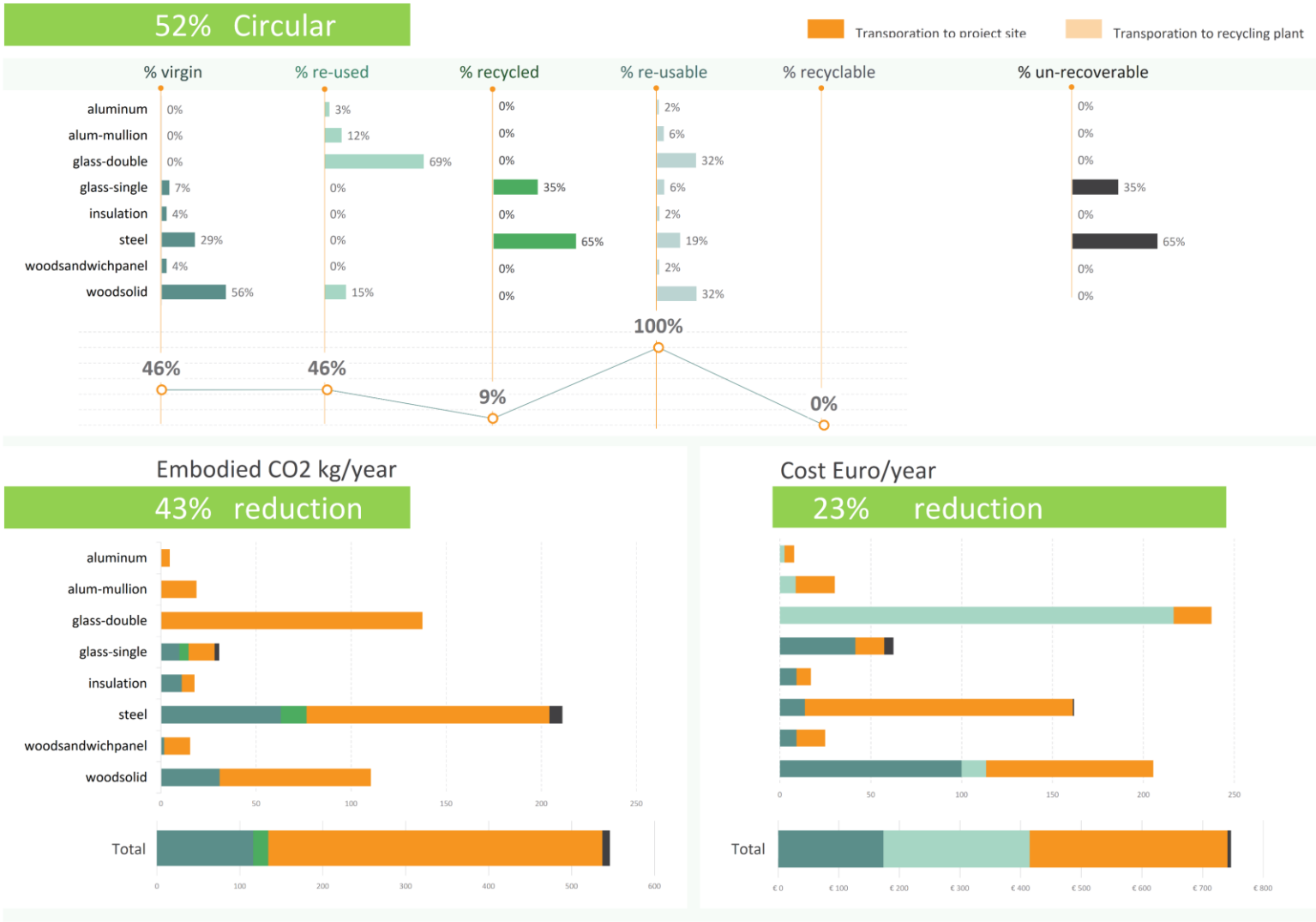




Design Case

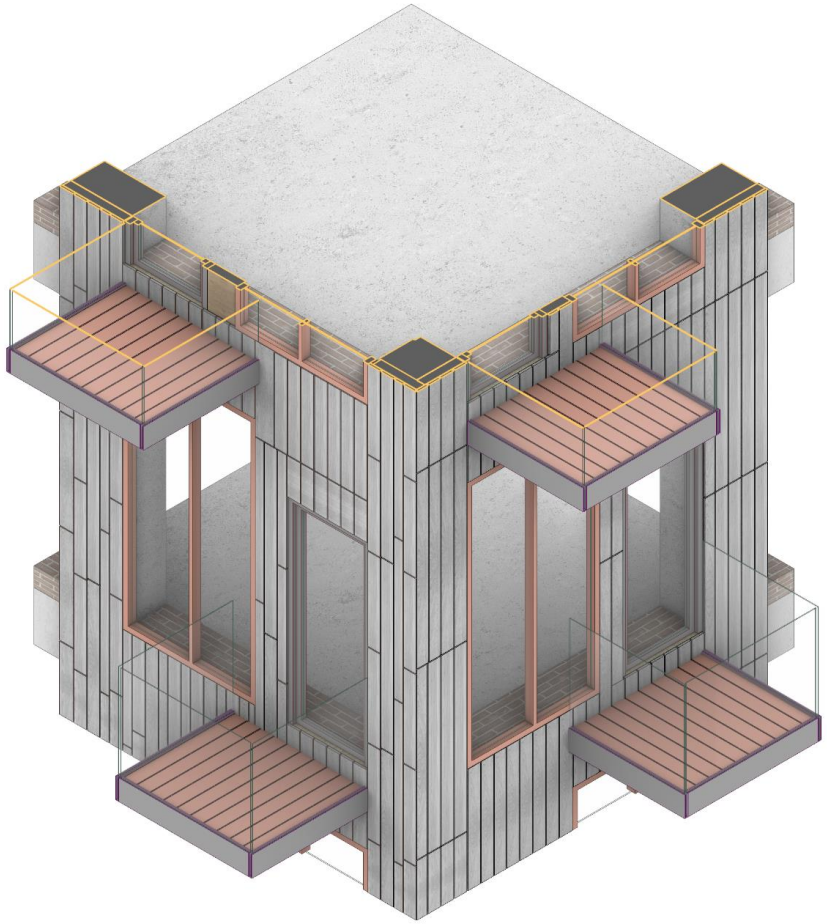
Location: Hague Expected Lifetime: 20yrs

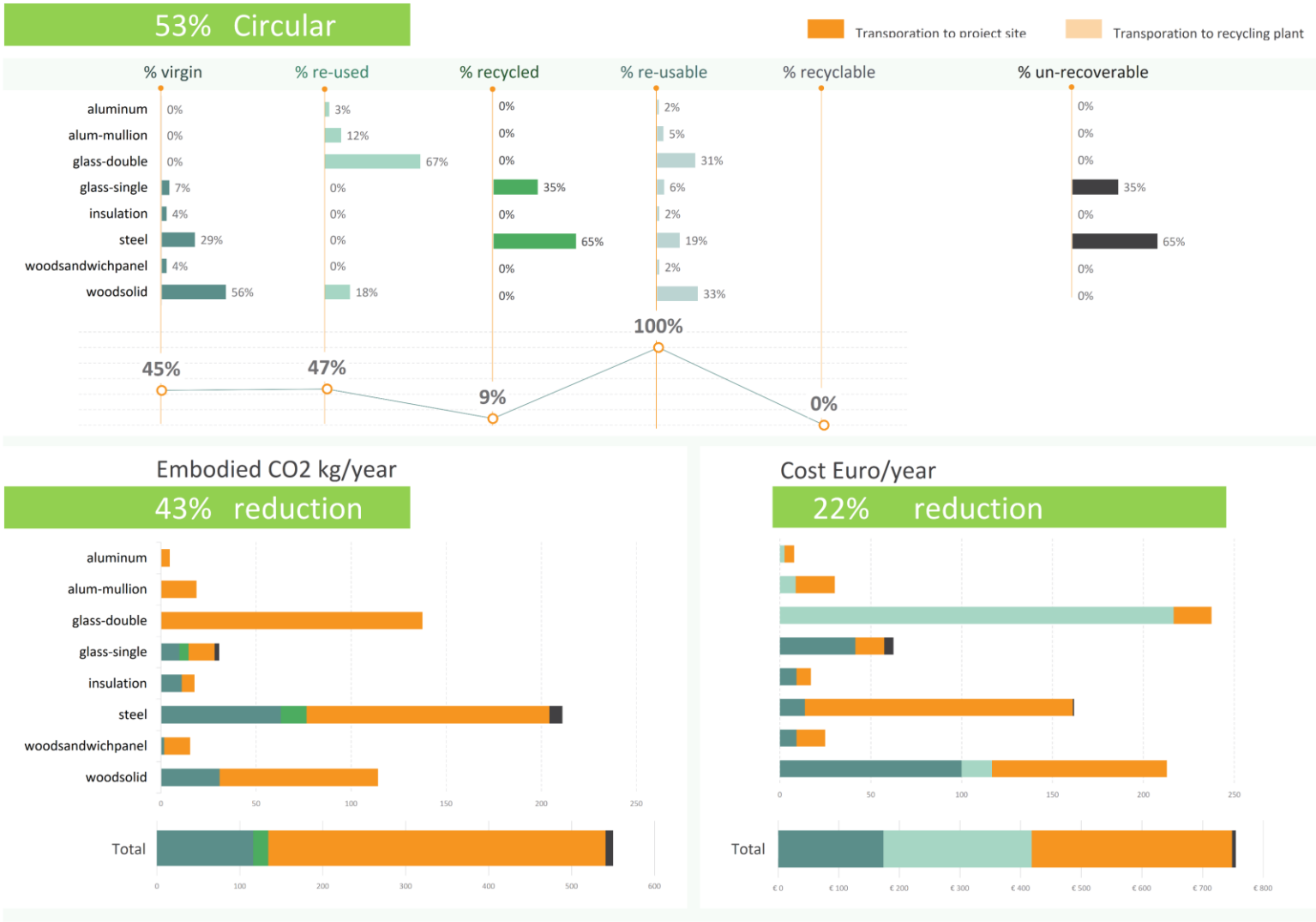




Design Case

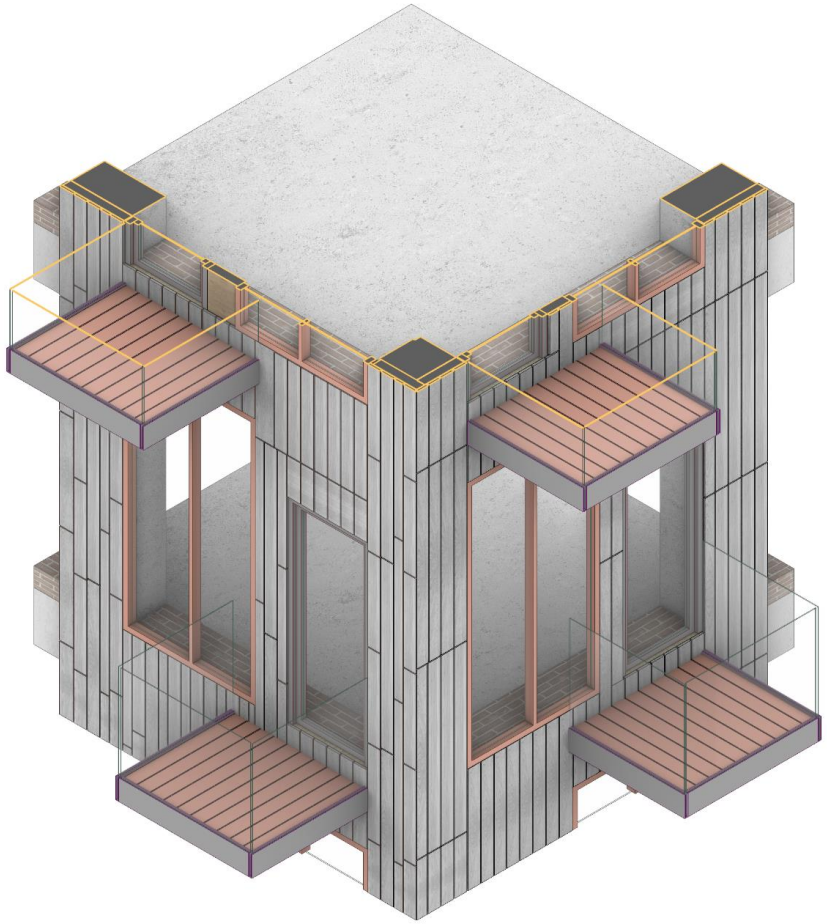
Location: Hague Expected Lifetime: 20yrs

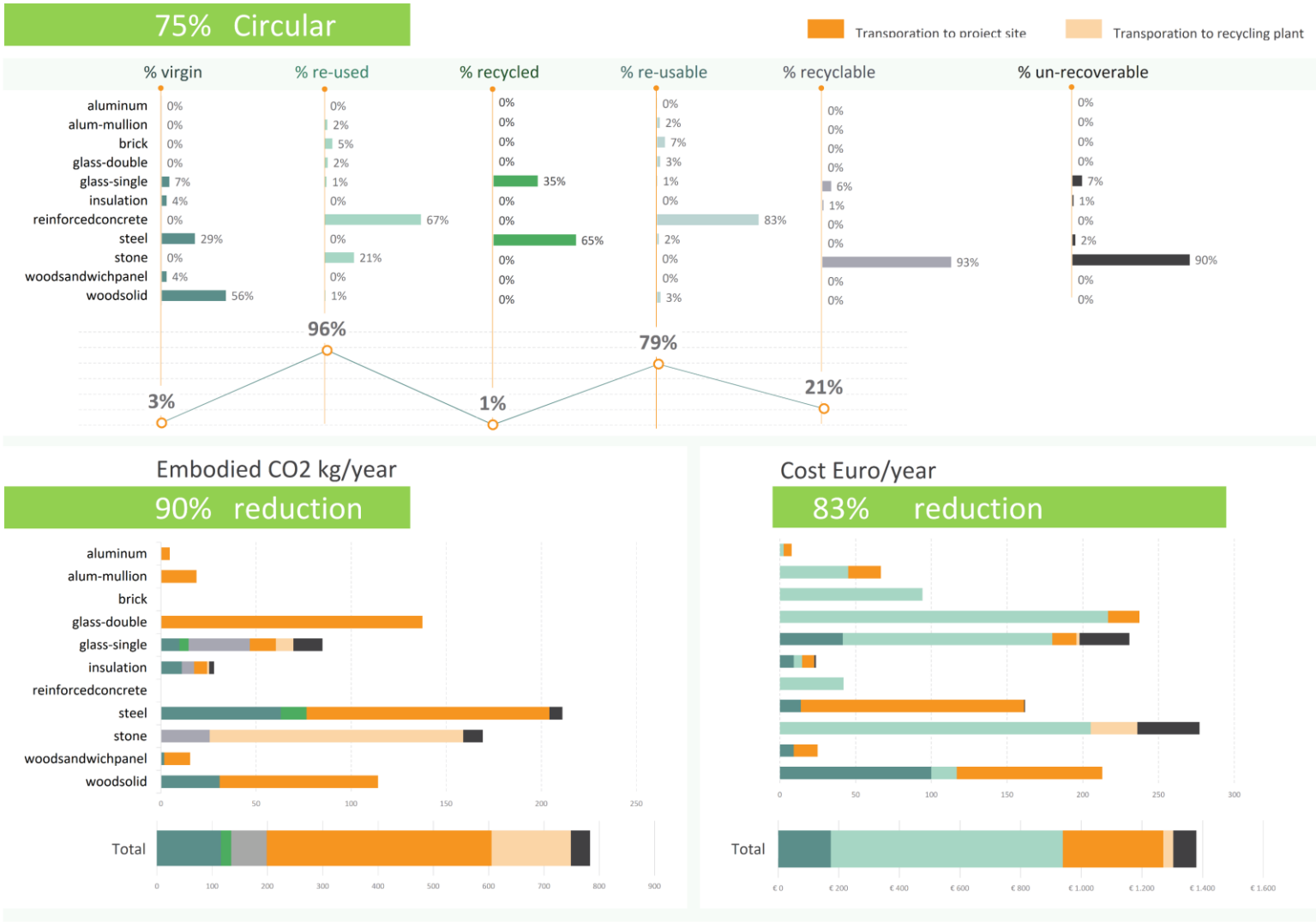




Design Case

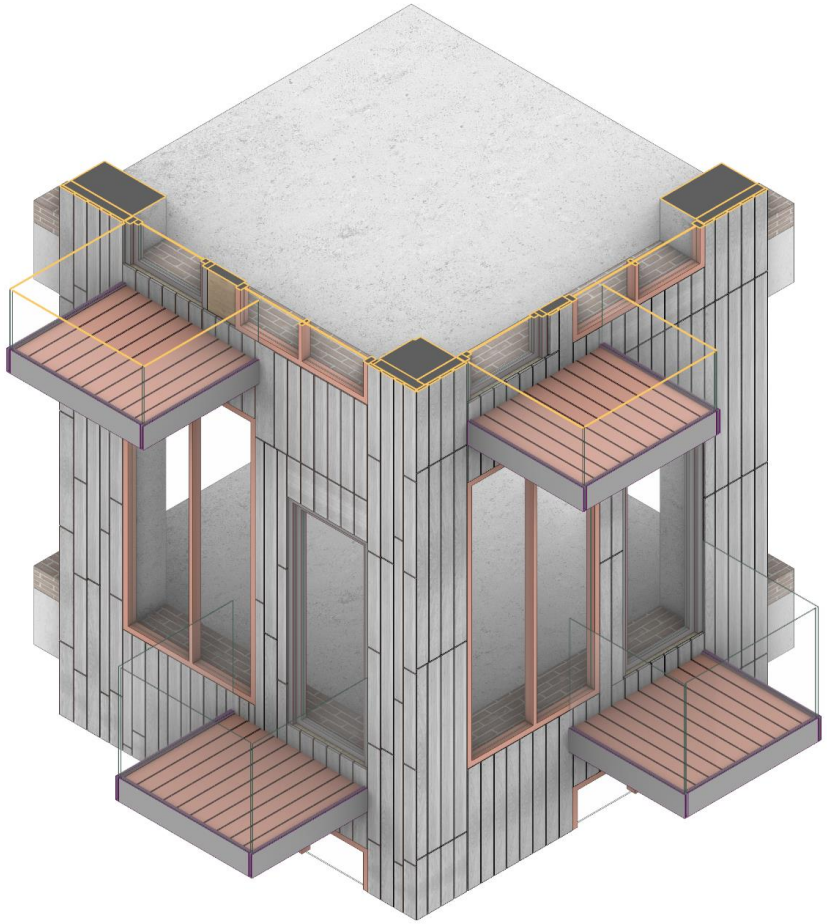
Location: Hague Expected Lifetime: 20yrs

