WELCOME !

GRADUATION PRESENTATION | LIEVE CROONEN | 06-11-2020

A sustainable and reusable concrete facade system

An approach to improve the use of concrete in the Dutch housing market

LIEVE CROONEN

4212096

SUSTAINABLE DESIGN STUDIO

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DELEGATE OF THE BOARD OF EXAMINERS: LOUIS LOUSBERG

1 **INTRODUCTION**

Background

Problem

Research question

Framework

INTRODUCTION

2

THEORETICAL RESEARCH

- Circular economy
- Concept of Reuse
- Rethink
- Reduce
- Reuse

Concept design criteria

✓ INTRODUCTION

✓ THEORETICAL RESEARCH

3 **ANALYSIS PHASE**

Case study – Standardisation

Case study – Modular building systems

Final design criteria

INTRODUCTION

RESEARCH

ANALYSIS

4 **DESIGN PHASE**

Explanation of the design strategy

INTRODUCTION

RESEARCH

ANALYSIS

DESIGN PROCESS

5 **FINAL DESIGN STRATEGY**

Building system strategy

Final design strategy

✓ INTRODUCTION

✓ RESEARCH

✓ ANALYSIS

✓ DESIGN PROCESS

✓ FINAL DESIGN STRATEGY

6 **CONCLUSION**

INTRODUCTION

THEORITICAL RESEARCH

ANALYSIS PHASE

RESEARCH THROUGH DESIGN

FINAL DESIGN STRATEGY

CONCLUSION

7 **DICUSSION & RECOMMANDATIONS**

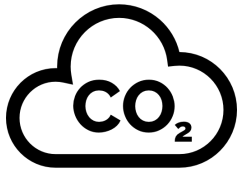
INTRODUCTION

50%

ALL NATURAL RESOURCES

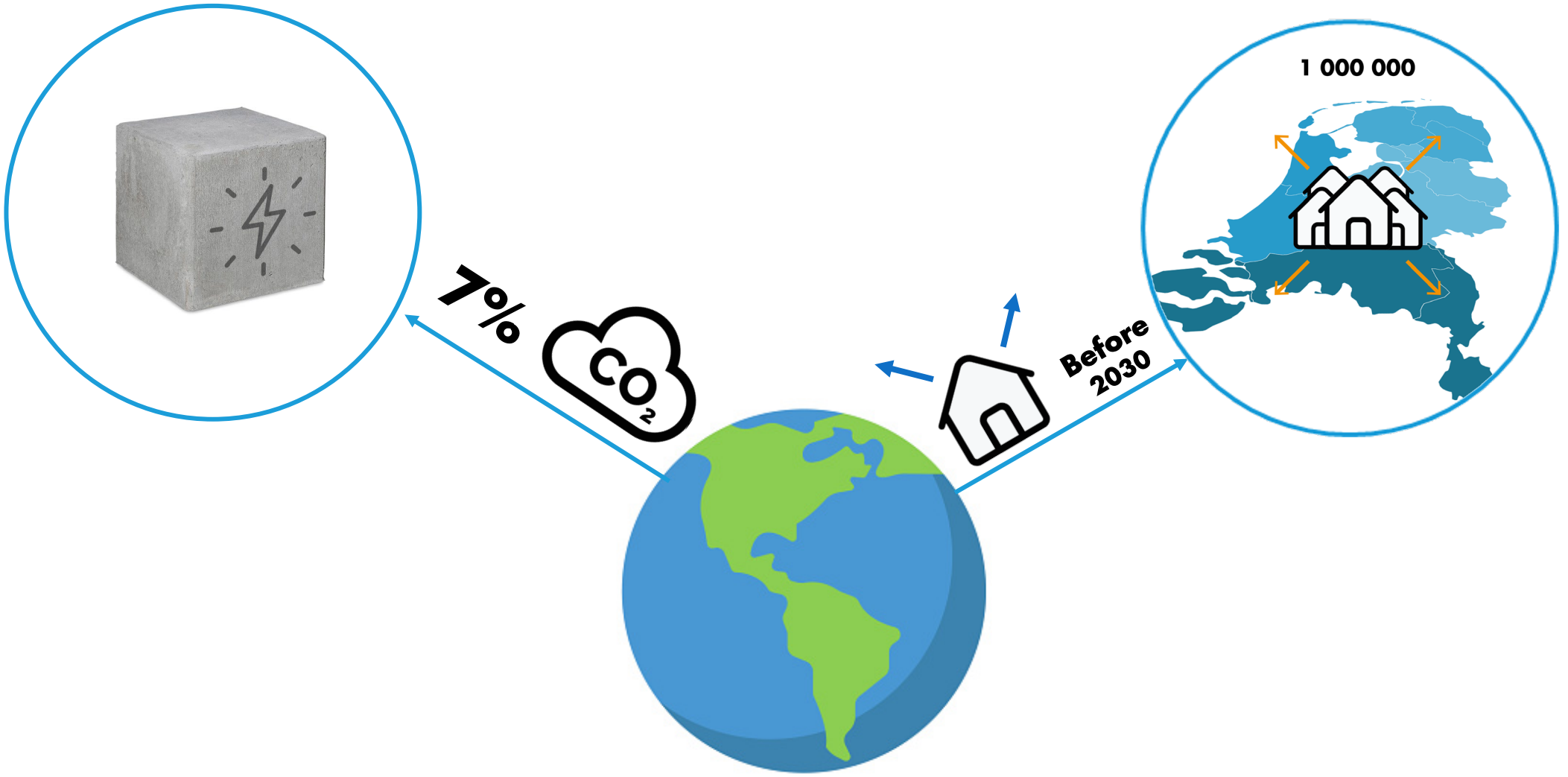
40%

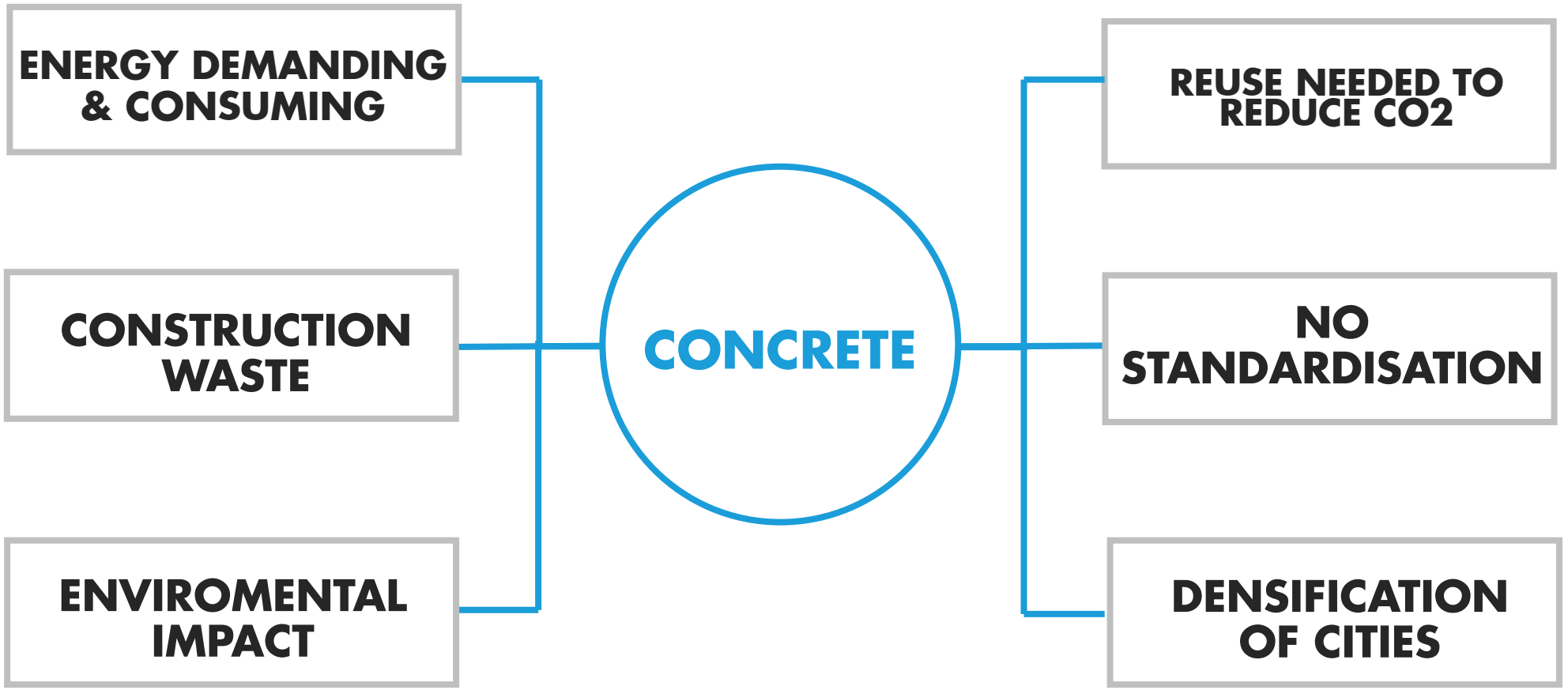
CO2 EMISSONS



38%

TOTALE WASTE PRODUCTION


7%
CO_2
Before 2030
1 000 000


ENERGY DEMANDING & CONSUMING
CONSTRUCTION WASTE
ENVIROMENTAL IMPACT
CONCRETE
REUSE NEEDED TO REDUCE CO2
NO STANDARDISATION
Ddensification OF CITIES

How can a sustainable concrete facade system be designed for the Dutch housing market in order to make it reusable?

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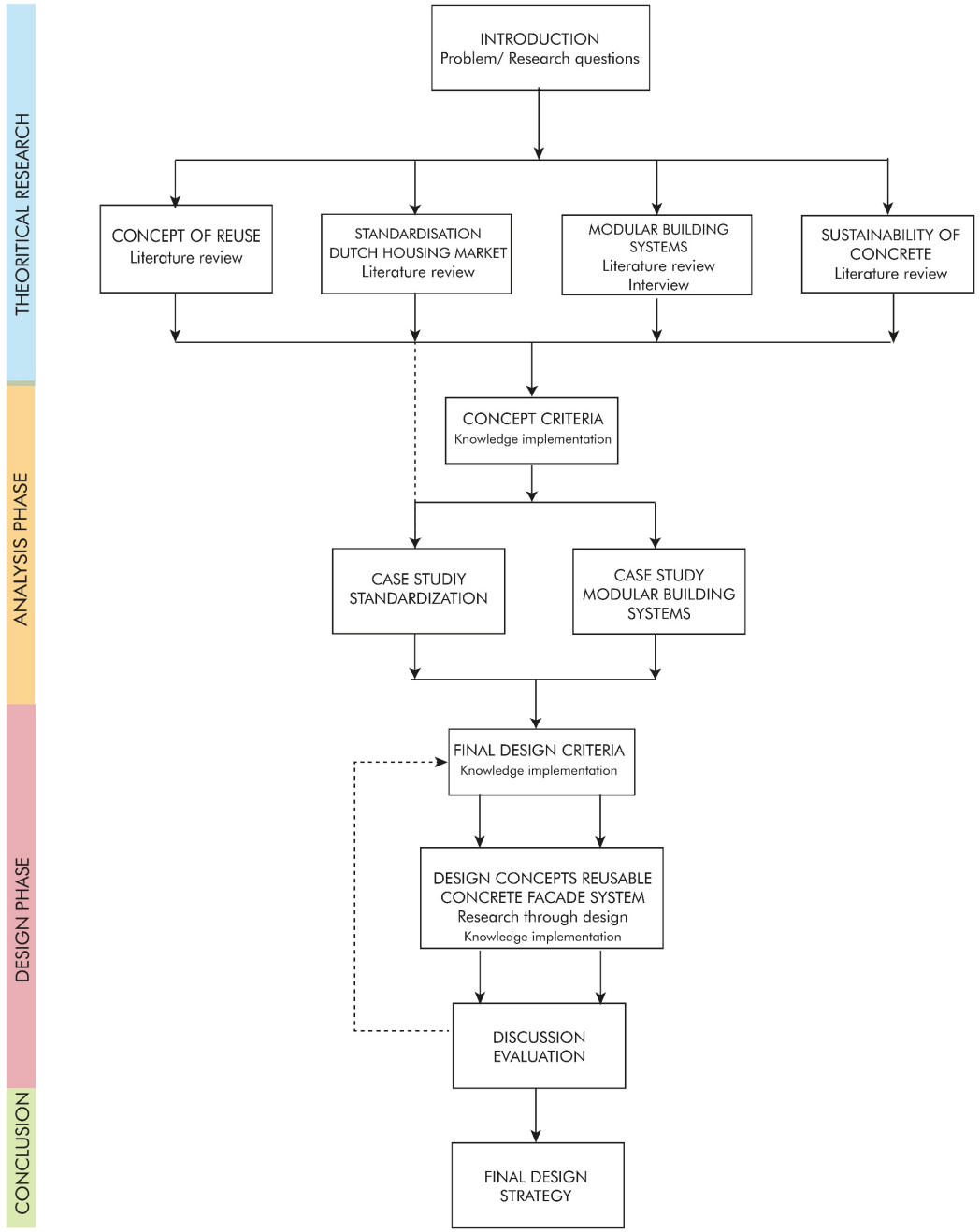
Methodology

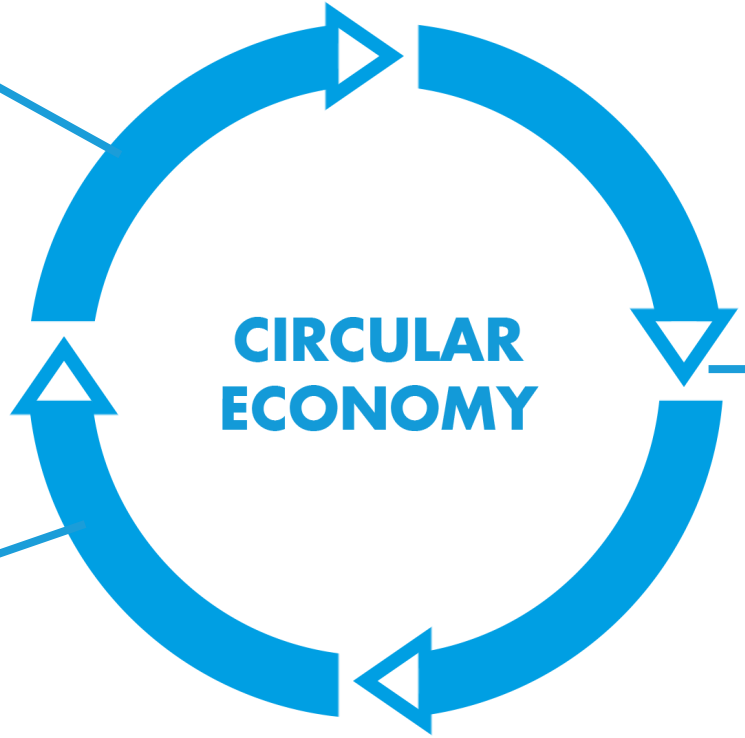


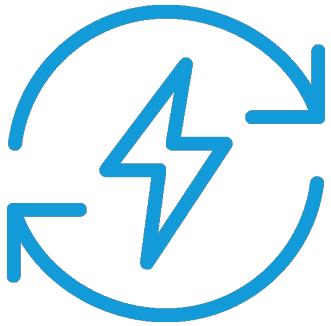
THEORETICAL RESEARCH

Circular economy

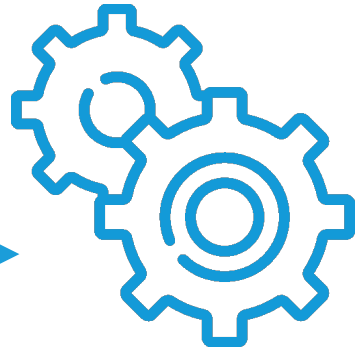
According to Ellen MacArthur Foundation (2012)

