BARTE VAN DER ZIJDEN

FACILITATING SUSTAINABLE BUILDING DESIGNS

THE DEVELOPMENT OF A COMPUTATIONAL TOOL FOR EARLY-STAGE ASSESSMENT OF ENVIRONMENTAL IMPACT OF BUILDINGS

TU Delft ARUP

STRUCTURE

Context and problem

Stakeholders

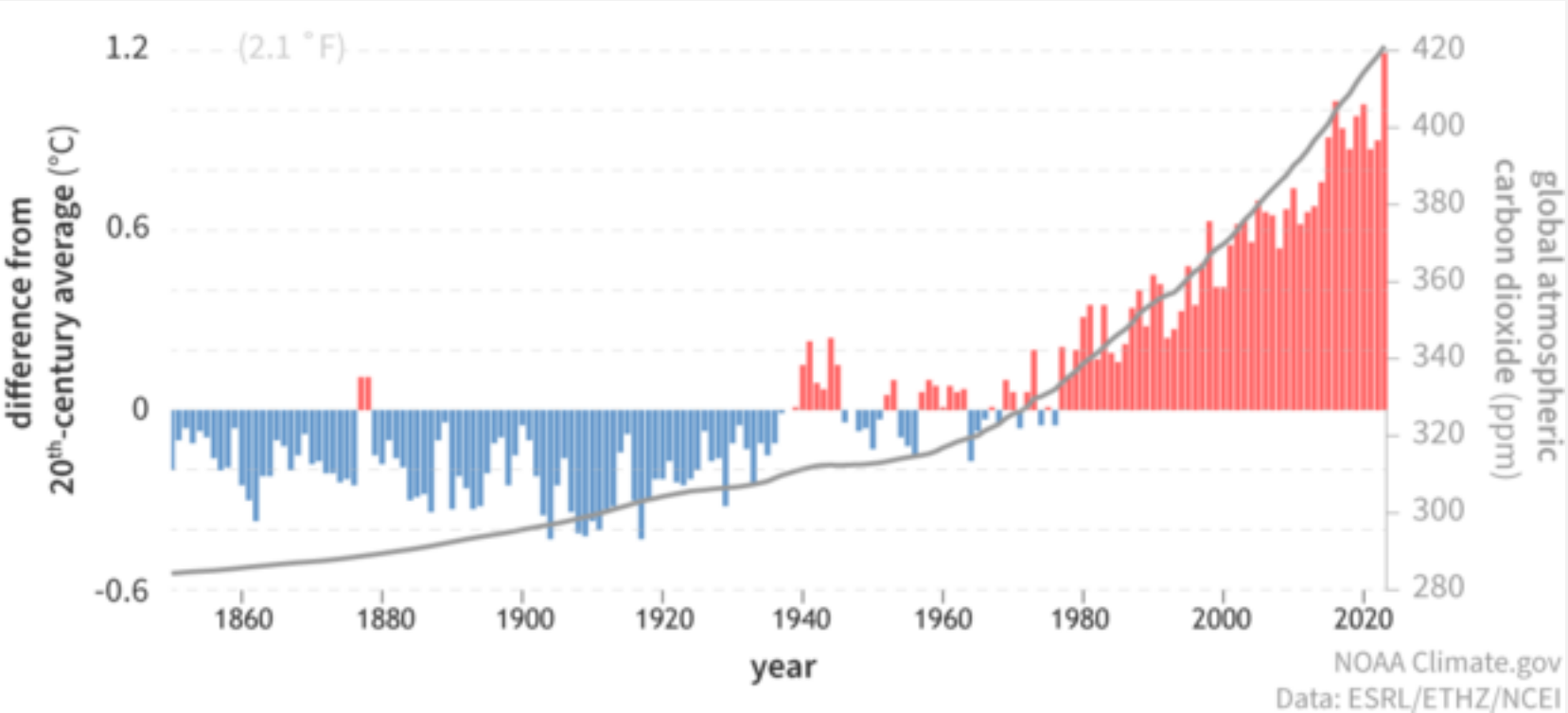
Current assessment method

The tool

Development

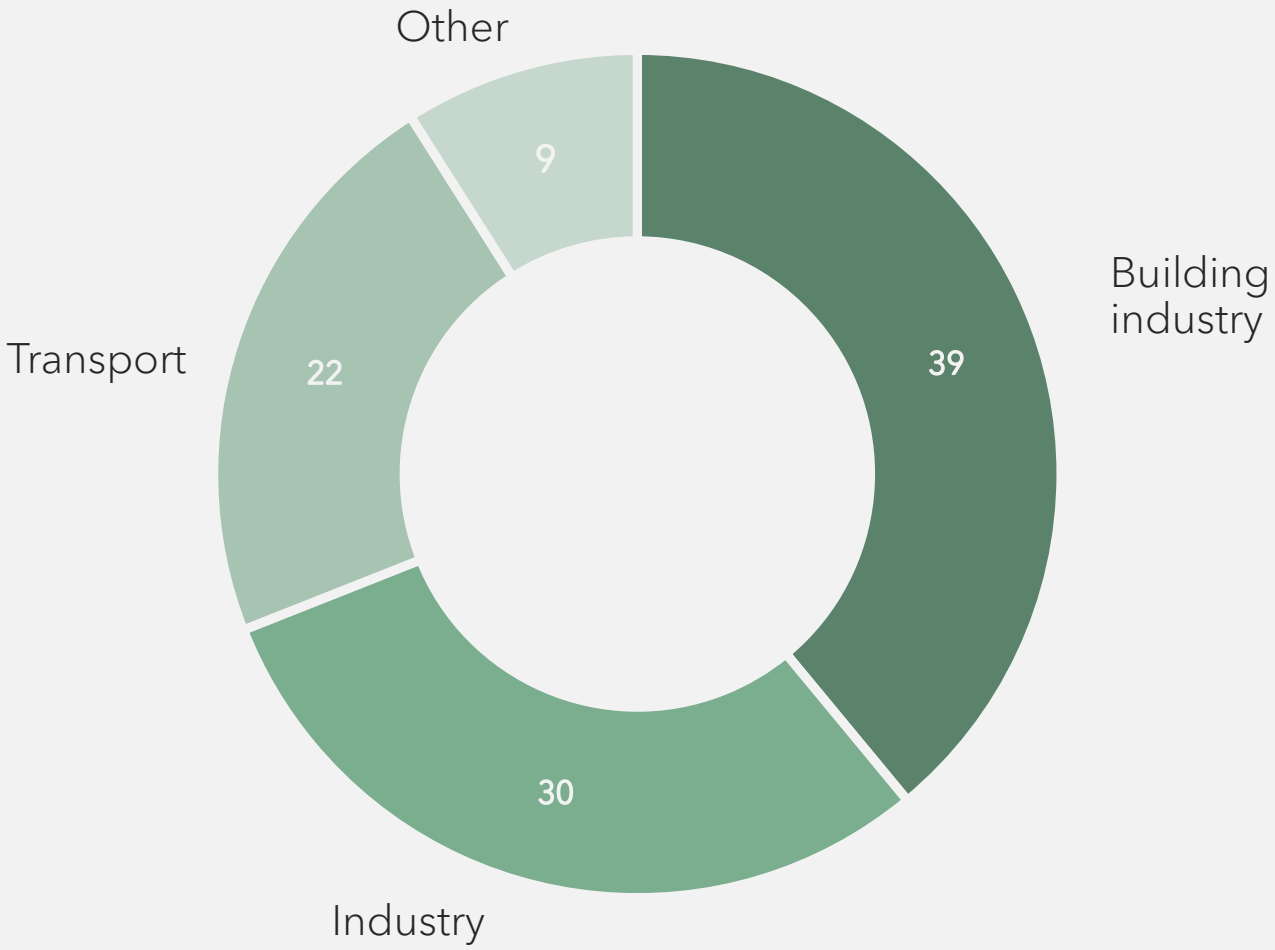
EARTH'S TEMPERATURE

And related to carbon emissions



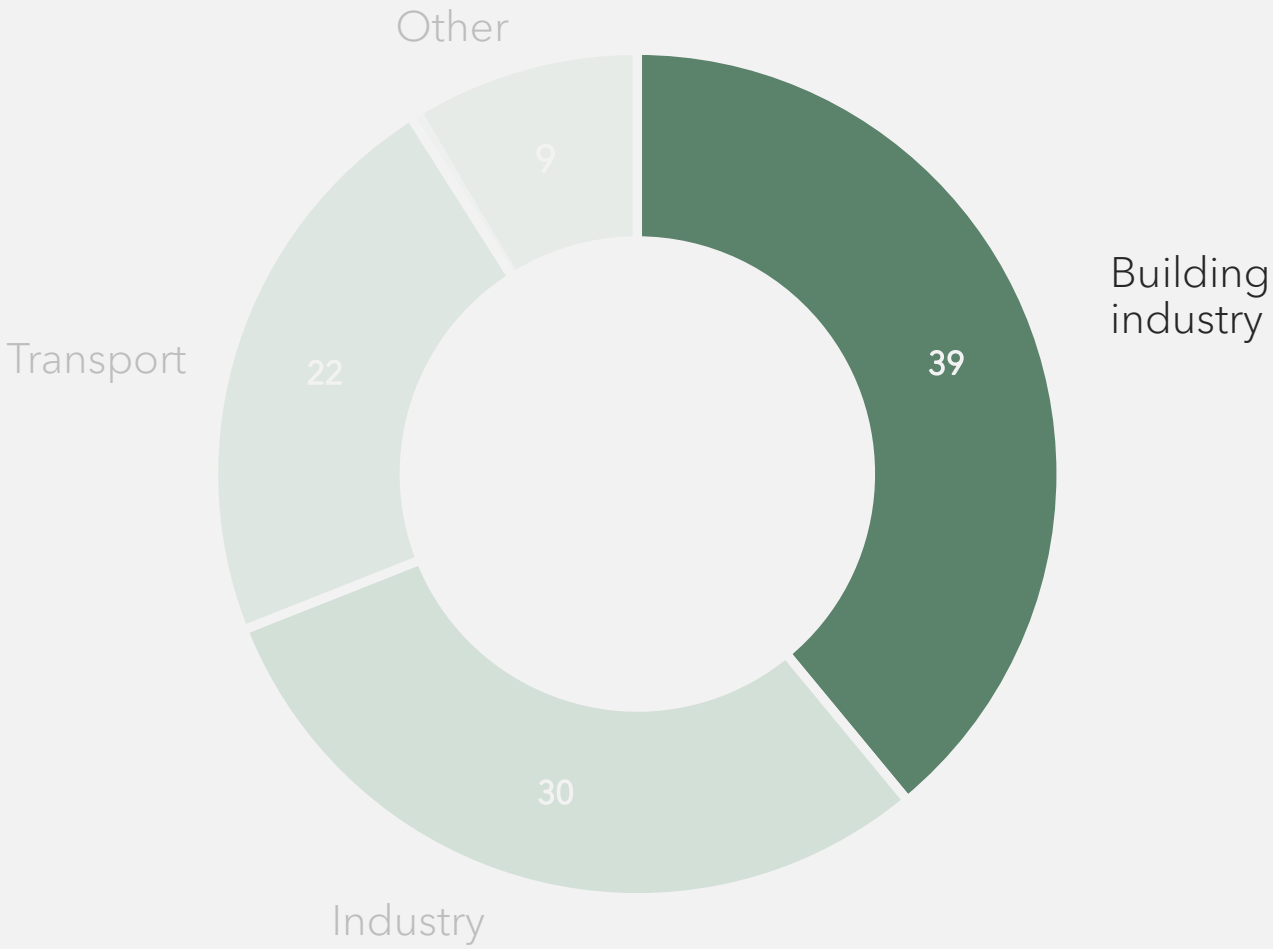
CO_2 EMISSIONS

Per industry sector



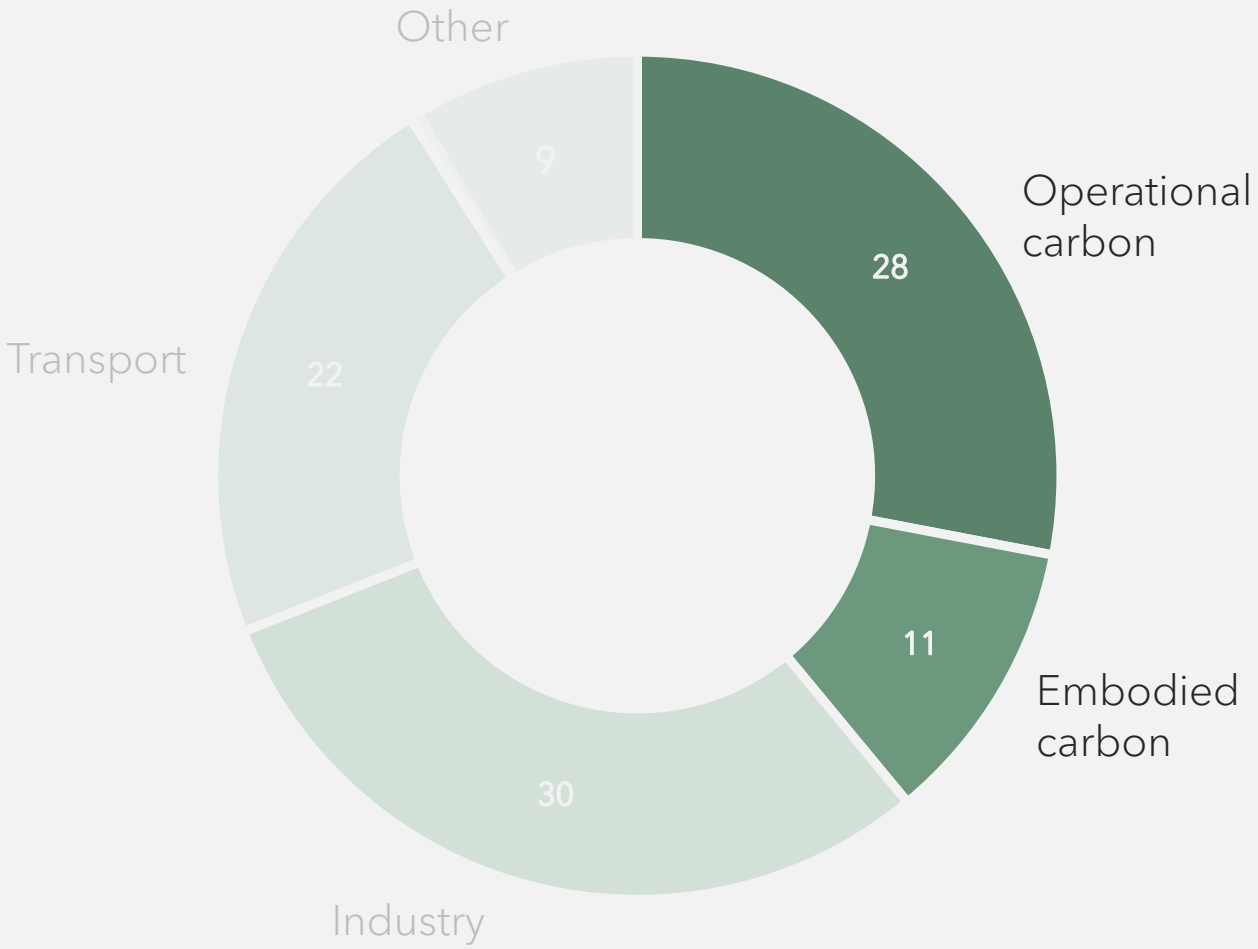
CO_2 EMISSIONS

Building sector



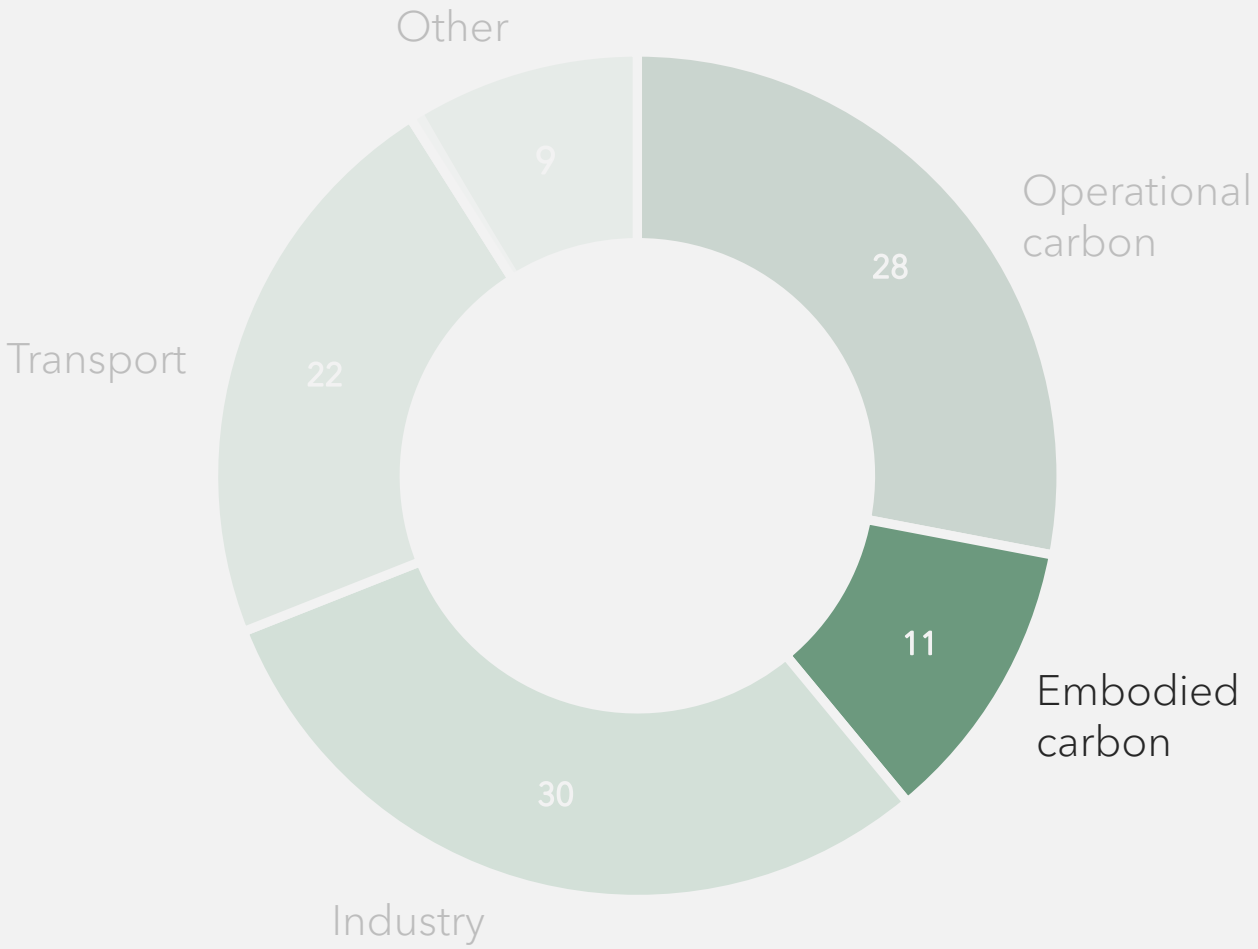
CO_2 EMISSIONS

Embodied vs. operational carbon



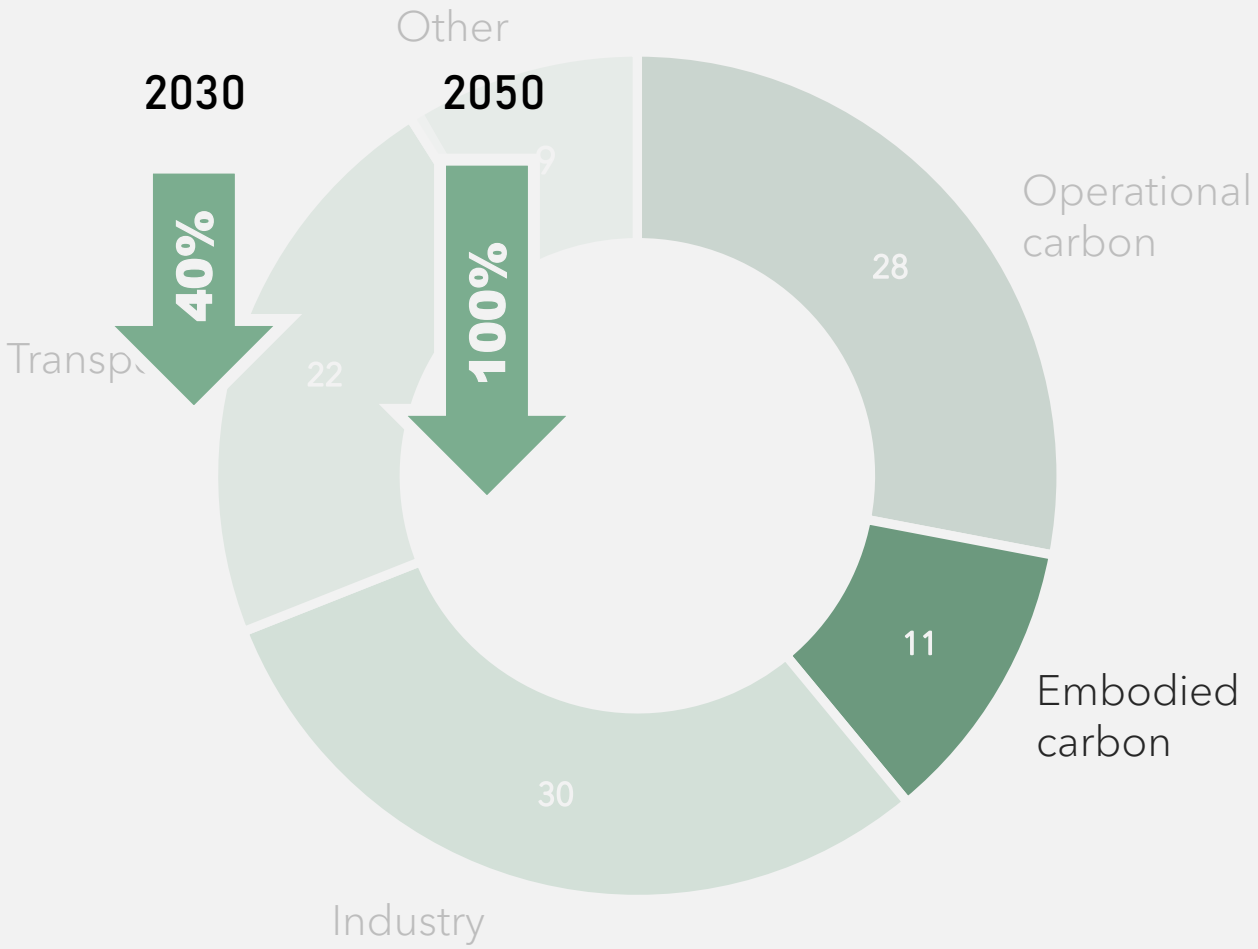
CO_2 EMISSIONS

Embodied carbon



CO_2 EMISSIONS

Reduction goals embodied carbon



CALCULATION METHODOLOGY

Environmental impact buildings

CALCULATION METHODOLOGY

Environmental impact buildings

=

Impact factor per material

X

Quantity + type of materials

CALCULATION METHODOLOGY