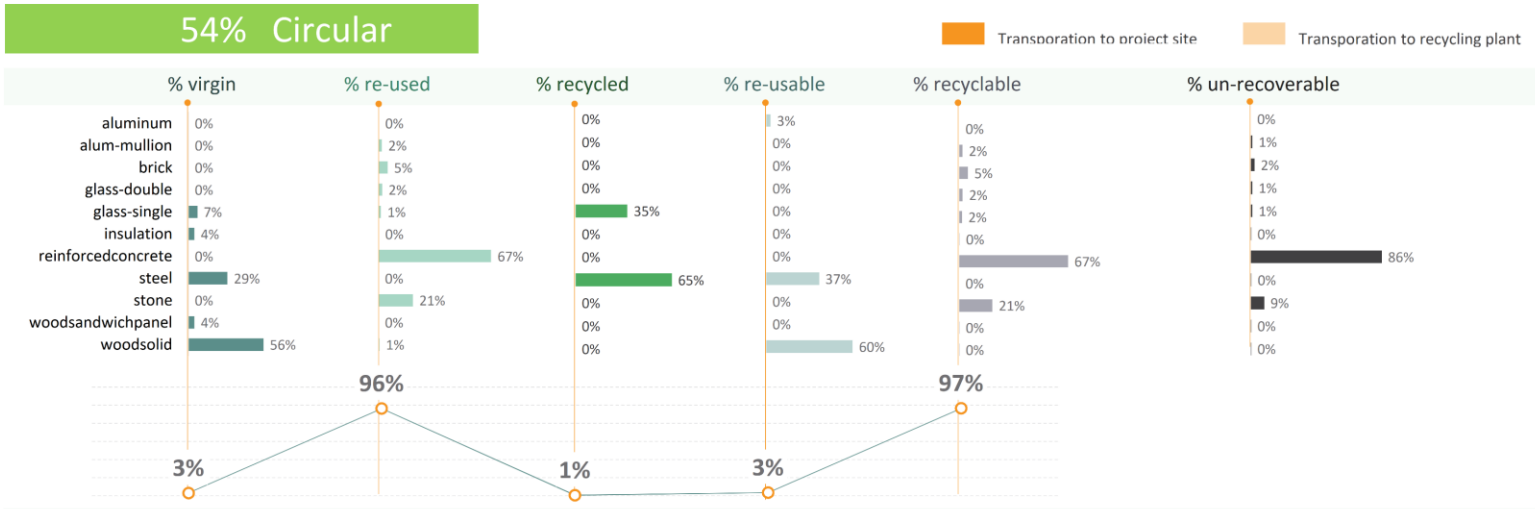


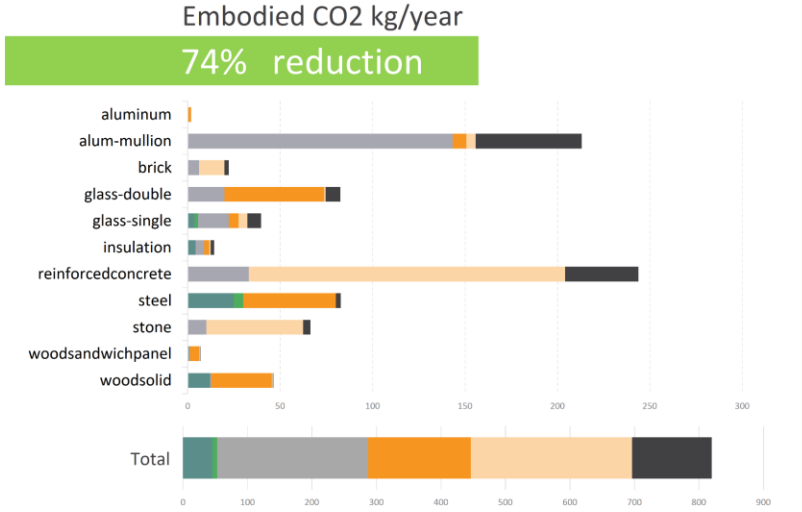


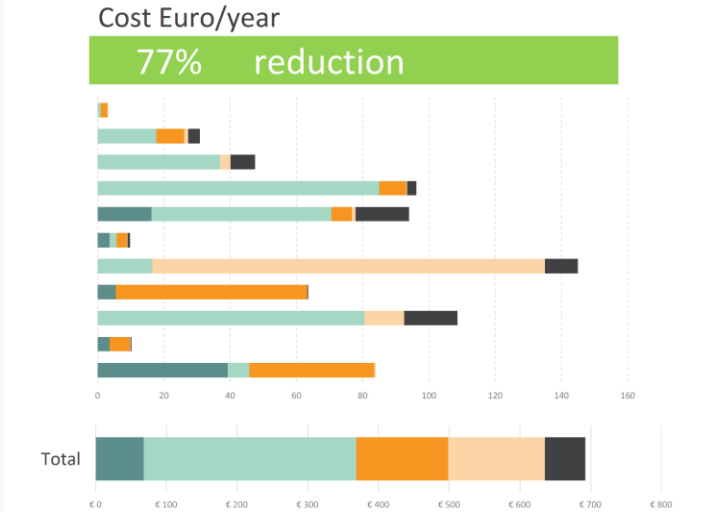
Design Case

Location: Hague Expected Lifetime: 20yrs



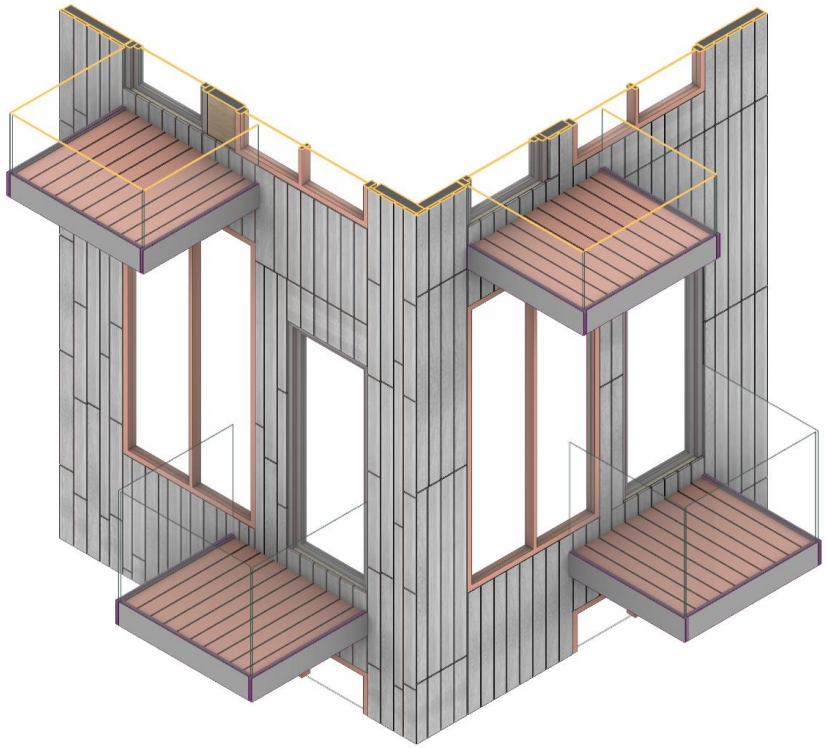


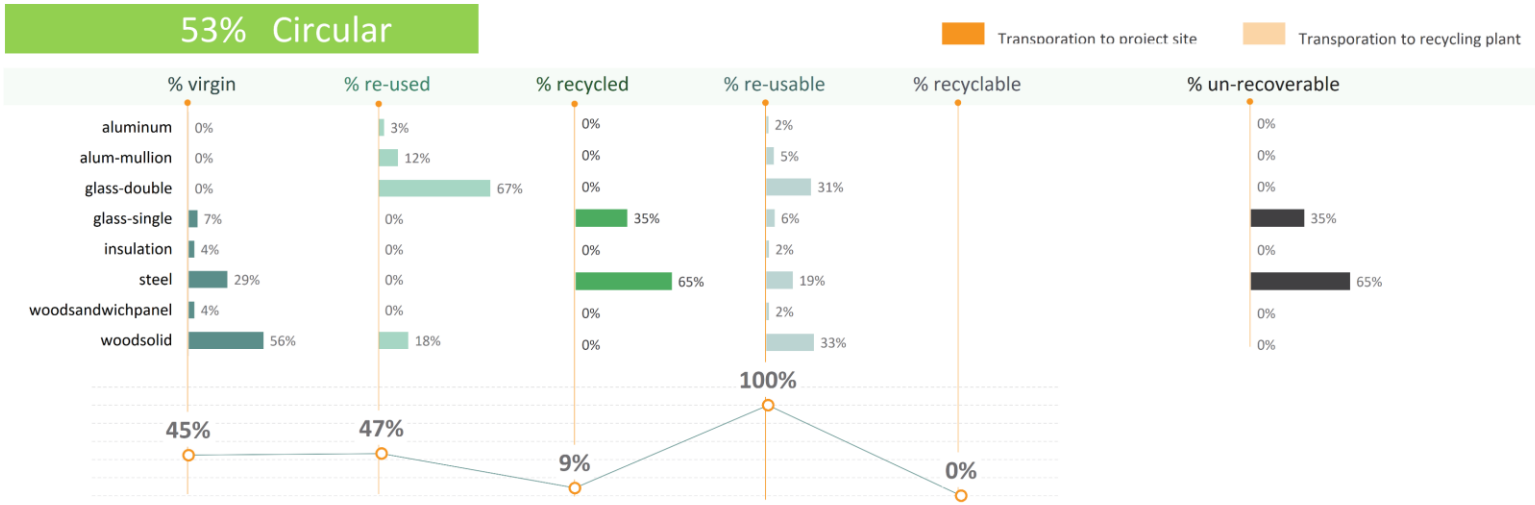


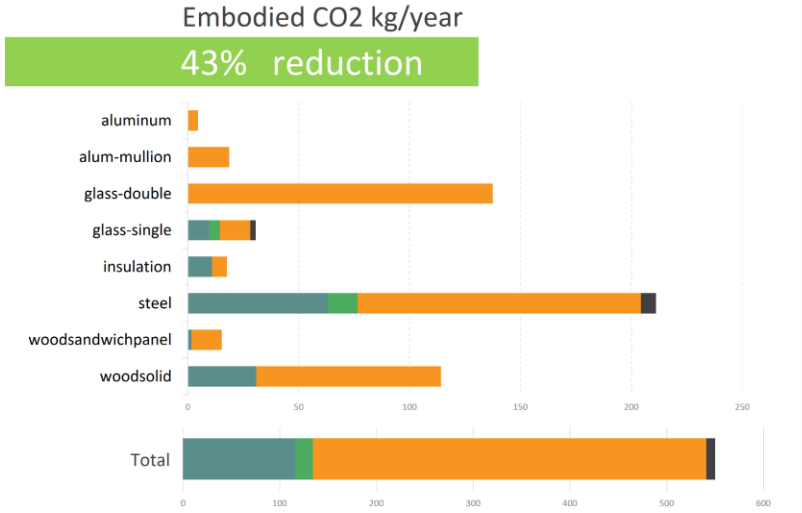


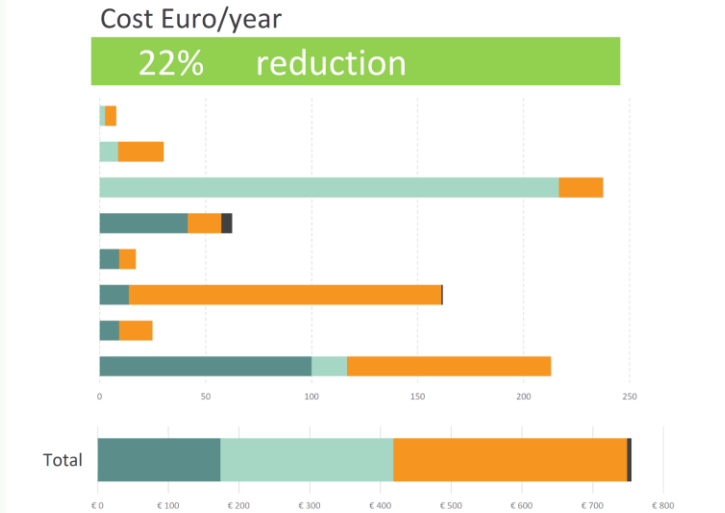
Design Case

Location: Hague Expected Lifetime: 20yrs



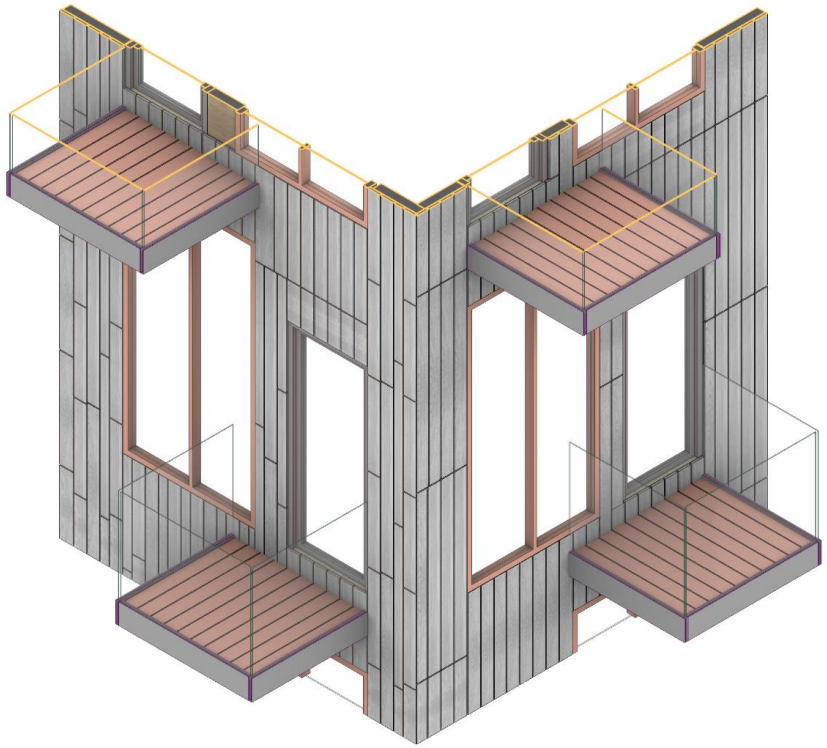


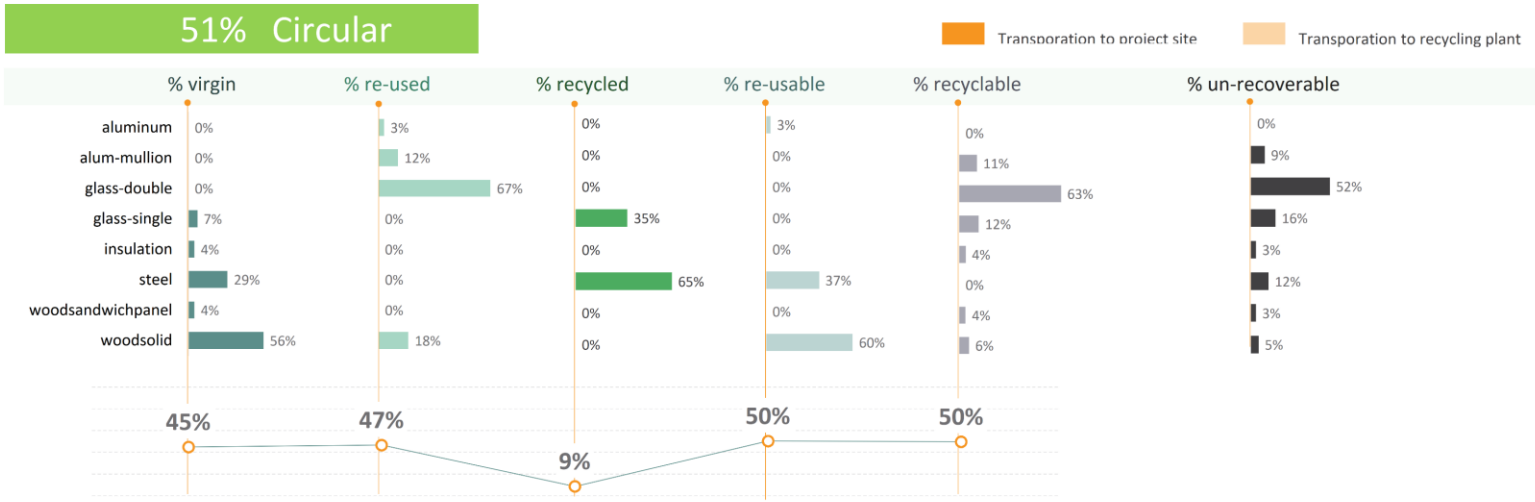


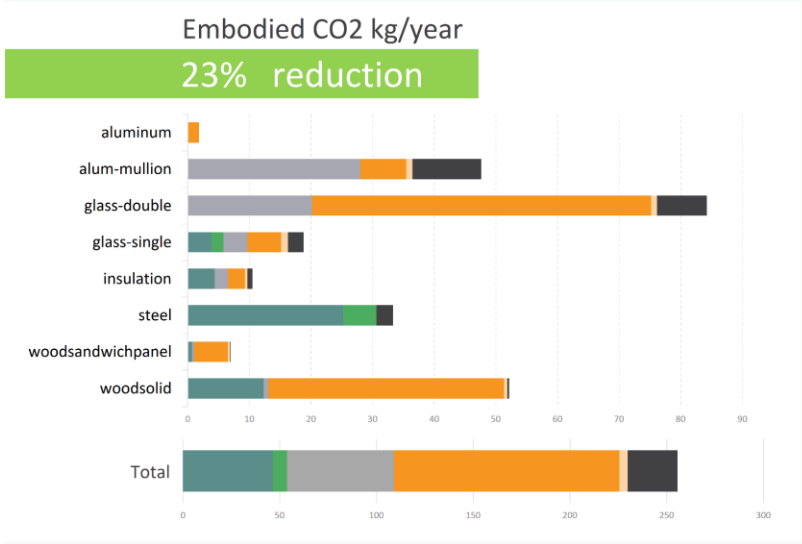


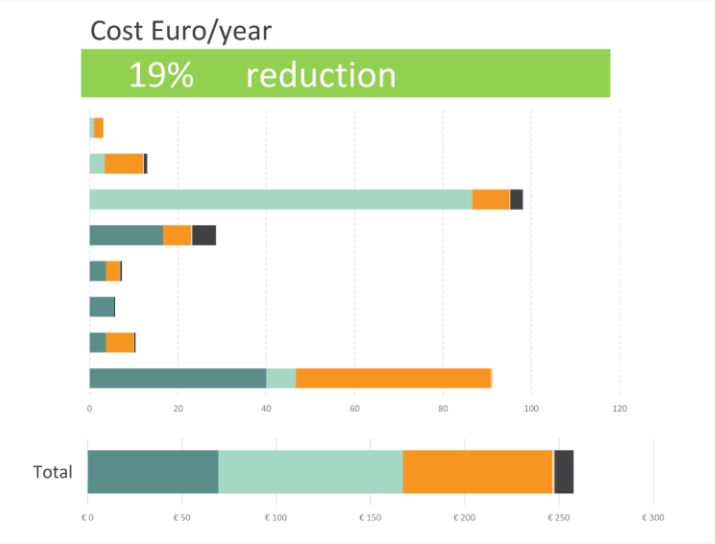
Design Case

Location: Hague Expected Lifetime: 50yrs



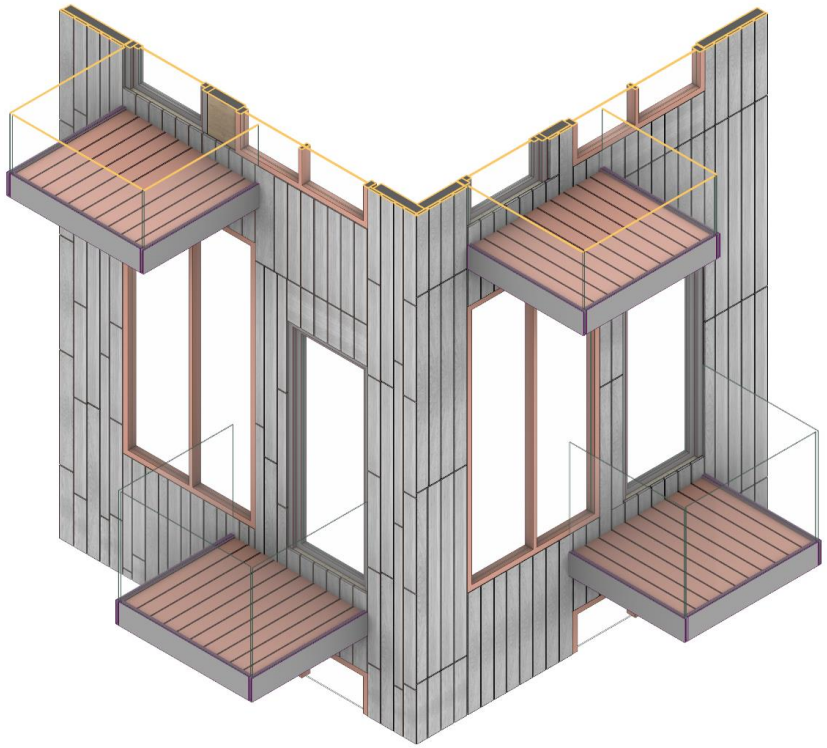


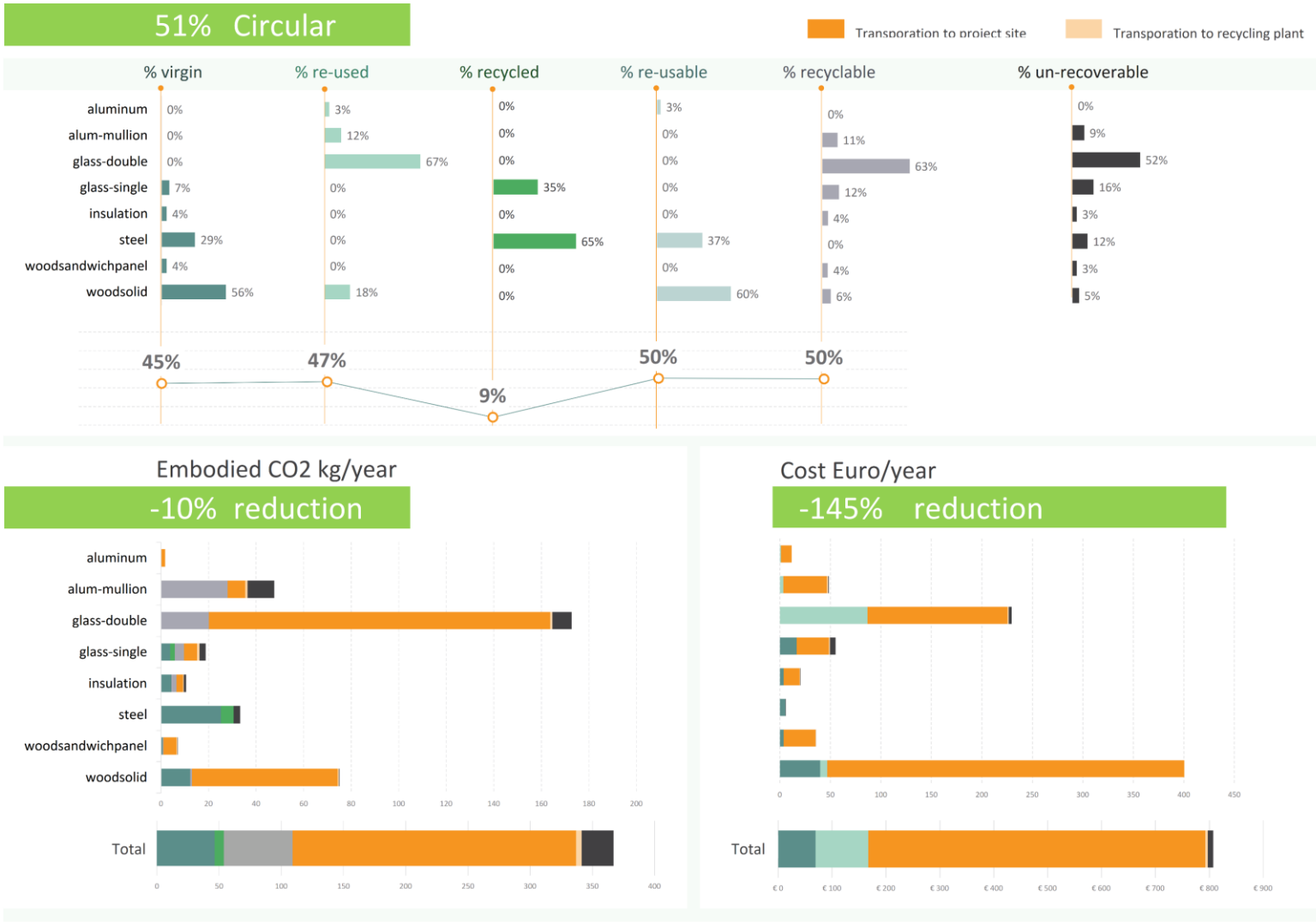




Design Case

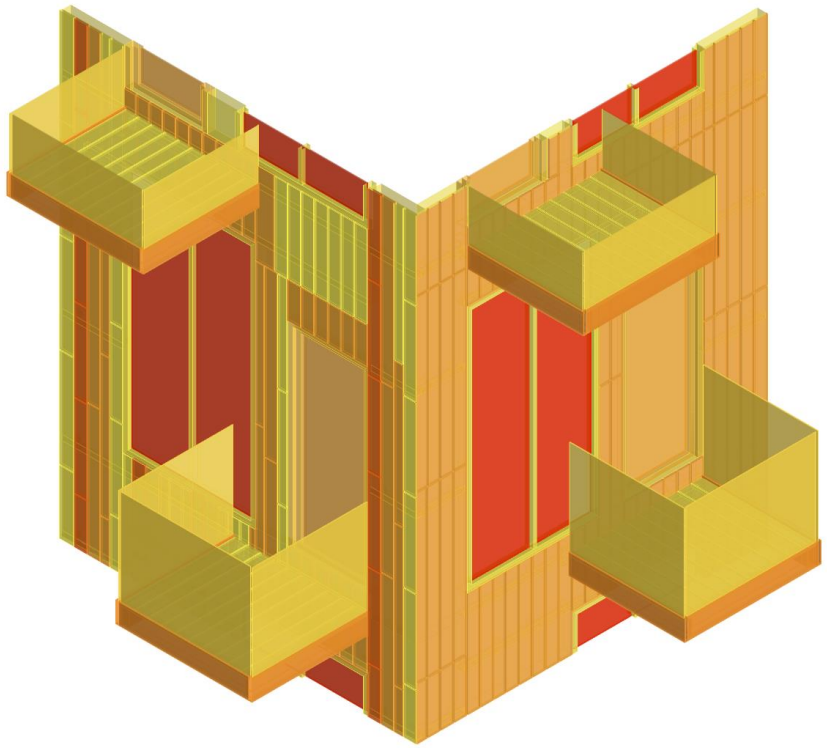
Location: Hague Expected Lifetime: 50yrs