Close loop of raw materials

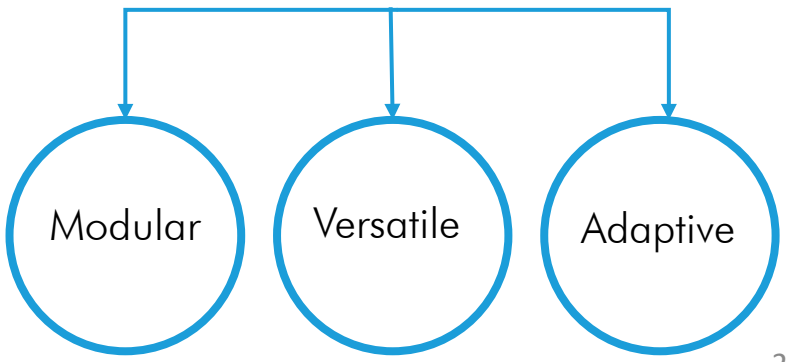




Use of renewable energy



Use of diverse systems



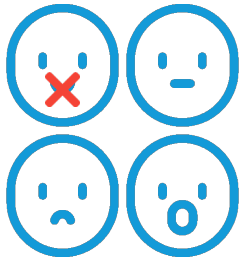
Reuse of a product
in its original form

- Minimal processing
- Preserving the (high) value of the product

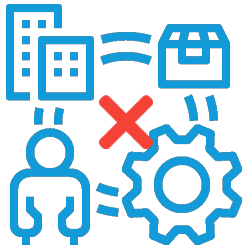
Close down waste
streams

Market
No confidence

Government
Conflicting regulations & subsidies

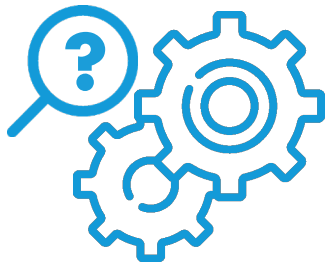


Negative consumer behaviour
Negative perception of reused concrete

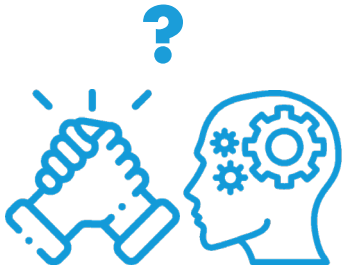


Mismatch supply & demand

Risk
Skewed relationship between contractor and customer



Lack of quality control



Lack of knowledge and collaboration

Level of priority

Refuse

Rethink

Reduce

Reuse

Repair

Refurbish

Remanufacture

Repurpose

Recycle

Recover

Level of value of a element

10R's – Jaqueline Cramer

Level of priority

Refuse

Rethink

Reduce

Reuse

Repair

Refurbish

Remanufacture

Repurpose

Recycle

Recover

Focus of the project

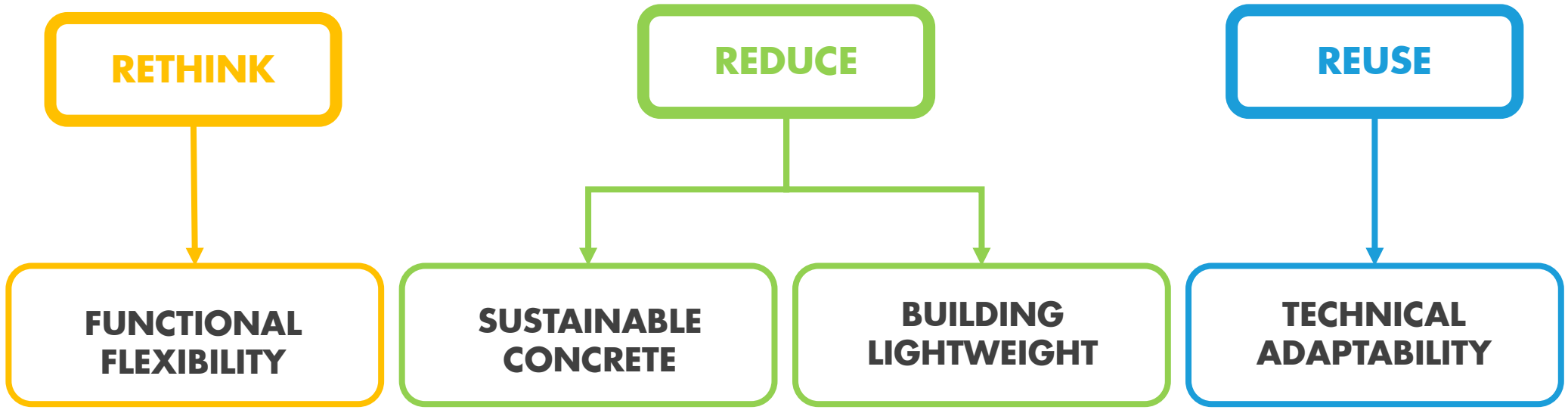
10R's – Jaqueline Cramer

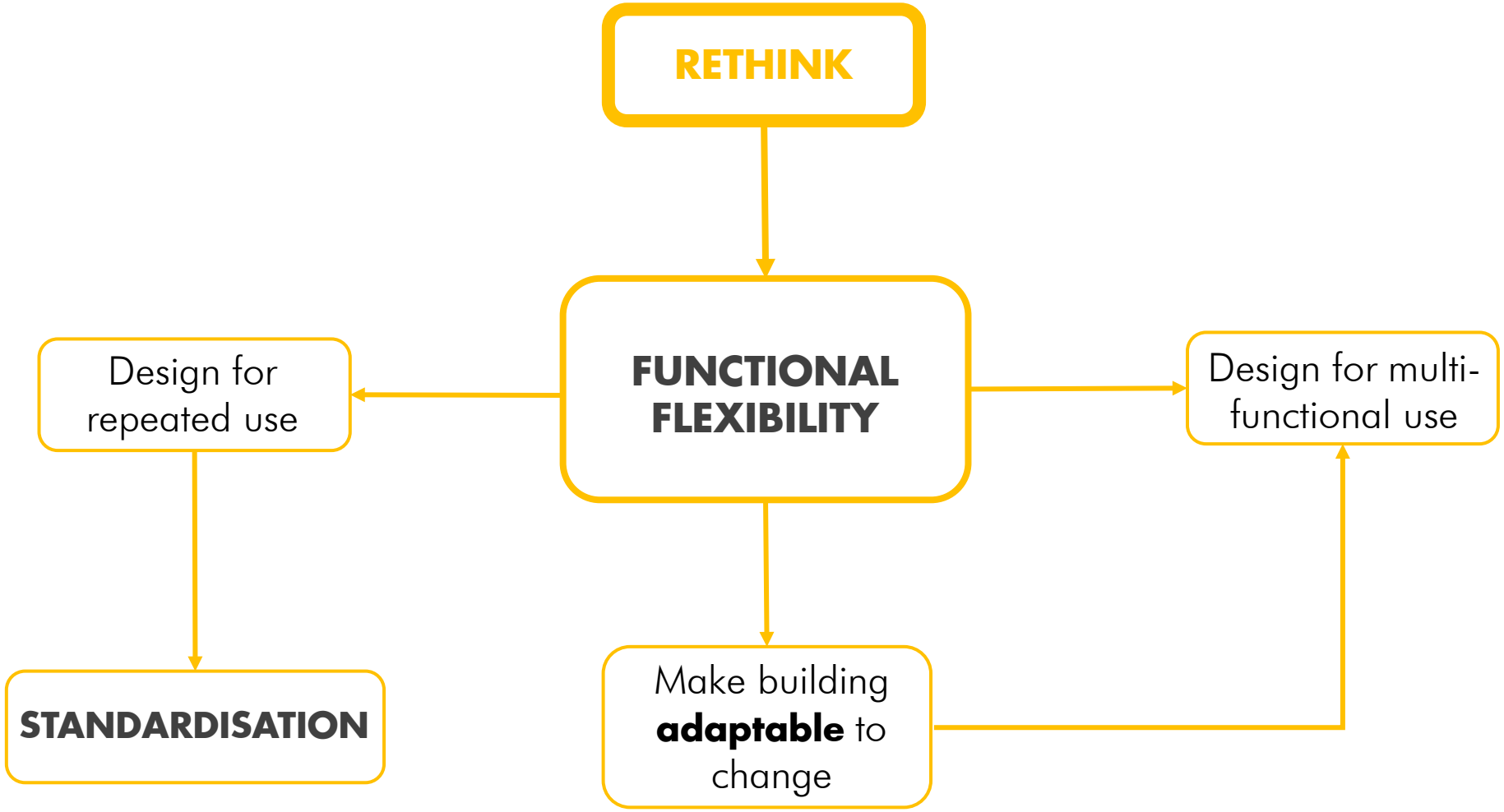
Rethink or redesign the project in view of circularity

Decrease the use of concrete and cement (make it more sustainable)

Ability to reuse the concrete facade system in a new lifecycle

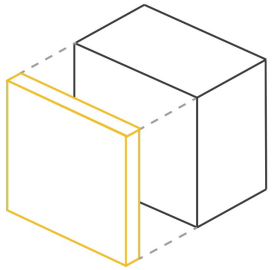
Maximize the life cycle of concrete




RETHINK
FUNCTIONAL FLEXIBILITY
Design for repeated use
Design for multi-functional use
STANDARDISATION
Make building **adaptable** to change

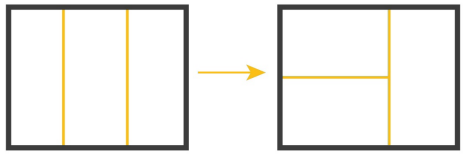
SCENARIOS

<20 years



Change of facade finish
due to change in preferences

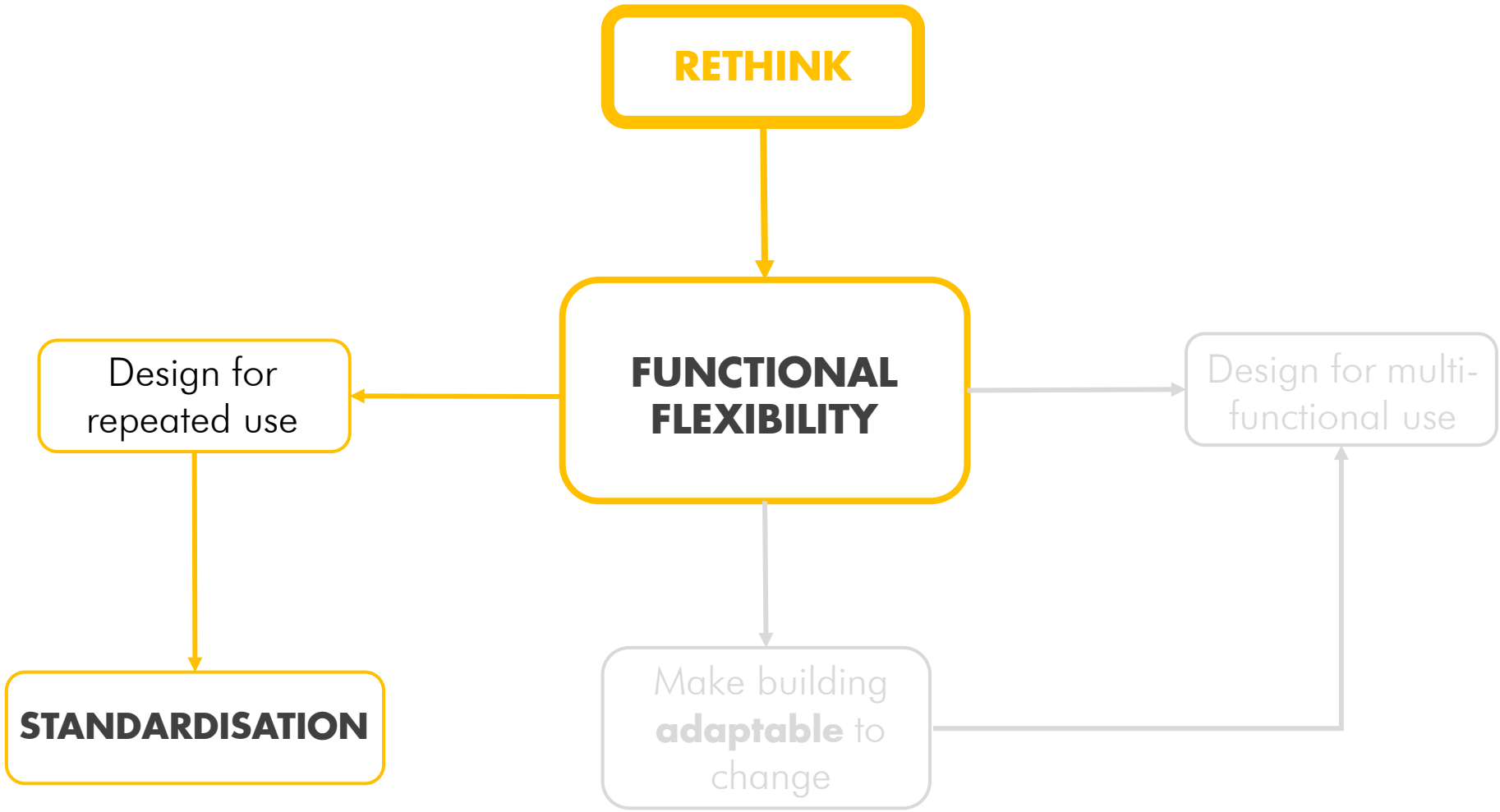
>20 years



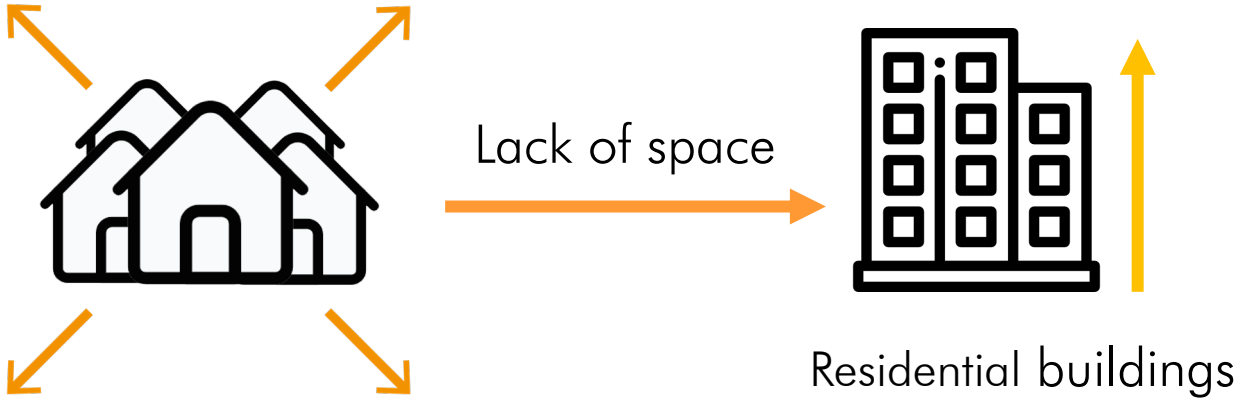
Different lay out
due to newer requirements building, taste or function change

50-100 years

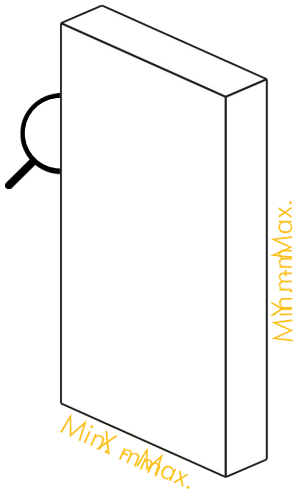
Reuse of panels
due to wanting a complete new design

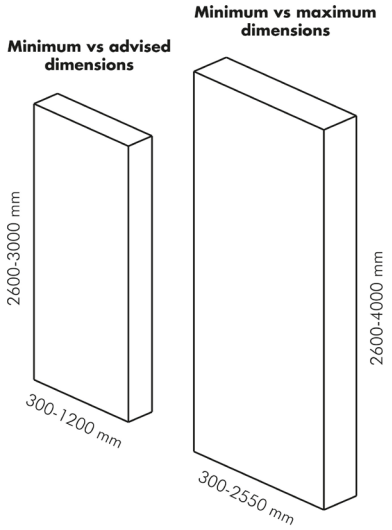

RETHINK
FUNCTIONAL FLEXIBILITY
Design for repeated use
STANDARDISATION
Design for multi-functional use
Make building adaptable to change

Why?