Environmental impact buildings

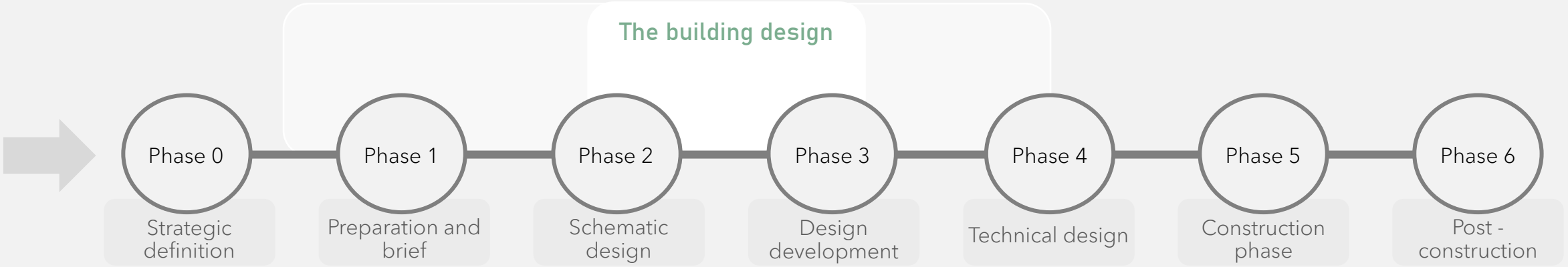
Databases with environmental product declarations

The building design

Impact value = Impact factor per material X Quantity + type of materials

PROJECT DEVELOPMENT

Building design development



PROJECT DEVELOPMENT

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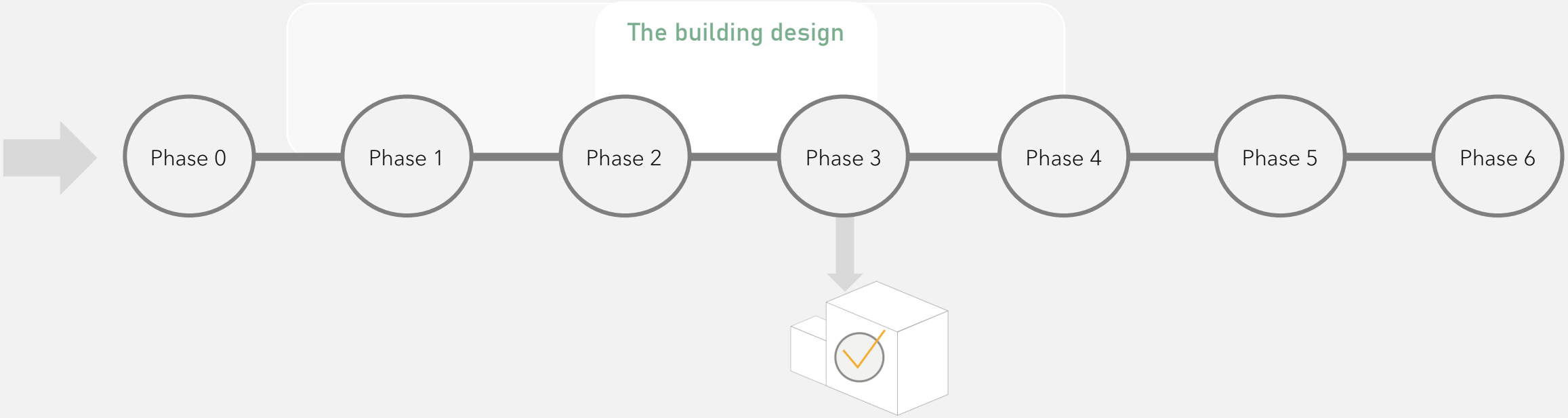
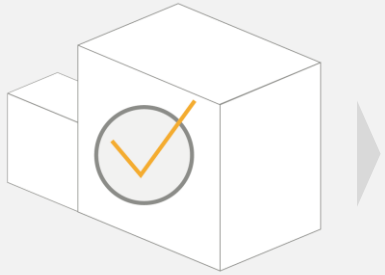


IMPACT ASSESSMENT

Current method



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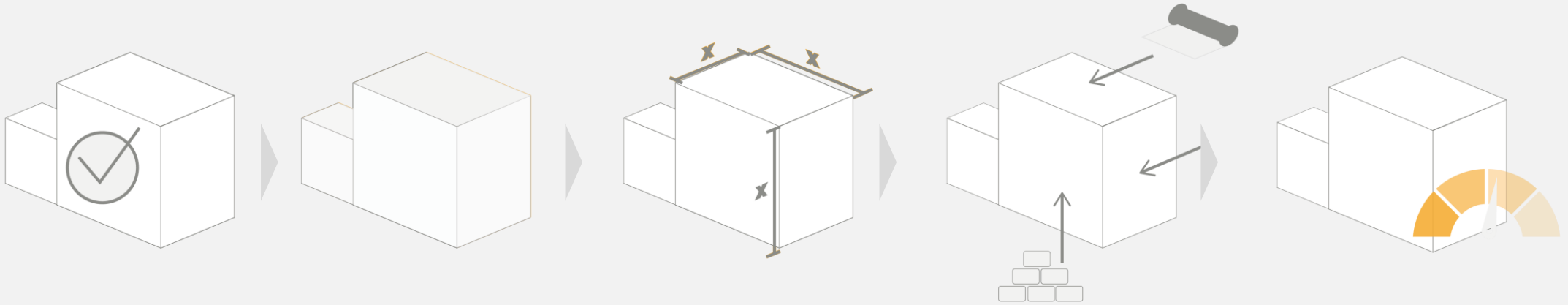
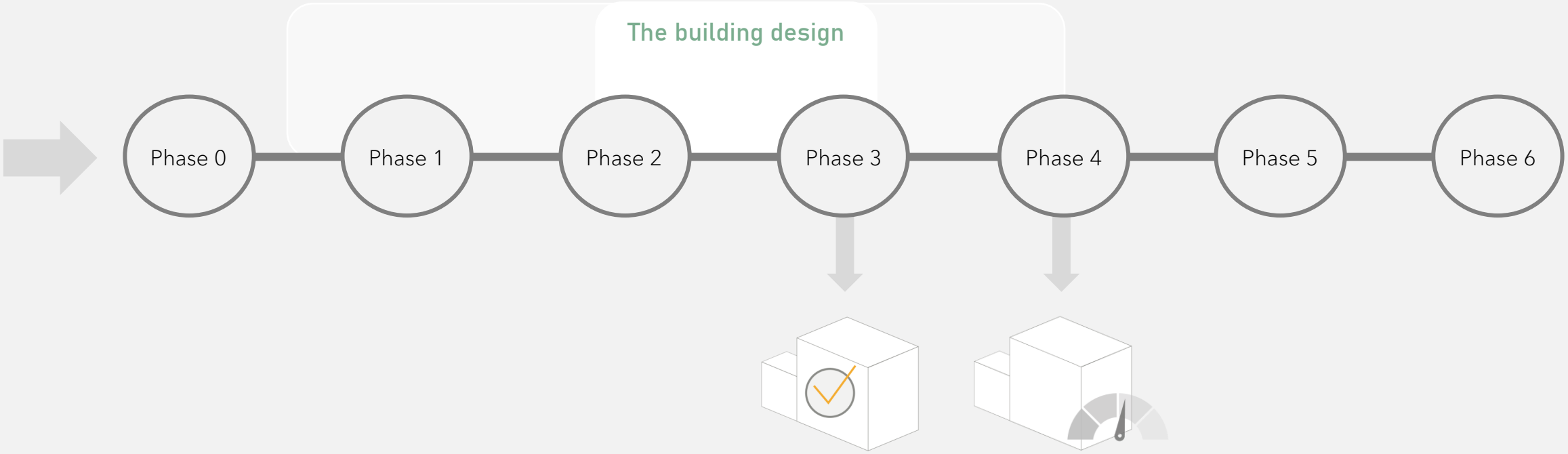


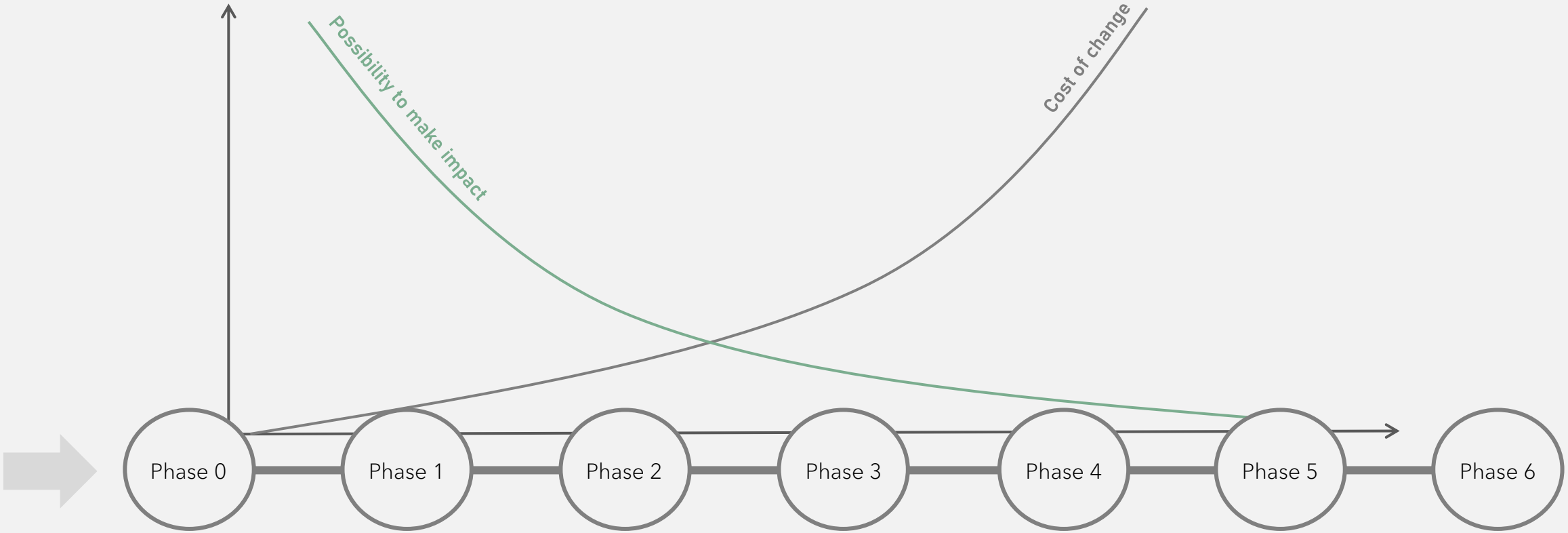
IMPACT ASSESSMENT

Current process & design phases



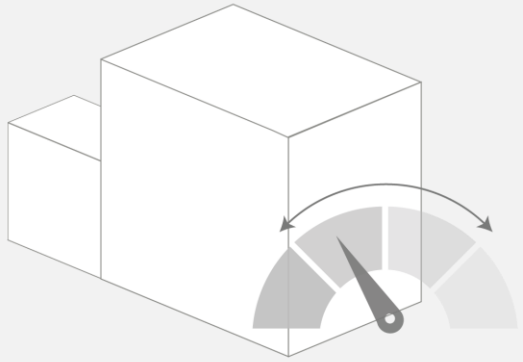
IMPACT ASSESSMENT

Current process & possibility to make impact



CONTEXTUALIZING NEW DESIGNS

Whole-building environmental impact data



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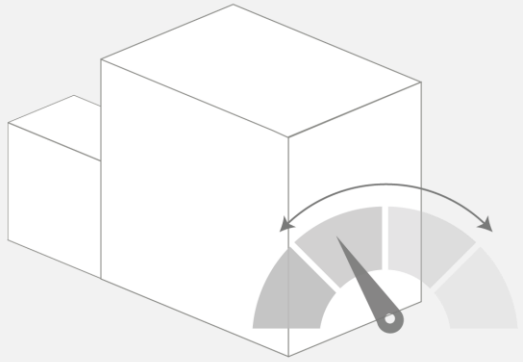

vs.