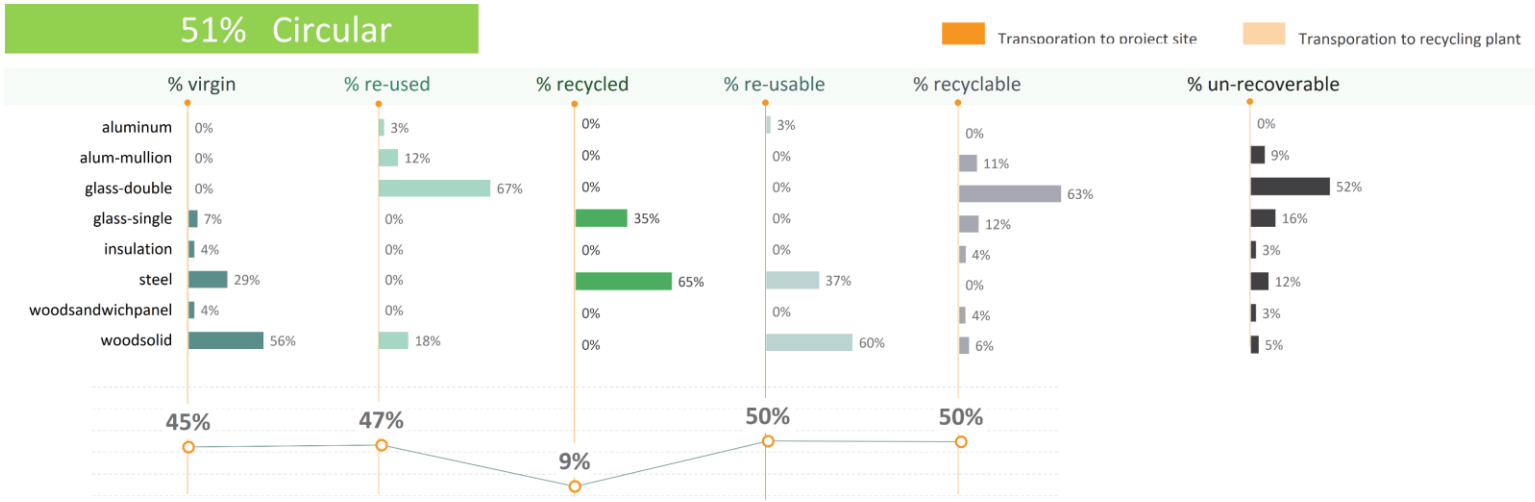


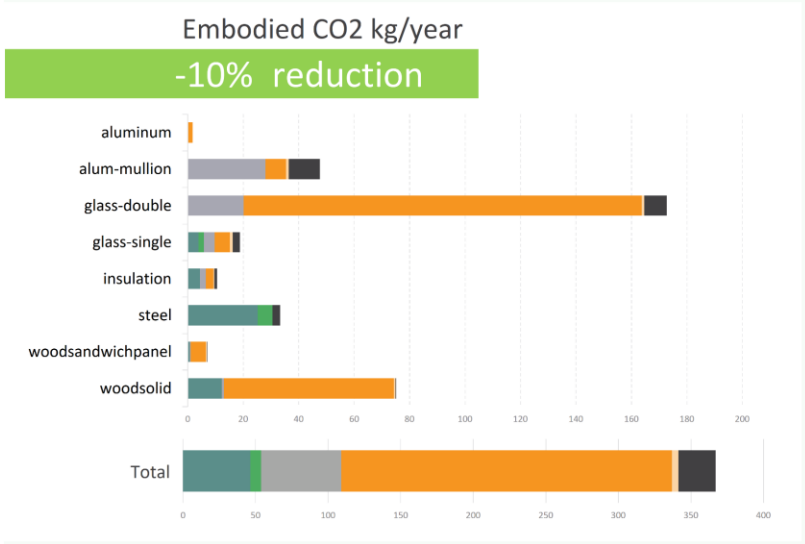


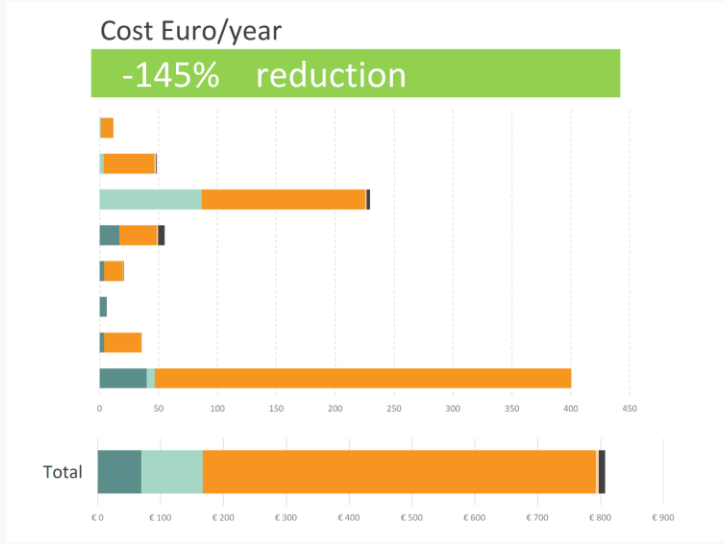
Design Case

Location: Hague Expected Lifetime: 50yrs









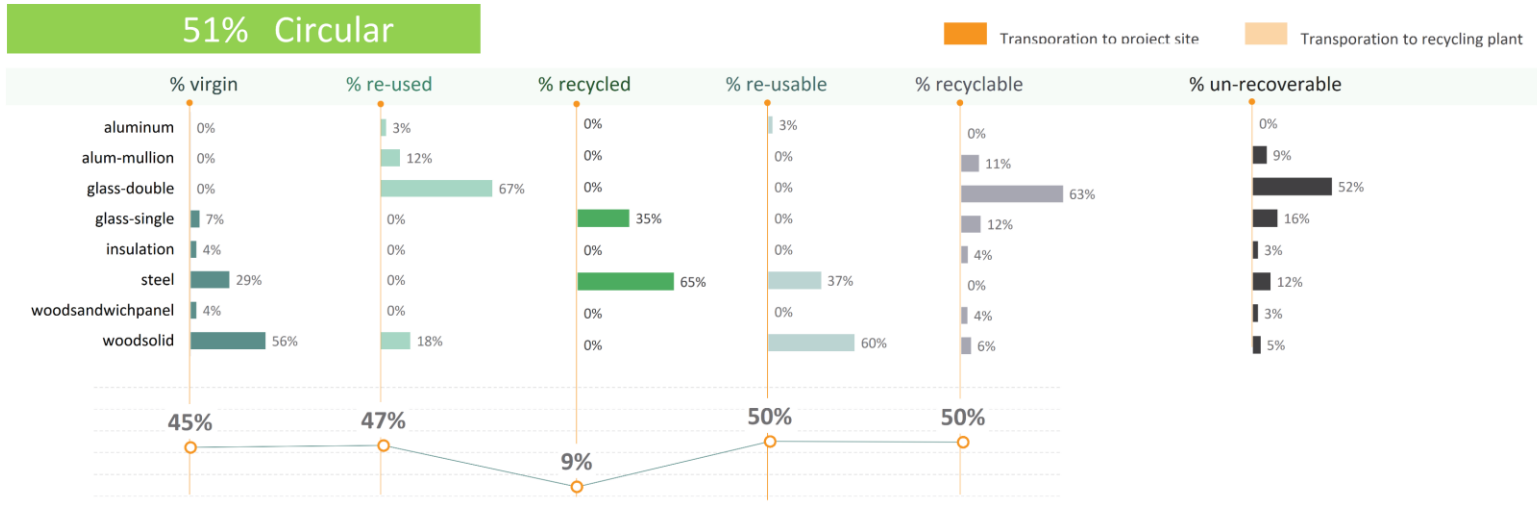
Design Case

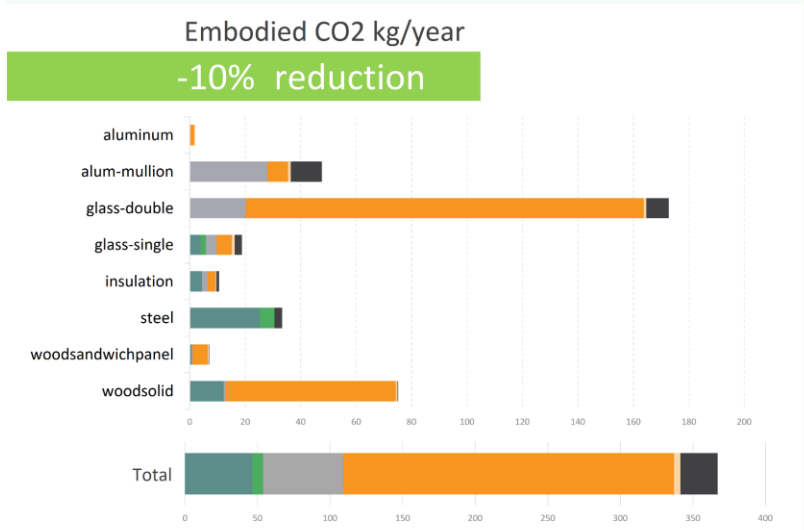
Location: Hague Expected Lifetime: 50yrs

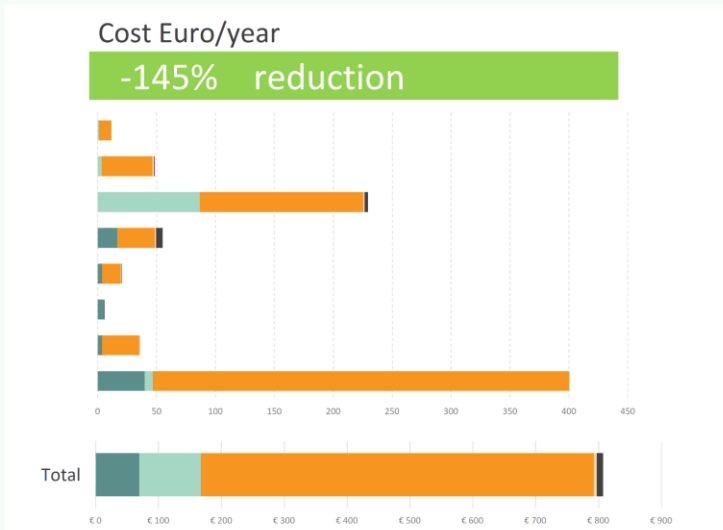
	AW	AX	AY	AZ	BA	BB	BC	BD	BE
1	recyclable nt (kg)	CO2 due to unrecoverable e (kg)	Embodied CO2 (kg/yr)	CO2 of a linear equivalent (kg)	CO2 reduction	Cost of virgin content (Euro)	Cost of reused content y/yr)	Cost due to transport y/yr)	Cost of transportation of clable content (Eur	Cost of Land
2				%						
3	0,00	0,00	1229,76	100%	0,00	16,80	0,00	0	0	
4	2,48	43,57	107,48	79%	0,00	37,67	0,00	68,31	14,49	
5	1,03	7,78	13,48	70%	0,00	2,16	0,00	2,11	0,83	
6	5,16	41,78	71,02	69%	0,00	55,34	0,00	17,90	21,29	
7	47,30	0,00	474,66	100%	0,00	14,58	0,00	0,00	0,00	
8	4,10	130,22	892,62	92%	0,00	82,08	0,00	260,45	31,57	
9										
10										
11	2,52	23,60	21,31	42%	16,60	0,00	69,80	0,00	3,99	
12	1,16	69,59	52,71	31%	2,36	0,00	277,99	0,00	0,24	
13	1,16	69,59	52,71	31%	2,36	0,00	277,99	0,00	0,24	
14	0,39	23,20	17,57	31%	0,79	0,00	92,66	0,00	0,08	
15	0,00	6,85	5,14	31%	4,04	0,00	29,37	0,00	0,00	
16										
17										
18	0,30	10,68	6,17	10%	0,00	2,42	70,49	0,00	0,00	
19	5,83	7,49	58,54	93%	0,00	1,80	49,45	0,00	0,00	
20	5,36	6,89	53,79	93%	0,00	1,65	45,44	0,00	0,00	
21	1,35	13,80	13,75	48%	0,00	14,44	91,08	0,00	0,00	
22	0,06	5,08	3,07	14%	1,56	0,00	29,70	0,00	0,00	
23	0,08	6,77	4,09	14%	2,08	0,00	39,60	0,00	0,00	
24										

material info | Distance calc | lifecycle management | Design c

Ready



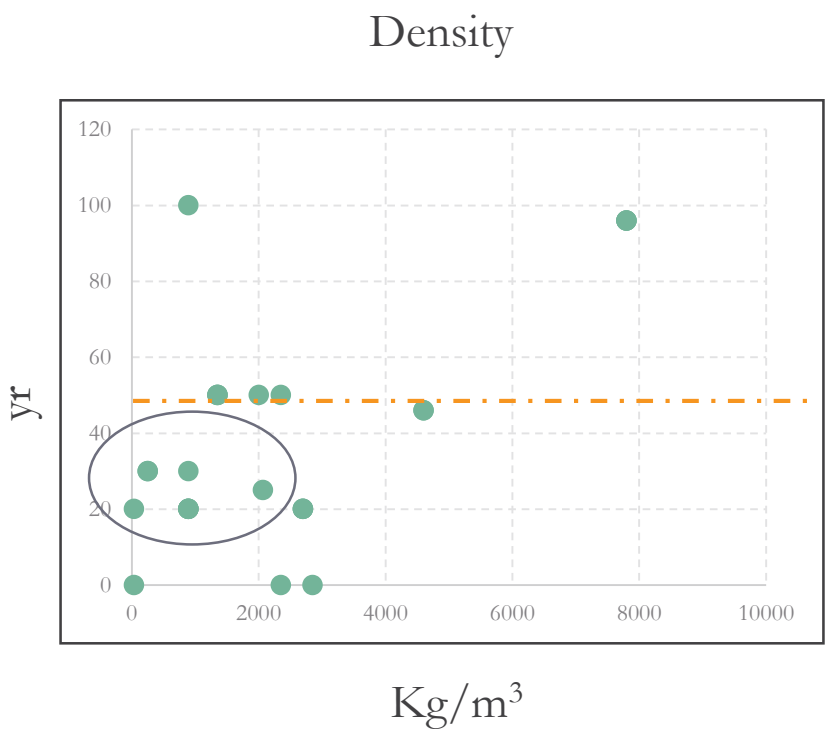


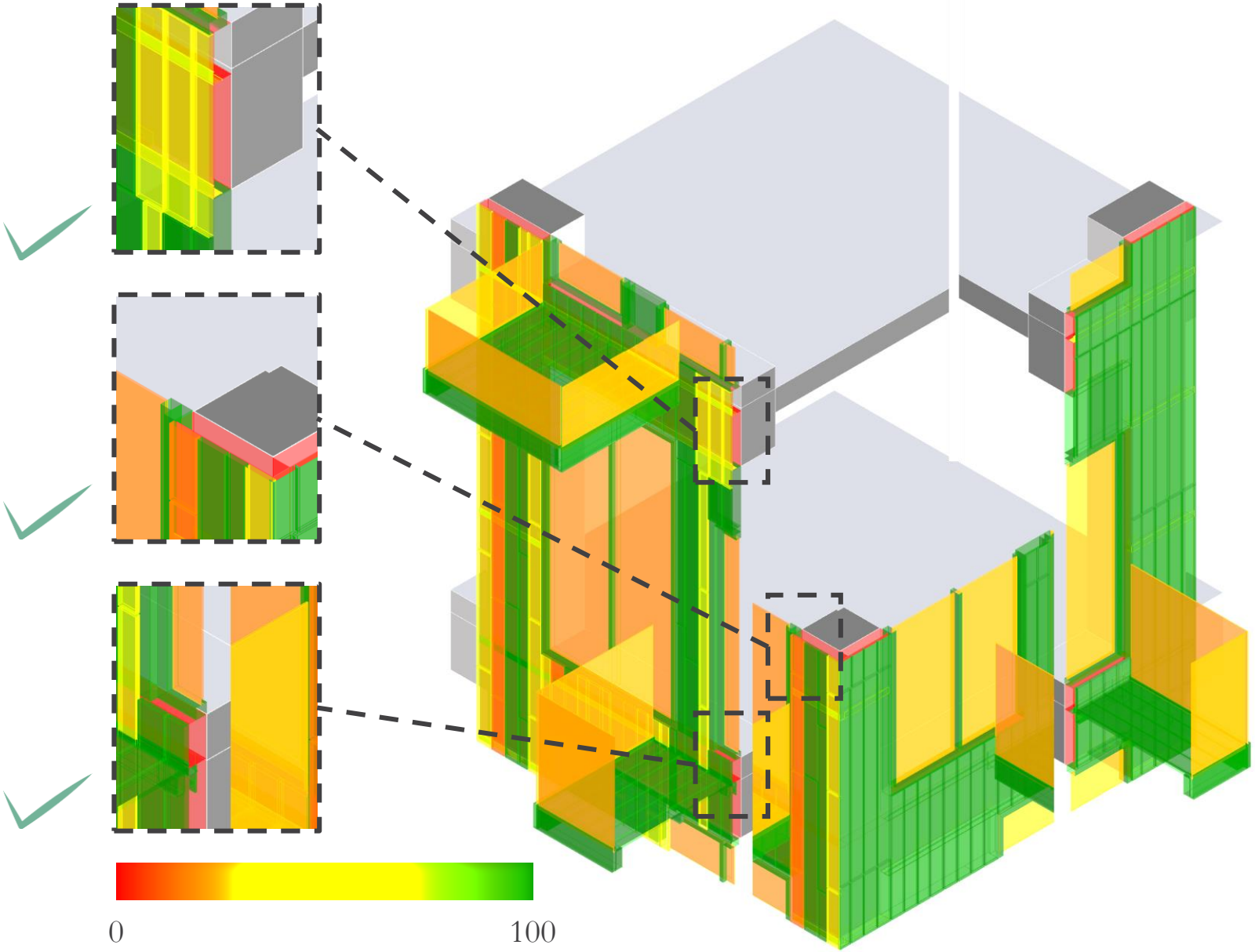


Ankur Gupta | 4732960

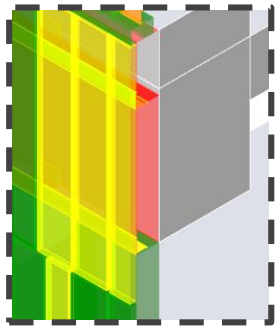
Design Case

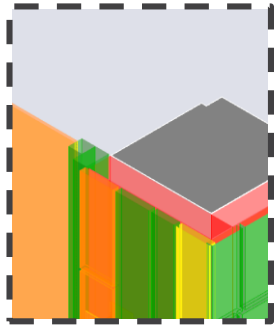
Location: Hague Expected Lifetime: 50yrs