Standardisation makes
reuse easier to use in future





Input

Standardisation
case study

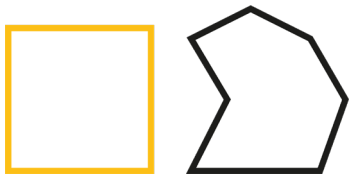
DESIGN CRITERIA

Find minimum and maximum dimensions for Dutch housing market

Minimum and maximum dimensions

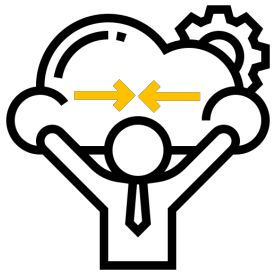
Standardisation

Repetition in production process



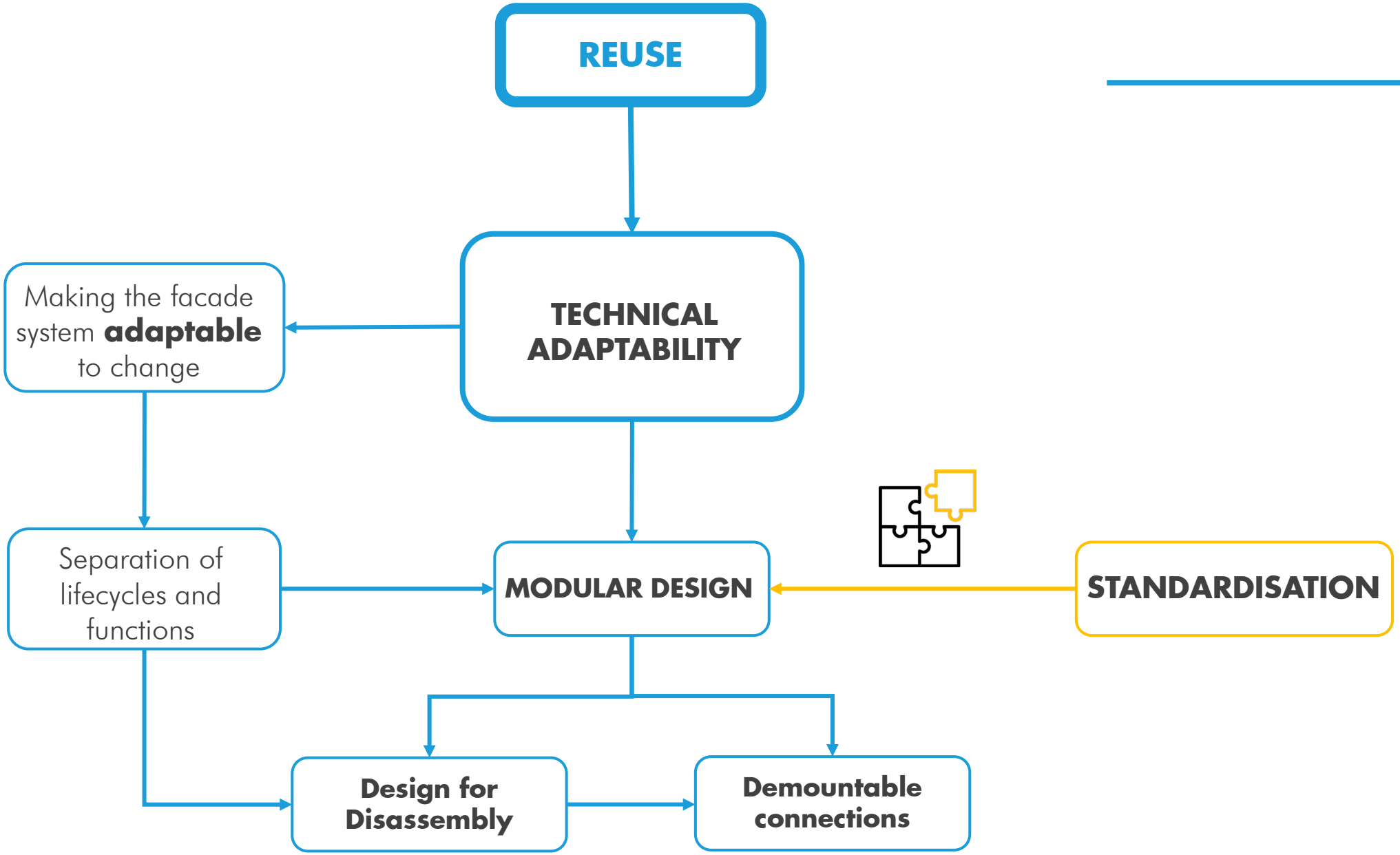
Simple form

As less different kind of panels to speed up production process

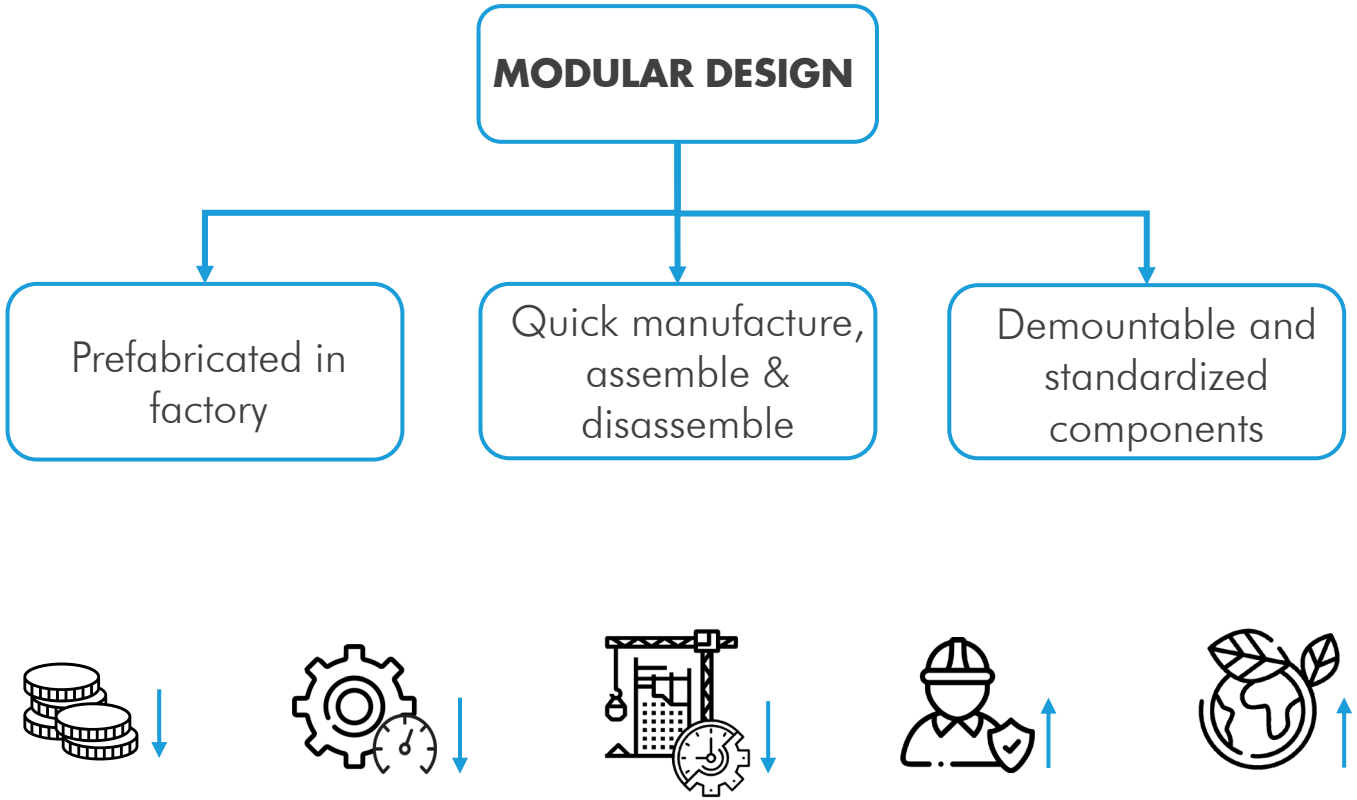


Consequences for flexibility & diversity

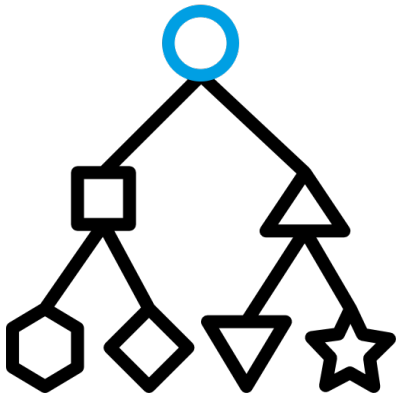
DESIGN CRITERIA


REUSE
TECHNICAL ADAPTABILITY
Making the facade system **adaptable** to change
Separation of lifecycles and functions
MODULAR DESIGN
STANDARDISATION
Design for Disassembly
Demountable connections

Building modular



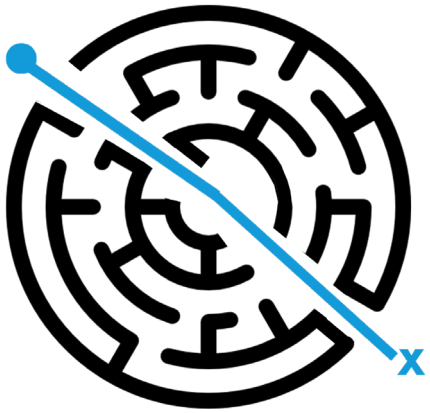
Design for disassembly



Independence
Separation of elements,
its lifecycles and functions to
increase lifespan

DESIGN CRITERIA
Separation of functions and
lifecycles

Easy and fast assembly &
disassembly

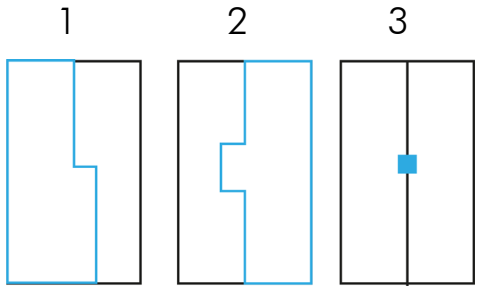


Exchangeability
Designing a simple & easy product,
to enhance its production, assembling
and disassembling

DESIGN CRITERIA
Exchangability of connection
(complexity)

Connections easy to inspect,
assemble and disassemble

Demountable connections



Minimize the number of different connections,
(materials and components)

DESIGN CRITERIA
Number of connections per panel

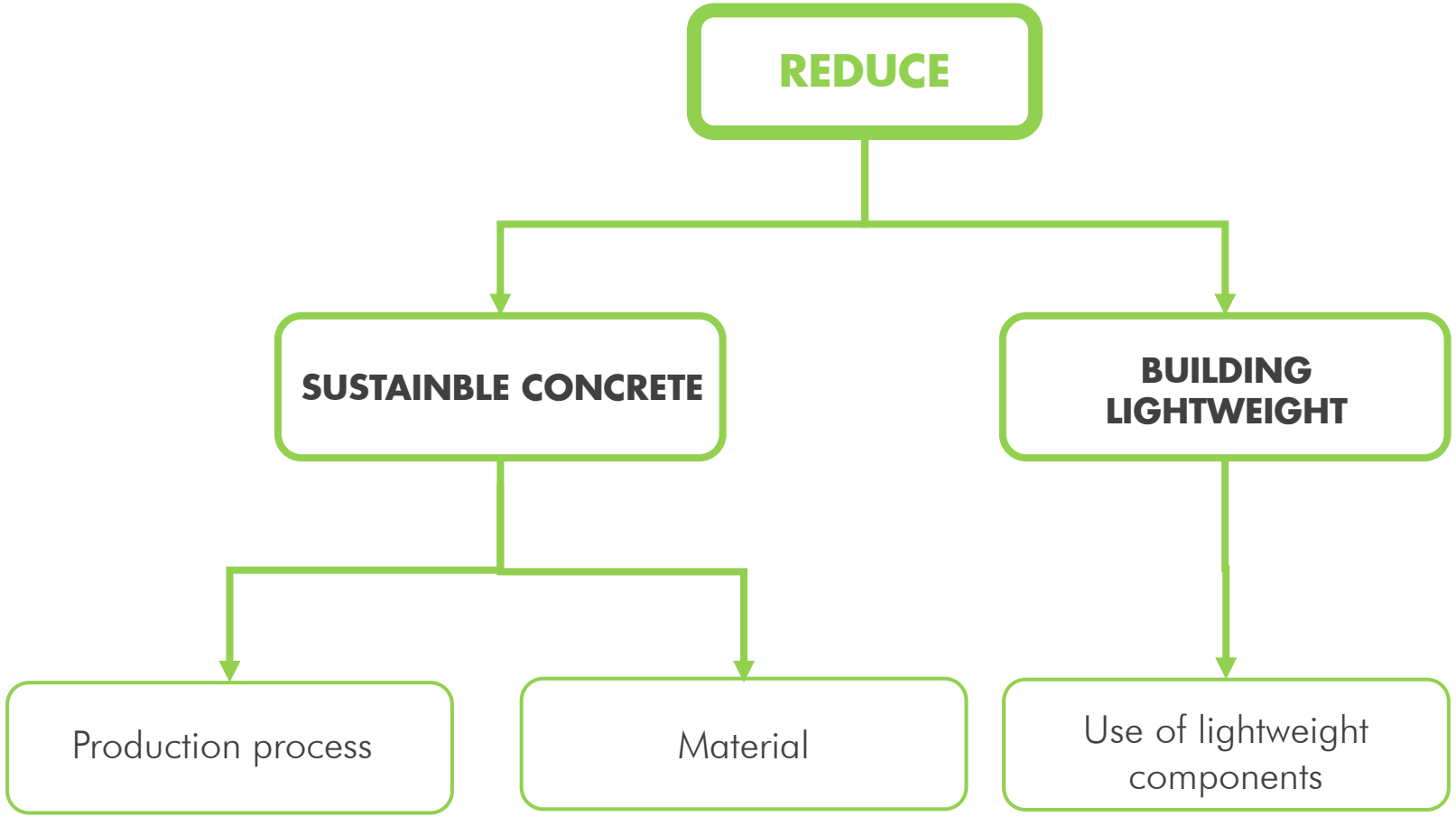
Use of a flexible dry connection
1 Overlapping, 2 interlocking and 3 external connections

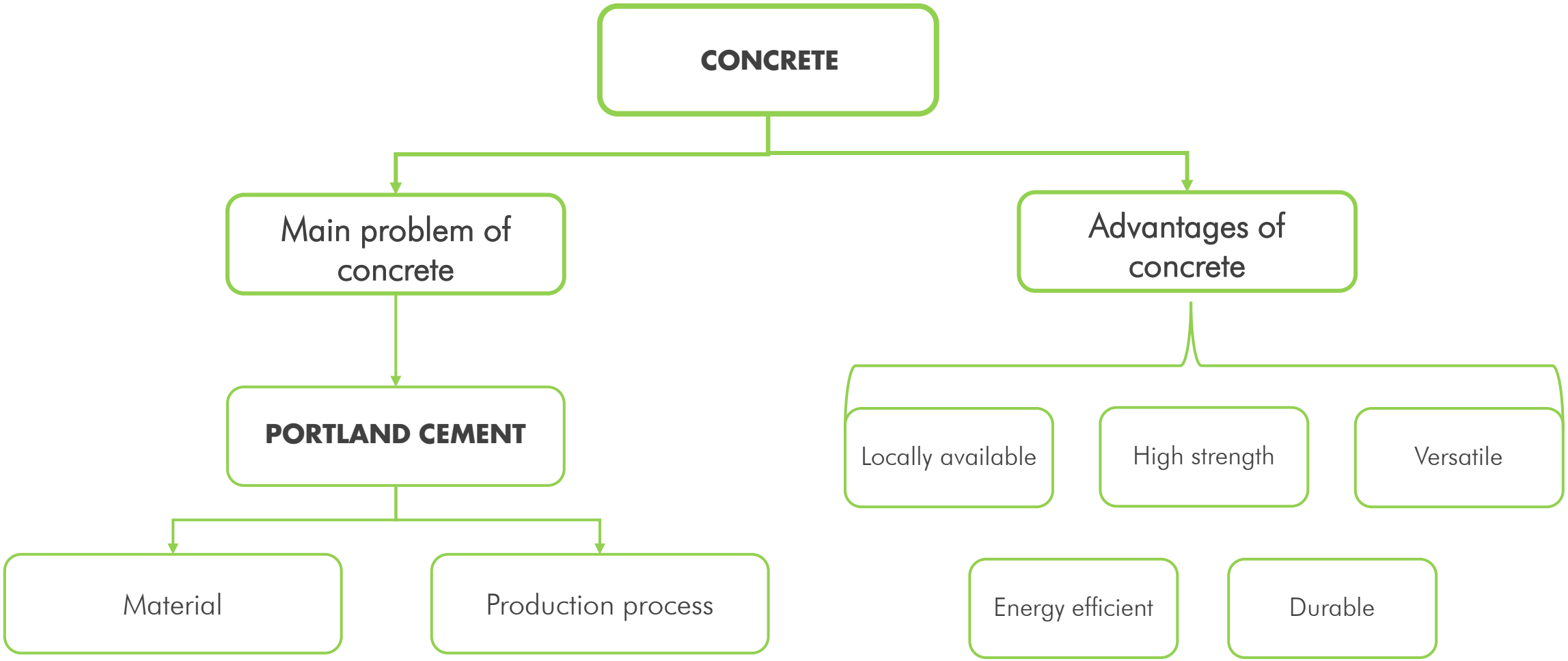
DESIGN CRITERIA
Use of dry connections (demountable)