CONTEXTUALIZING NEW DESIGNS

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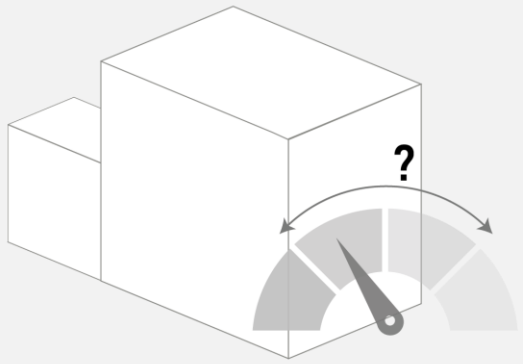


vs.

CURRENT METHOD

Manual process | no integration | no context to compare

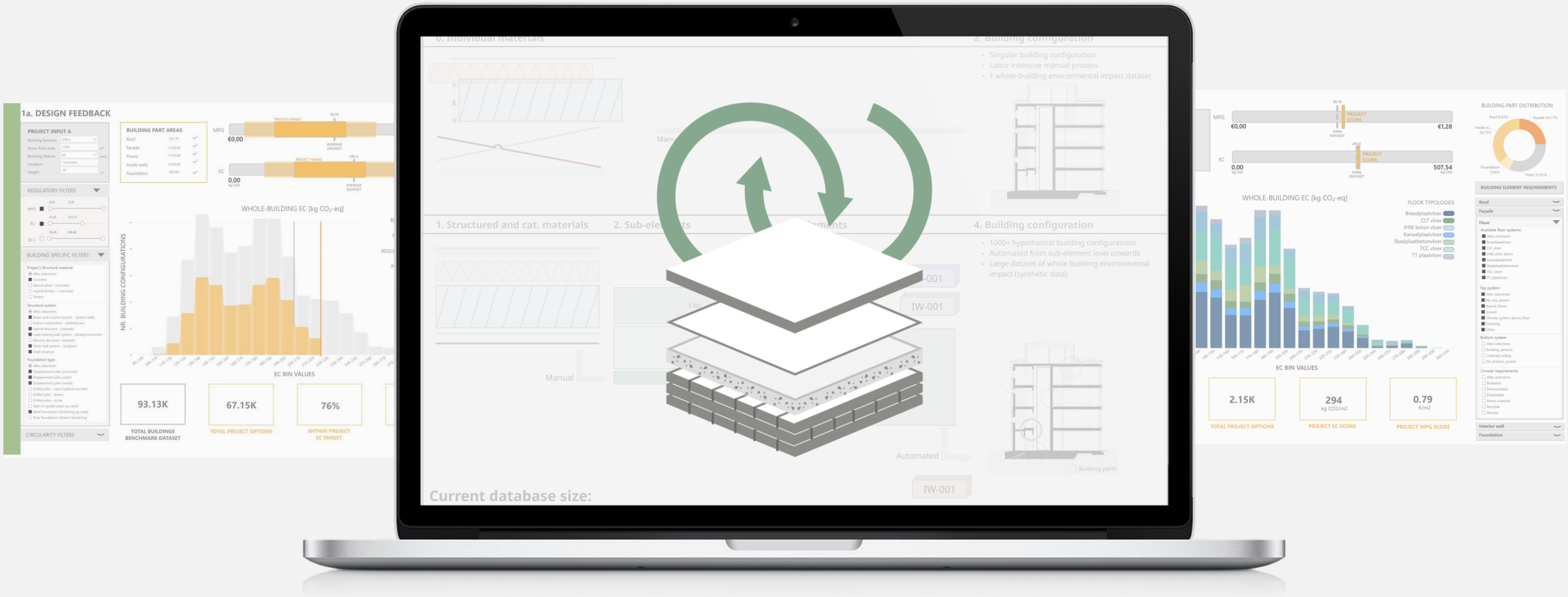
THE RESEARCH

Main question

How can a computational tool support early-stage design decisions towards building designs with lower embodied environmental impact?

TOOL

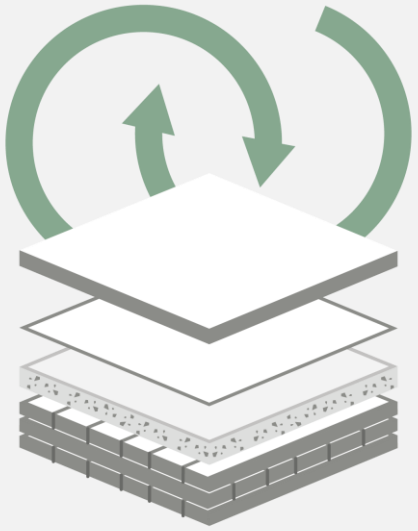
Final product: Early-stage environmental impact assessment tool



TOOL OBJECTIVE

To integrate environmental impact assessment in the design process

More sustainable buildings door integration van assessment in the design process



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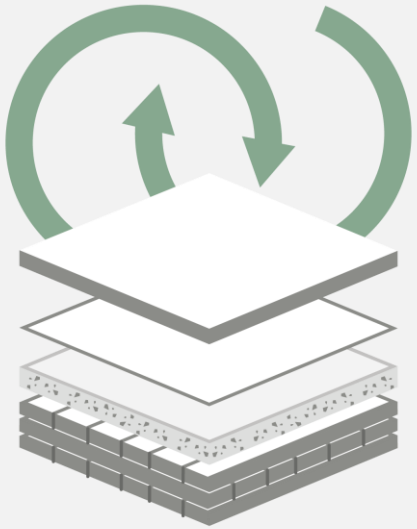
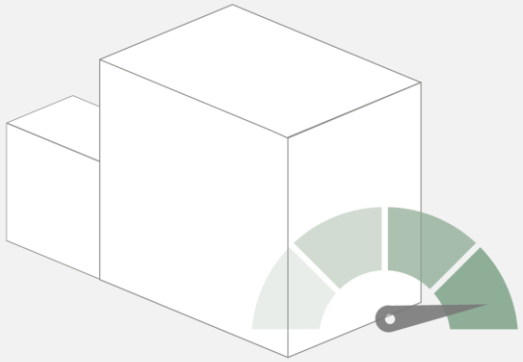
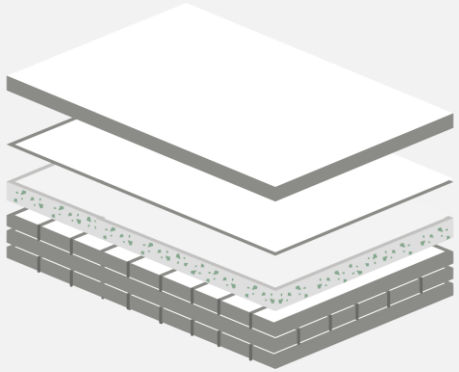




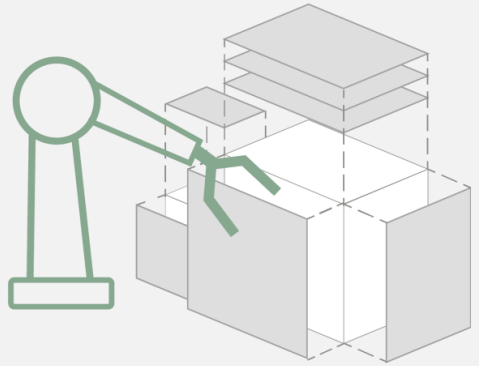
TOOL

Key innovations



1. Element assessment

2. Structured data saving

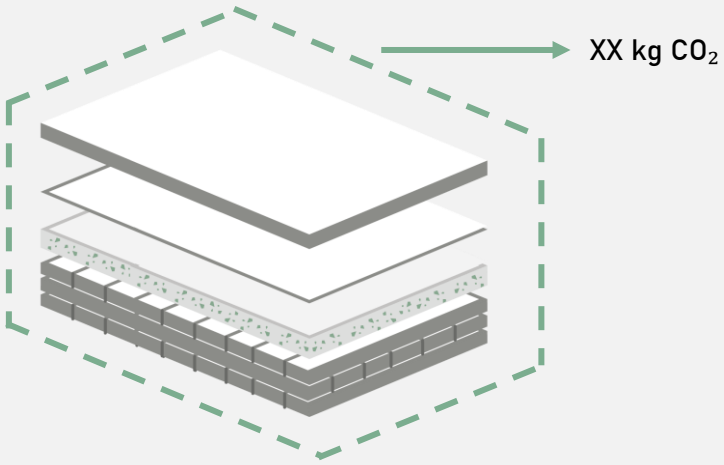


3. Automated building configuration

1. ELEMENT ASSESSMENT

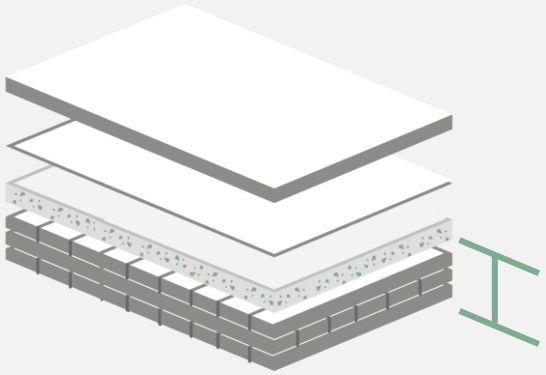
As opposed to individual materials

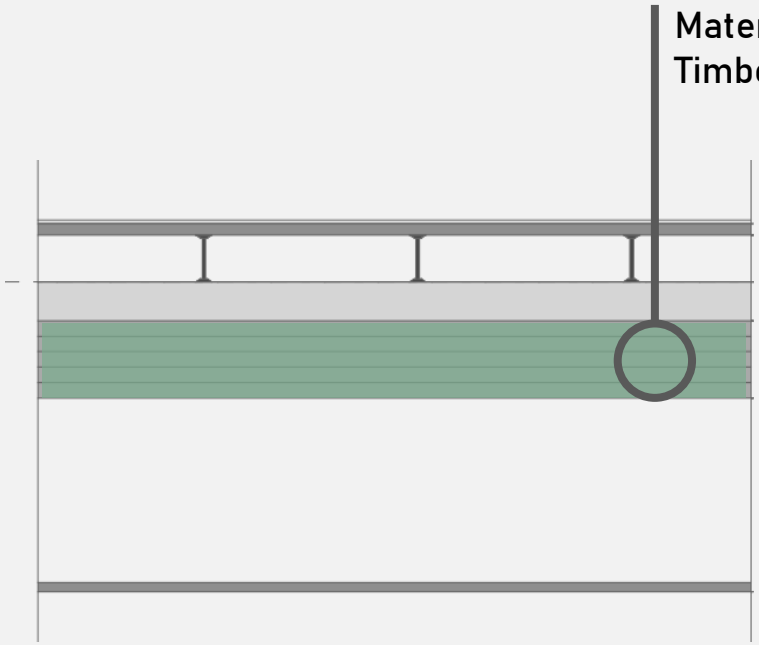
- Assessment: the calculation of environmental impact values
- Element: the complete build-up of materials of one building part



1. ELEMENT ASSESSMENT

Element > sub-elements





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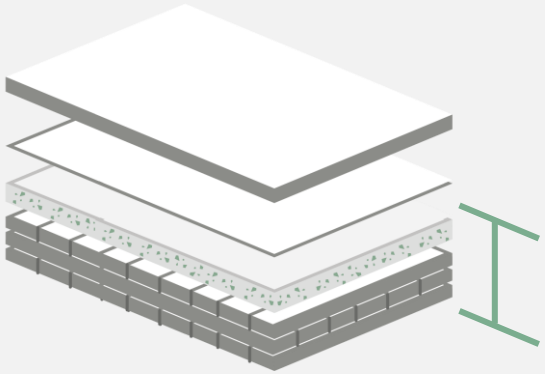
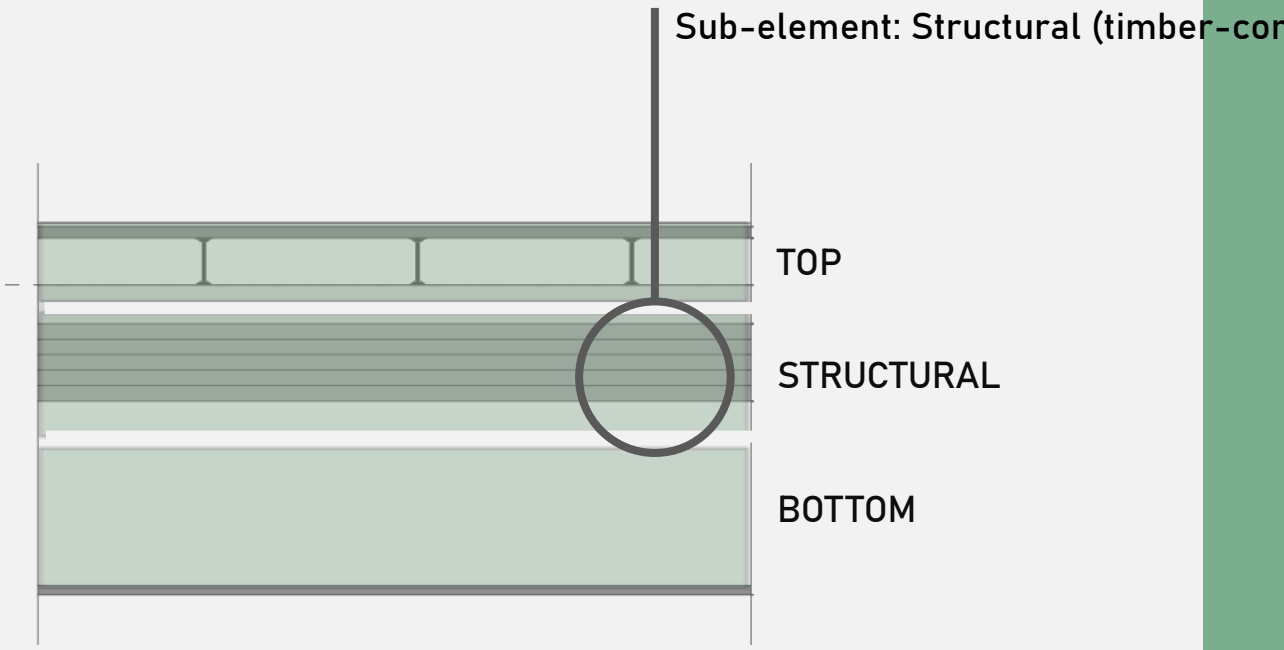
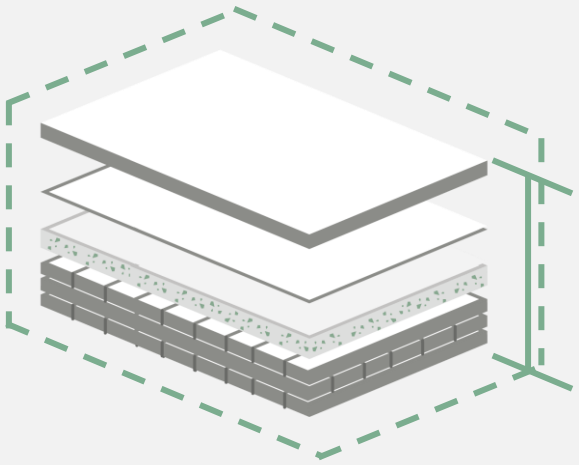
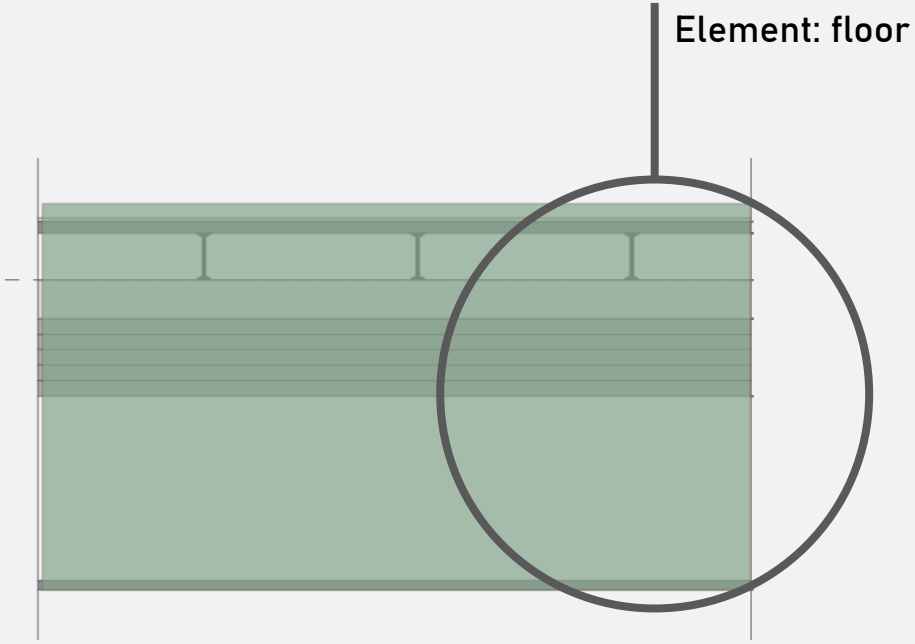