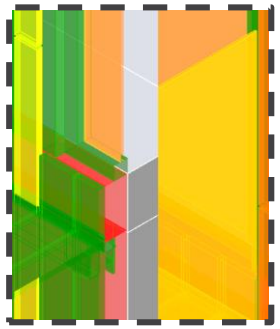


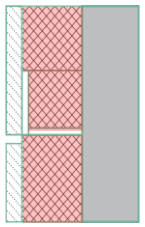


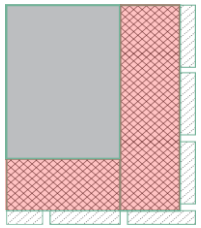
Design Case

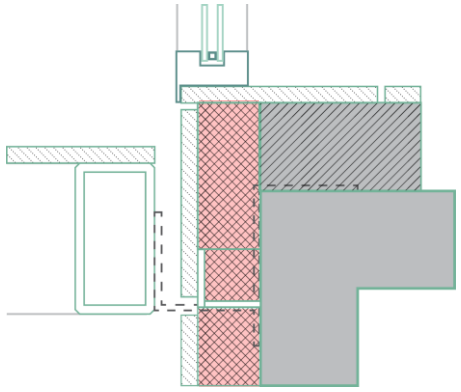


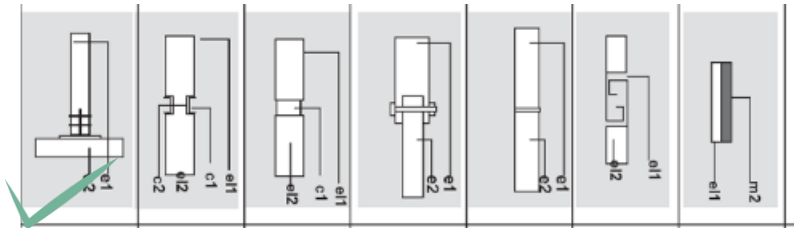


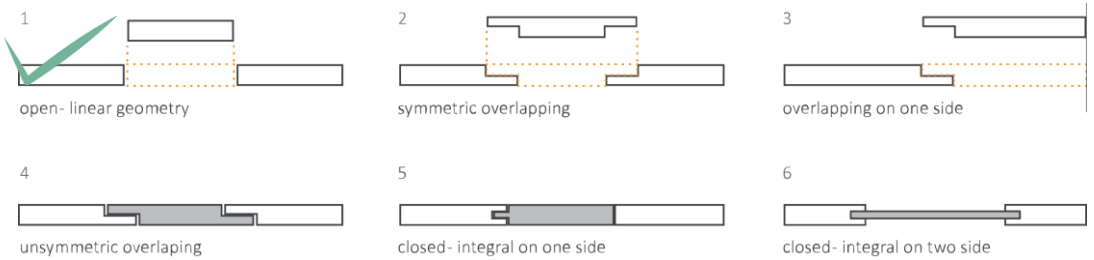


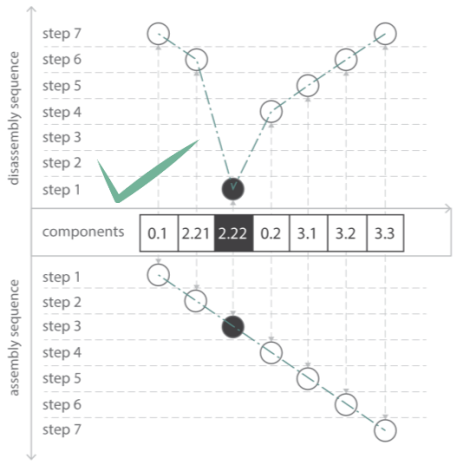


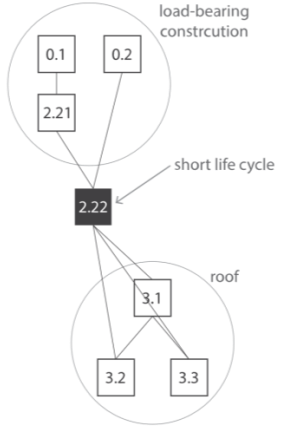





e1
e2
c2
el2
c1
el1
el2
c1
el1
e1
e2
e1
e2
el2
el1
el1
m2

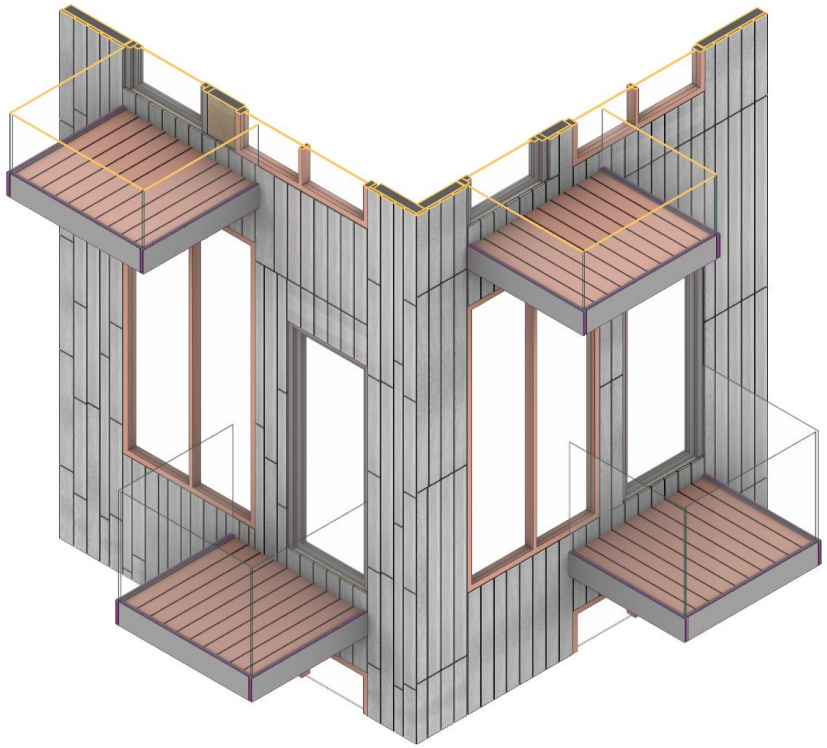

1
open- linear geometry
2
symmetric overlapping
3
overlapping on one side
4
unsymmetric overlaping
5
closed- integral on one side
6
closed- integral on two side


disassembly sequence
step 7
step 6
step 5
step 4
step 3
step 2
step 1
components
0.1
2.21
2.22
0.2
3.1
3.2
3.3
assembly sequence
step 1
step 2
step 3
step 4
step 5
step 6
step 7

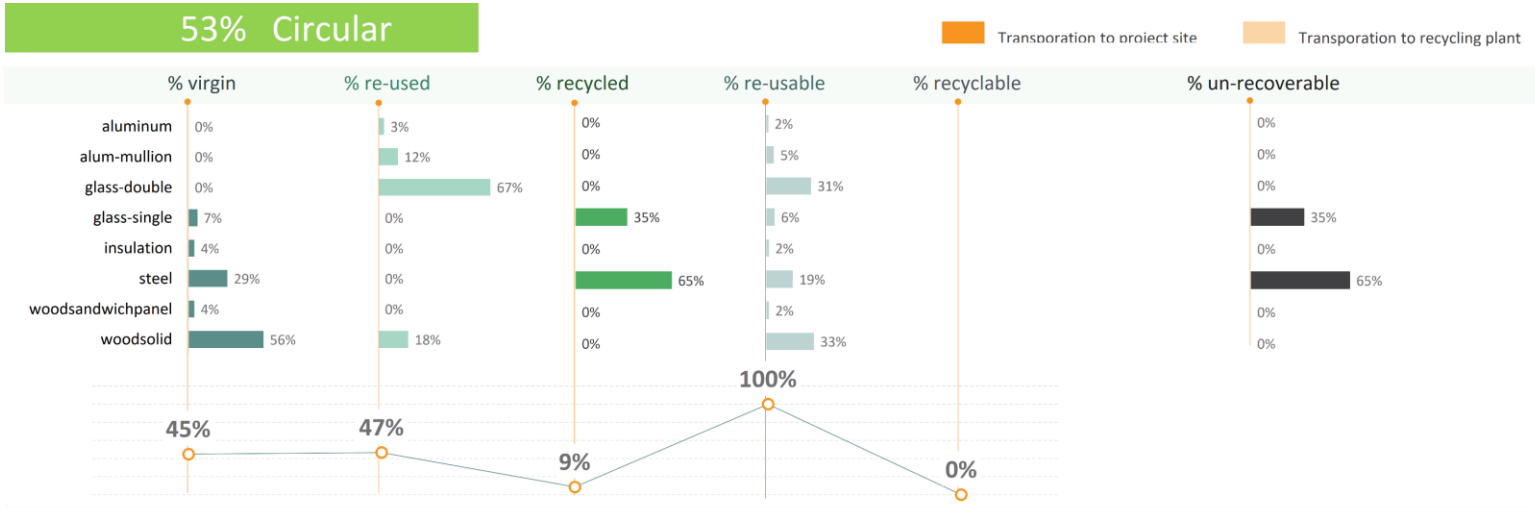

load-bearing
constrcution
0.1
0.2
2.21
short life cycle
2.22
roof
3.1
3.2
3.3

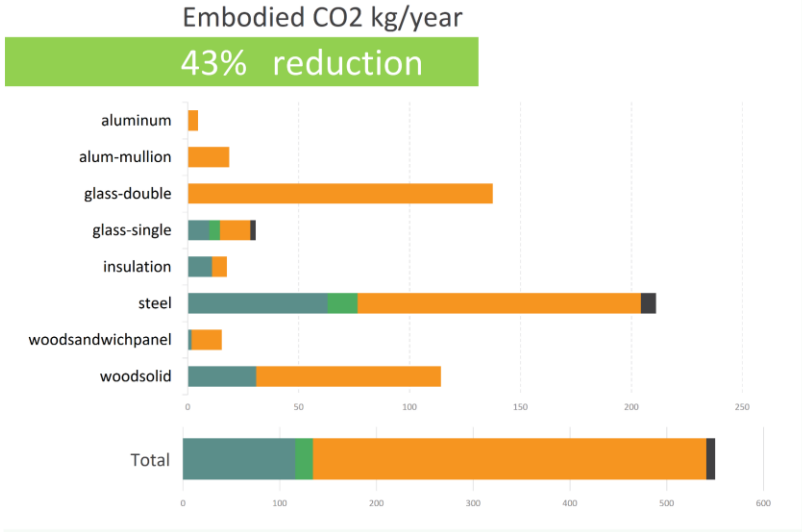
Design Case

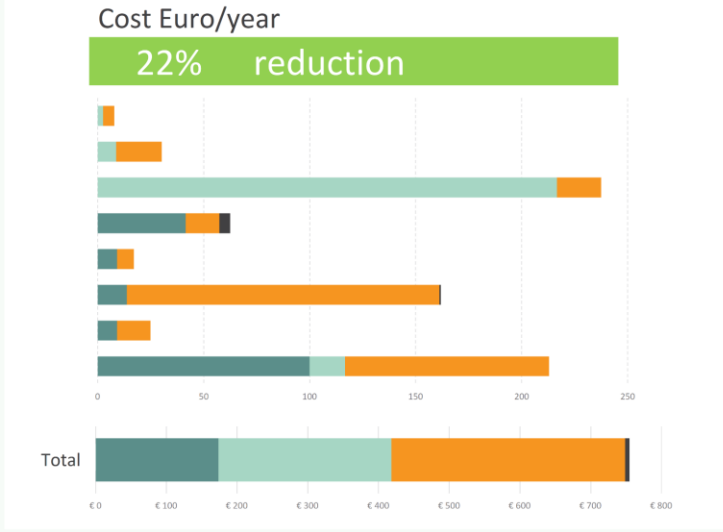
Location: Hague Expected Lifetime: 20yrs



Preliminary assessment (assumed disassembly)

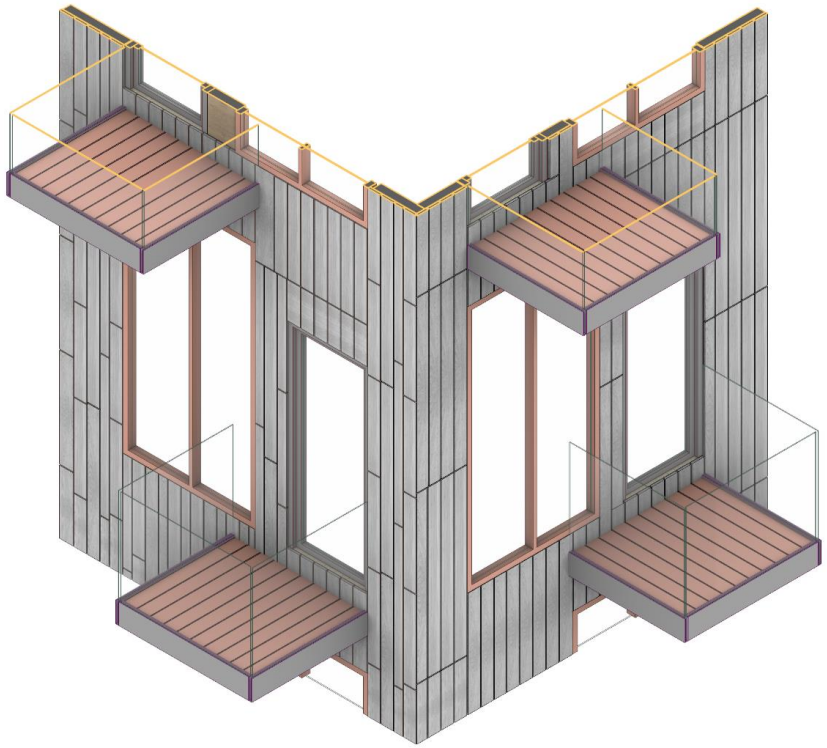




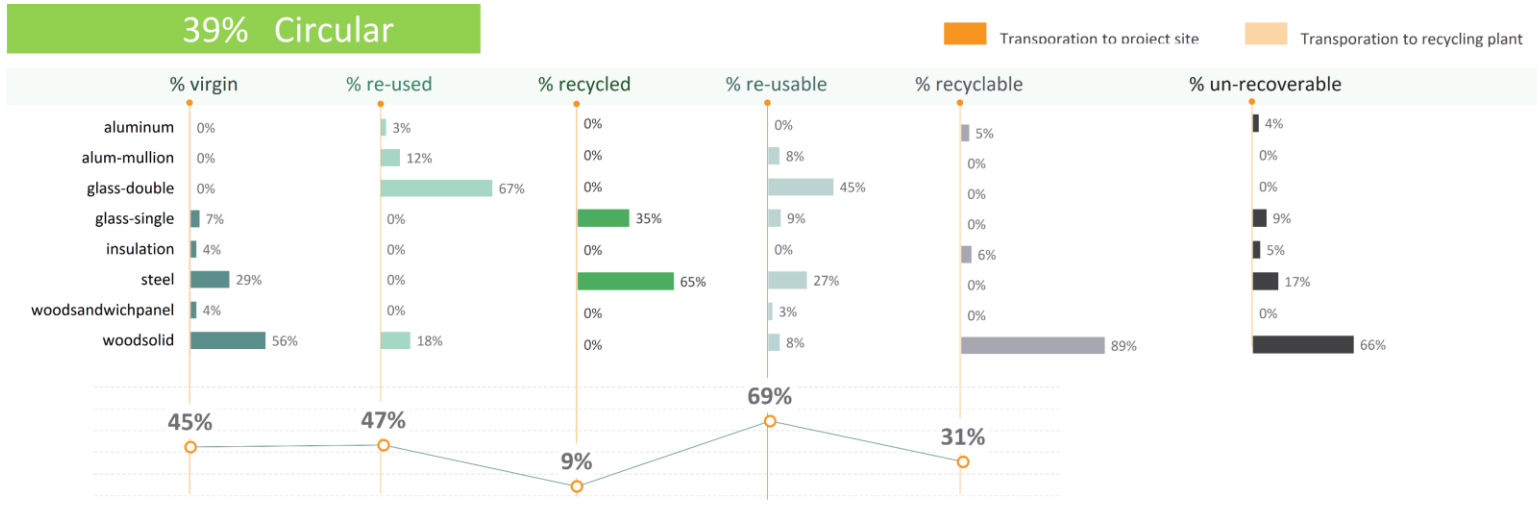


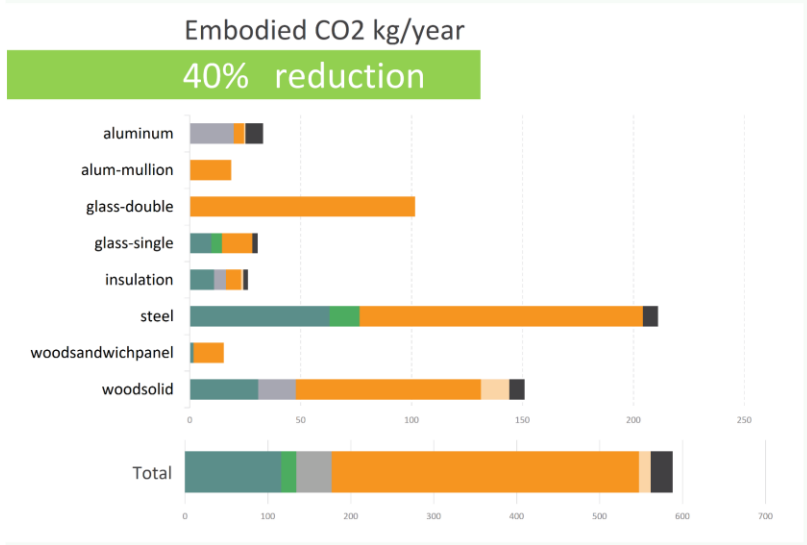
Design Case

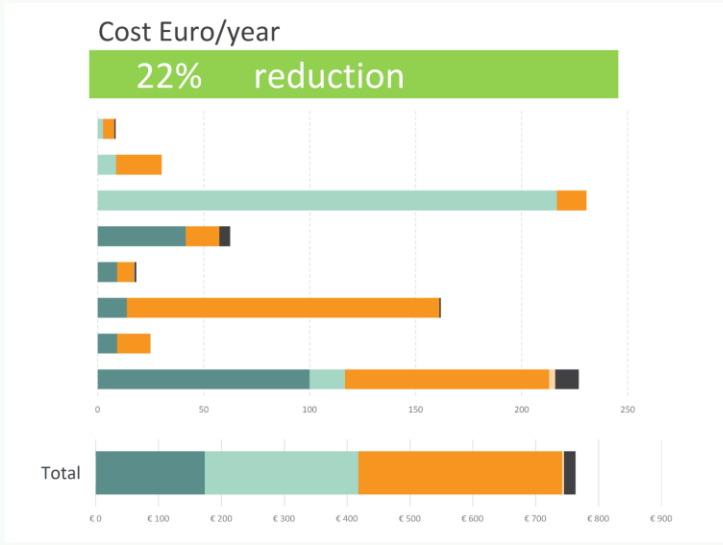
Location: Hague Expected Lifetime: 20yrs