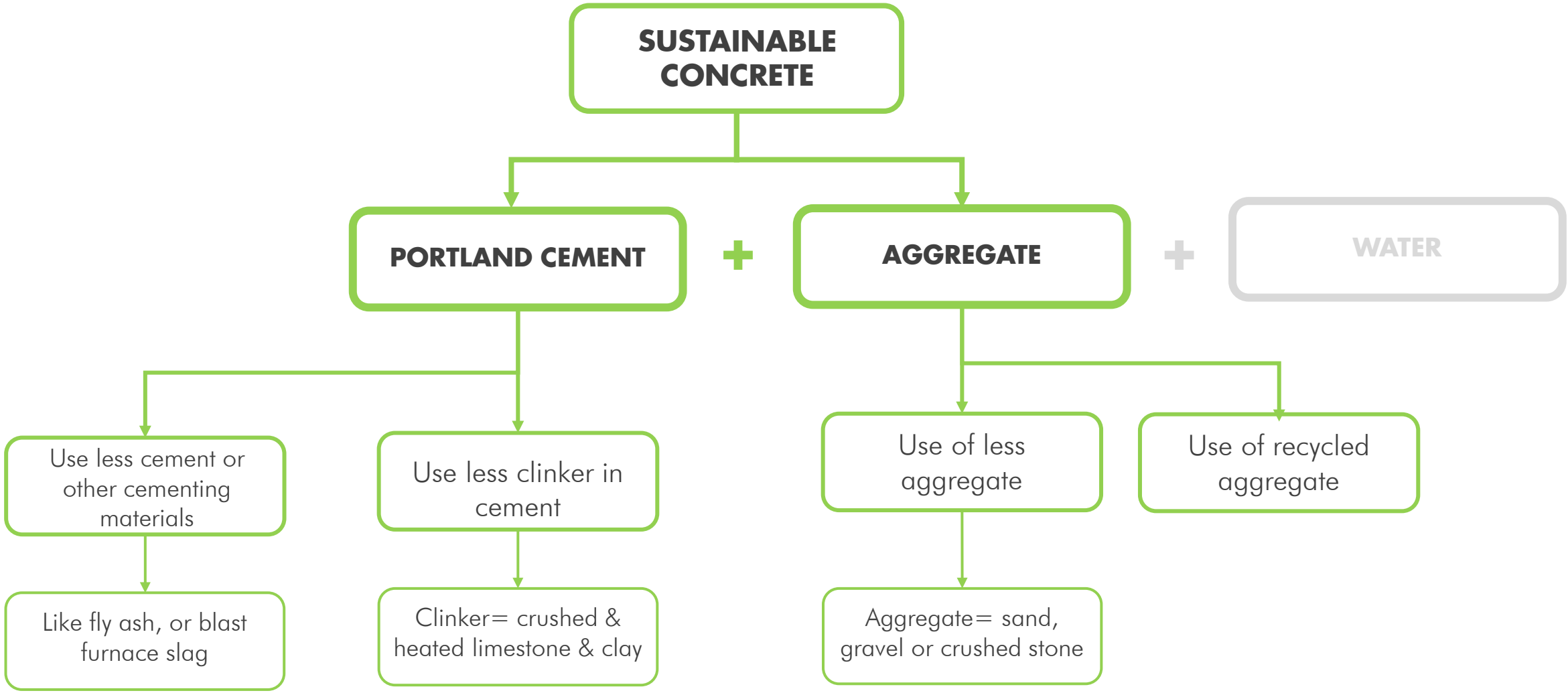
The form of the components edge
has influence on the assembly sequence

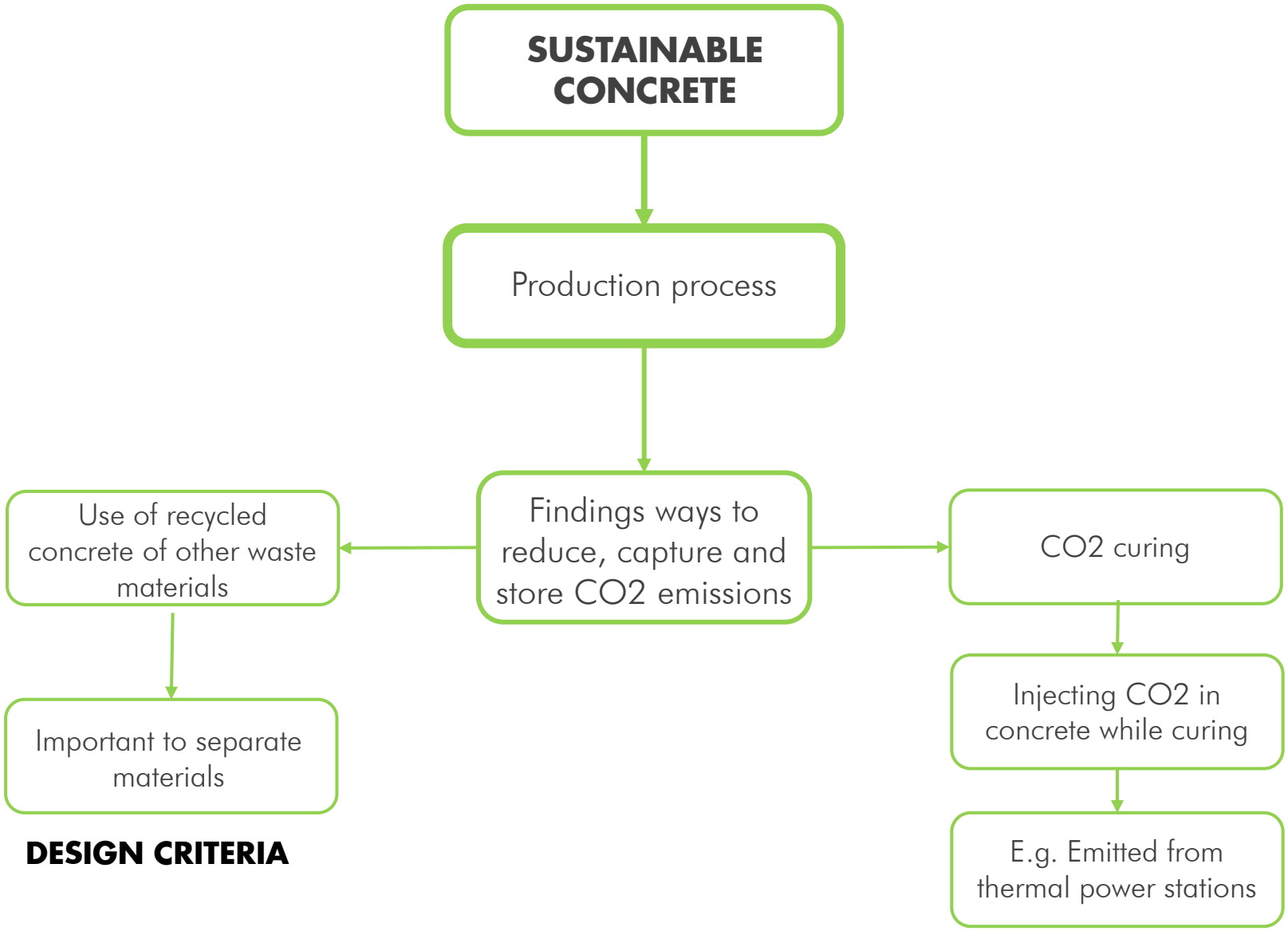
DESIGN CRITERIA
Complexity

How can a sustainable concrete façade system be designed for the Dutch housing market in order to make it reusable?


REDUCE
SUSTAINBLE CONCRETE
BUILDING LIGHTWEIGHT
Production process
Material
Use of lightweight components


CONCRETE
Main problem of concrete
Advantages of concrete
PORTLAND CEMENT
Locally available
High strength
Versatile
Material
Production process
Energy efficient
Durable


SUSTAINABLE CONCRETE
PORTLAND CEMENT
+
AGGREGATE
+
WATER
Use less cement or other cementing materials
Like fly ash, or blast furnace slag
Use less clinker in cement
Clinker= crushed & heated limestone & clay
Use of less aggregate
Aggregate= sand, gravel or crushed stone
Use of recycled aggregate



DESIGN CRITERIA

BUILDING LIGHTWEIGHT

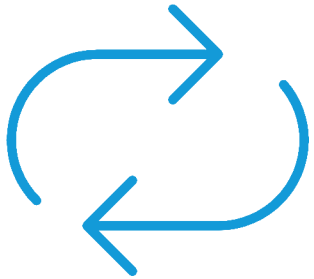
Use of lightweight components

Different types of concrete

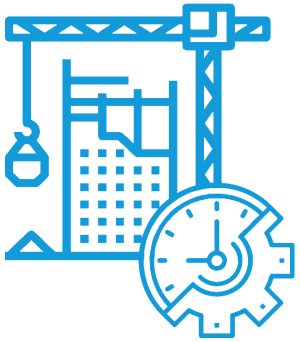
(Structural) lightweight aggregate concrete

- Concrete poured on-site
- Precast concrete

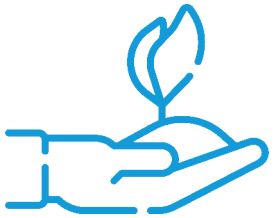
Concept criteria



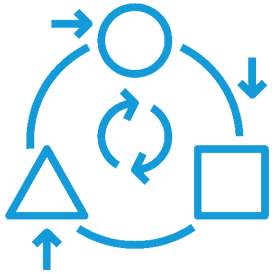
Standardisation



Building efficiency



Sustainability



Adaptability

RETHINK

STANDARDIZATION

- As less different kind of panels
- Simple form
- Suitable dimensions

REDUCE

SUSTAINABILITY

MATERIAL

- Separation of materials
- Sustainable materials

BUILDING LIGHTWEIGHT

- Use of lightweight components (less material & CO2)

REUSE

BUILDING EFFICIENCY

CONNECTIONS

- Use of dry connections
- As less connections as possible
- Connections can be easily inspected
- Complexity of the connections

ASSEMBLING & DISASSEMBLING

- Separation of functions and life cycles
- Easy and fast assembly & disassembly

REUSE & RETHINK

ADAPTABILITY

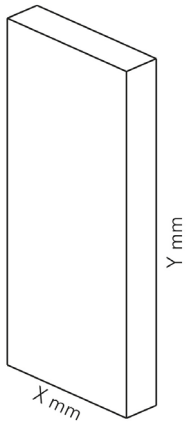
- Adabtale to change
- Separation of functions and life cycles

Design/Case study criteria	1
General requirements	
Prefab	
Stackable	
Load bearing capacity	
Technical requirements	
Thermal insulation	
Fire safety	
Sound insulation	
Standardization	
Number of different panels	
Simple form	
Dimensions	
Building efficiency	
Connections	
Use of dry connections (demountable)	
Number of connections per panel	
Connections can easily be inspected	
Complexity	
Building efficiency	
Assembling & disassembling	
Separation of functions and lifecycles (replacement)	
Easy and fast assembly & disassembly	
Adaptability	
Adaptable to change	
Sustainability	
Material	
Separation of materials	
Sustainable materials	
Building lightweight	
Use of lightweight components	
(Lightweight) form	
Aesthetics	
Hidden connections	
Overall points	
Total	

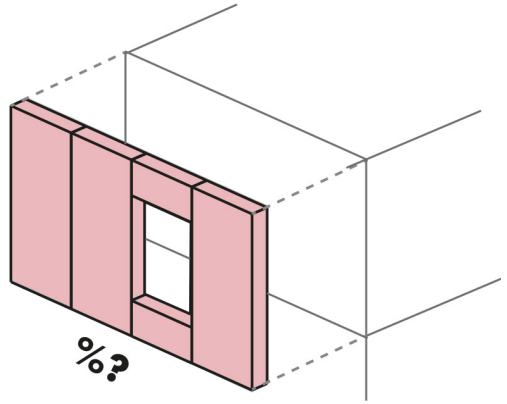
ANALYSIS PHASE

Why?

How can a sustainable concrete facade system be designed for the Dutch housing market in order to make it reusable?

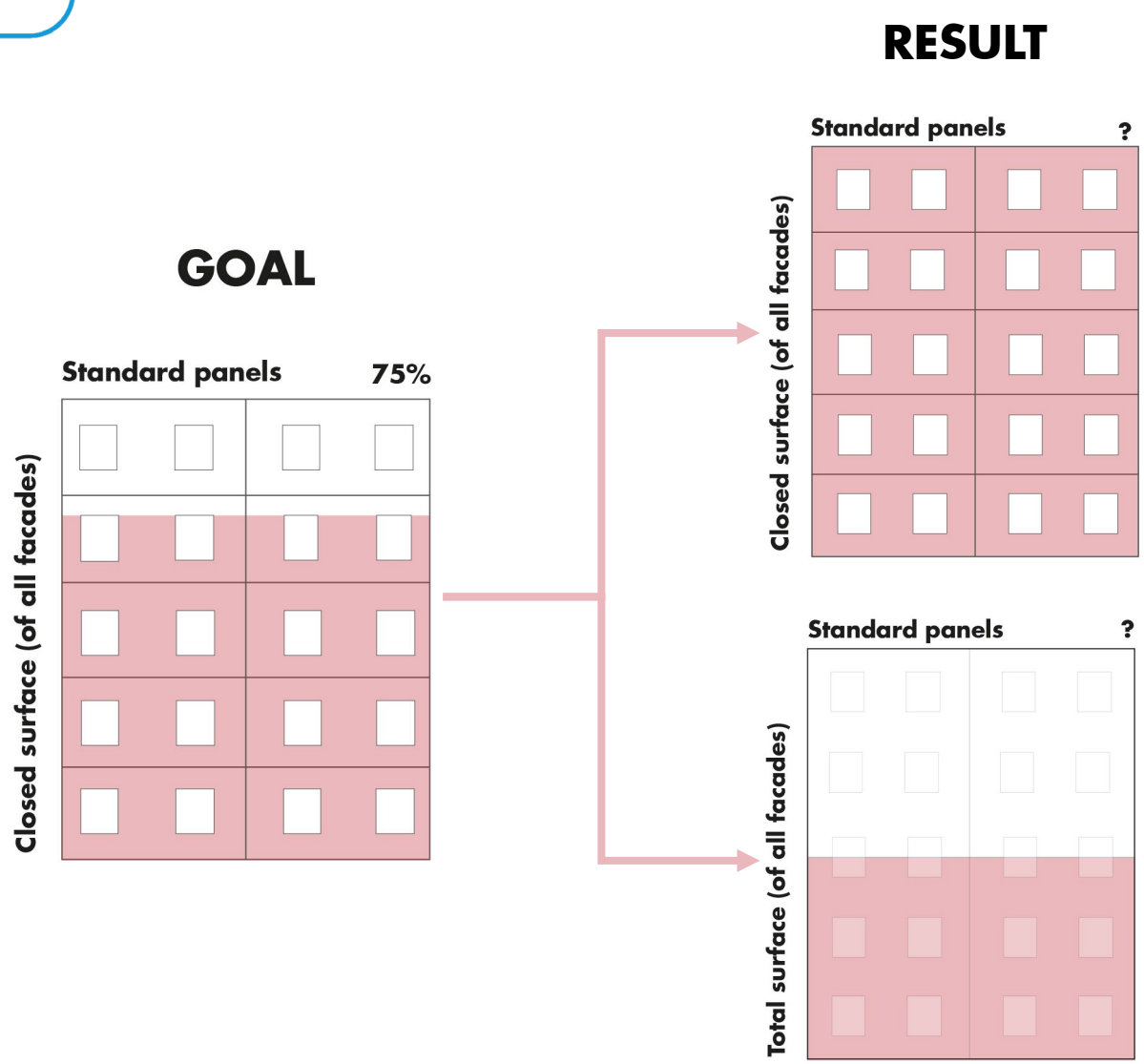


Best suitable dimensions

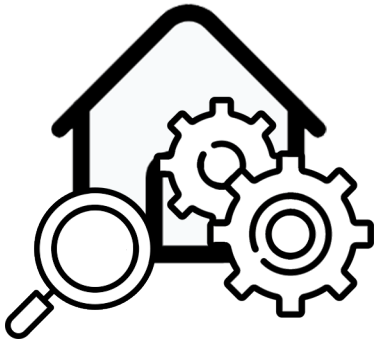


How much can be filled with standard panels?