1. ELEMENT ASSESSMENT

Element = complete build-up of materials of one building part





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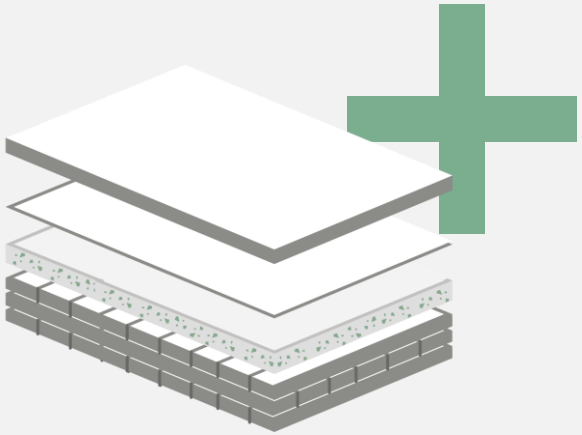
As opposed to individual materials



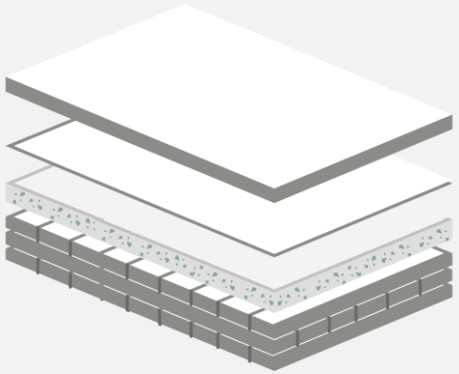
- Element:

\+ Als je niet alle laagjes weet, kan je nog steeds assessment doen > early –stage maakt mogelijk
\+ Efficiency and accuracy in calculations
\+ Saving valid material combinations
\+ Saving data for future projects
\+ Including material connections

Punten nog goed samenvatten

2. ELEMENT DATABASE

Problem: data loss



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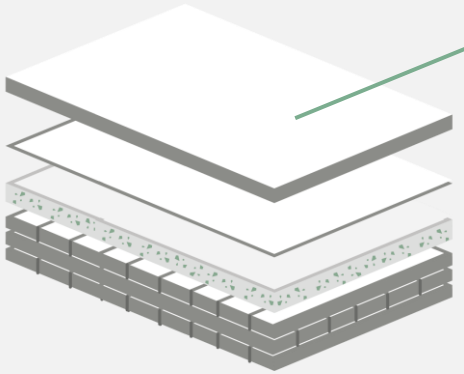
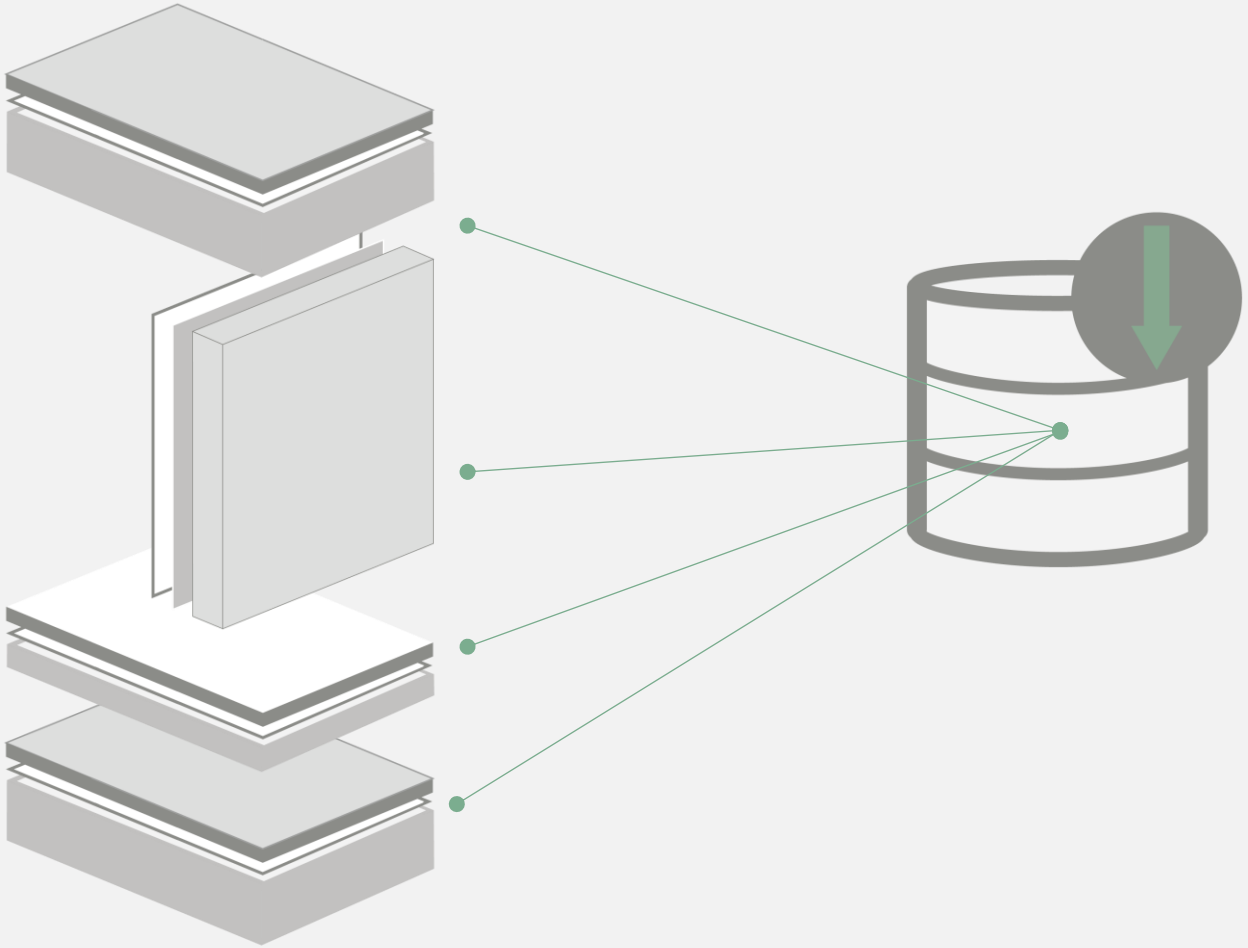


Saved element data:

- *Element ID*
- *Building part*
- *Structural system*
- *Sub-elements*
- *Material layers*
- *Environmental impact values*
- *Force system(s)*
- *Typical span*
- *Thickness*

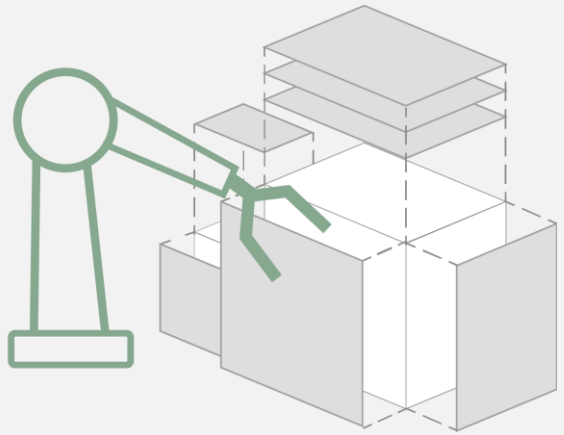
2. ELEMENT DATABASE

Database per building part



3. BUILDING CONFIGURATION

Automated process of composing a building



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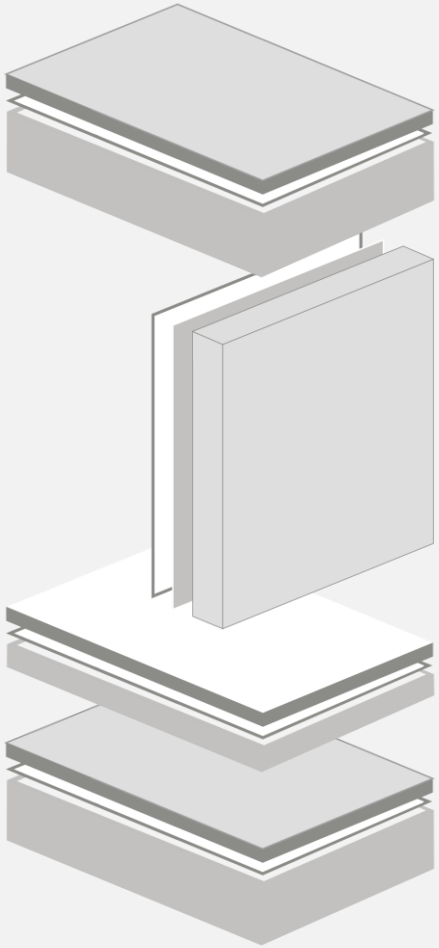

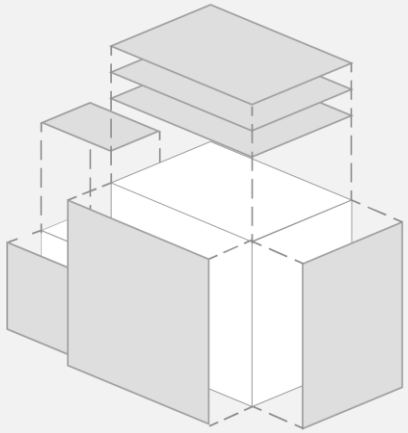

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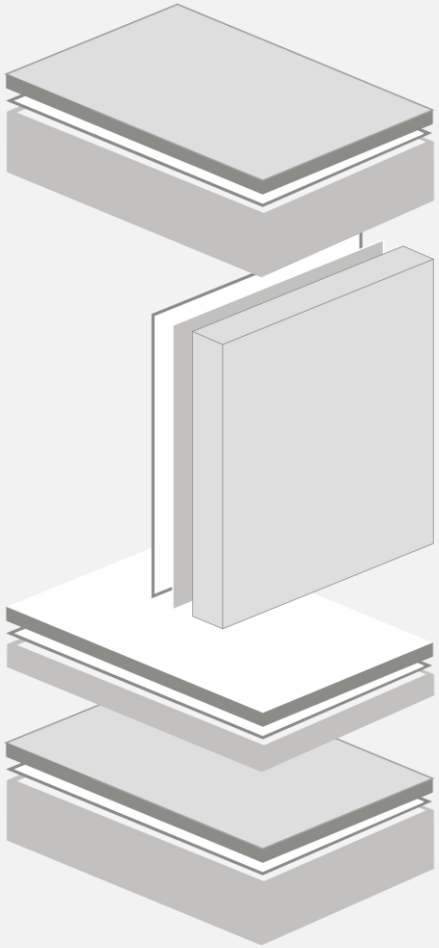
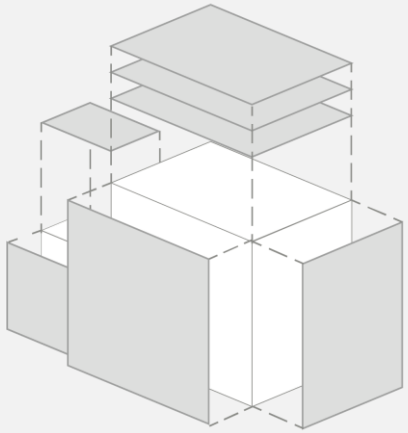


10 x roof EL

10 x façade EL

10 x floor EL

10 x foundation EL



= 10.000 building configurations

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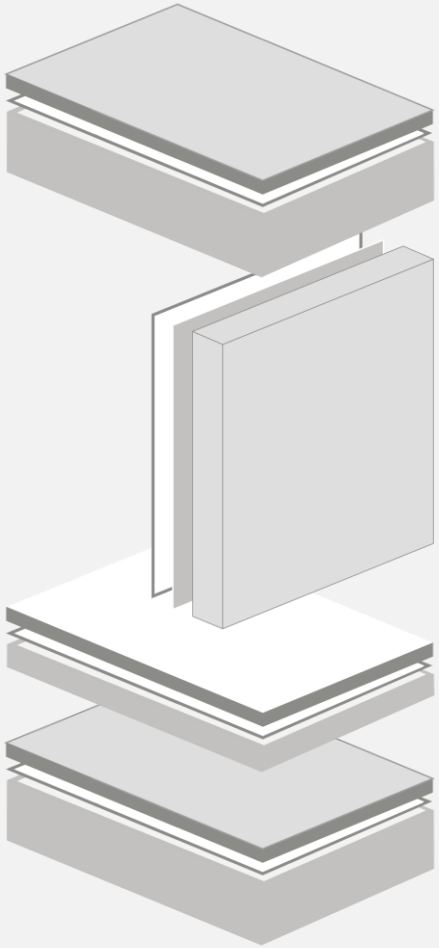

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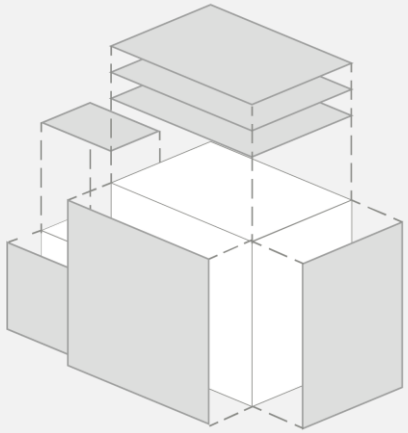
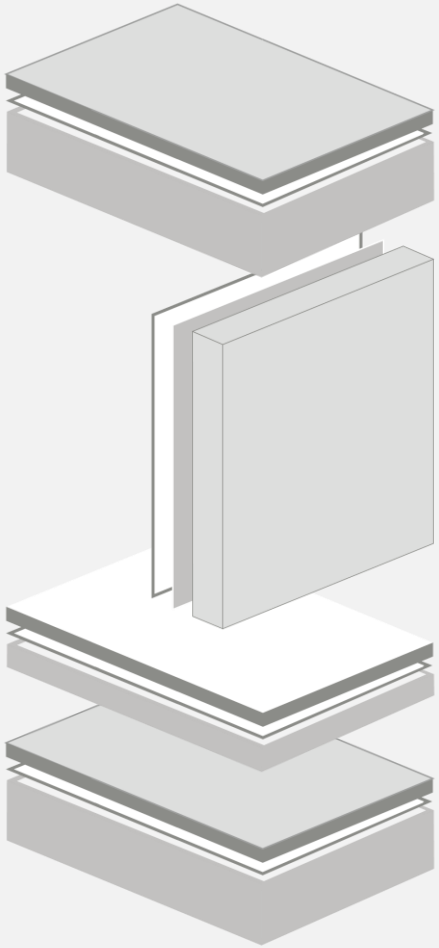


= 10.000 building configurations

+ their environmental impact
  structural data
  etc.....