Advanced assessment (after designing for disassembly)



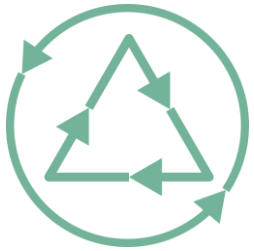




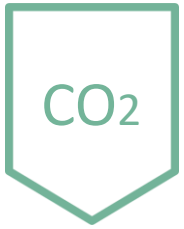
Design Case

Assessment criteria

Circular flow



Low CO_2



Tech. performance

Life expectancy

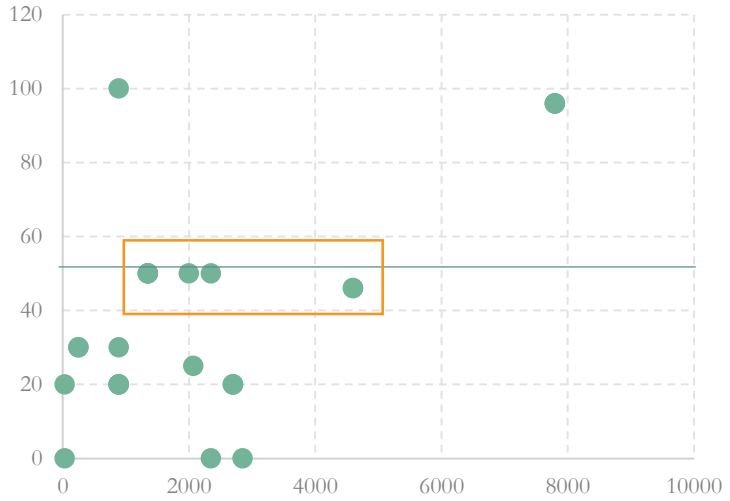
Usability

- Should help make a sustianable choice
- Enable access to available material
- Easy to use
- Transparent information

Design Case

Conclusion

High circularity ≠ Low Environmental impacts

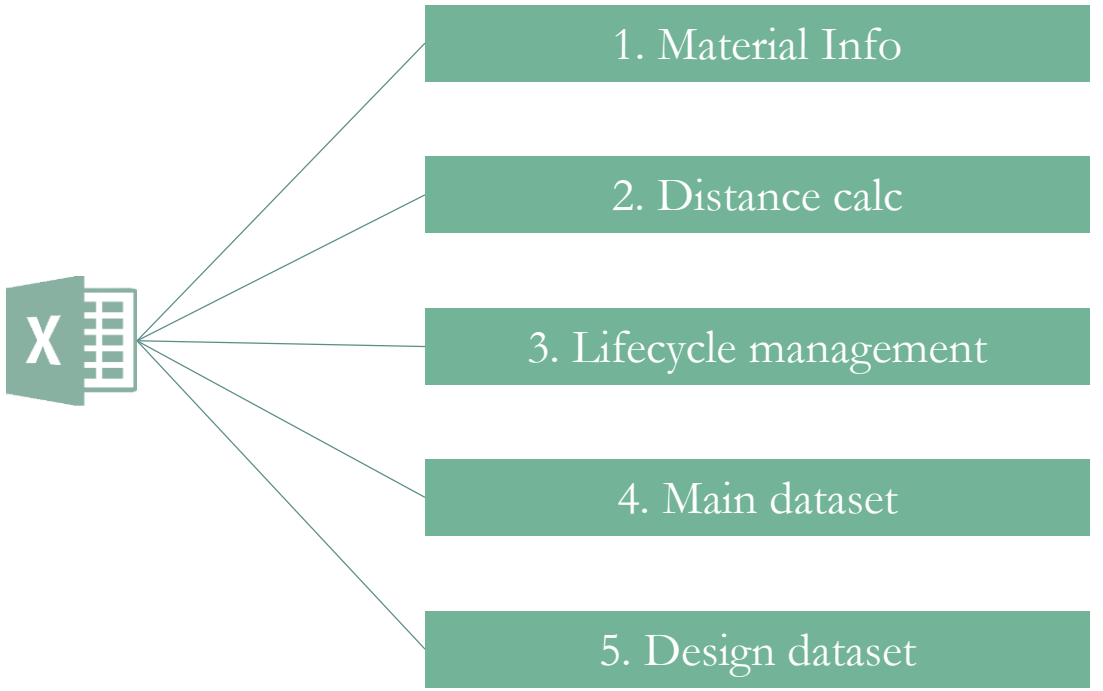


Not everything has to be Demountable

Assessment Framework

1 Material Database

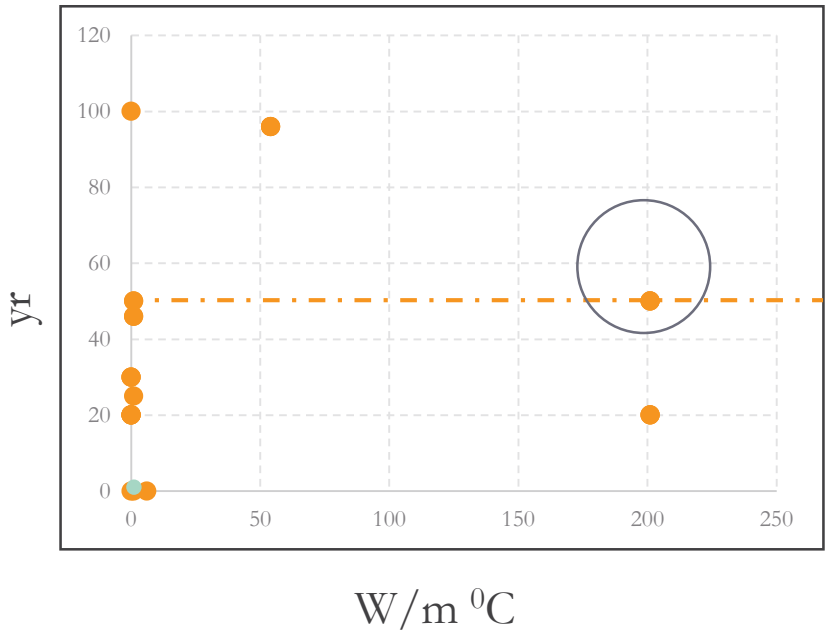
A tabular database of secondary material stored in Excel

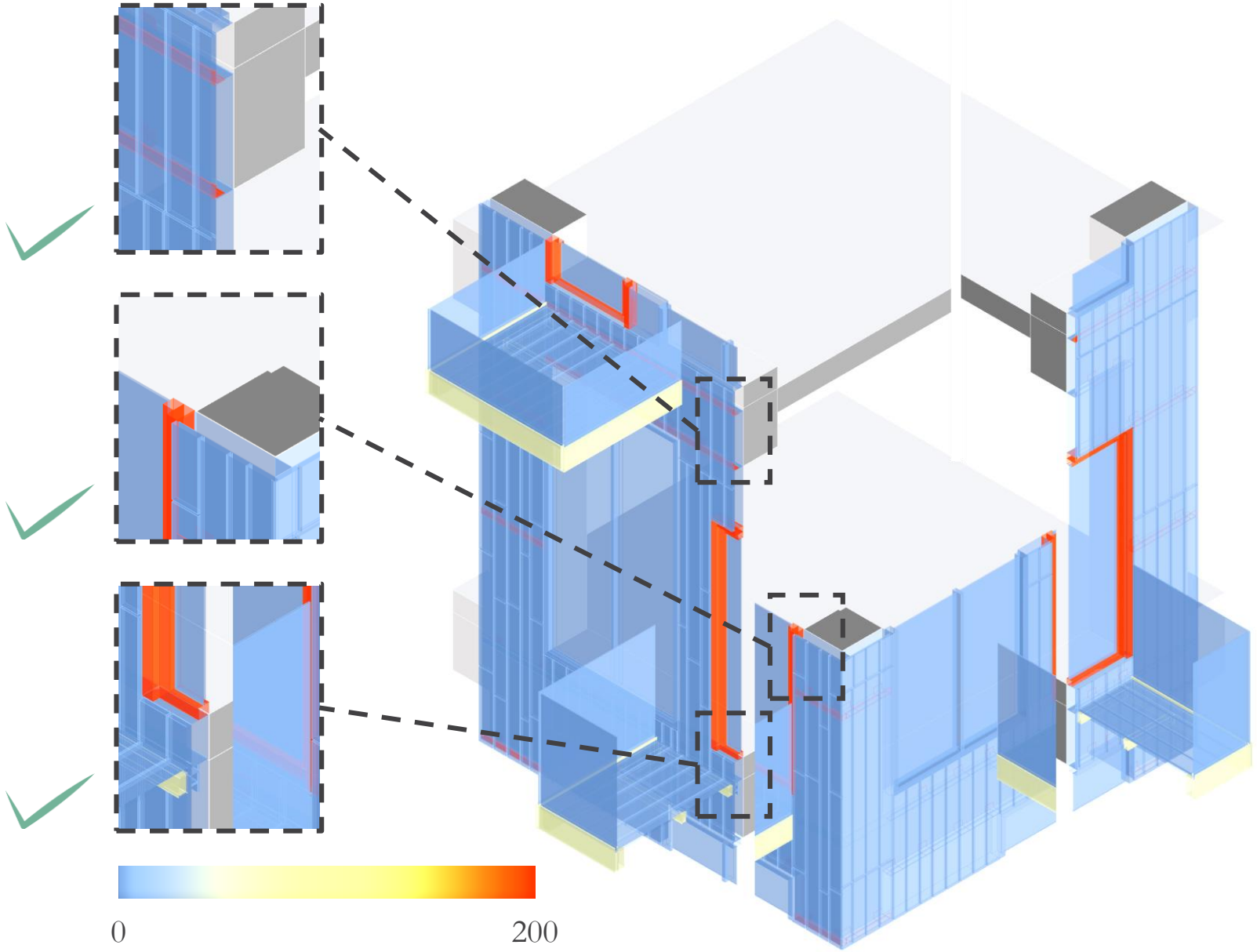


Design Case

Location: Hague Expected Lifetime: 50yrs

Thermal conductivity

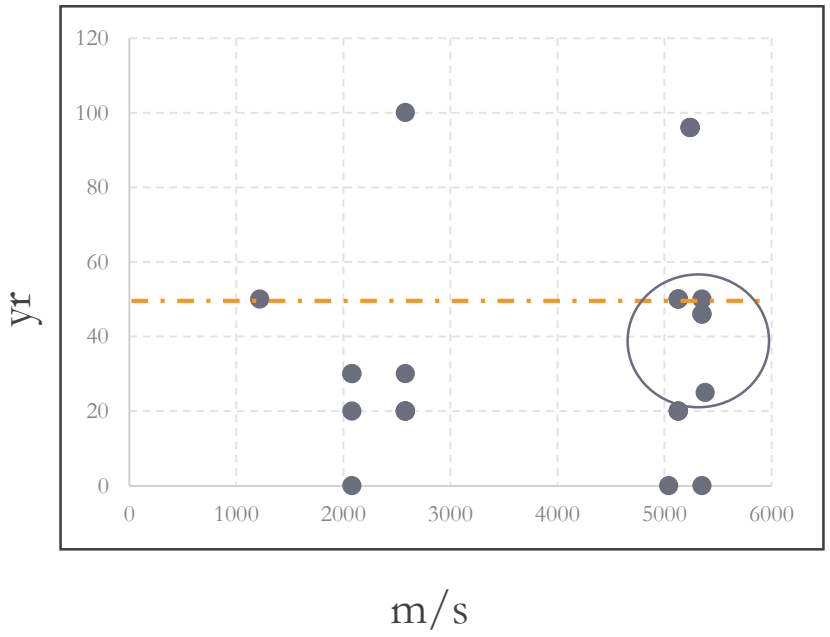


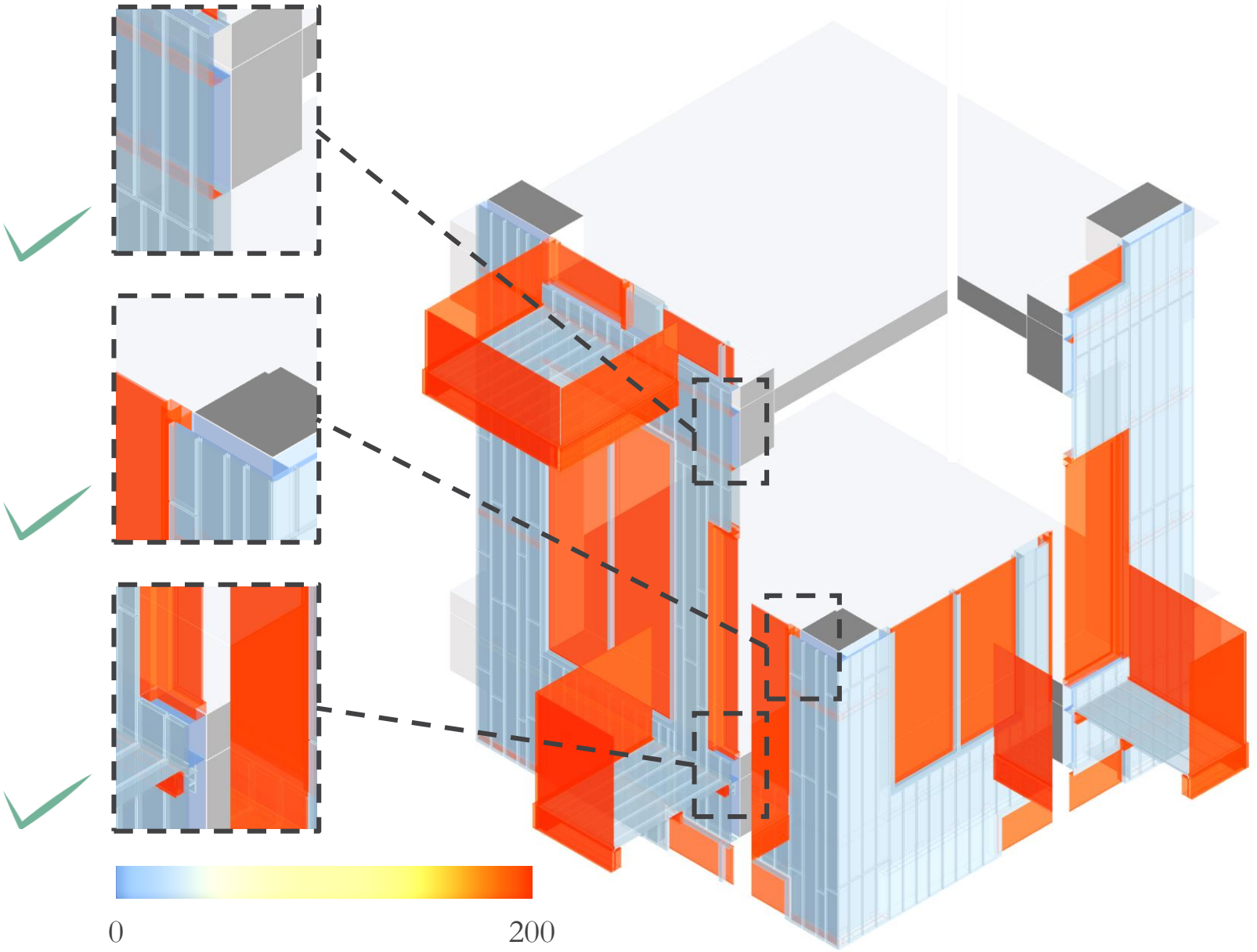


Design Case

Location: Hague Expected Lifetime: 50yrs

Acoustic velocity





Conclusion

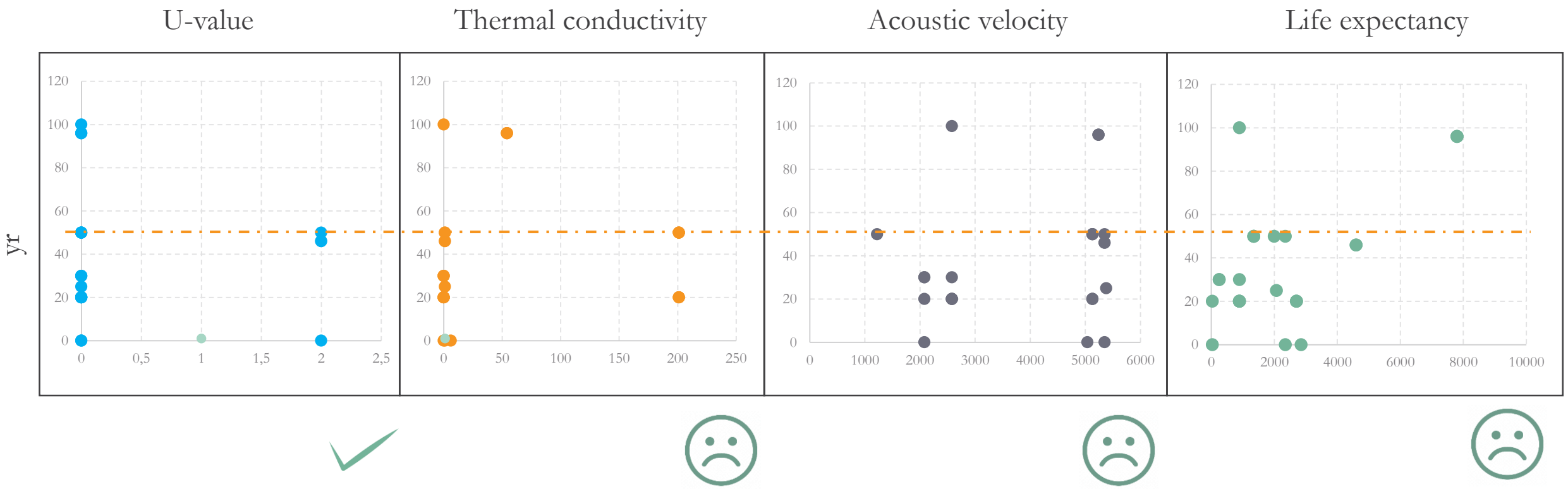
Main Question

What **information** is required by a designer to use second-hand material in building design – ensuring **circular flow** of materials at end of use, while keeping **low** environmental **impacts**, **cost** and **energy** consumption? And **when** and **how** should it be provided to them?