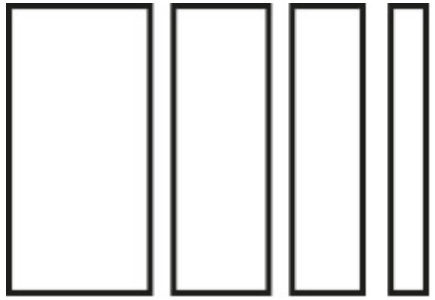
Why?


GOAL
Standard panels
75%
Closed surface (of all facades)
RESULT
Standard panels
?
Closed surface (of all facades)
Standard panels
?
Total surface (of all facades)

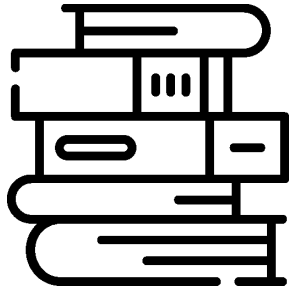
How?



5 Case studies



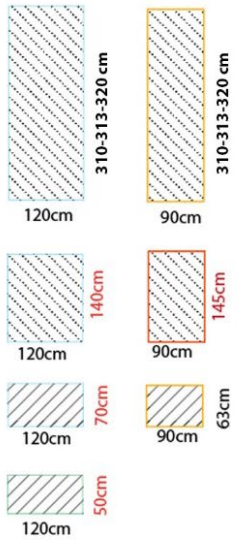
Four standard panel widths

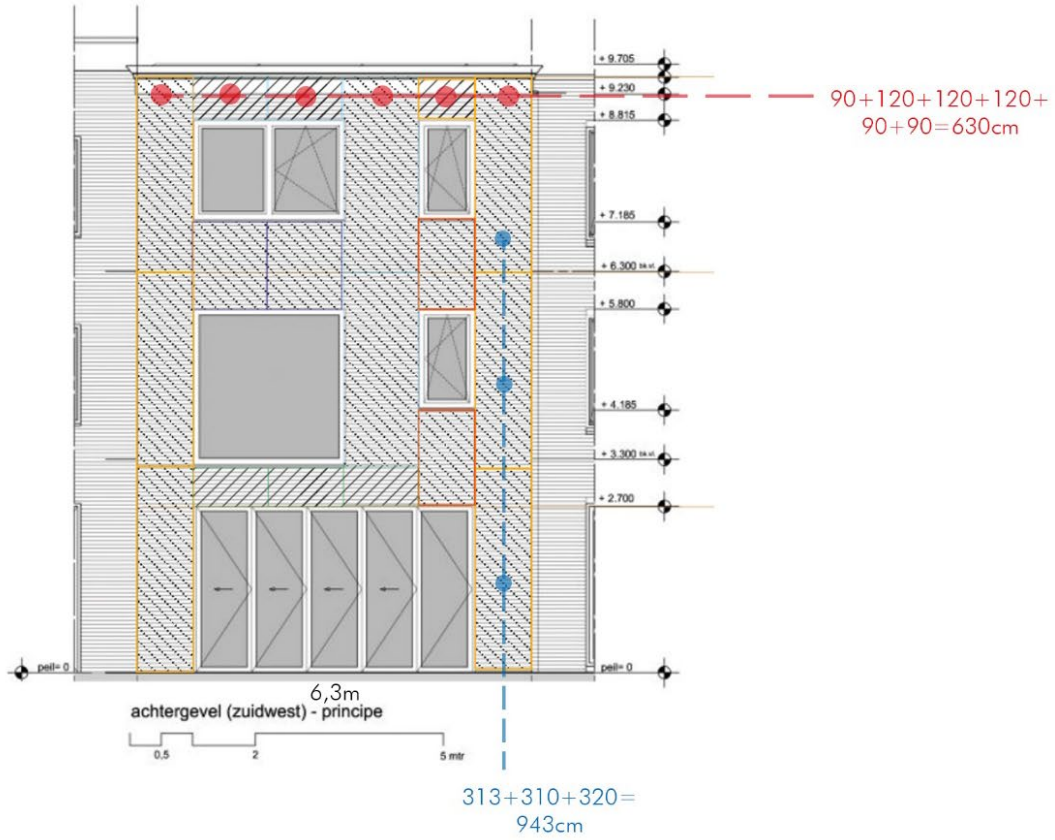


Input of literature study

How?

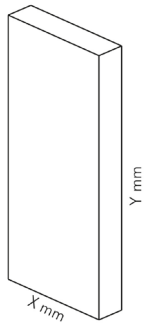
- Restrictions
  - With a margin error of 5%



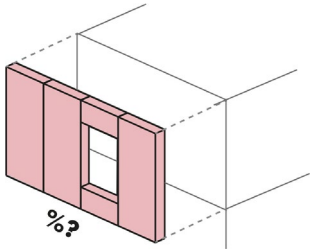


What?

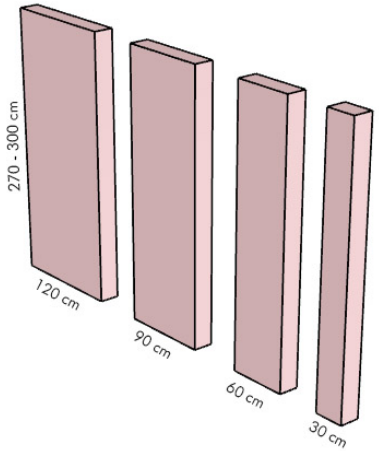
Range needed for flexibility



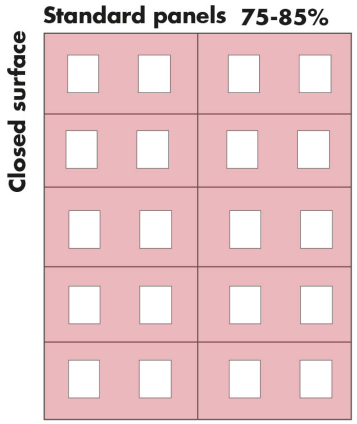
Best suitable dimensions

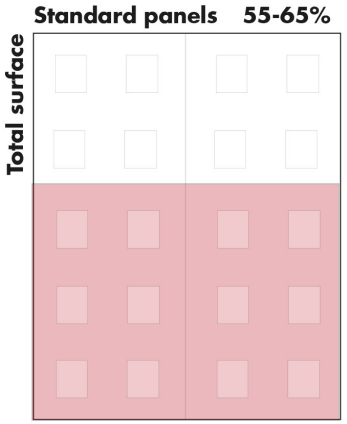


How much can be filled with standard panels?

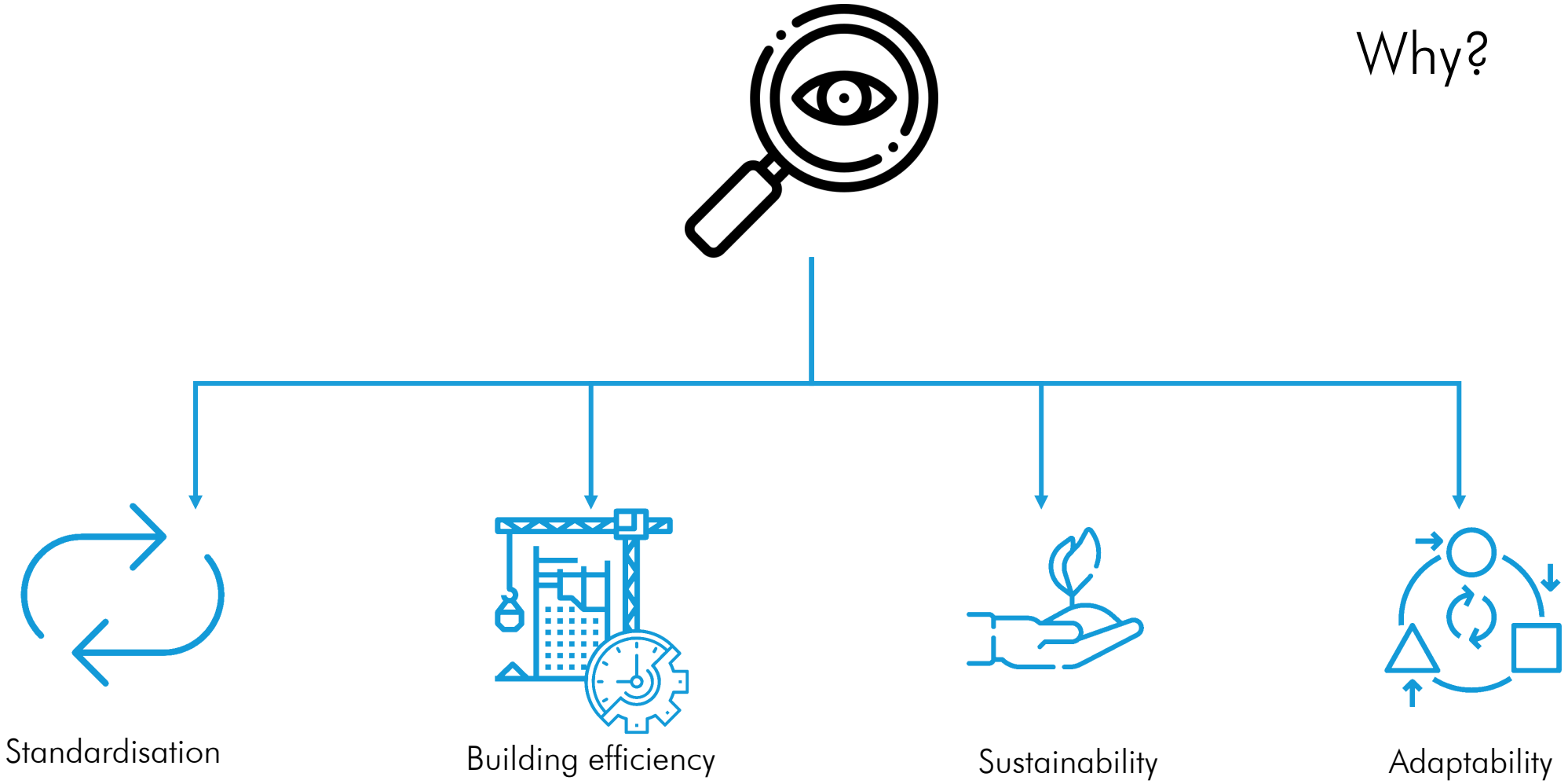


Within a 30 cm grid





Why?


Standardisation
Building efficiency
Sustainability
Adaptability

How?

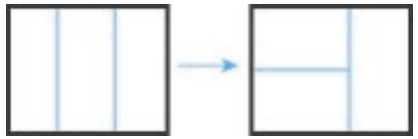
Assessment by concept criteria list

What?

Safety

Amount of material used

Man power needed



Lay-out flexibility

Final design criteria

RETHINK

STANDARDIZATION

- As less different kind of panels
- Simple form
- Suitable dimensions

REDUCE

SUSTAINABILITY

MATERIAL

- Separation of materials
- Sustainable materials
- Amount of material used

BUILDING LIGHTWEIGHT

- Use of lightweight components (less material & CO2)

REUSE

BUILDING EFFICIENCY

CONNECTIONS

- Use of dry connections
- As less connections as possible
- Connections can be easily inspected
- Complexity of the connections

ASSEMBLING & DISASSEMBLING

- Easy and fast assembly & disassembly
- Separation of functions and life cycles
- Safety
- Manpower needed

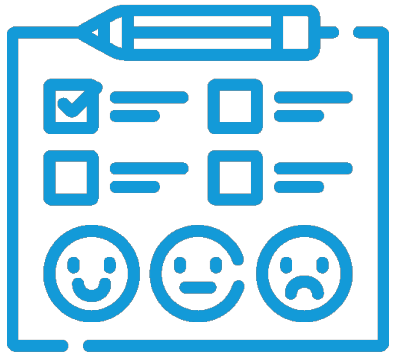
RETHINK

ADAPTABILITY

- Adaptable to change
- Lay-out flexibility

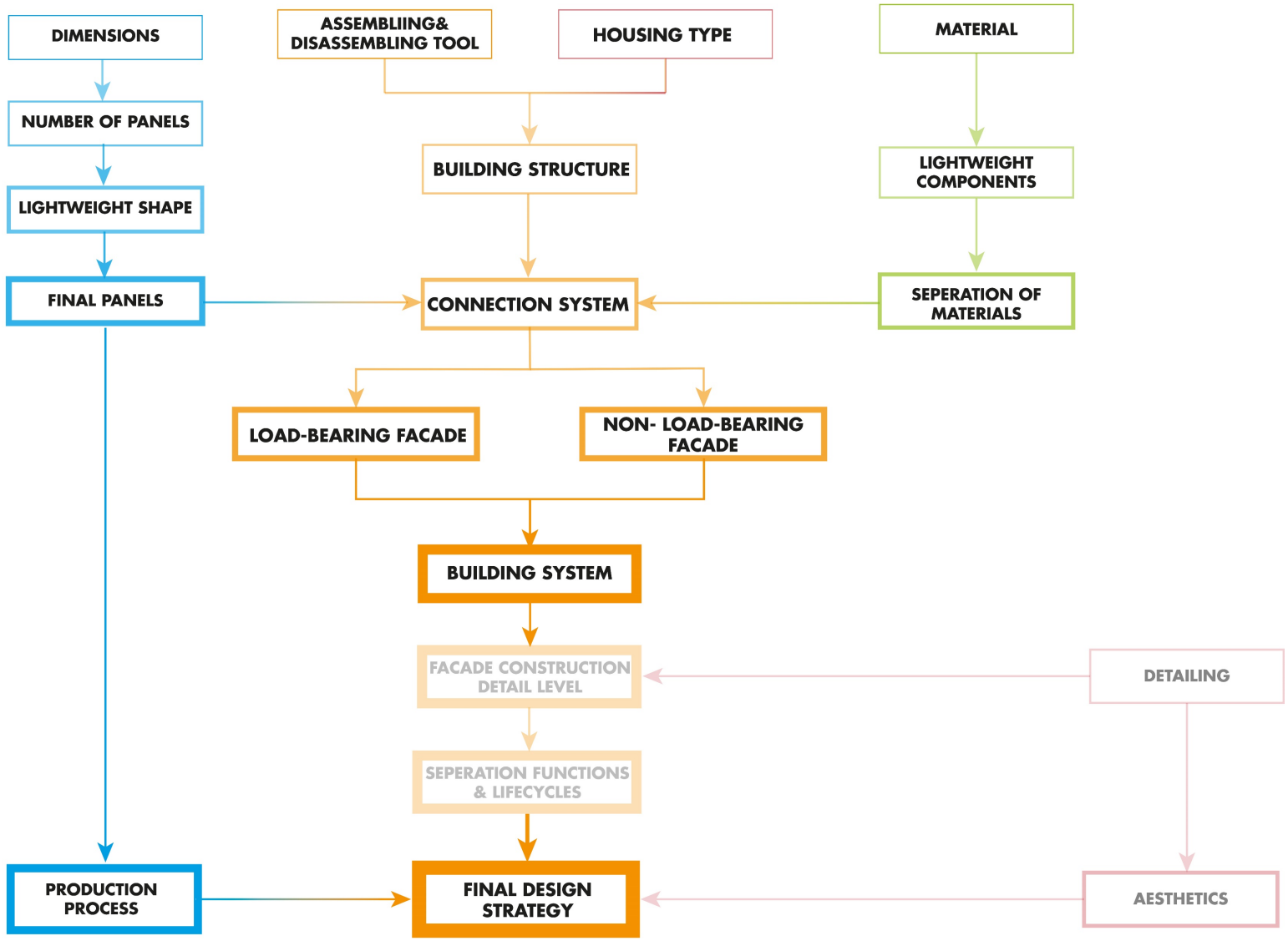
Final design criteria	Minimum	Maximum
General requirements		
Prefab (thickness)	100/120 mm	-
Stackable	-	-
Load bearing capacity	-	-
Technical requirements		
Thermal insulation	4.5 m2K/W	-
Fire safety	120 minutes	-
Sound insulation	>52 DB	
Water tightness		
Standardization		
Number of different panels	1	4
Simple form		
Dimensions	300 mm	1200 mm
Building efficiency		
Connections		
Use of dry connections (demountable)	-	-
Number of connections per panel	1	4
Connections can easily be inspected	-	-
Complexity	-	-
Assembling & disassembling		
Easy and fast assembly & disassembly	-	-
Separation of functions and lifecycles (replacement)	-	-
Safety	-	-
Man power needed		
Adaptability		
Lay-out flexibility	-	-
Adaptable to change	-	-
Sustainability		
Material		
Separation of materials	-	-
Sustainable materials	-	-
Amount of materials used		
Building lightweight		
Use of lightweight components	-	-
(Lightweight) form	-	-
Aesthetics		
Finishing	-	-
Hidden connections	-	-
Overall points		
Total		

