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A dialog about circular economy – although not two buildings are the same

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Erhvervs PhD

MT Højgaard

Situated in Denmark

100 years of experience

Construction and civil engineering

Research and development

Social responsibility

A big knowledge bank and knowledge sharing
Our motivation for CE?
How do we understand CE?
How do we practice it?

Our motivation

The construction industry is responsible for:

25% of human induced CO_2-emissions [1]

40% Of the material produced and consumed globally (by volume) [1]

40% of the worlds waste generation (by volume) [1]

80% Demand increase for construction from 1980-2008 [2]

Preparing for the future:

A great amount of materials ever extracted in human history are located in the built environment [4]

It is estimated that the anthropogenic stock outweighs the natural resource stock [5]

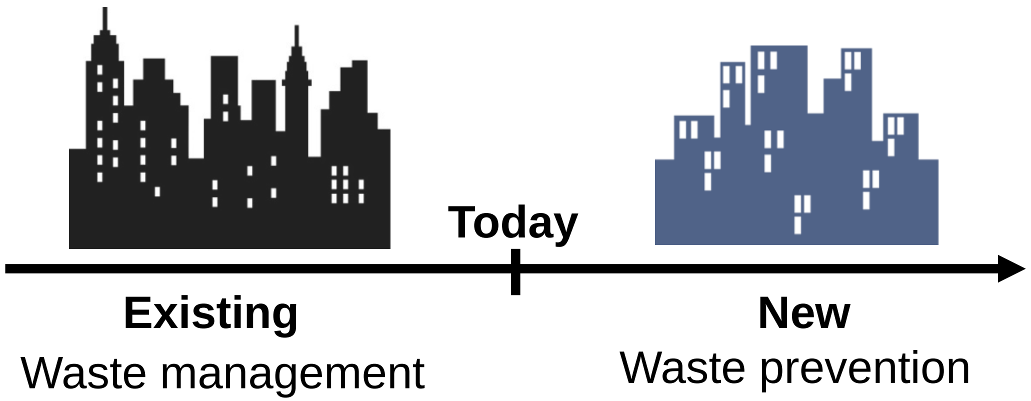
Politics and legislation in DK:

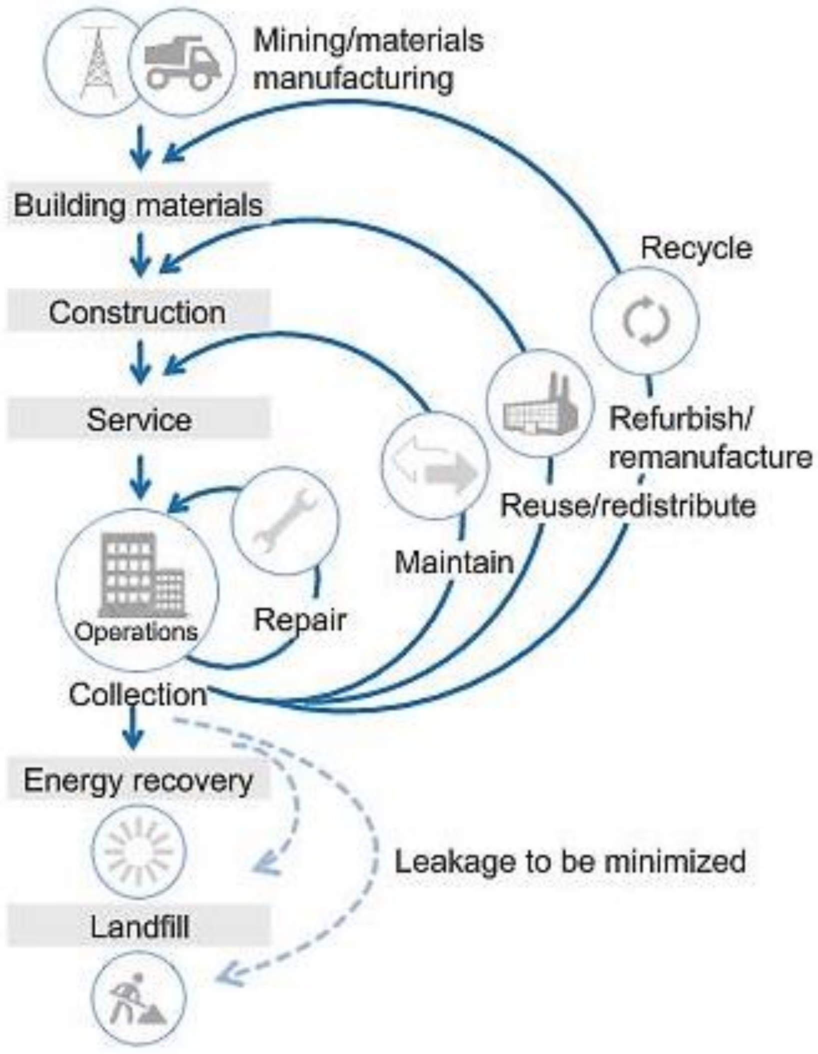
- CE Advisory Board's recommendations for the government 2017
- The Danish governments' CE strategy 2018
- Danish Standardisation 2018
- EU waste directive 2018