- Geometry
- Availability
- Materiality
- Life expectancy
- Quantity
- Circularity indicator
- Embodied CO_2 kg/yr
- Cost euro/yr
- Techncial indicators
- Initial design phase
- Assessment framework

Design Case

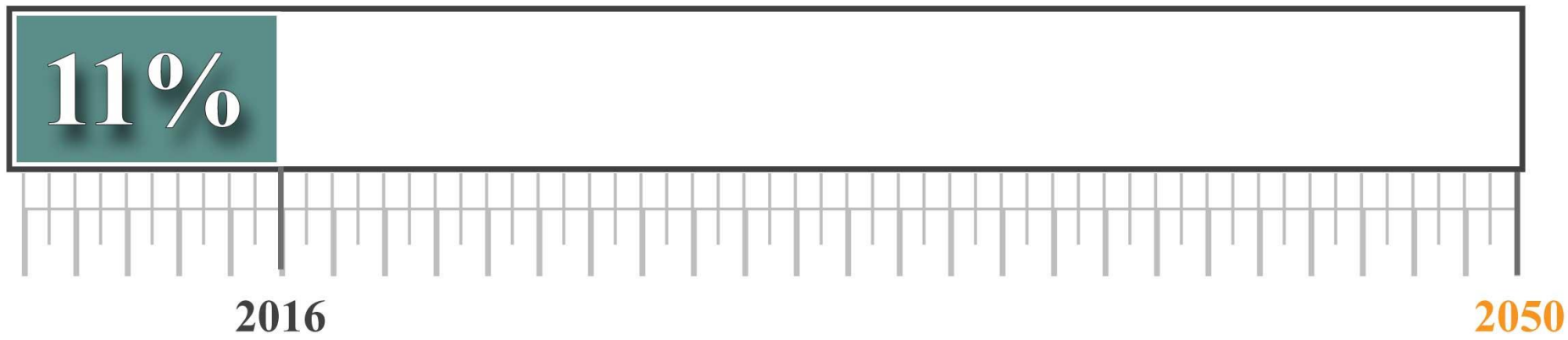
Location: Hague Expected Lifetime: 50yrs