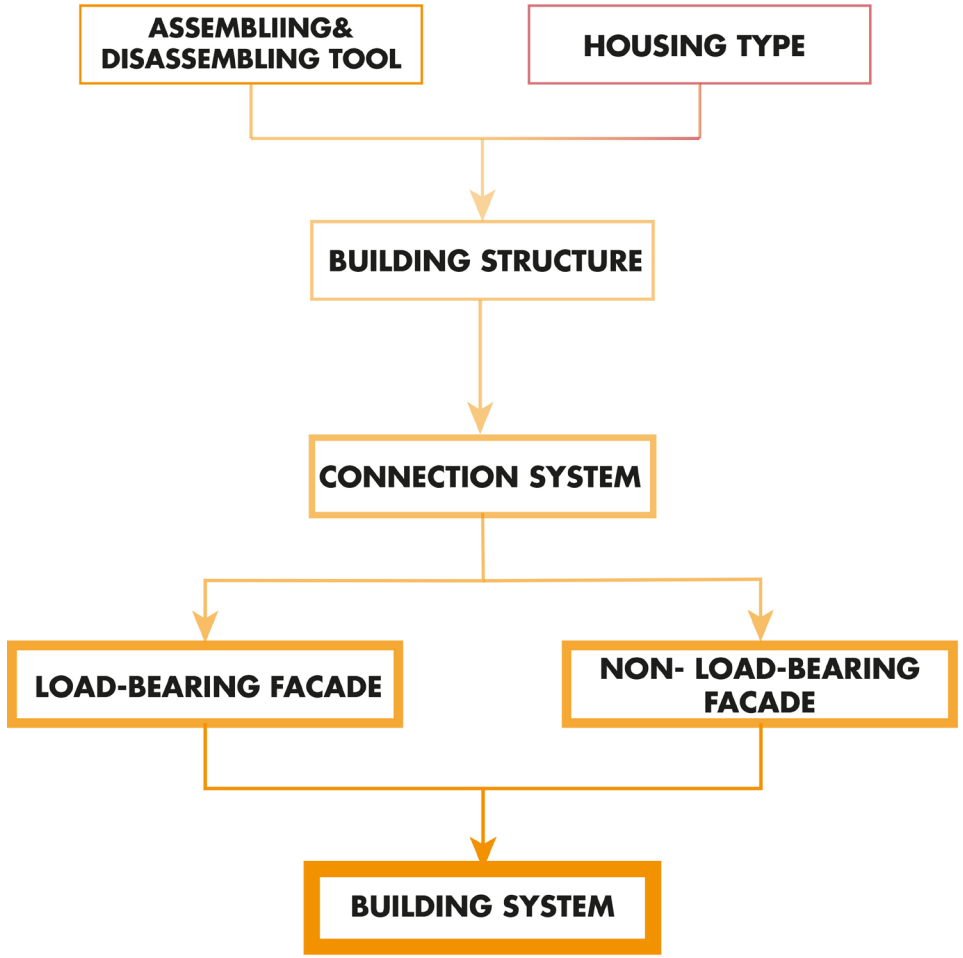
Assessment method for the design phase



Choices made by assessment through final criteria list

DESIGN PHASE


DIMENSIONS
NUMBER OF PANELS
LIGHTWEIGHT SHAPE
FINAL PANELS
ASSEMBLIING& DISASSEMBLING TOOL
HOUSING TYPE
BUILDING STRUCTURE
CONNECTION SYSTEM
MATERIAL
LIGHTWEIGHT COMPONENTS
SEPERATION OF MATERIALS
LOAD-BEARING FACADE
NON- LOAD-BEARING FACADE
BUILDING SYSTEM
FACADE CONSTRUCTION DETAIL LEVEL
SEPERATION FUNCTIONS & LIFECYCLES
DETAILING
PRODUCTION PROCESS
FINAL DESIGN STRATEGY
AESTHETICS

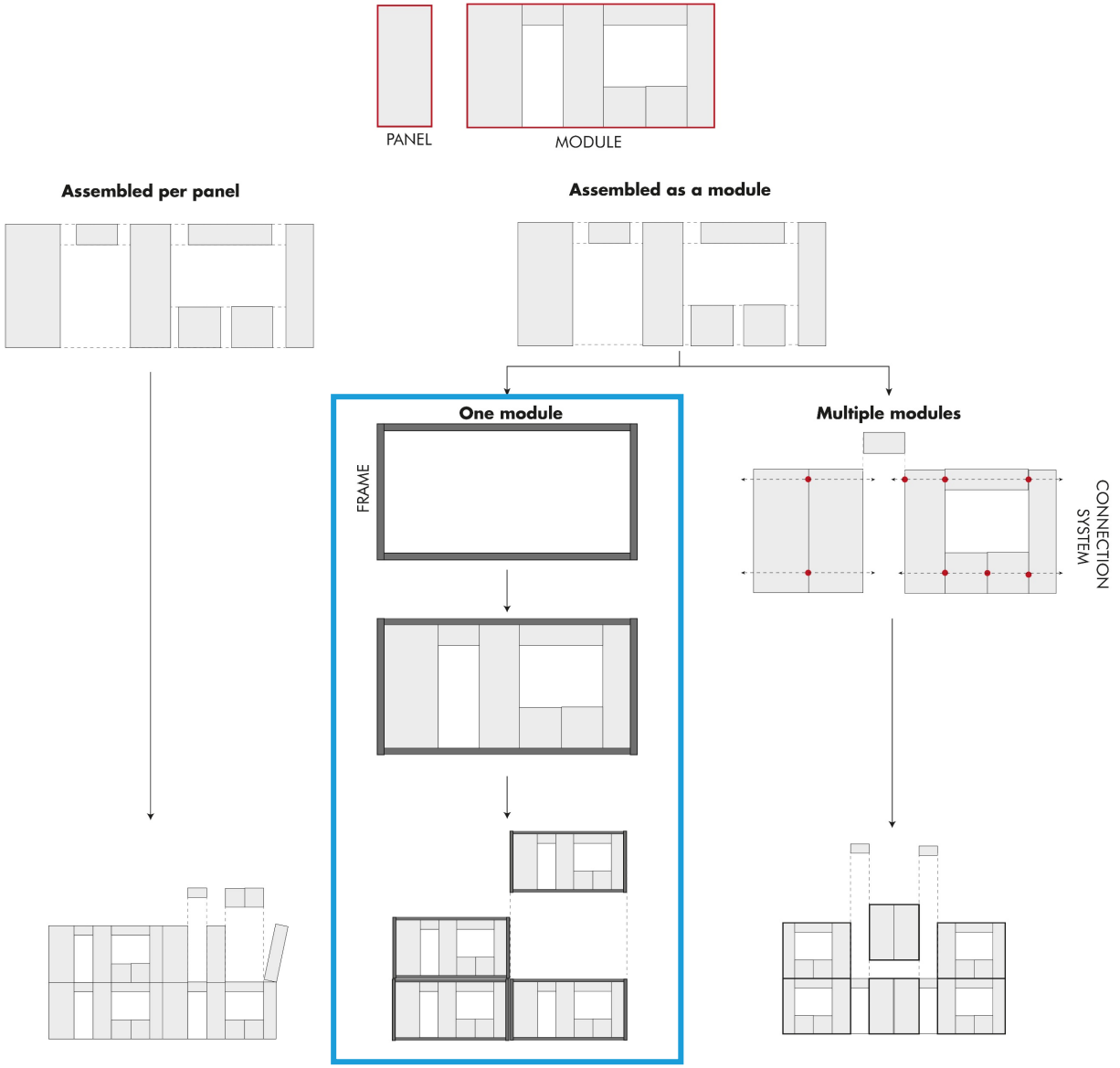

ASSEMBLIING&
DISASSEMBLING TOOL
HOUSING TYPE
BUILDING STRUCTURE
CONNECTION SYSTEM
LOAD-BEARING FACADE
NON- LOAD-BEARING FACADE
BUILDING SYSTEM

Housing type/target audience

RESIDNETIL BUILDING PARTIES

CHARACTERISTICS

OWNER OCCUPIED HOMES	HOUSING CORPORATION	PRIVATE RENTAL
		
- Good acoustic performance - Outdoor space: balcony / garden / roof terrace - Flexibility to change facade - Flexibility to have an open or unique facade	- Flexibility in adapting, enlarging or reducing a home - Less available money --> as cheap as possible - Smaller or no outdoor spaces - Every home has the same facade	- Flexibility to change lay out home - Hav often same facades in one building - Outdoor space: balcony / garden / roof terrace - Acoutsic performance

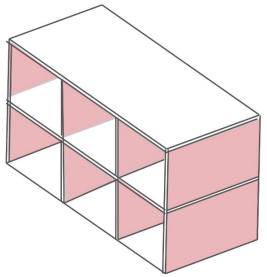


How?

Assessment by final criteria list

1 **Span: wall~wall**

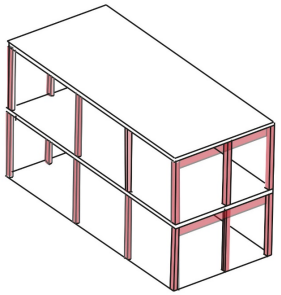
Load bearing wals of oncrete with concrete hollow-core slabs



+ facades easily replaced
+ 100% open facade possible
- Space less flexible, placement of walls determines the layout

2 **Span: portal~wall or portal~portal**

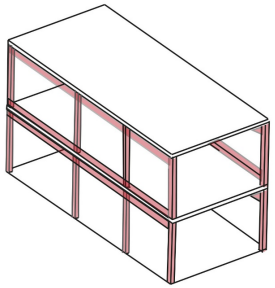
Bearing portals of concrete



+ facades easily replaced
+ 100% open facade possible
- Portals can obstruct the lay out, but less than option 1

3 **Span: facade~facade**

Building structure of concrete



+ very flexible, no walls or columns in the space
_ Replacement of facade is difficult. Only infill of facade easy to replace

RESIDNETIL BUILDING PARTIES

CHARACTERISTICS

OWNER OCCUPIED HOMES

- Good acoustic performance
- Outdoor space: balcony / garden / roof terrace
- Flexibility to change facade
- Flexibility to have an open or unique facade

PRIVATE RENTAL

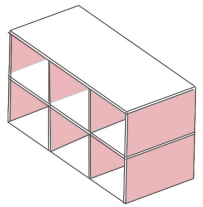
- Flexibility to change lay out home
- Have often same facades in one building
- Outdoor space: balcony / garden / roof terrace
- Acoutsic performance

HOUSING CORPORATION

- Flexibility in adapting, enlarging or reducing a home
- Social housing - affordable --> as cheap as possible
- Smaller or no outdoor spaces
- Every home has the same facade

1 Span: wall~wall

Load bearing wals of oncrete with concrete hollow-core slabs



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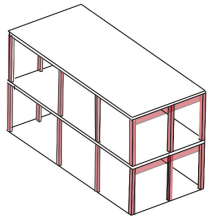
2 Span: portal~wall or portal~portal

Bearing portals of concrete



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+ 100% open facade possible
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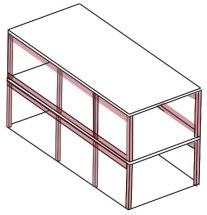
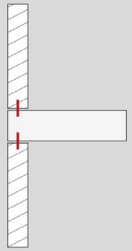
3 Span: facade~facade

Building structure of concrete



+ very flexible, no walls or columns in the space
_ Replacement of facade is difficult. Only infill of facade easy to replace

CONNECTION SYSTEM 1
Wall-Floor-Wall



PROS

BALCONY
Attachment of balcony is possible

HIDDEN
Hidden connections, no joint widths because of connections

EASILY INSPECTED
Horizontal connections can easily be inspected

SIMPLE
The connection system is simple

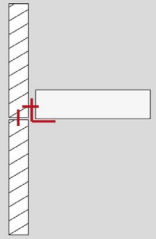
CONS

TAKES UP SPACE
The connection type takes up space of the surface

MORE CONNECTIONS
There are more connections needed per panel

DIFFICULT TO INSPECT
Vertical connections are difficult to inspect

CONNECTION SYSTEM 2
Wall-Wall-Floor



PROS

FINISHING
The finishing flows seamlessly

HIDDEN
Hidden connections, no joint widths because of connections

EASILY INSPECTED
Vertical connections can easily be inspected

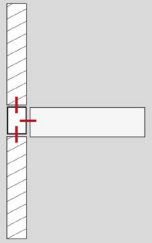
SHEAR WALL
The connection system is simple

CONS

BALCONY
Attachment of balcony is not possible

MORE CONNECTIONS
There are more connections needed per panel + extra connections for the floor