3. BUILDING CONFIGURATION

Automated process of composing a building



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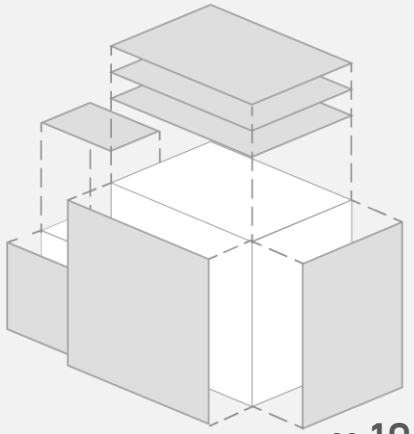
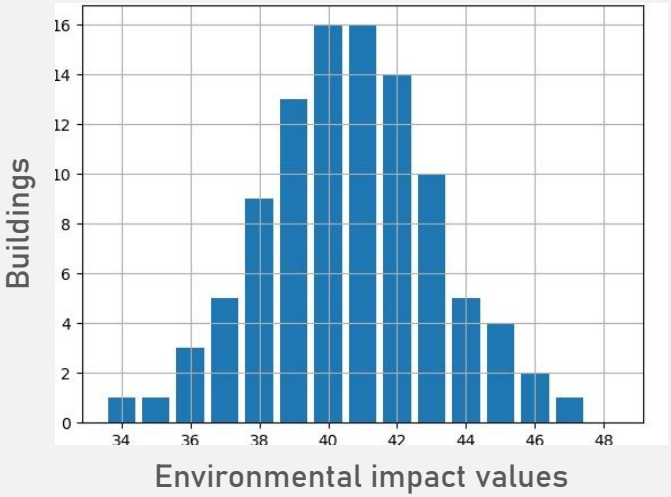
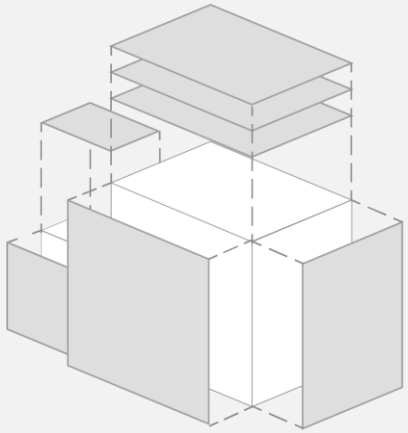


x 10.000



3. BUILDING CONFIGURATION

Benchmark dataset



= 10.000 building configurations

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RECAP NAAR VERGELIJKING OUD EN NIEUW

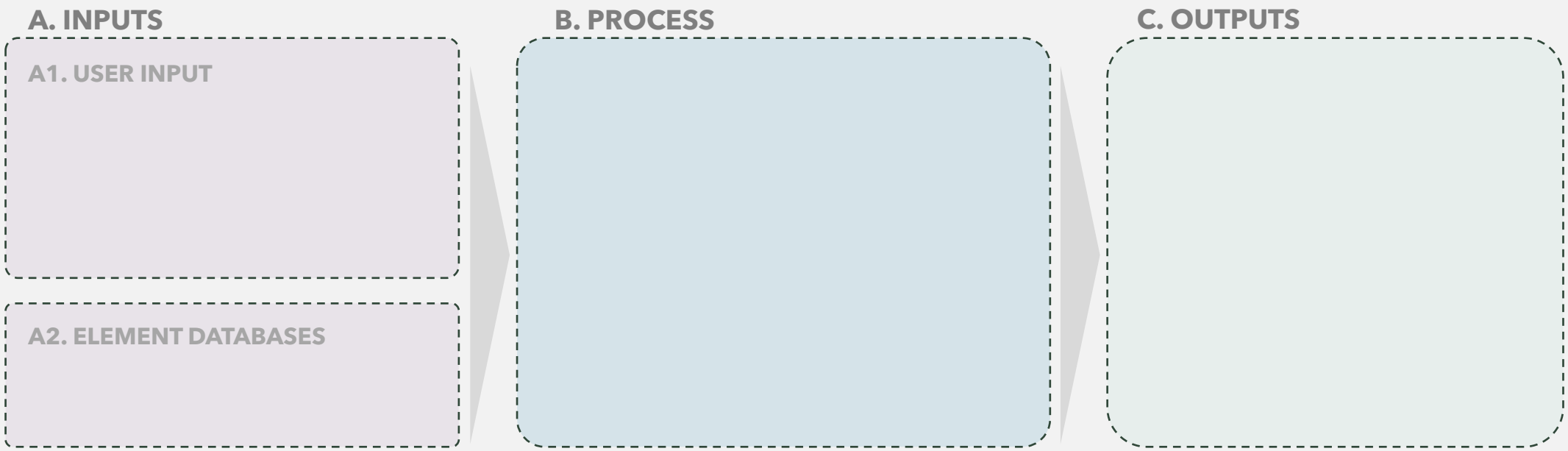
dd

TOOL MODULES

And dataflow

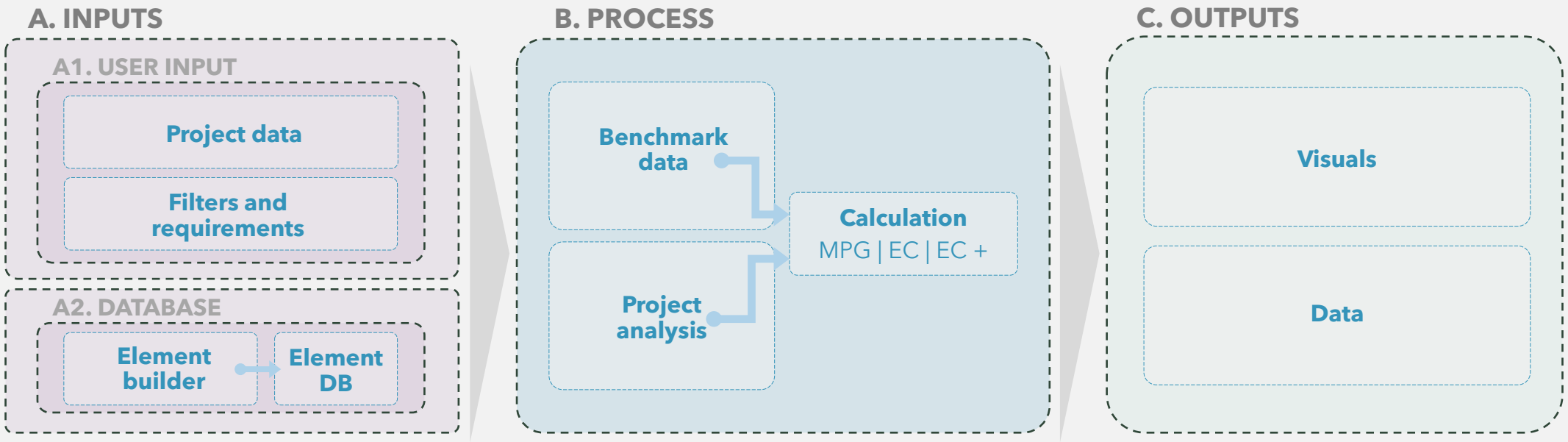
TOOL MODULES

Supported by the database



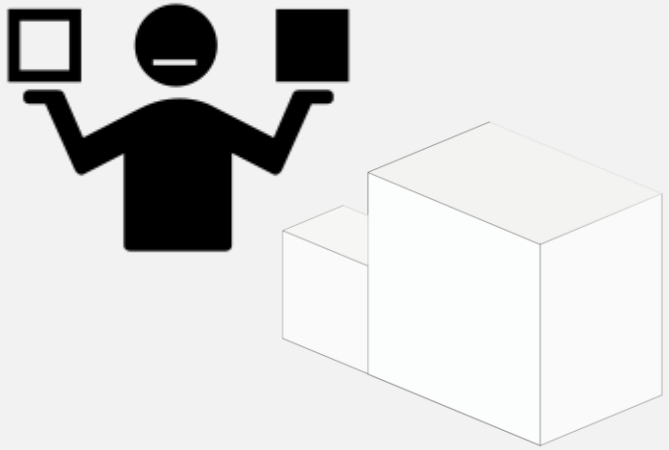
TOOL MODULES

And sub-components



EXAMPLE

New project in design phase 0



Known data:

Building floor area: 1750 m2
Building function: Office

Location XX >which is sand ground

Welke range aan EC kom ik te zitten?

INPUT

User input – project data

PROJECT INPUT A

Building function	Office	
Gross floor area:	1750	m^2
Building lifetime	50	years
Location	Amsterdam	

INPUT

User input – project data

PROJECT INPUT A

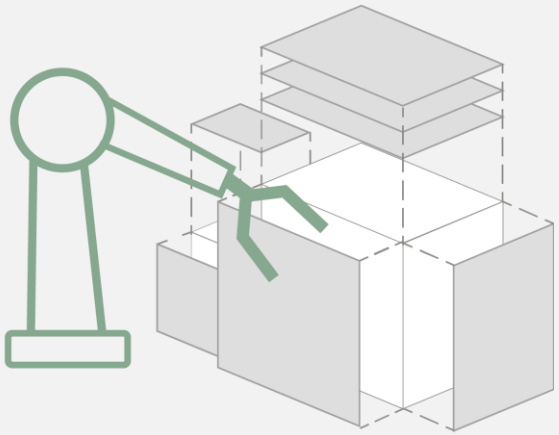
Building function	Office	
Gross floor area:	1750	m^2
Building lifetime	50	years
Location	Amsterdam	
Height	60	m

BUILDING PART AREAS

Roof	531,75	m^2
Facade	1.330,00	m^2
Floors	1.750,00	m^2
Inside walls	1.470,00	m^2
Foundation	420,00	m^2

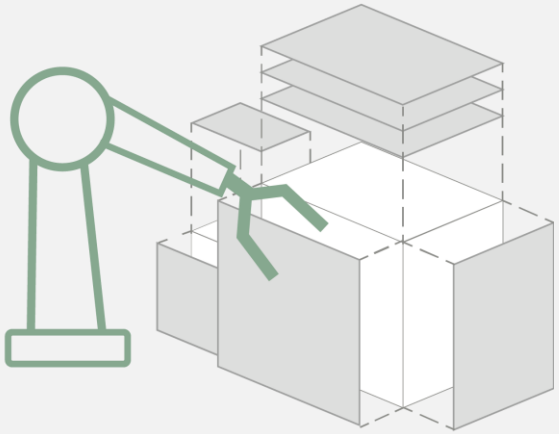
PROCESS

Creating the benchmark dataset



PROCESS

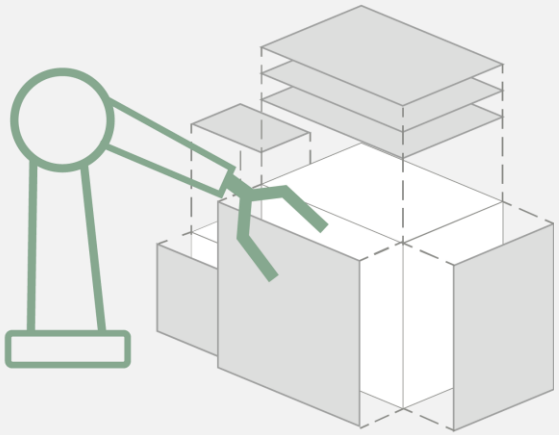
Complete benchmark dataset calculation

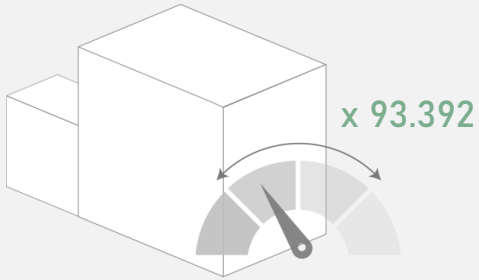


Impact values = Impact factor per material X Quantity + type of materials

PROCESS

Complete benchmark dataset calculation





PROCESS

Impact value calculation methodologies

1. MPG
2. EC
3. EC+

PROCESS

Impact value calculation methodologies

1. MPG - MilieuPrestatie gebouwen – according to Dutch building regulations [€]
2. EC
3. EC+

PROCESS

Impact value calculation methodologies

1.	MPG	-	MilieuPrestatie gebouwen	– according to Dutch building regulations	[€]
2.	EC	-	Embodied carbon	– according to Paris Proof	[kg CO2]
3.	EC+				

PROCESS

Impact value calculation methodologies

1.	MPG	-	MilieuPrestatie gebouwen	– according to Dutch building regulations	[€]
2.	EC	-	Embodied carbon	– according to Paris Proof	[kg CO2]
3.	EC+	-	Embodied carbon	– circularity factors integrated	[kg CO2]

MPG = MilieuPrestatie gebouwen

EC = Embodied carbon values (according to Paris Proof)

EC+ = Embodied carbon (circularity metrics included)