Context

Circular Material Use rate

Total raw-material demand in Europe

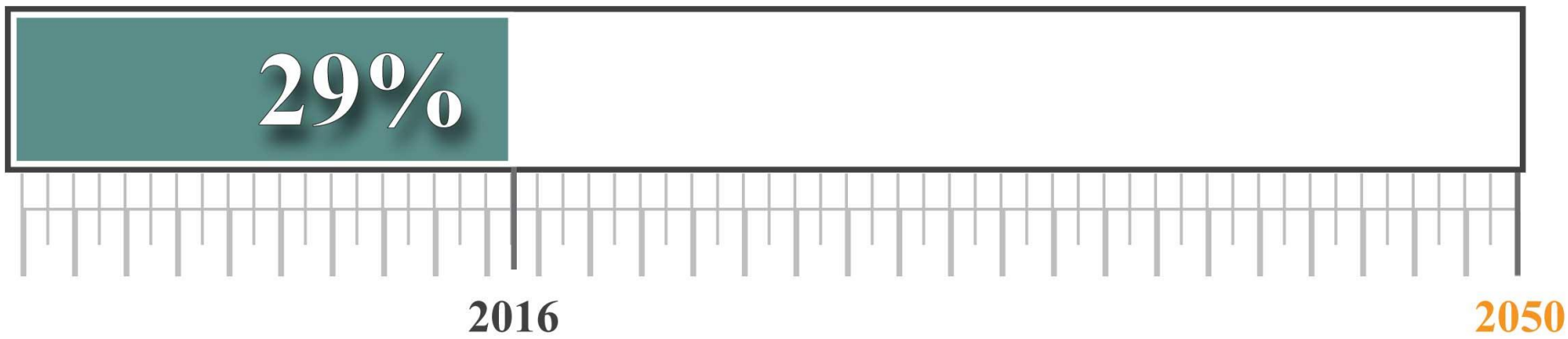


Secondary material

Context

Circular Material Use rate

Total material demand in The Netherlands

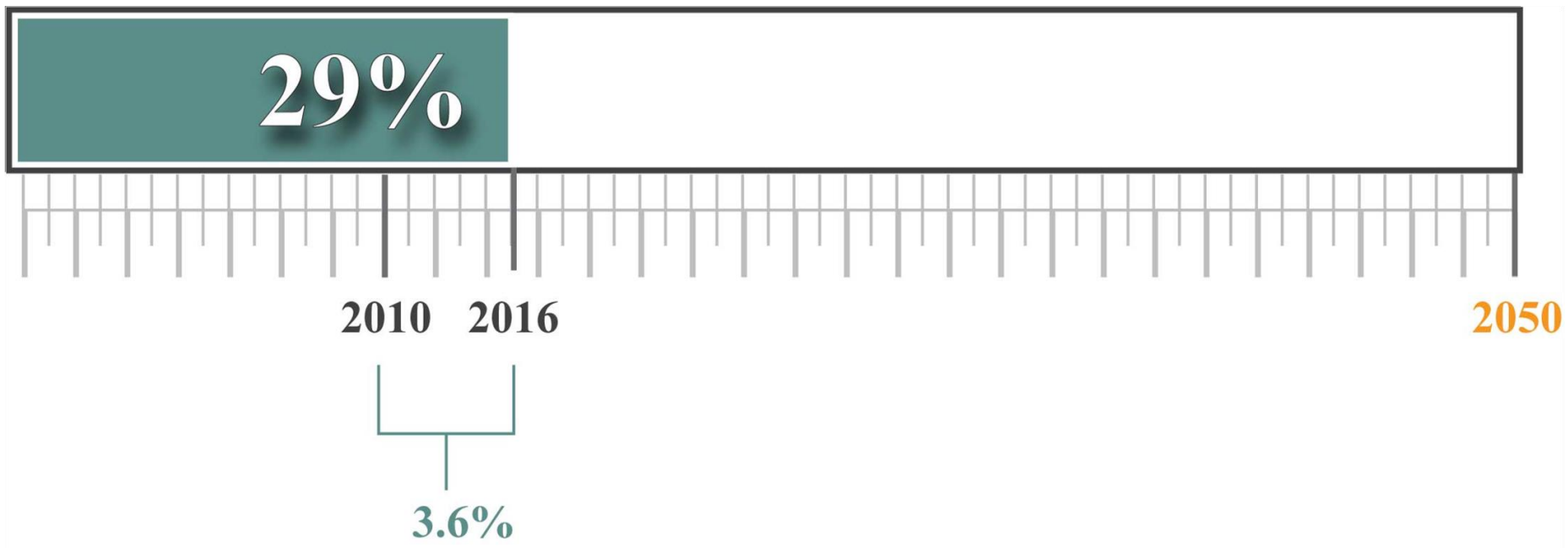


Secondary material

Context

Circular Material Use rate

Total material demand in The Netherlands

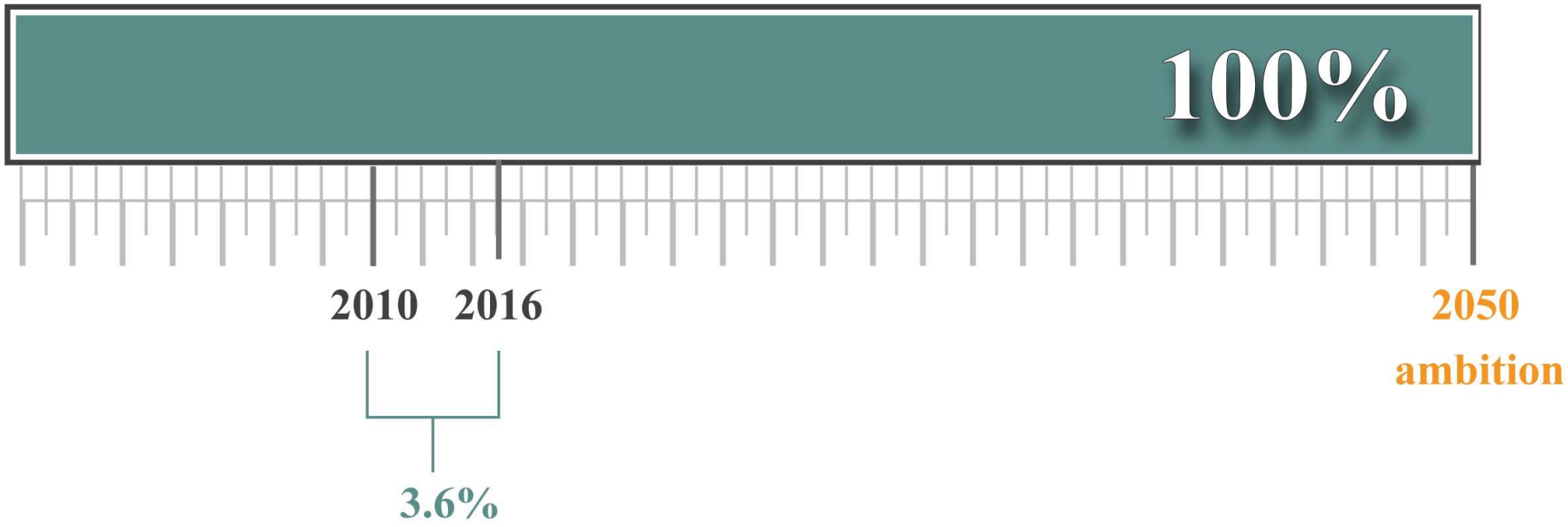


Secondary material

Context

Circular Material Use rate

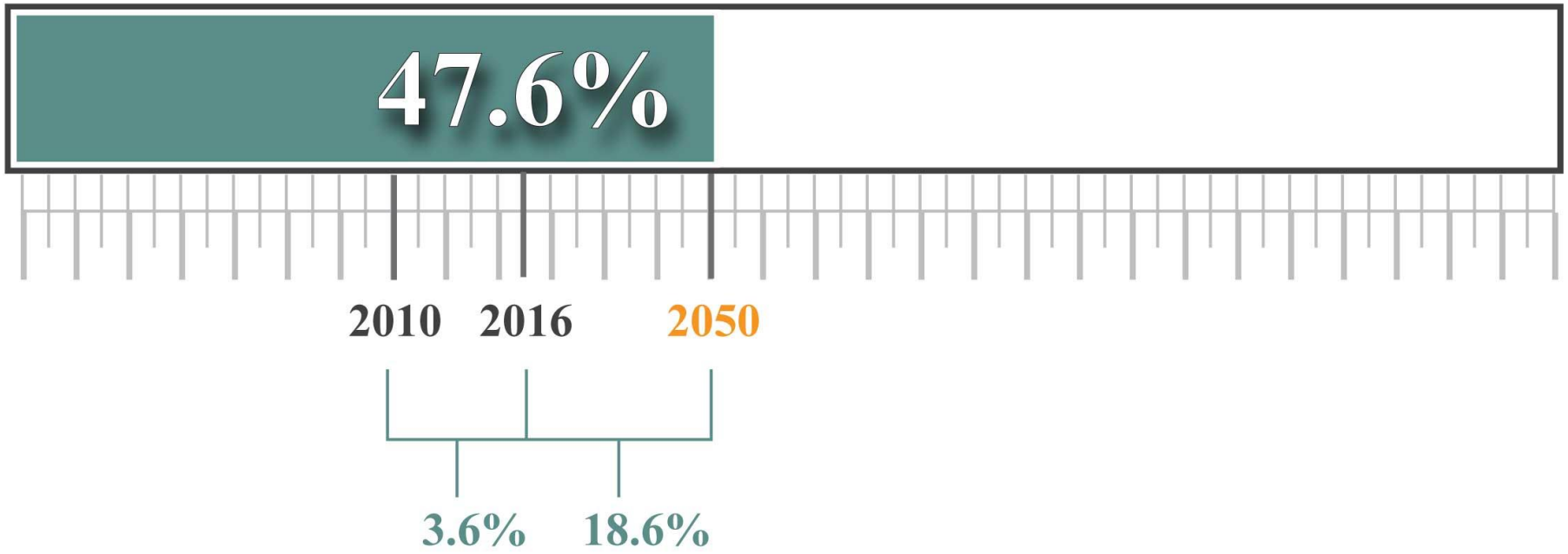
Total material demand in Europe



Secondary material by 2050

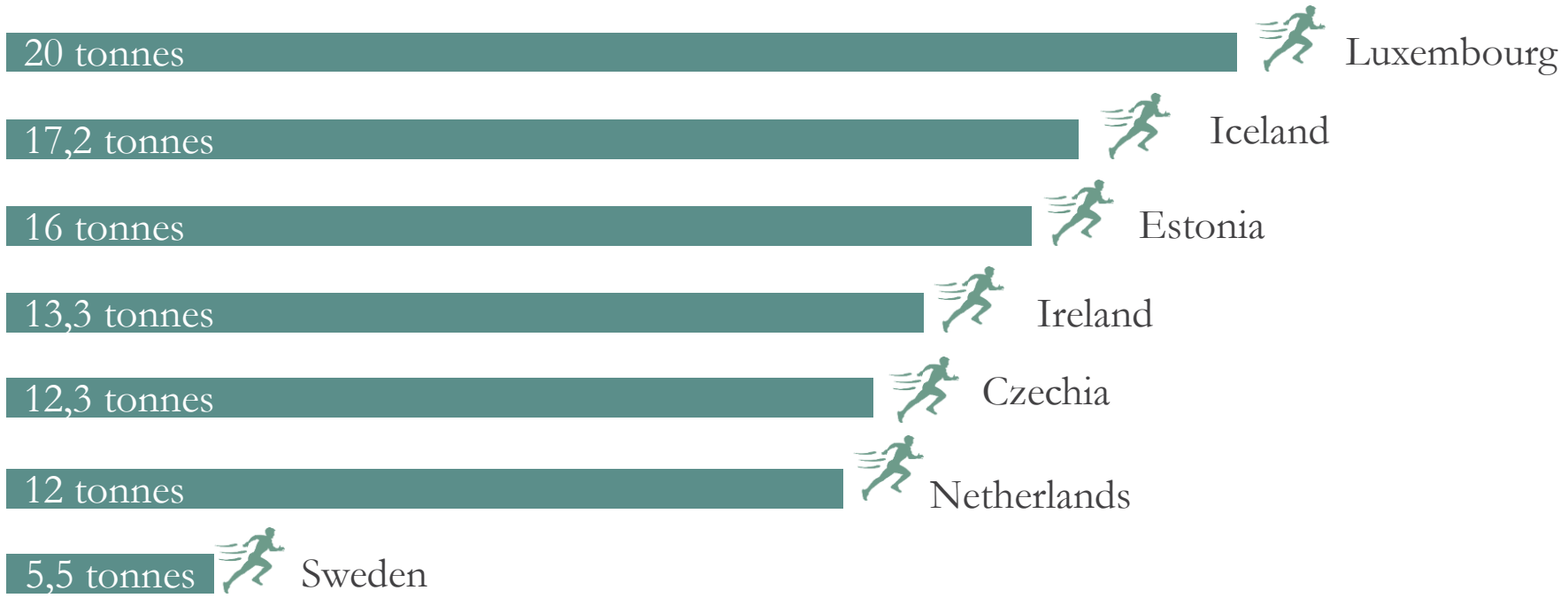
Circular Material Use rate

Total material demand in Europe



Probable secondary material by 2050

Greenhouse gas emissions per capita



3,2 tonnes higher than Europe's average

Assessment Framework

1 Material Database

A tabular database of secondary material stored in Excel

- Density
- U-value
- Thermal conductivity
- Carbon emissions

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Material	Density	Cost Euro/kg	Virgin CO2kg/kg	Recycling CO2/kg	Recycle efficiency	Landfill CO2/kg	Transport CO2/kg p. km	Age	Thermal conductivity	Acoustic velocity (m/s)	Uvalue	Fire rating
2						Ef	Cl	Ct					
3	woodboard	900	0,4	1,05	1,05	0,8	2,1	0,026	4	0,35	2580	0	4
4	woodsolid	890	2,27	0,7	0,7	0,8	1,4	0,026	4	0,35	2580	0	4
5	aluminum	2700	1,8	14,6	14,6	0,8	29,2	0,026	4	201	5130	0	4
6	alum-mullion	1350	1,8	14,6	14,6	0,8	29,2	0,026	4	201	5130	0	4
7	steel	7800	0,6	2,75	2,75	0,8	5,5	0,026	4	54	5240	0	4
8	woodsandwichpanel	250	2,6	0,5	0,5	0,8	1	0,026	4	0,03	2080	0	4
9	alumsandwichpanel	50	2,6	0,2	0,2	0,8	0,4	0,026	4	0,03	2080	0	4
10	glass-single	2350	7,85	1,83	1,83	0,8	3,66	0,026	4	1,1	5350	1,5	4
11	glass-double	4600	7,85	1,83	1,83	0,8	3,66	0,026	4	1,1	5350	2,5	4
12	glass-tripple	6900	7,85	1,83	1,83	0,8	3,66	0,026	4	1,1	5350	3,5	4
13	brick	2070	1,4	0,23	0,23	0,8	0,46	0,026	4	0,8	5380	0	4
14	insulation	32	2,6	3,1	3,1	0,8	6,2	0,026	4	0,03	2080	0	4
15	acp	50	1.81	0,2	0,2	0,8	0,4	0,026	4	0,03	5130	0	4
16	concrete	2000	0,05	0,1	0,1	0,8	0,2	0,026	4	0,7	1220	0	4
17	reinforcedconcrete	2000	0,05	0,1	0,1	0,4	0,2	0,026	4	0,7	1220	0	4

Assessment Framework

1 Material Database

A tabular database of secondary material stored in Excel

1. Material Info

- Density
- U-value
- Thermal conductivity
- Carbon emissions

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Material	Density	Cost Euro/kg	Virgin CO2kg/kg	Recycling CO2/kg	Recycle efficiency	Landfill CO2/kg	Transport CO2/kg p/km	Age	Thermal conductivity	Acoustic velocity (m/s)	Uvalue	Fire rating
2						Ef	Cl	Ct					
3	woodboard	900	0,4	1,05	1,05	0,8	2,1	0,026	4	0,35	2580	0	4
4	woodsolid	890	2,27	0,7	0,7	0,8	1,4	0,026	4	0,35	2580	0	4
5	aluminum	2700	1,8	14,6	14,6	0,8	29,2	0,026	4	201	5130	0	4
6	alum-mullion	1350	1,8	14,6	14,6	0,8	29,2	0,026	4	201	5130	0	4
7	steel	7800	0,6	2,75	2,75	0,8	5,5	0,026	4	54	5240	0	4
8	woodsandwichpanel	250	2,6	0,5	0,5	0,8	1	0,026	4	0,03	2080	0	4
9	alumsandwichpanel	50	2,6	0,2	0,2	0,8	0,4	0,026	4	0,03	2080	0	4
10	glass-single	2350	7,85	1,83	1,83	0,8	3,66	0,026	4	1,1	5350	1,5	4
11	glass-double	4600	7,85	1,83	1,83	0,8	3,66	0,026	4	1,1	5350	2,5	4
12	glass-tripple	6900	7,85	1,83	1,83	0,8	3,66	0,026	4	1,1	5350	3,5	4
13	brick	2070	1,4	0,23	0,23	0,8	0,46	0,026	4	0,8	5380	0	4
14	insulation	32	2,6	3,1	3,1	0,8	6,2	0,026	4	0,03	2080	0	4
15	acp	50	1.81	0,2	0,2	0,8	0,4	0,026	4	0,03	5130	0	4
16	concrete	2000	0,05	0,1	0,1	0,8	0,2	0,026	4	0,7	1220	0	4
17	reinforcedconcrete	2000	0,05	0,1	0,1	0,4	0,2	0,026	4	0,7	1220	0	4

Assessment Framework

1 Material Database

A tabular database of secondary material stored in Excel

2. Distance calc

Product locations	From Gronigen	From Amsterdam	From Hague	From Zwolle	From Hengelo	From Arnhem	From Eindhoven	distance	project site
gronigen	0	10	100	60	40	80	200	100	hague
amsterdam	10	0	50	50	100	60	100	50	hague
hague	150	50	0	60	150	75	100	0	hague
zwolle	50	40	65	0	30	30	125	65	hague
hengelo	40	60	150	30	0	40	125	150	hague
arnhem	80	60	75	30	30	0	65	75	hague
eindhoven	200	100	100	125	125	65	0	100	hague

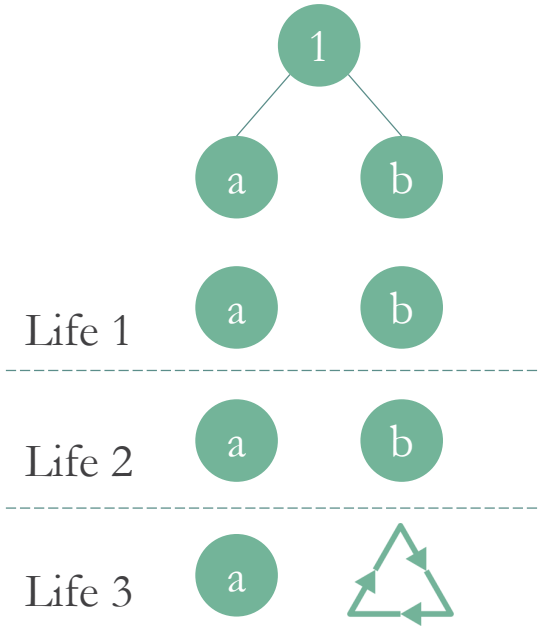
Column1	Column2
project site	hague
Use life yr	50

Assessment Framework

1 Material Database

A tabular database of secondary material stored in Excel

3. Lifecycle management



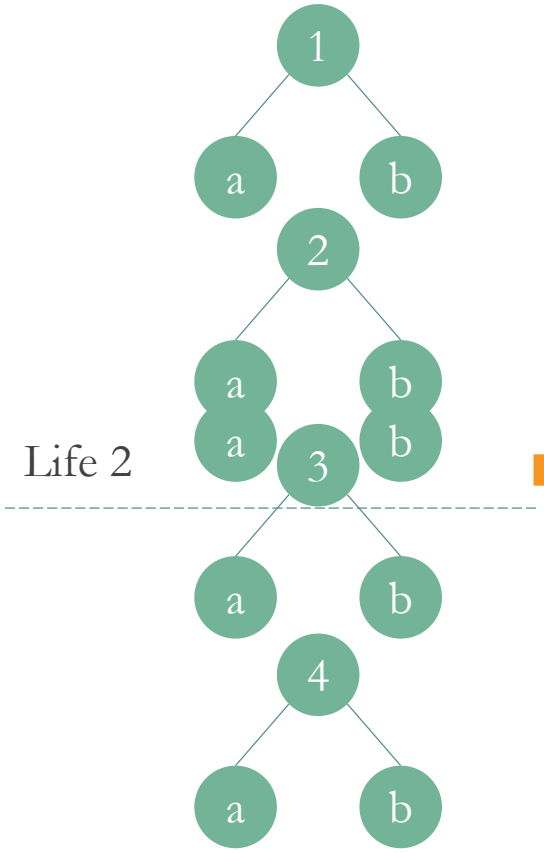
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	lookup code	product code	lifecycle	Material	Total Weight (kg)	Virgin feedstock (%)	Weight of Virgin mass (k	Reused feedstock (%)	Weight of Re-used content (kg)	Recycled feddstock (%)	Weight of Recycled content(kg)	Recycled efficiency	Waste of recyded content(kg)