CONNECTION SYSTEM 3
Wall-Connection-Floor-Wall



PROS

FEW CONNECTIONS
Needs just a few connection points to attach walls and floor

FASTEST CONSTRUCTION TIME
It has the shortest construction time

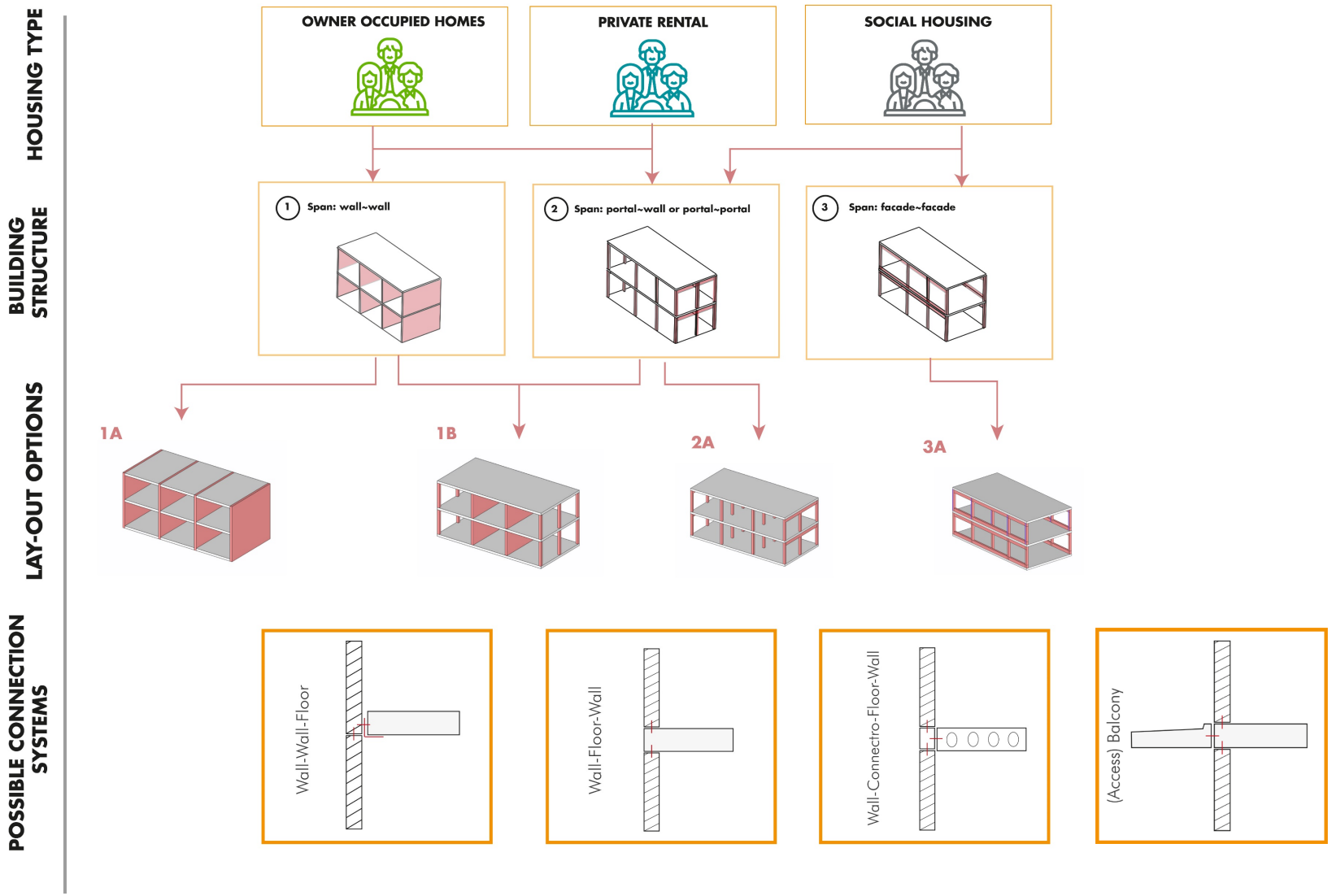
EASILY INSPECTED
Vertical and horizontal connections can easily be inspected

CONS

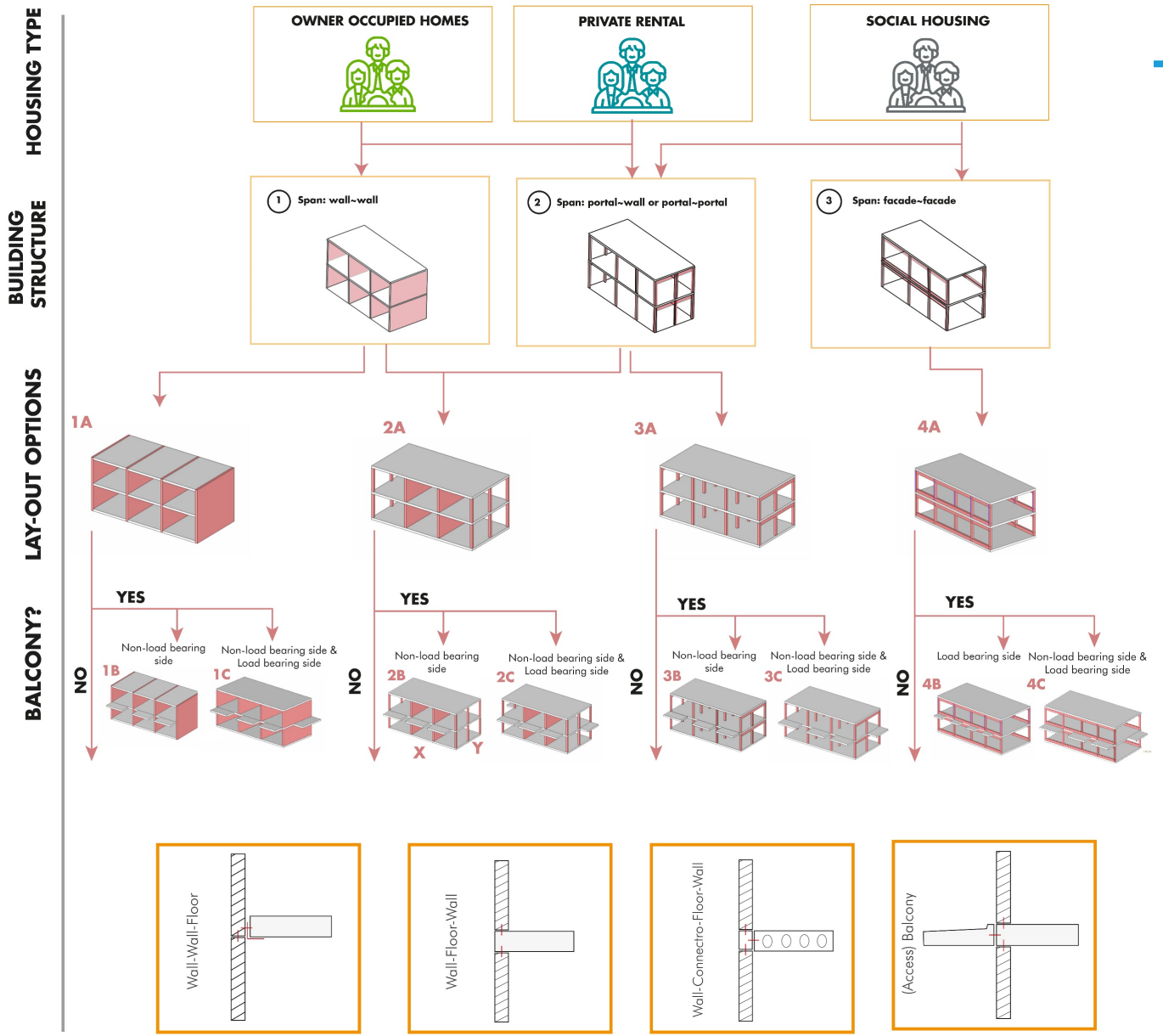
BALCONY
Attachment of balcony is not possible

COMPLEX
Complex system that is expensive and requires specialized workers

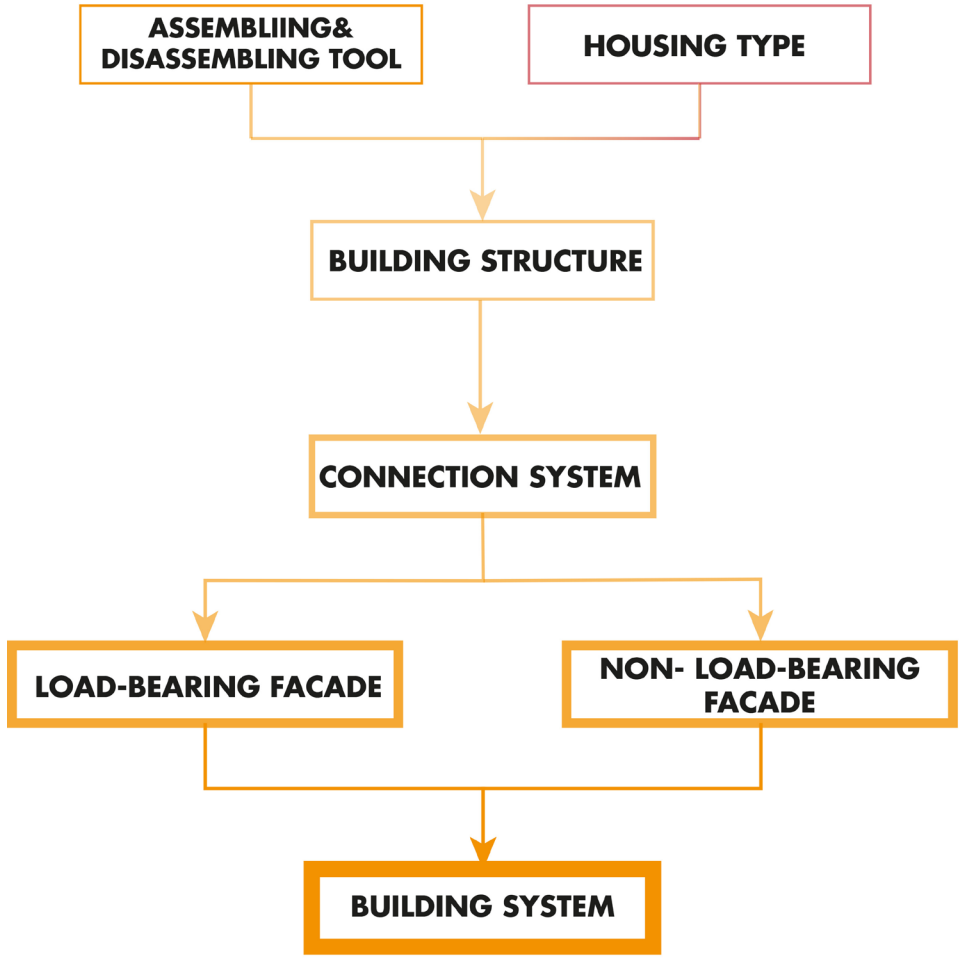
VISIBLE
Visible connections, may cause joint widths and a thermal bridge


HOUSING TYPE
BUILDING STRUCTURE
LAY-OUT OPTIONS
POSSIBLE CONNECTION SYSTEMS
OWNER OCCUPIED HOMES
PRIVATE RENTAL
SOCIAL HOUSING
1 Span: wall~wall
2 Span: portal~wall or portal~portal
3 Span: facade~facade
1A
1B
2A
3A
Wall-Wall-Floor
Wall-Floor-Wall
Wall-Connectro-Floor-Wall
(Access) Balcony

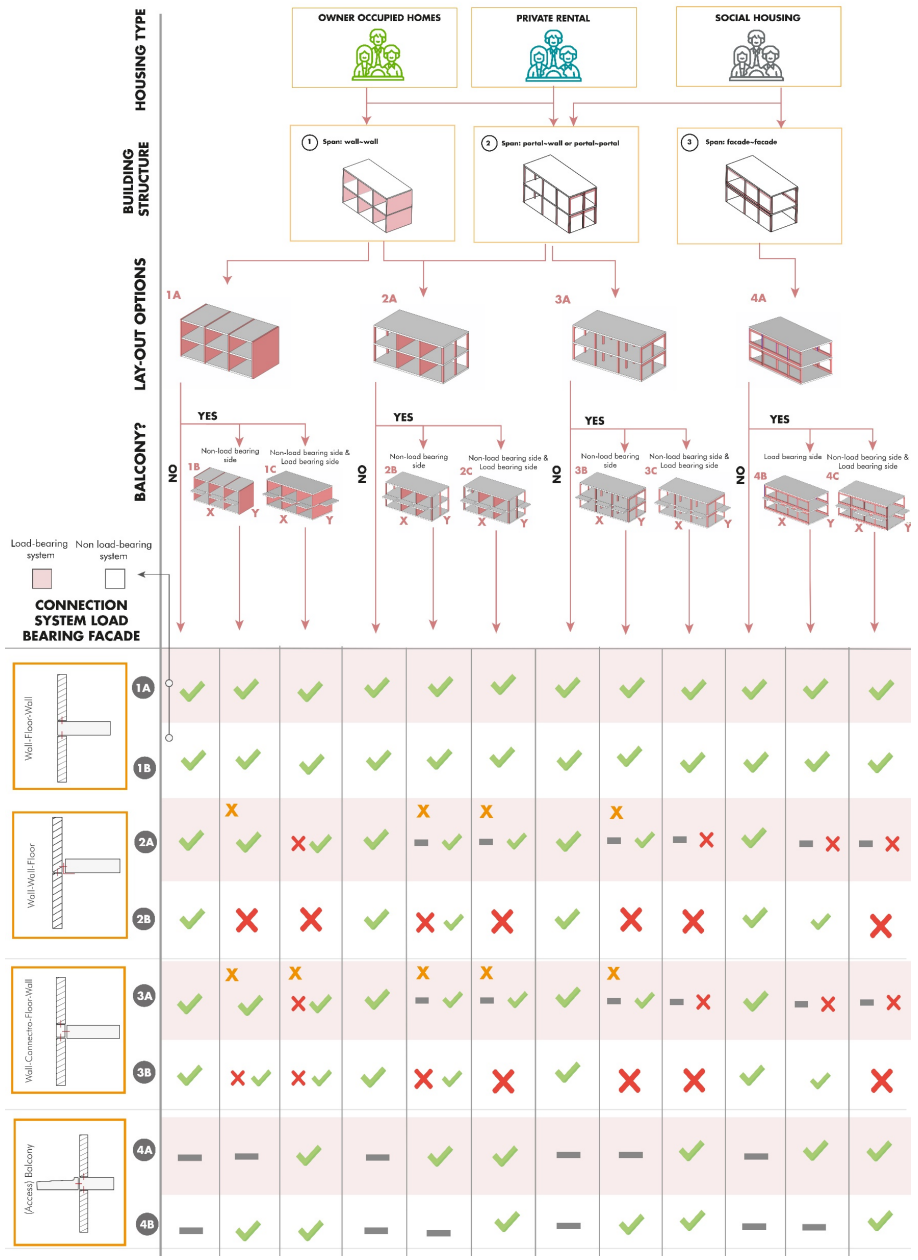
Decision chart



FINAL DESIGN STRATEGY



How can a sustainable concrete facade system be designed for the Dutch housing market in order to make it reusable?



LEGEND

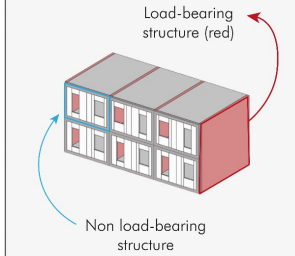
- Connection system is possible
- Connection system is not possible
- Warning: use of muliple connection systems
- Inapplicable
- Two icons means that it is suitable, not suitable or inapplicable for a part of the building structure. This is further explained in the building system examples

LEGEND

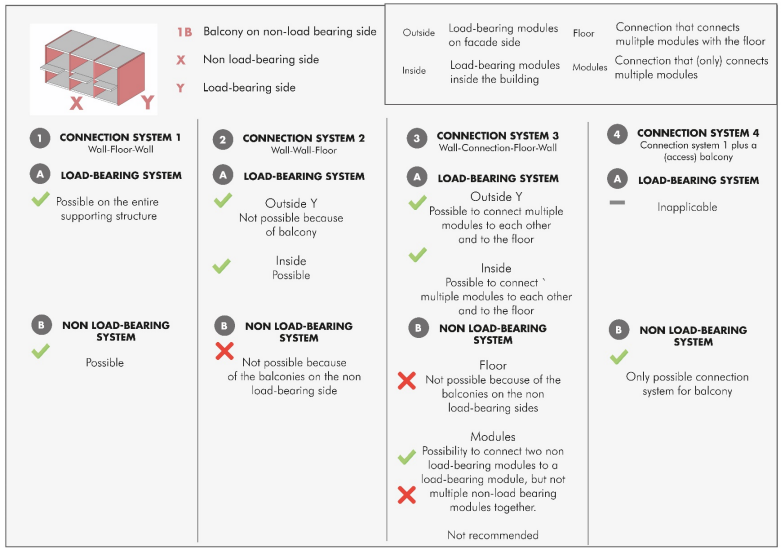
1. **CONNECTION SYSTEM 1** Wall-Floor-Wall
2. **CONNECTION SYSTEM 2** Wall-Wall-Floor
3. **CONNECTION SYSTEM 3** Wall-Connection-Floor-Wall
4. **CONNECTION SYSTEM 4** Connection system 1 plus a (access) balcony