PROCESS

EC+ calculation

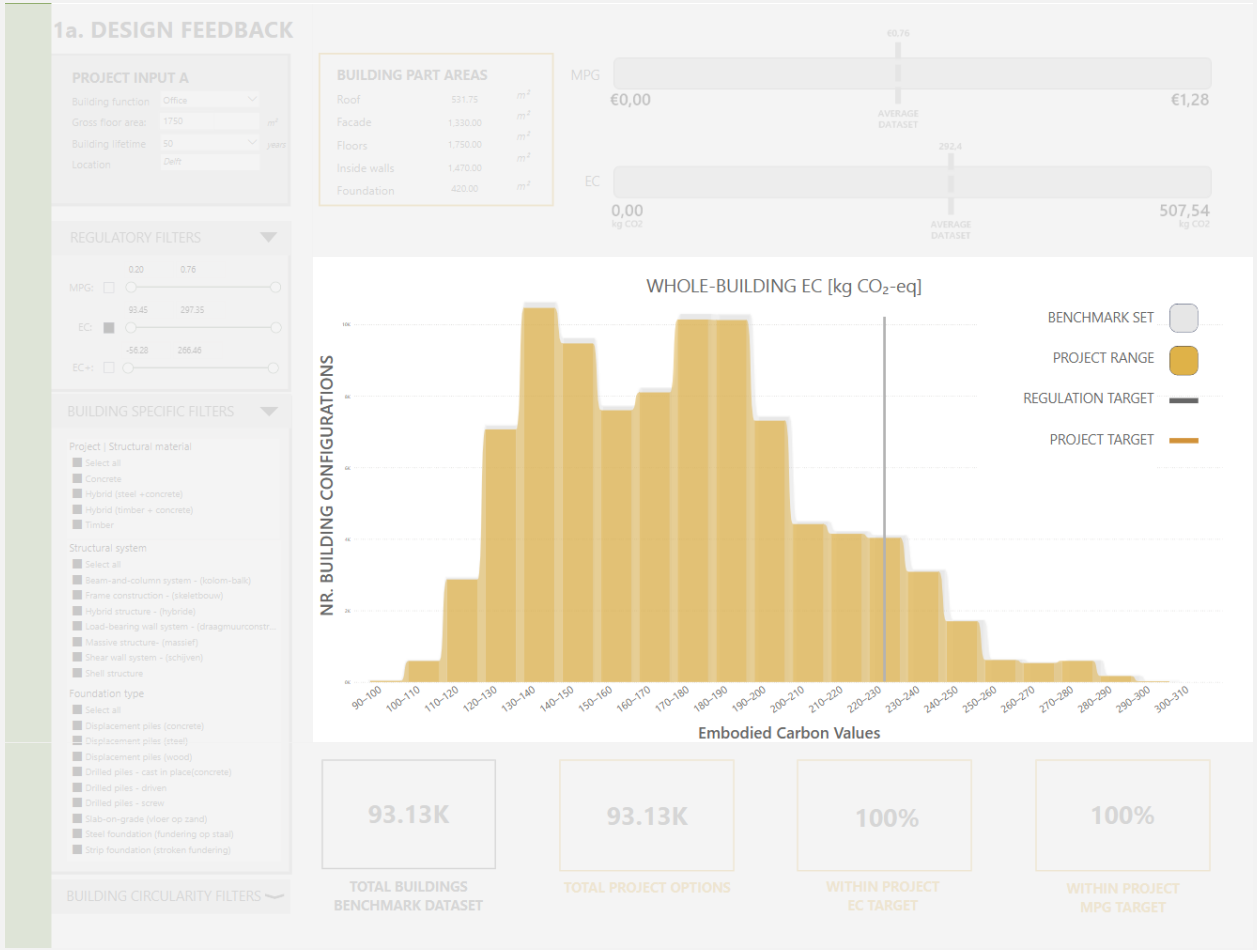
1. Carbon storage

2. Replace cycle

3. Reuse e.o.l. ‘discount’

OUTPUT

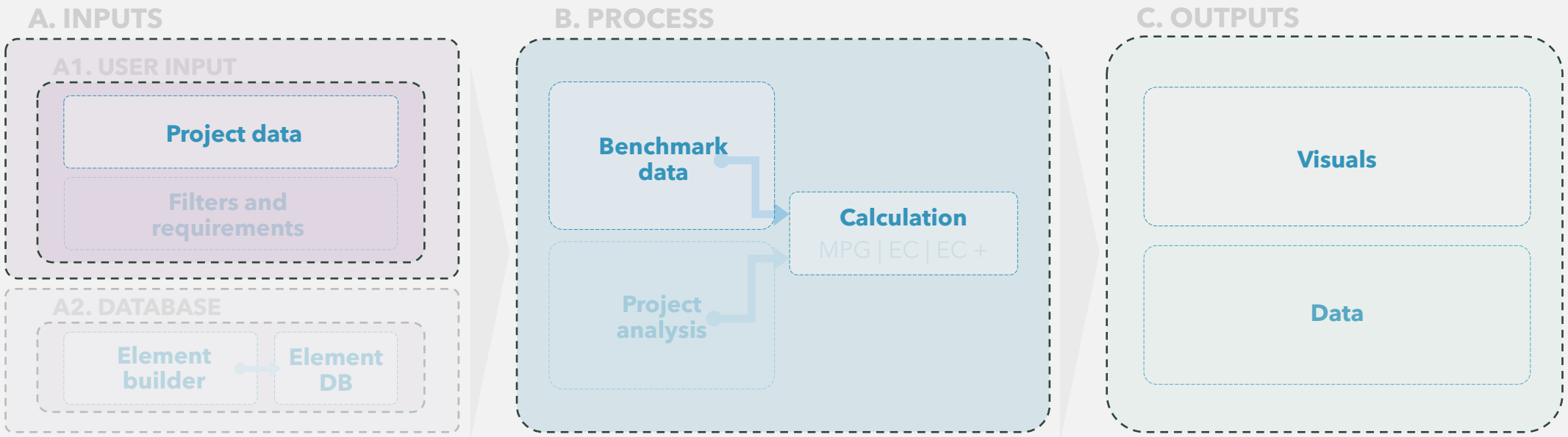
Benchmark dataset



All possible building configurations
+ environmental impact data

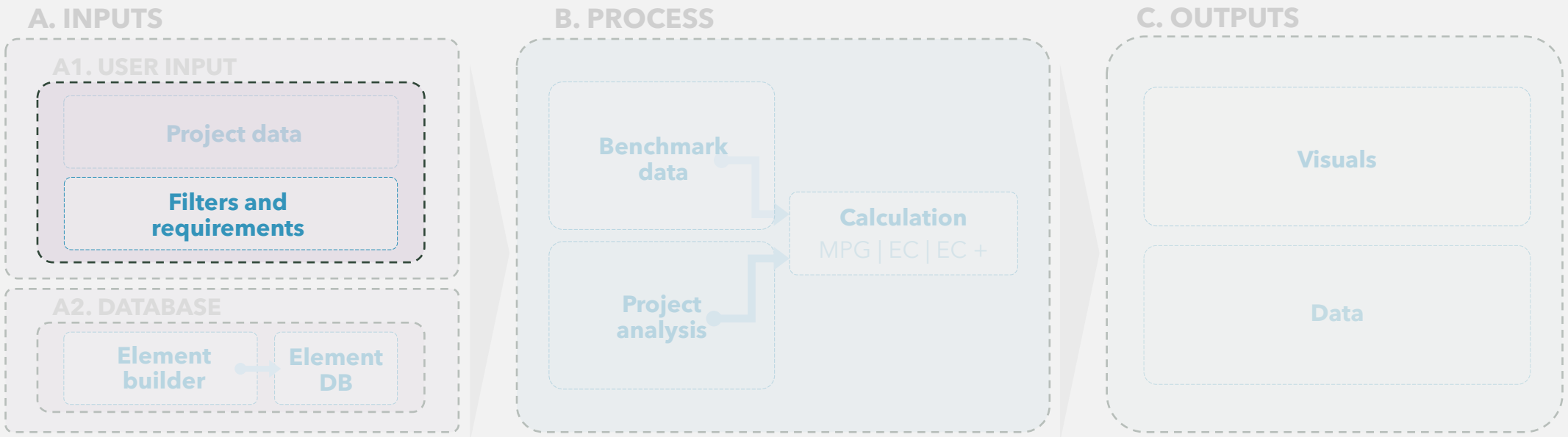
TOOL MODULES

And sub-components



TOOL MODULES

And sub-components



INPUT

Filters | Phase 1a

General filters

REGULATORY FILTERS

VERIFICATION STATUS

Building filters

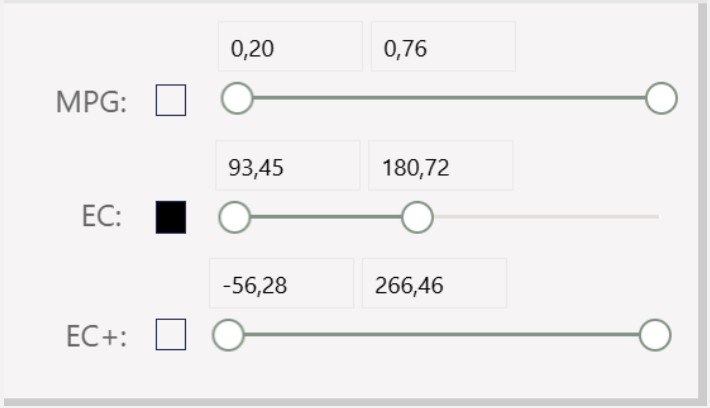
BUILDING SPECIFIC FILTERS

INPUT

Filters | Phase 1a

General filters

REGULATORY FILTERS



VERIFICATION STATUS

Verified building elements

- (●) All elements
- ( ) Verified building elements only

Building filters

BUILDING SPECIFIC FILTERS

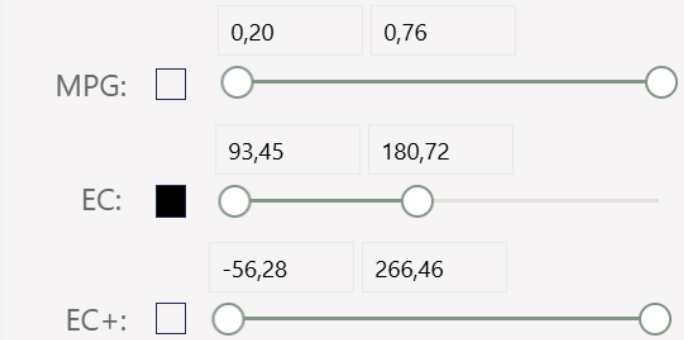
BUILDING SPECIFIC FILTERS

INPUT

Filters | Phase 1a

General filters

REGULATORY FILTERS



VERIFICATION STATUS

Verified building elements

- (●) All elements
- ( ) Verified building elements only

Building filters

BUILDING SPECIFIC FILTERS

Building height

- [ ] Select all
- [■] High-rise | 40 - 70 meters
- [ ] Low-rise | 0 - 15 meters
- [ ] Mid-rise | 15 - 40 meters
- [ ] Tall buildings | 70 + meters

Project | Structural material

- [ ] Select all
- [■] Concrete
- [ ] Hybrid (steel +concrete)
- [ ] Hybrid (timber + concrete)
- [ ] Timber

BUILDING SPECIFIC FILTERS

Input

INPUT

Filters | Phase 1b

General filters

REGULATORY FILTERS

MPG: 0,20 – 0,76

EC: 93,45 – 180,72

EC+: -56,28 – 266,46

VERIFICATION STATUS

Verified building elements

- (●) All elements
- ( ) Verified building elements only

Building filters

BUILDING SPECIFIC FILTERS

Building height

- [ ] Select all
- [■] High-rise | 40 - 70 meters
- [ ] Low-rise | 0 - 15 meters
- [ ] Mid-rise | 15 - 40 meters
- [ ] Tall buildings | 70 + meters

Project | Structural material

- [ ] Select all
- [■] Concrete
- [ ] Hybrid (steel +concrete)
- [ ] Hybrid (timber + concrete)
- [ ] Timber

BUILDING SPECIFIC FILTERS

Structural system

- [■] Select all
- [■] Beam-and-column system - (kolom-balk)
- [■] Frame construction - (skeletbouw)
- [■] Hybrid structure - (hybride)
- [■] Load-bearing wall system - (draagmuurconstr...
- [■] Massive structure- (massief)
- [■] Shear wall system - (schijven)
- [■] Shell structure

Foundation type

- [■] Select all
- [■] Displacement piles (concrete)
- [■] Displacement piles (steel)
- [■] Displacement piles (wood)
- [■] Drilled piles - cast in place(concrete)
- [■] Drilled piles - driven
- [■] Drilled piles - screw
- [■] Slab-on-grade (vloer op zand)
- [■] Steel foundation (fundering op staal)
- [■] Strip foundation (stroken fundering)

INP

1a. DESIGN FEEDBACK

PROJECT INPUT A

Building function	Office	
Gross floor area:	1750	m^2
Building lifetime	50	years
Location	Delft	

REGULATORY FILTERS

MPG: 0.20 – 0.76

EC: 93.45 – 186.56

EC+: 56.28 – 266.46

BUILDING SPECIFIC FILTERS

Project | Structural material

- Select all
- Concrete
- Hybrid (steel +concrete)
- Hybrid (timber + concrete)
- Timber

Structural system

- Select all
- Beam-and-column system - (kolom-balk)
- Frame construction - (skeletbouw)
- Hybrid structure - (hybride)
- Load-bearing wall system - (draagmuurconstr...
- Massive structure- (massief)
- Shear wall system - (schijven)
- Shell structure

Foundation type

- Select all
- Displacement piles (concrete)
- Displacement piles (steel)
- Displacement piles (wood)
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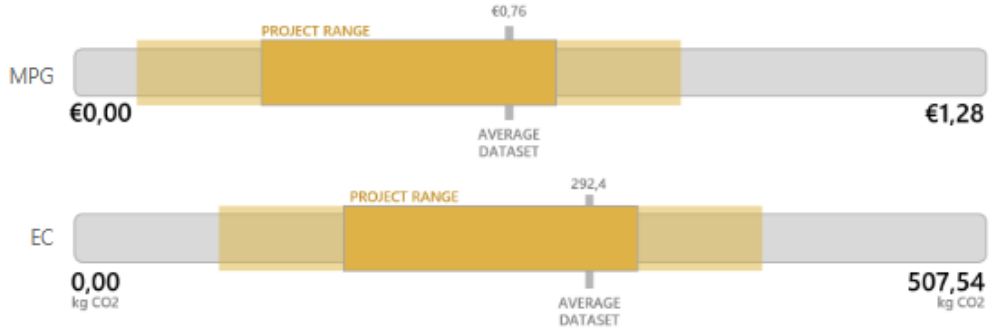
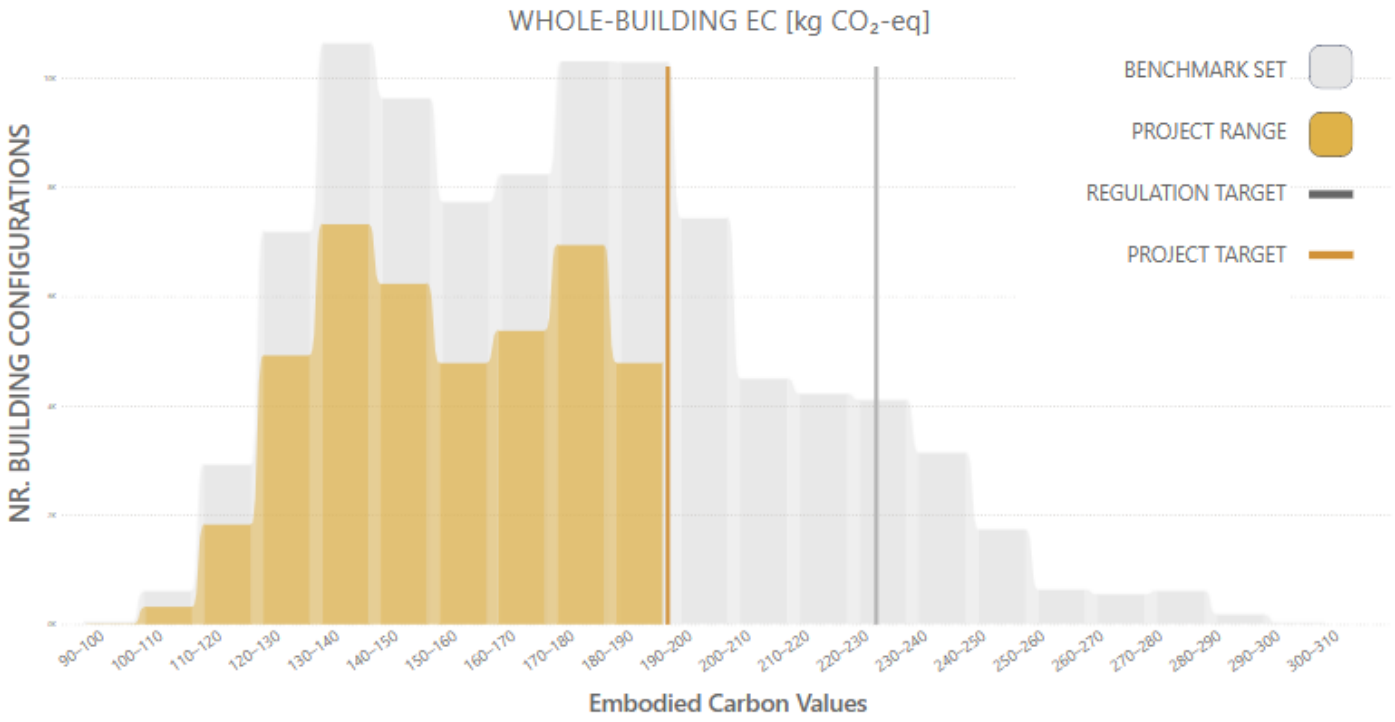
- Drilled piles - driven
- Drilled piles - screw
- Slab-on-grade (vloer op zand)
- Steel foundation (fundering op staal)
- Strip foundation (stroken fundering)

BUILDING CIRCULARITY FILTERS

BUILDING PART AREAS

Roof	531.75	m^2
Facade	1,330.00	m^2
Floors	1,750.00	m^2
Inside walls	1,470.00	m^2
Foundation	420.00	m^2





93.13K	37.39K	43%	100%
TOTAL BUILDINGS BENCHMARK DATASET	TOTAL PROJECT OPTIONS	WITHIN PROJECT EC TARGET	WITHIN PROJECT MPG TARGET

ut

1a. DESIGN FEEDBACK

PROJECT INPUT A

Building function	All	
Gross floor area:	0	m^2
Building lifetime	All	years
Location	Delft	

REGULATORY FILTERS

MPG: 0.20 – 0.76

EC: 93.45 – 297.35

EC+: -56.28 – 266.46

BUILDING SPECIFIC FILTERS

Project | Structural material

- Select all
- Concrete
- Hybrid (steel +concrete)
- Hybrid (timber + concrete)
- Timber

Structural system

- Select all
- Beam-and-column system - (kolom-balk)
- Frame construction - (skeletbouw)
- Hybrid structure - (hybride)
- Load-bearing wall system - (draagmuurconstr...
- Massive structure- (massief)
- Shear wall system - (schijven)
- Shell structure

Foundation type

- Select all
- Displacement piles (concrete)
- Displacement piles (steel)
- Displacement piles (wood)
- Drilled piles - cast in place(concrete)
- Drilled piles - driven
- Drilled piles - screw
- Slab-on-grade (vloer op zand)
- Steel foundation (fundering op staal)
- Strip foundation (stroken fundering)