Circular economy in buildings

- Managing the constant flow of resources
- Within a restorative and regenerating capacity
- By intention and design
- To keep materials at their highest utility and value at all times
- Choosing which resources to use, where to extract them and how to use them
- Designing for whole building life cycle

[6] [7]





Source: Ellen MacArthur Foundation; World Economic Forum; The Boston Consulting Group

How do we work with CE concept when all buildings are unique?

Joining forces

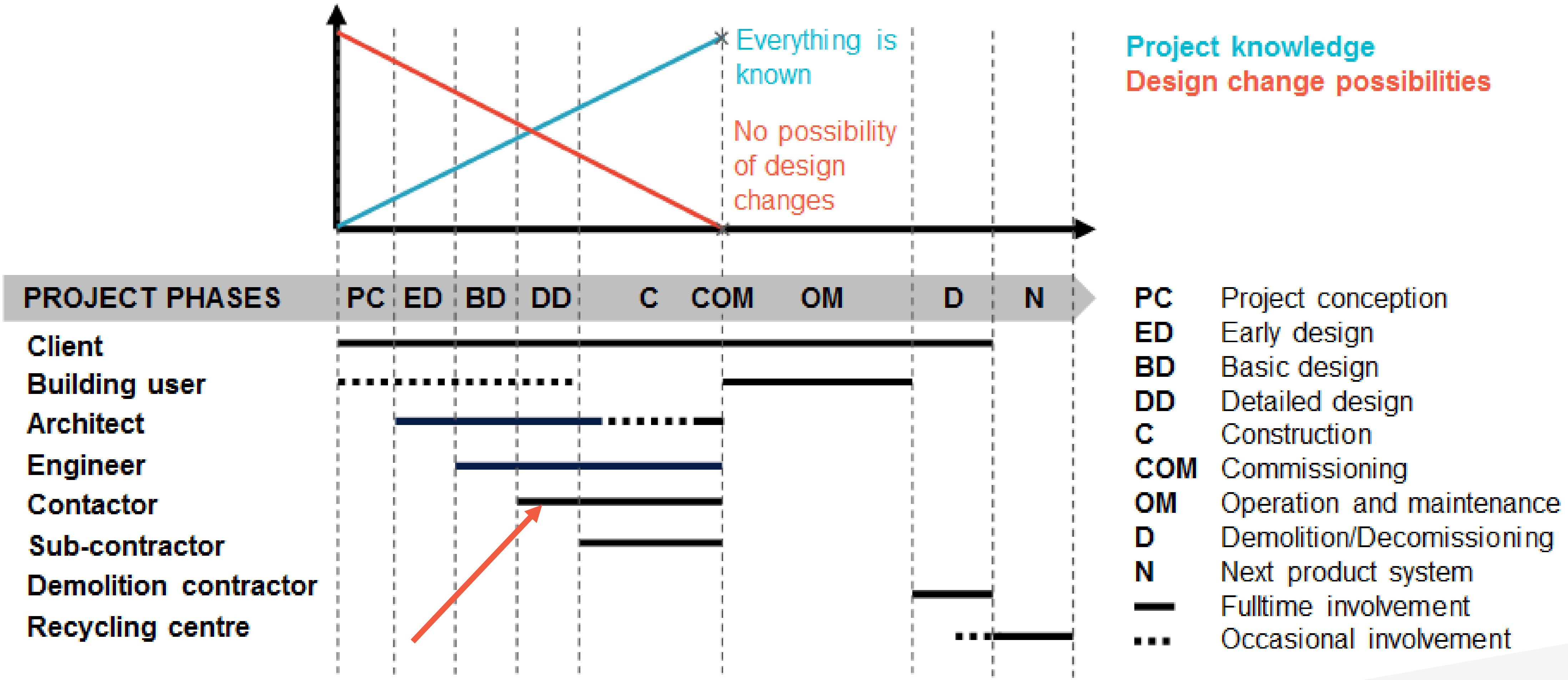
From intuition towards decisions based on well-founded scientifical facts and data