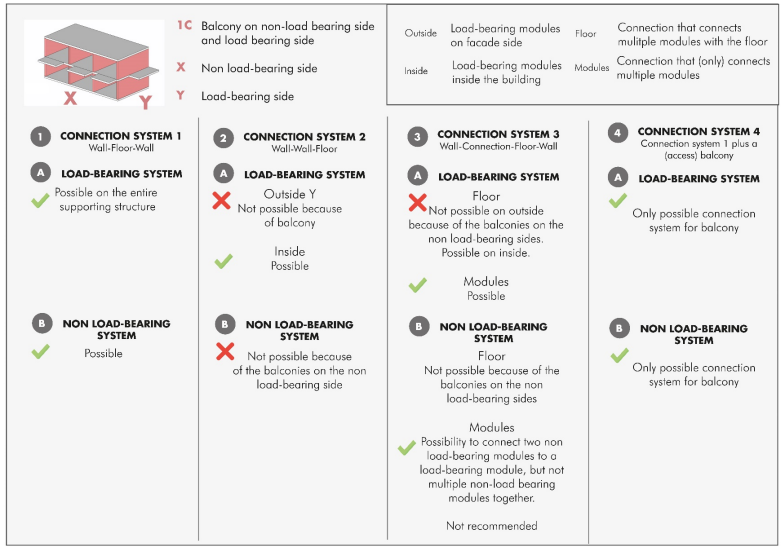
A **LOAD-BEARING SYSTEM**

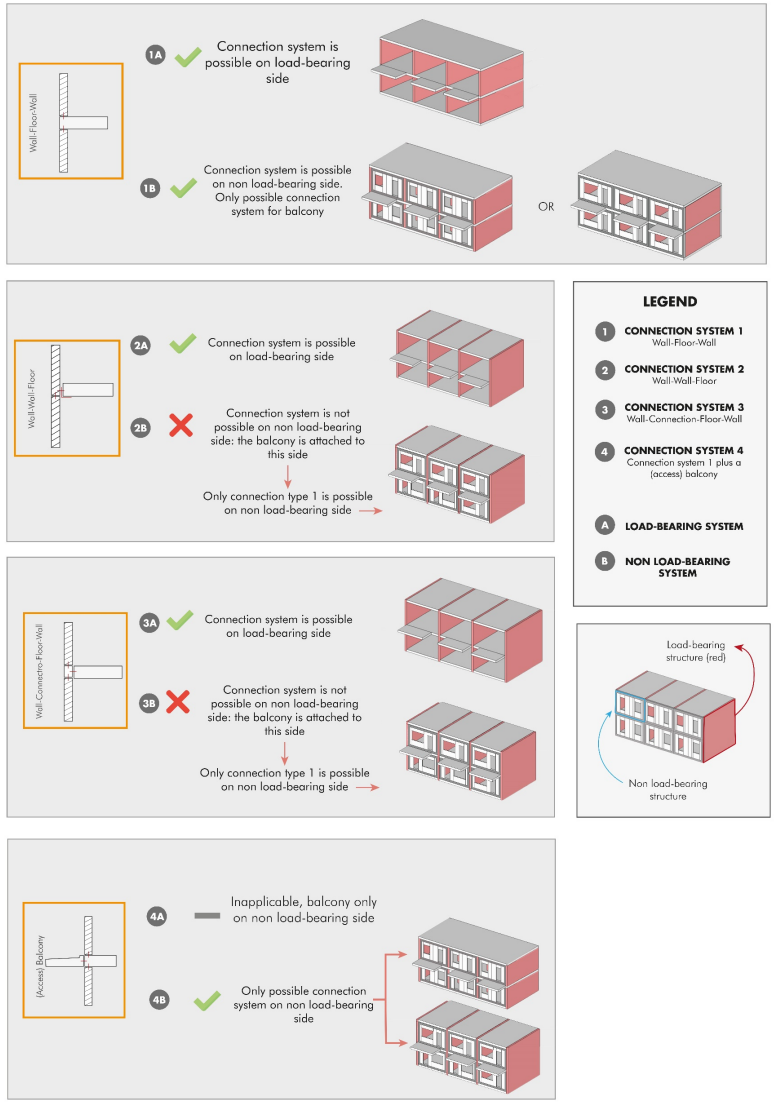
B **NON LOAD-BEARING SYSTEM**

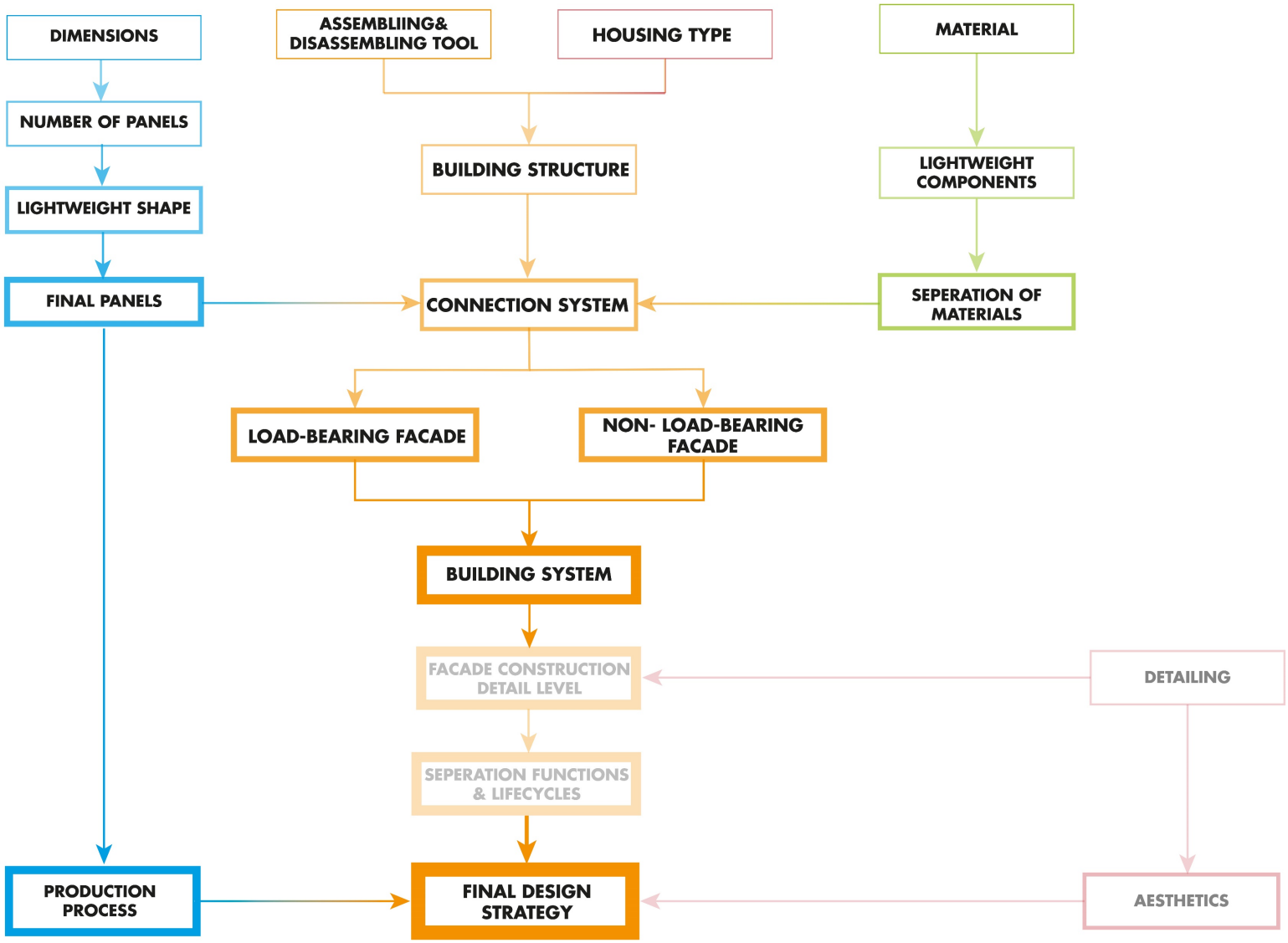


Design tool


1B Balcony on non-load bearing side
X Non load-bearing side
Y Load-bearing side
Outside Load-bearing modules on facade side
Inside Load-bearing modules inside the building
Floor Connection that connects mulitple modules with the floor
Modules Connection that (only) connects multiple modules
1 CONNECTION SYSTEM 1 Wall-Floor-Wall
A LOAD-BEARING SYSTEM
Possible on the entire supporting structure
B NON LOAD-BEARING SYSTEM
Possible
2 CONNECTION SYSTEM 2 Wall-Wall-Floor
A LOAD-BEARING SYSTEM
Outside Y
Not possible because of balcony
Inside
Possible
B NON LOAD-BEARING SYSTEM
Not possible because of the balconies on the non load-bearing side
3 CONNECTION SYSTEM 3 Wall-Connection-Floor-Wall
A LOAD-BEARING SYSTEM
Outside Y
Possible to connect multiple modules to each other and to the floor
Inside
Possible to connect multiple modules to each other and to the floor
B NON LOAD-BEARING SYSTEM
Floor
Not possible because of the balconies on the non load-bearing sides
Modules
Possibility to connect two non load-bearing modules to a load-bearing module, but not multiple non-load bearing modules together.
Not recommended
4 CONNECTION SYSTEM 4 Connection system 1 plus a (access) balcony
A LOAD-BEARING SYSTEM
Inapplicable
B NON LOAD-BEARING SYSTEM
Only possible connection system for balcony

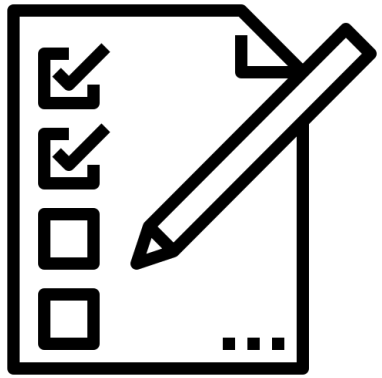

1C Balcony on non-load bearing side and load bearing side
X Non load-bearing side
Y Load-bearing side
Outside Load-bearing modules on facade side
Inside Load-bearing modules inside the building
Floor Connection that connects mulitple modules with the floor
Modules Connection that (only) connects multiple modules
1 CONNECTION SYSTEM 1 Wall-Floor-Wall
A LOAD-BEARING SYSTEM
Possible on the entire supporting structure
B NON LOAD-BEARING SYSTEM
Possible
2 CONNECTION SYSTEM 2 Wall-Wall-Floor
A LOAD-BEARING SYSTEM
Outside Y
Not possible because of balcony
Inside
Possible
B NON LOAD-BEARING SYSTEM
Not possible because of the balconies on the non load-bearing side
3 CONNECTION SYSTEM 3 Wall-Connection-Floor-Wall
A LOAD-BEARING SYSTEM
Floor
Not possible on outside because of the balconies on the non load-bearing sides. Possible on inside.
Modules
Possible
B NON LOAD-BEARING SYSTEM
Floor
Not possible because of the balconies on the non load-bearing sides
Modules
Possibility to connect two non load-bearing modules to a load-bearing module, but not multiple non-load bearing modules together.
Not recommended
4 CONNECTION SYSTEM 4 Connection system 1 plus a (access) balcony
A LOAD-BEARING SYSTEM
Only possible connection system for balcony
B NON LOAD-BEARING SYSTEM
Only possible connection system for balcony


Wall-Floor-Wall
1A Connection system is possible on load-bearing side
1B Connection system is possible on non load-bearing side. Only possible connection system for balcony
OR
Wall-Wall-Floor
2A Connection system is possible on load-bearing side
2B Connection system is not possible on non load-bearing side: the balcony is attached to this side
Only connection type 1 is possible on non load-bearing side
Wall-Connection-Floor-Wall
3A Connection system is possible on load-bearing side
3B Connection system is not possible on non load-bearing side: the balcony is attached to this side
Only connection type 1 is possible on non load-bearing side
(Access) Balcony
4A Inapplicable, balcony only on non load-bearing side
4B Only possible connection system on non load-bearing side
LEGEND
1 CONNECTION SYSTEM 1 Wall-Floor-Wall
2 CONNECTION SYSTEM 2 Wall-Wall-Floor
3 CONNECTION SYSTEM 3 Wall-Connection-Floor-Wall
4 CONNECTION SYSTEM 4 Connection system 1 plus a (access) balcony
A LOAD-BEARING SYSTEM
B NON LOAD-BEARING SYSTEM
Load-bearing structure (red)
Non load-bearing structure


DIMENSIONS
NUMBER OF PANELS
LIGHTWEIGHT SHAPE
FINAL PANELS
ASSEMBLIING& DISASSEMBLING TOOL
HOUSING TYPE
BUILDING STRUCTURE
MATERIAL
LIGHTWEIGHT COMPONENTS
SEPERATION OF MATERIALS
CONNECTION SYSTEM
LOAD-BEARING FACADE
NON- LOAD-BEARING FACADE
BUILDING SYSTEM
FACADE CONSTRUCTION DETAIL LEVEL
SEPERATION FUNCTIONS & LIFECYCLES
DETAILING
AESTHETICS
PRODUCTION PROCESS
FINAL DESIGN STRATEGY

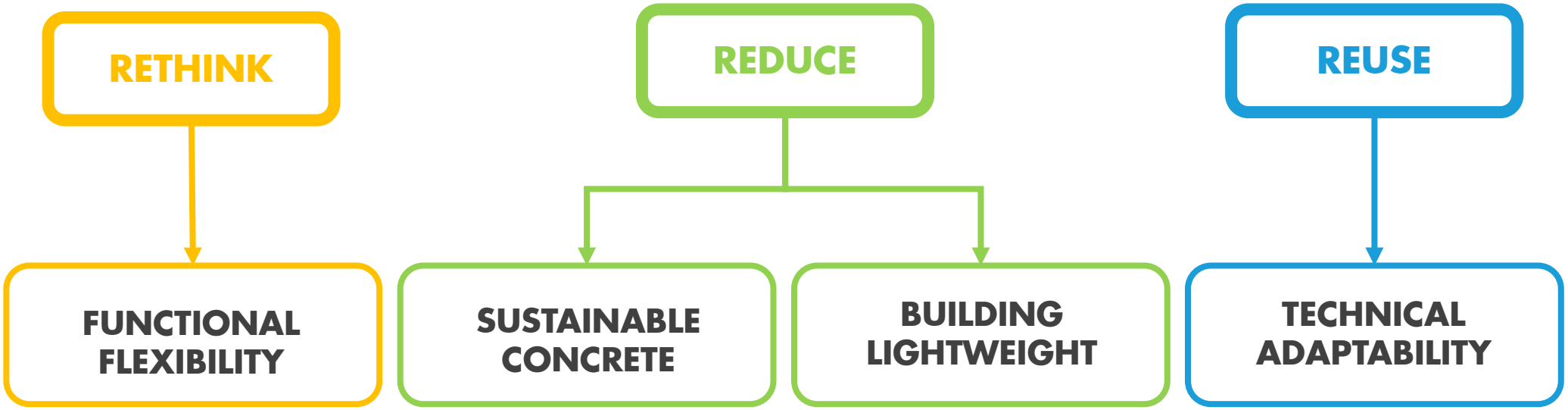
CONCLUSION

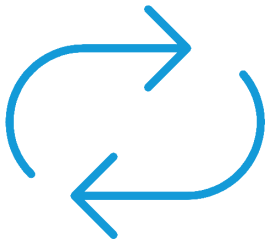
How can a sustainable concrete facade system be designed for the Dutch housing market in order to make it reusable?



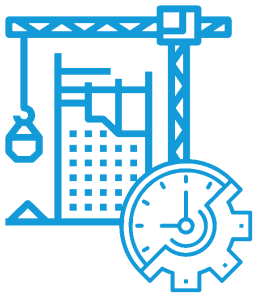
Design tool

Final design strategy & decision chart

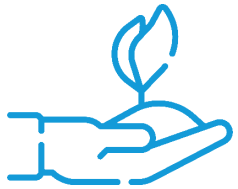

RETHINK
REDUCE
REUSE
FUNCTIONAL FLEXIBILITY
SUSTAINABLE CONCRETE
BUILDING LIGHTWEIGHT
TECHNICAL ADAPTABILITY



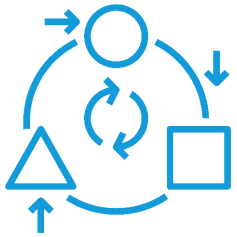
Standardisation



Building efficiency



Sustainability



Adaptability

DISCUSSION & RECOMMANDATIONS

- What are the chances of success?
  - Overcoming the barriers of reuse
  - Developing a circular business case

- Limitations
  - Standardisation case study

- Mixture of concrete and wooden panels
- Reuse of concrete facade system in office sector?
- Developing a circular business case for the facade system

THANK YOU!