BUILDING CIRCULARITY FILTERS

BUILDING PART AREAS

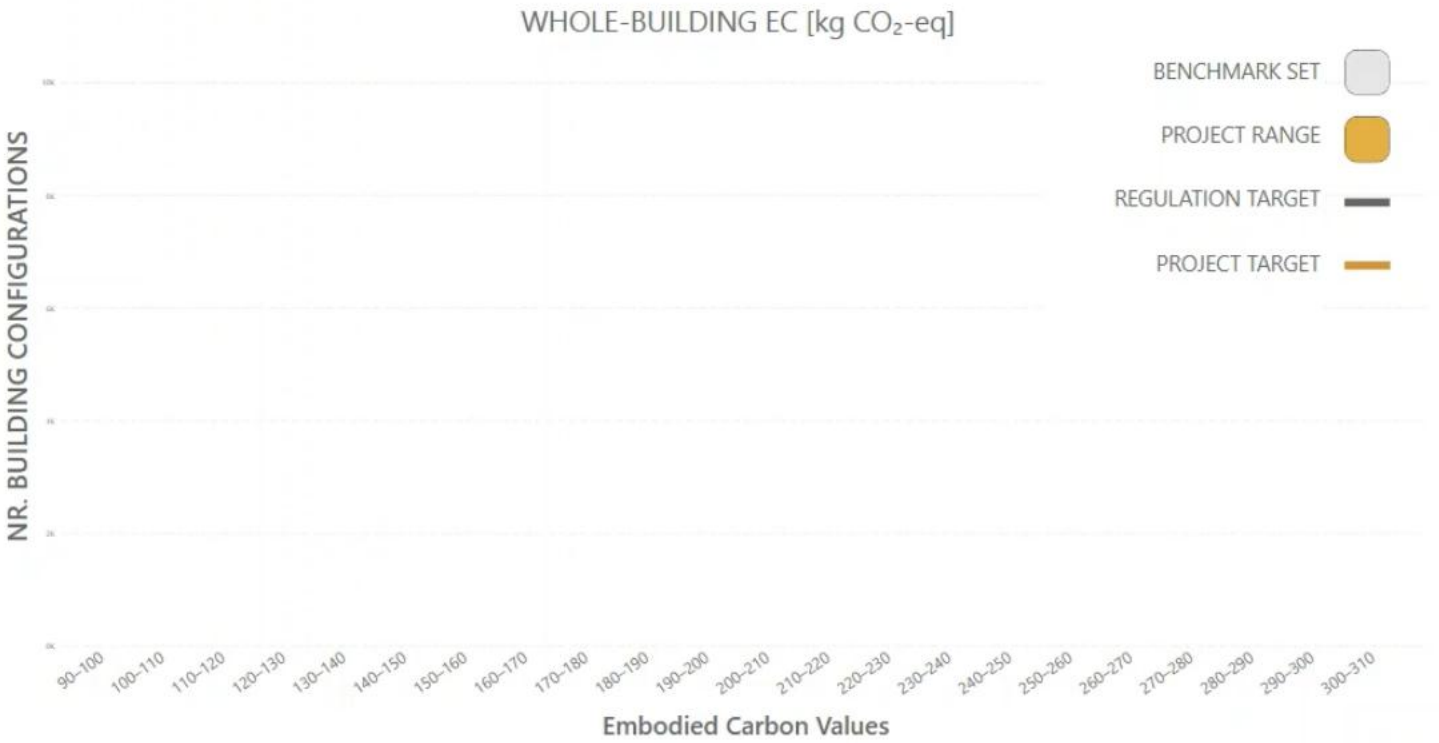
Roof	0.00	m^2
Facade	0.00	m^2
Floors	0.00	m^2
Inside walls	0.00	m^2
Foundation	0.00	m^2

MPG

€0,00 — €1,28

EC

0,00 kg CO2 — 507,54 kg CO2



--K	--K	100%	100%
TOTAL BUILDINGS BENCHMARK DATASET	TOTAL PROJECT OPTIONS	WITHIN PROJECT EC TARGET	WITHIN PROJECT MPG TARGET

INPUT

1a. DESIGN FEEDBACK

PROJECT INPUT A

Building function	Office	
Gross floor area:	1750	m^2
Building lifetime	50	years
Location	Delft	

REGULATORY FILTERS

MPG: 0.20 – 0.76

EC: 93.45 – 186.56

EC+: 56.28 – 266.46

BUILDING SPECIFIC FILTERS

Project | Structural material

- Select all
- Concrete
- Hybrid (steel +concrete)
- Hybrid (timber + concrete)
- Timber

Structural system

- Select all
- Beam-and-column system - (kolom-balk)
- Frame construction - (skeletbouw)
- Hybrid structure - (hybride)
- Load-bearing wall system - (draagmuurconstr...
- Massive structure- (massief)
- Shear wall system - (schijven)
- Shell structure

Foundation type

- Select all
- Displacement piles (concrete)
- Displacement piles (steel)
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- Drilled piles - cast in place(concrete)
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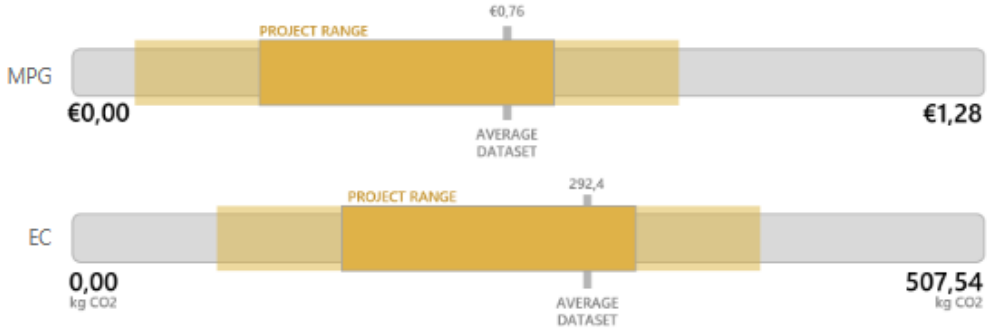
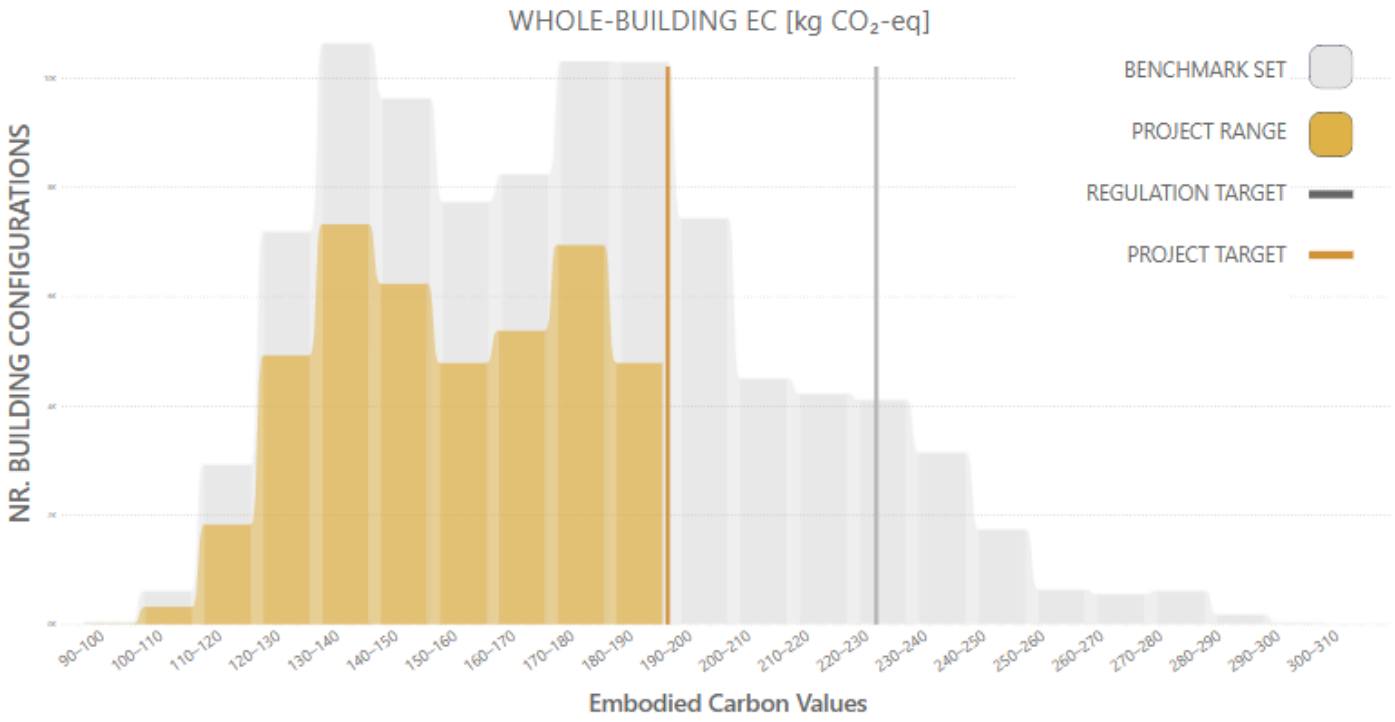
- Strip foundation (stroken fundering)

BUILDING CIRCULARITY FILTERS

BUILDING PART AREAS

Roof	531.75	m^2
Facade	1,330.00	m^2
Floors	1,750.00	m^2
Inside walls	1,470.00	m^2
Foundation	420.00	m^2





93.13K	37.39K	43%	100%
TOTAL BUILDINGS BENCHMARK DATASET	TOTAL PROJECT OPTIONS	WITHIN PROJECT EC TARGET	WITHIN PROJECT MPG TARGET

INPUT

Filters | Phase 1b

General filters

REGULATORY FILTERS

VERIFICATION STATUS

Building filters

BUILDING SPECIFIC FILTERS

Element filters

ELEMENT FILTERS

- ROOF
- FAÇADE
- INTERIOR WALL
- FLOOR
- FOUNDATION

INPUT

Filters | Phase 1b

General filters

REGULATORY FILTERS

VERIFICATION STATUS

Building filters

BUILDING SPECIFIC FILTERS

Element filters

ELEMENT FILTERS

ROOF

FAÇADE

INTERIOR WALL

FLOOR

FOUNDATION

FLOOR

Floortype
- Select all
- Breedplaatvloer
- CLT_vloer
- IHW_vloer_beton
- Kanaalplaatvloer
- Staalplaatbetonvloer
- TCC_vloer
- TT_plaatvloer

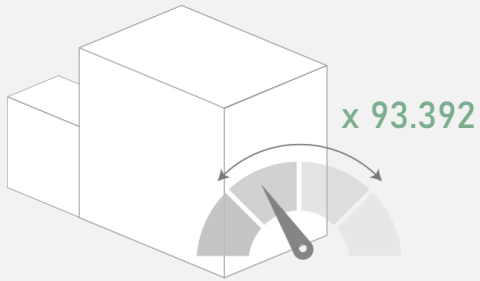
Top system
- Select all
- No_top_system
- Raised_floors
- Screed
- Climate_system_above_floor
- Finishing
- Other

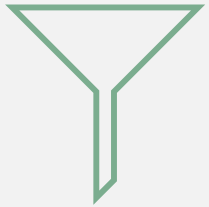
Bottom system
- Select all
- Building_services
- Lowered_ceiling
- No_bottom_system

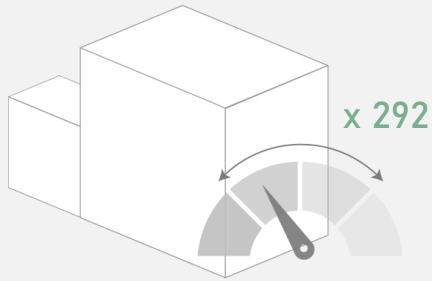
Circular requirements
- Select all
- Biobased
- Demountable
- Detachable
- Mono-material
- Reclyble
- Reused