2													
3	0a2	0a	2	reinforcedconcrete	33600	0	0	1	33600	0	0	0,4	0
4	1a2	1a	2	brick	2691	0	0	1	2691	0	0	0,8	0
5	2a2	2a	2	insulation	83,2	0	0	1	83,2	0	0	0,8	0
6	3a2	3a	2	glass-single	705	0	0	1	705	0	0	0,8	0
7	3a3	3a	3	glass-single	705	0	0	1	705	0	0	0,8	0
8	3a4	3a	4	glass-single	705	0	0	1	705	0	0	0,8	0
9	3b2	3b	2	alum-mullion	810	0	0	1	810	0	0	0,8	0
10	4a2	4a	2	stone	10260	0	0	1	10260	0	0	0,8	0
11						1							
12						1							
13	5a1	5a	1	glass-single	211,5	0,5	105,75	0	0	0,5	105,75	0,8	26,4375
14	6a1	6a	1	steel	280,8	0,7	196,56	0	0	0,3	84,24	0,8	21,06
15	7a1	7a	1	steel	280,8	0,7	196,56	0	0	0,3	84,24	0,8	21,06
16	8a1	8a	1	steel	93,6	0,7	65,52	0	0	0,3	28,08	0,8	7,02
17	9a1	9a	1	woodsolid	89	1	89	0	0	0	0	0,8	0
18						1							
19						1							
20	10a1	10a	1	woodsolid	106,8	0	0	1	106,8	0	0	0,8	0
21	11a1	11a	1	alum-mullion	99,9	0	0	1	99,9	0	0	0,8	0
22	11b1	11b	1	alum-mullion	91,8	0	0	1	91,8	0	0	0,8	0
23	11c1	11c	1	glass-double	184	0	0	1	184	0	0	0,8	0
24	12a1	12a	1	woodsandwichpanel	30	1	30	0	0	0	0	0,8	0
25	13a1	13a	1	woodsandwichpanel	40	1	40	0	0	0	0	0,8	0
26						1							
27						1							
28	14a2	14a	2	aluminum	9,072	0	0	1	9,072	0	0	0,8	0

Assessment Framework

1 Material Database

A tabular database of secondary material stored in Excel

4. Main database



Life 2

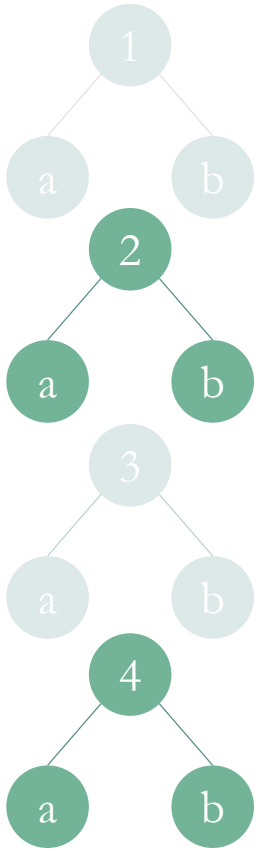
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Product code	NL/Sfb	Material	Life cycle level	U-value (W/m² K)	Thermal conductivity W/m	Acoustic velocity (m/s)	Density (kg/m3)	Volume (m3)	Weight (Kg)	Quantity	Length	Depth	Height	Location	Virgin CO2 (kg/kg)	Recy
2										M					0	Cv	Cr1
3	0a	28,2	reinforcedconcrete	2	0	0,7	1220	2000	16,8	33600	1	0	0	0	hague	0,1	0,1
4	1a	28,2	brick	2	0	0,8	5380	2070	1,3	2691	1	0	0	0	hague	0,23	0,23
5	2a	41,1	insulation	2	0	0,03	2080	32	2,6	83,2	1	0	0	0	hague	3,1	3,1
6	3a	31,1	glass-single	2	1,5	1,1	5350	2350	0,3	705	1	0	0	0	hague	1,83	1,83
7	3b	31.1	alum-mullion	2	0	201	5130	1350	0,6	810	1	0	0	0	hague	14,6	14,6
8	4a	43.1	stone	2	0	6	5040	2850	3,6	10260	1	0	0	0	hague	0,1	0,1
9																	
10																	
11	5a	31.1	glass-single	1	1,5	1,1	5350	2350	0,015	211,5	6	1500	8	1200	amsterdam	1,83	1,83
12	6a	31.2	steel	1	0	54	5240	7800	0,006	280,8	6	1580	40	240	hengelo	2,75	2,75
13	7a	31.3	steel	1	0	54	5240	7800	0,006	280,8	6	1500	80	200	hengelo	2,75	2,75
14	8a	31.4	steel	1	0	54	5240	7800	0,003	93,6	4	1420	50	100	hengelo	2,75	2,75
15	9a	31.5	woodsolid	1	0	0,35	2580	890	0,005	89	20	0	0	0	amsterdam	0,7	0,7
16																	
17																	
18	10a	31,6	woodsolid	1	0	0,35	2580	890	0,06	106,8	2	1600	100	3000	eindhoven	0,7	0,7
19	11a	31.6	alum-mullion	1	0	201	5130	1350	0,037	99,9	2	880	100	2340	arnhem	14,6	14,6
20	11b	31.7	alum-mullion	1	0	201	5130	1350	0,034	91,8	2	1000	100	2400	arnhem	14,6	14,6
21	11c	31.7	glass-double	1	2,5	1,1	5350	4600	0,02	184	2	760	12	2220	arnhem	1,83	1,83
22	12a	31.8	woodsandwichpanel	1	0	0,03	2080	250	0,06	30	2	0	0	0	hengelo	0,5	0,5
23	13a	31.8	woodsandwichpanel	1	0	0,03	2080	250	0,08	40	2	280	100	3020	hengelo	0,5	0,5
24																	

Assessment Framework

1 Material Database

A tabular database of secondary material stored in Excel

5. Design database



	A	B	C	D	E	F	G	H	I	J	K	L	M	
1	Product code	NL/Sfb	Material	Life cycle level	U-value (W/m²K)	Thermal conductivity W/m	Acoustic velocity (m/s)	Density (kg/m3)	Volume (m3)	Weight (Kg)	Quantity	Length	Depth	H
2										M				
3	0a	28,2	reinforcedconcrete	2	0	0,7	1220	2000	16,8	33600	1	0	0	0
4	1a	28,2	brick	2	0	0,8	5380	2070	1,3	2691	1	0	0	0
5	2a	41,1	insulation	2	0	0,03	2080	32	2,6	83,2	1	0	0	0
6														
7														
8	5a	31.1	glass-single	1	1,5	1,1	5350	2350	0,015	211,5	6	1500	8	1200
9	6a	31.2	steel	1	0	54	5240	7800	0,006	280,8	6	1580	40	240
10	10a	31,6	woodsolid	1	0	0,35	2580	890	0,06	106,8	2	1600	100	3000
11	11a	31.6	alum-mullion	1	0	201	5130	1350	0,037	99,9	2	880	100	2340
12	11b	31.7	alum-mullion	1	0	201	5130	1350	0,034	91,8	2	1000	100	2400
13	11c	31.7	glass-double	1	2,5	1,1	5350	4600	0,02	184	2	760	12	2220
14	15a	31,9	aluminum	2	0	201	5130	2700	0,0002	10,8	20	530	50	65
15	16a	31,9	aluminum	2	0	201	5130	2700	0,0016	34,56	8	3660	50	65
16	17a	31,9	insulation	1	0	0,03	2080	32	2,2	70,4	1	0	0	0
17	18a	32,1	woodsolid	1	0	0,35	2580	890	0,007	791,21	127	150	25	2050
18	19a	32,1	woodsolid	1	0	0,35	2580	890	0,003	32,04	12	25	100	1200