PROCESS

Project analysis

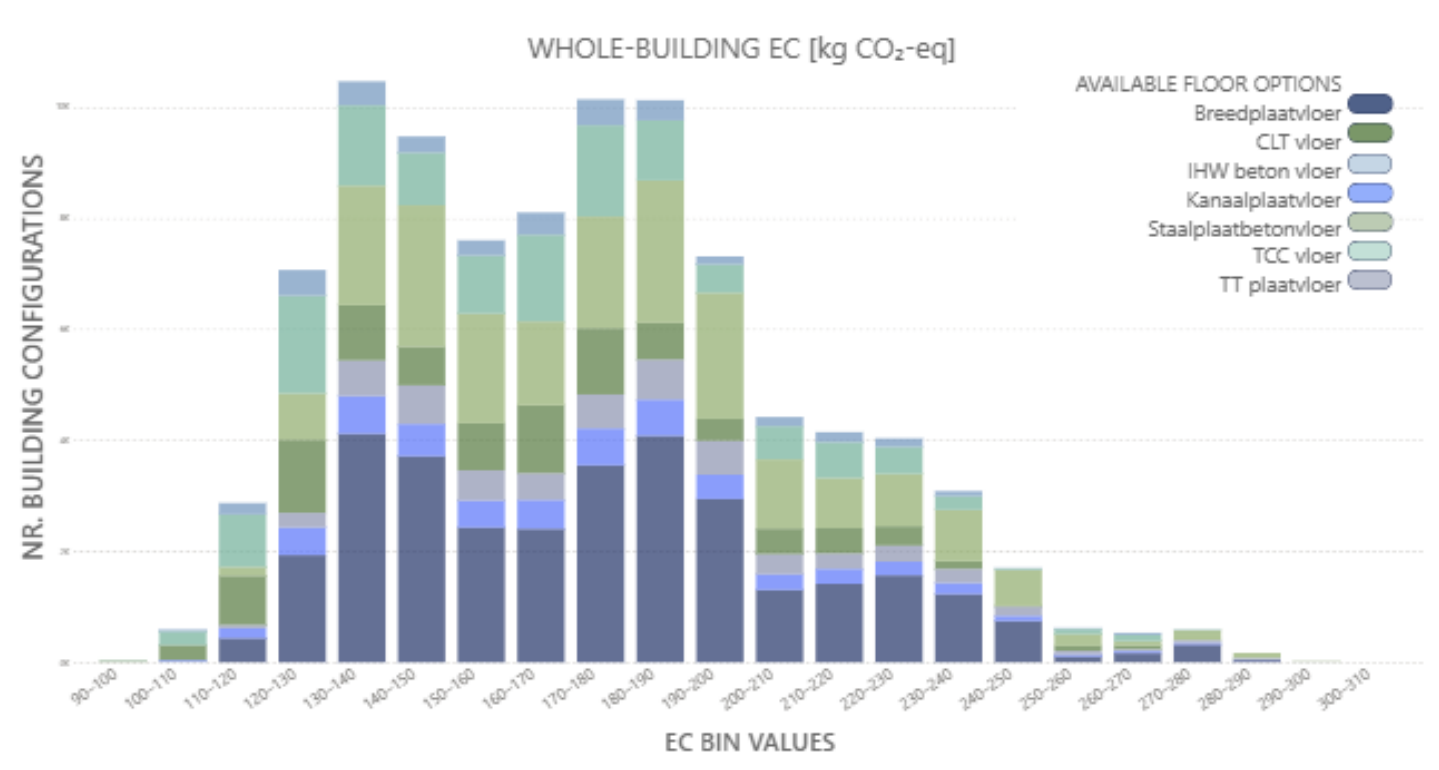






PROJECT DATA

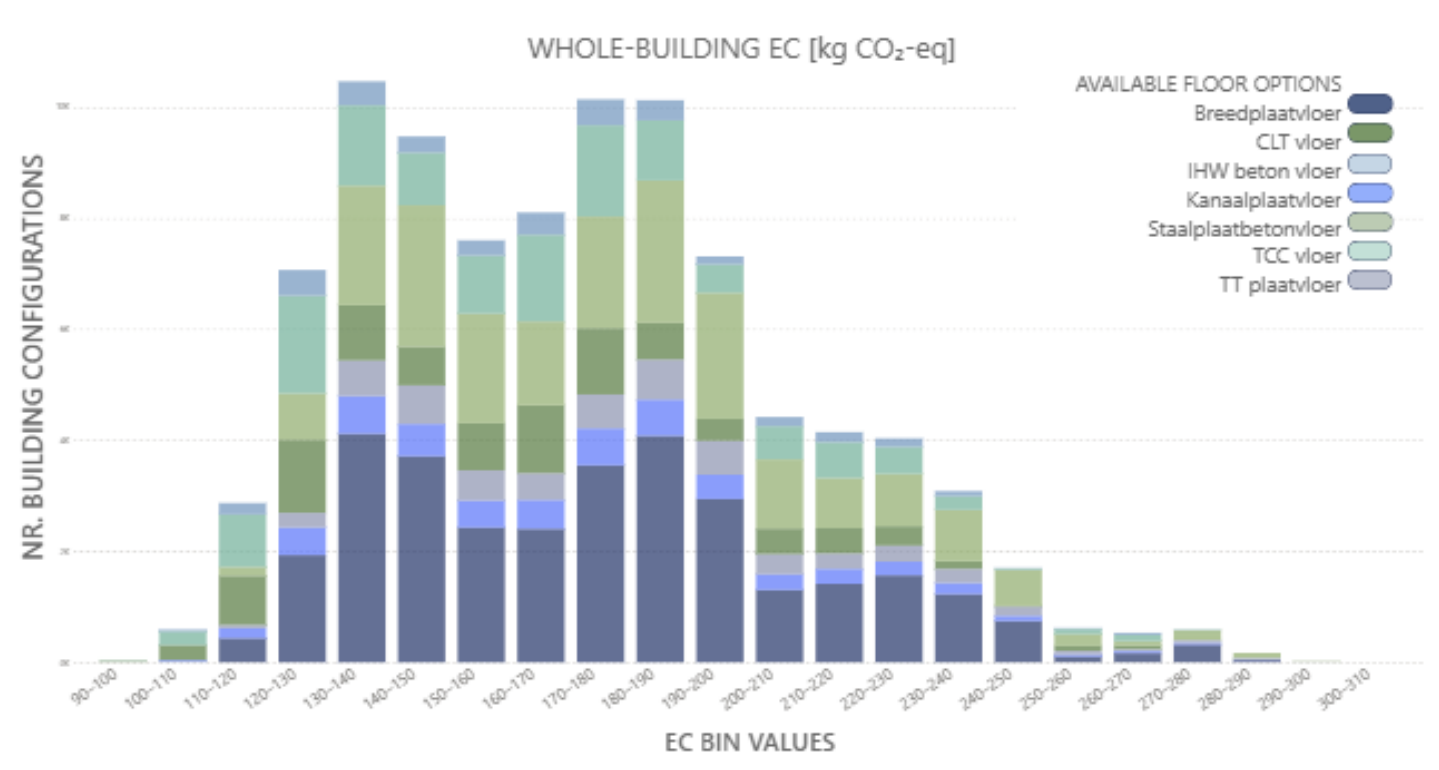
Benchmark data



B. PROCESS

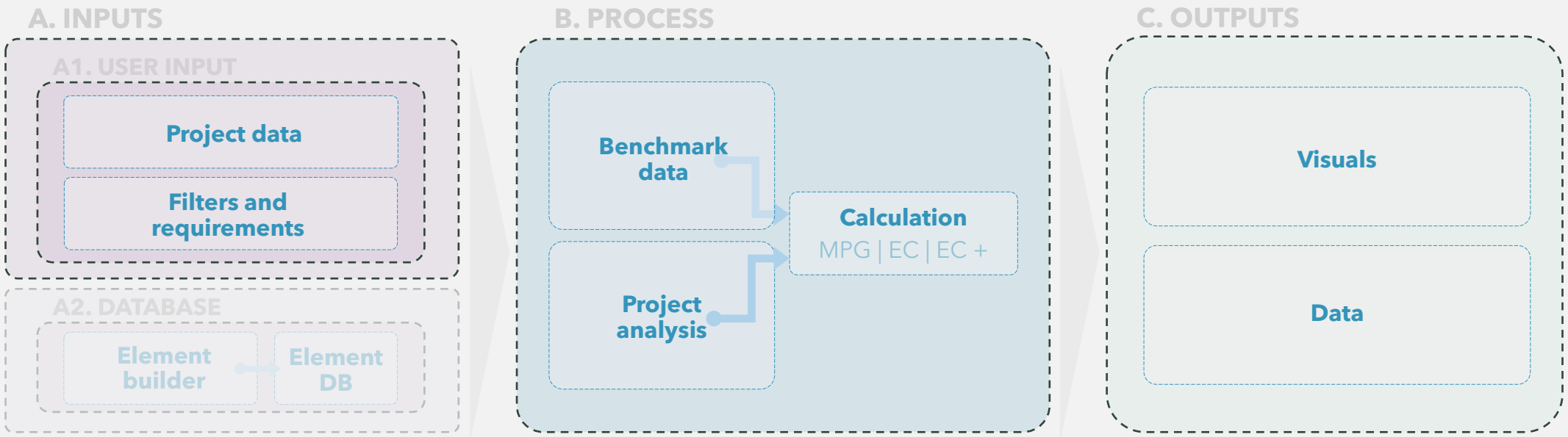
Benchmark data

Hier een soort concluderende slide
om het voorbeeld af te sluiten



TOOL MODULES

And sub-components

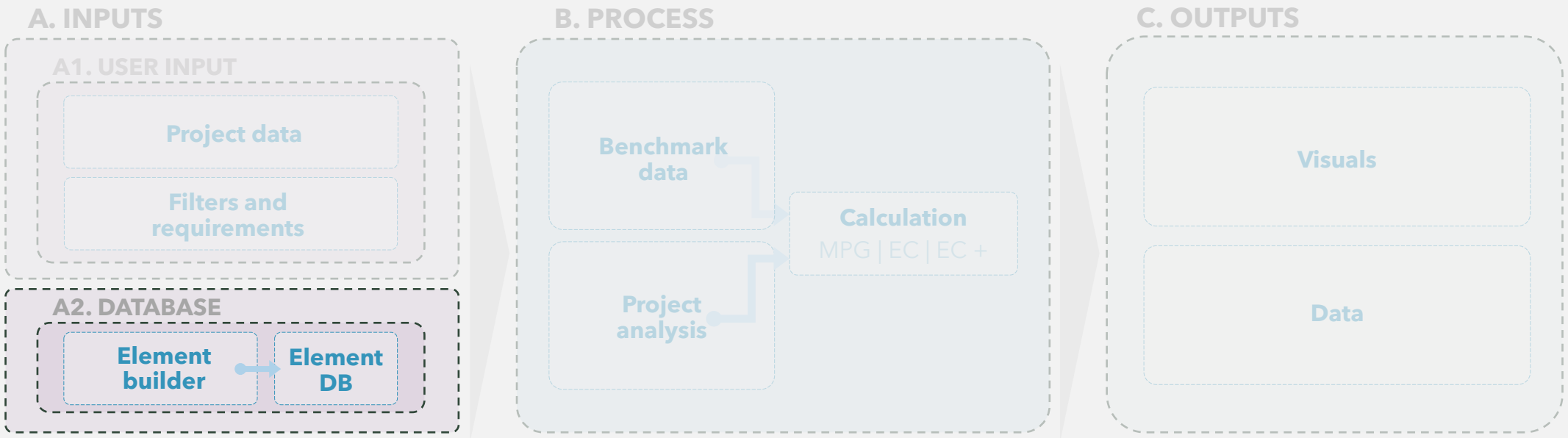


VOORBEELD VIDEO

+ video

TOOL MODULES

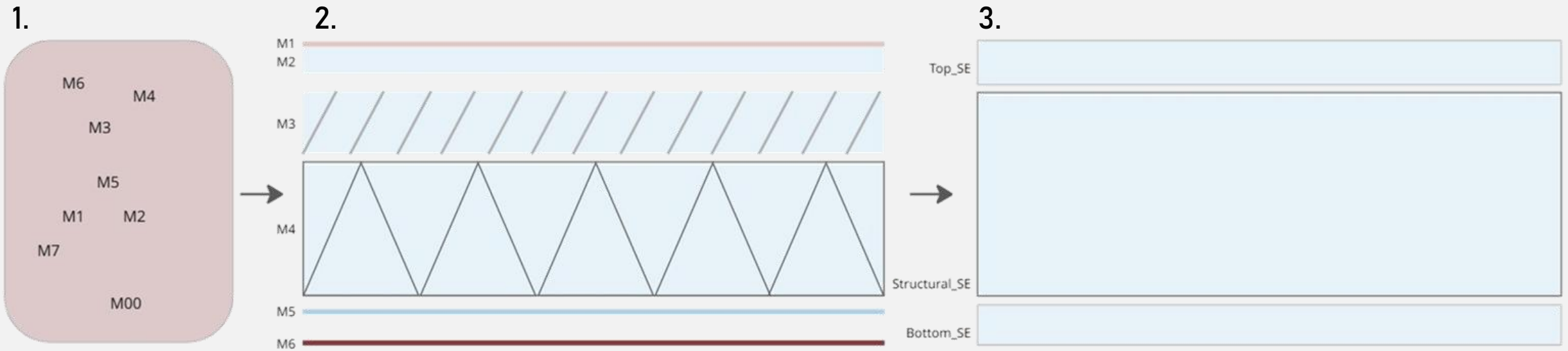
Element builder



DATABASE

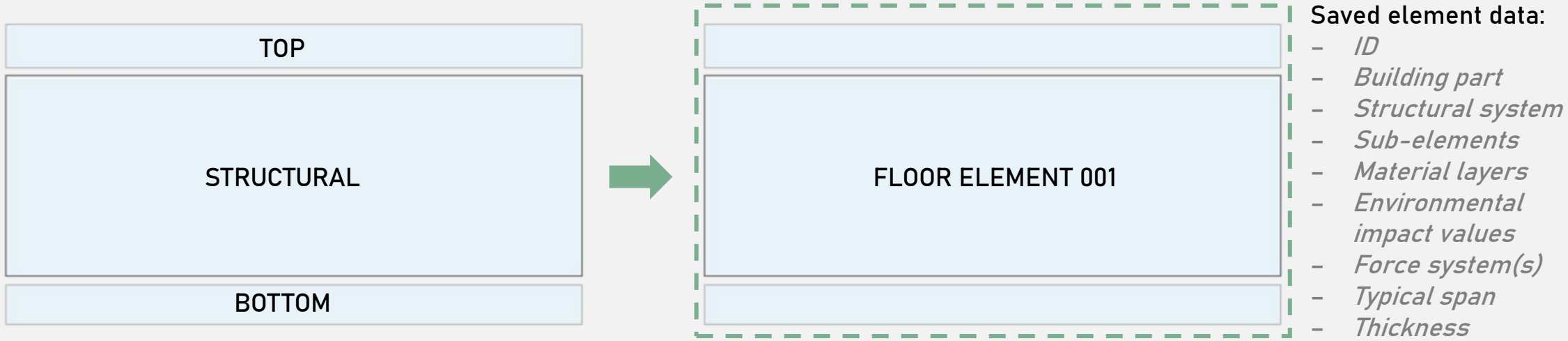
Element builder – filling the database

1. Unstructured EPD database
2. Material database (Structured and normalized)
3. Sub-element database (Top, structure and bottom)



DATABASE

Element builder - filling the database



DATABASE

Element builder - filling the database

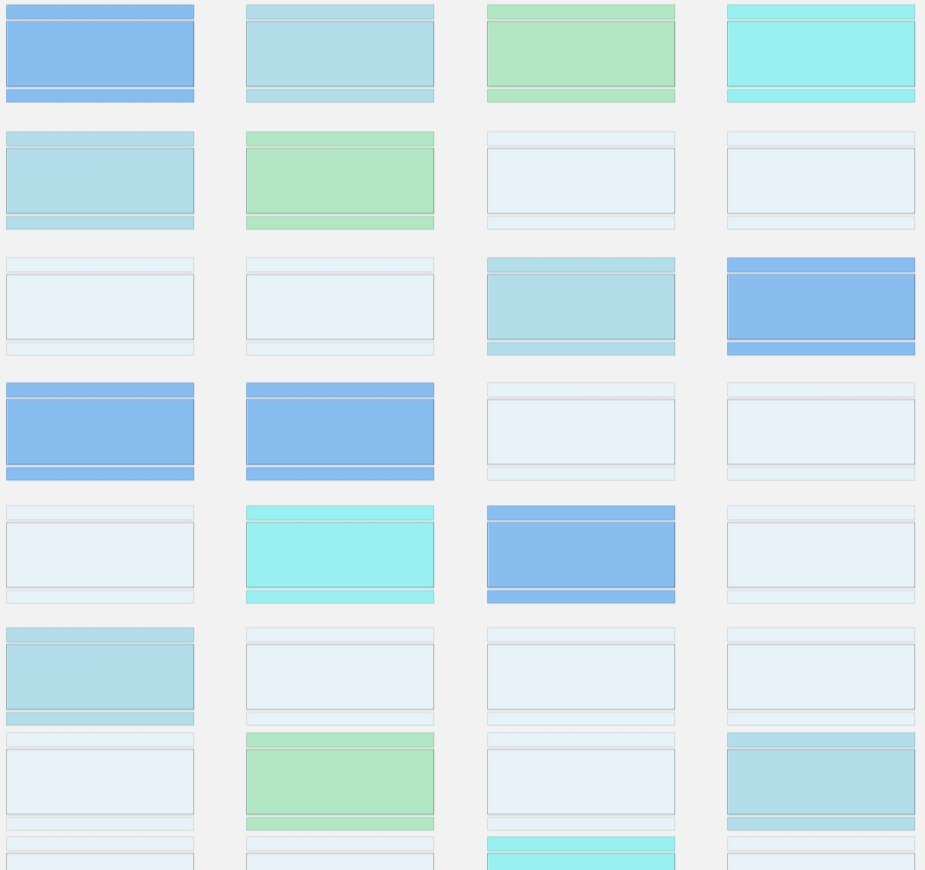
TOP: *11 options*

STRUCTURAL: *121 options*

BOTTOM: *12 options*

=

15.972 floor element options (with current database size)



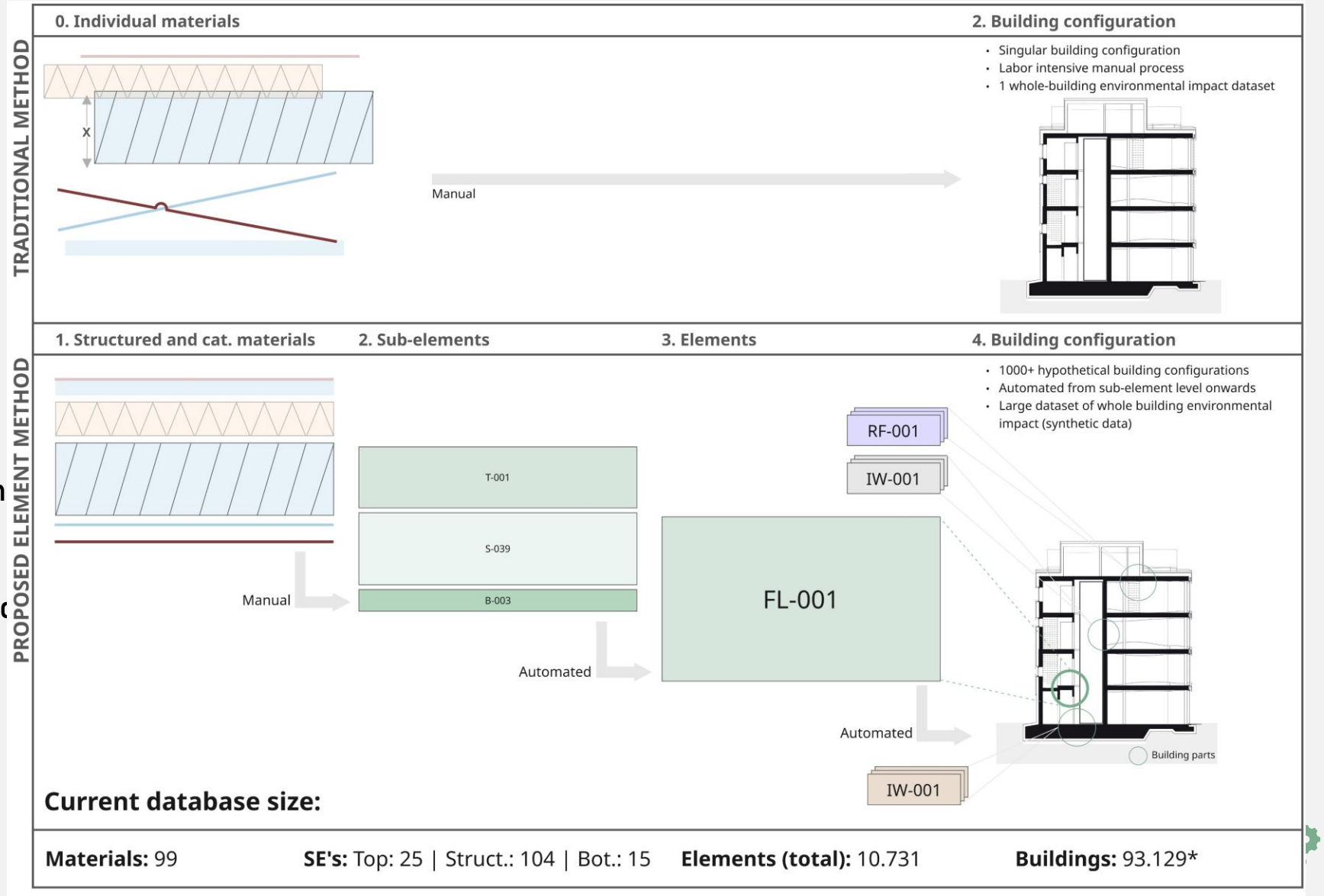
COMPARE

Benchmark data

Presenteer hier 1 v 1

In about half an hour th
options

Wood structure – hybrid



BIJKOMENDE VOORDELEN

Benchmark data

Leg hier uit dat door de enorme dataset je niet alleen maar UC 1 hebt, maar ook UC 2 en 3

CONCLUDERENDE SLIDE

Benchmark data

Integratie en vermakkelijking van berekening in design process>>
Meer duurzame gebouwen

DISCUSSION

TSubtitle

Wat wil je hier wel en niet zeggen?