Company supervisors		Industrial PhD	University supervisors	
				
Ninette Alto	**John Sommer**	**Leonora Eberhardt**	**Harpa Birgisdottir**	**Morten Birkved**
Technical Director, Sustainability MT Højgaard	Strategy & Business Development Director MT Højgaard	Industrial PhD student, Aalborg Universitet MT Højharrd	Senior researcher, Statens Byggeforskningsinstitut	Professor, Syddansk Universitet

Project period: 1/10/17 - 1/10/20

To speak the same language

80% buildings' environmental impact and resource flow is determined by the design decisions [1]



[11]

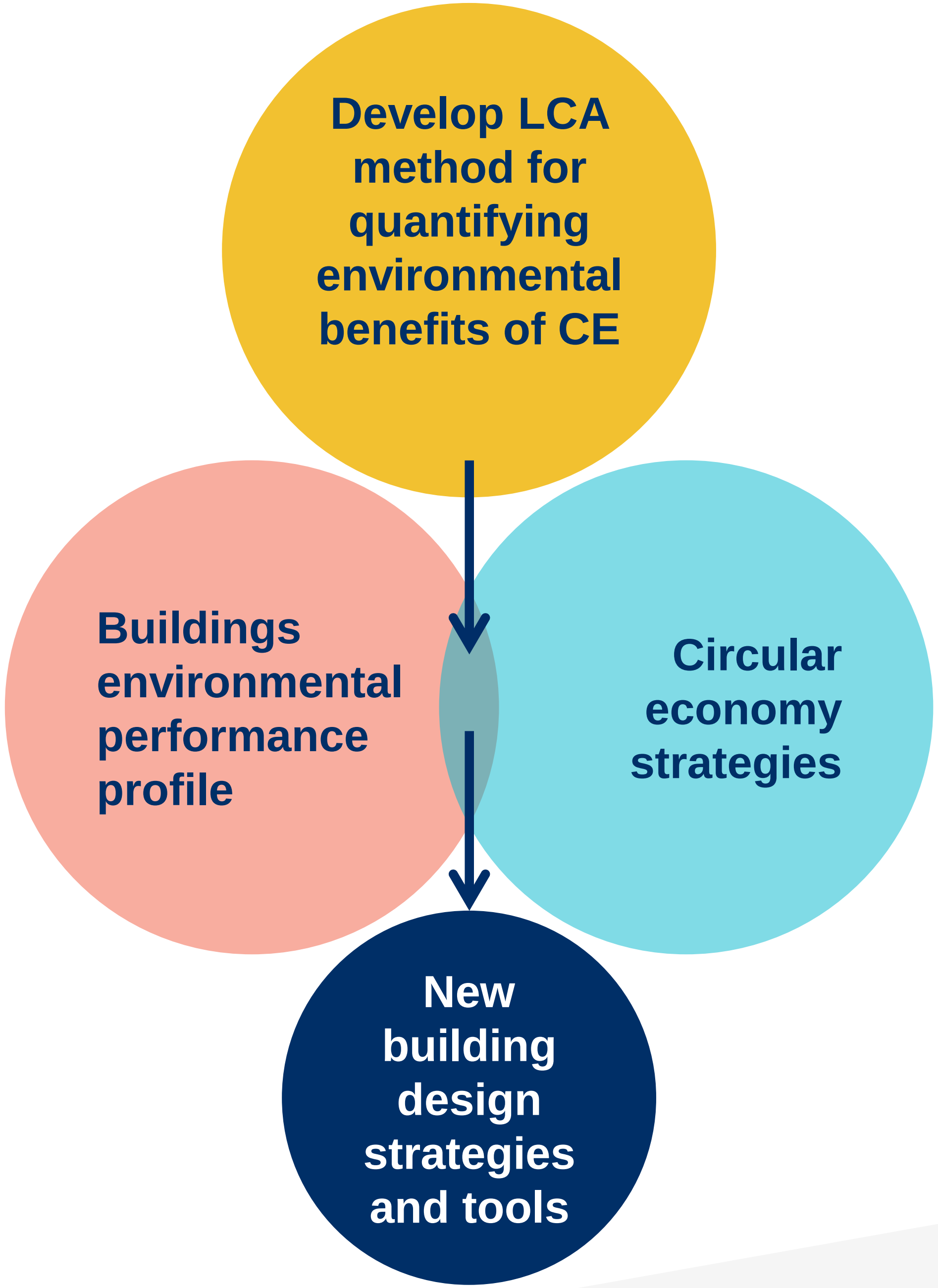
The industrial PhD project

We need to move our knowledge to the design phase, but it requires that we have the knowledge first!

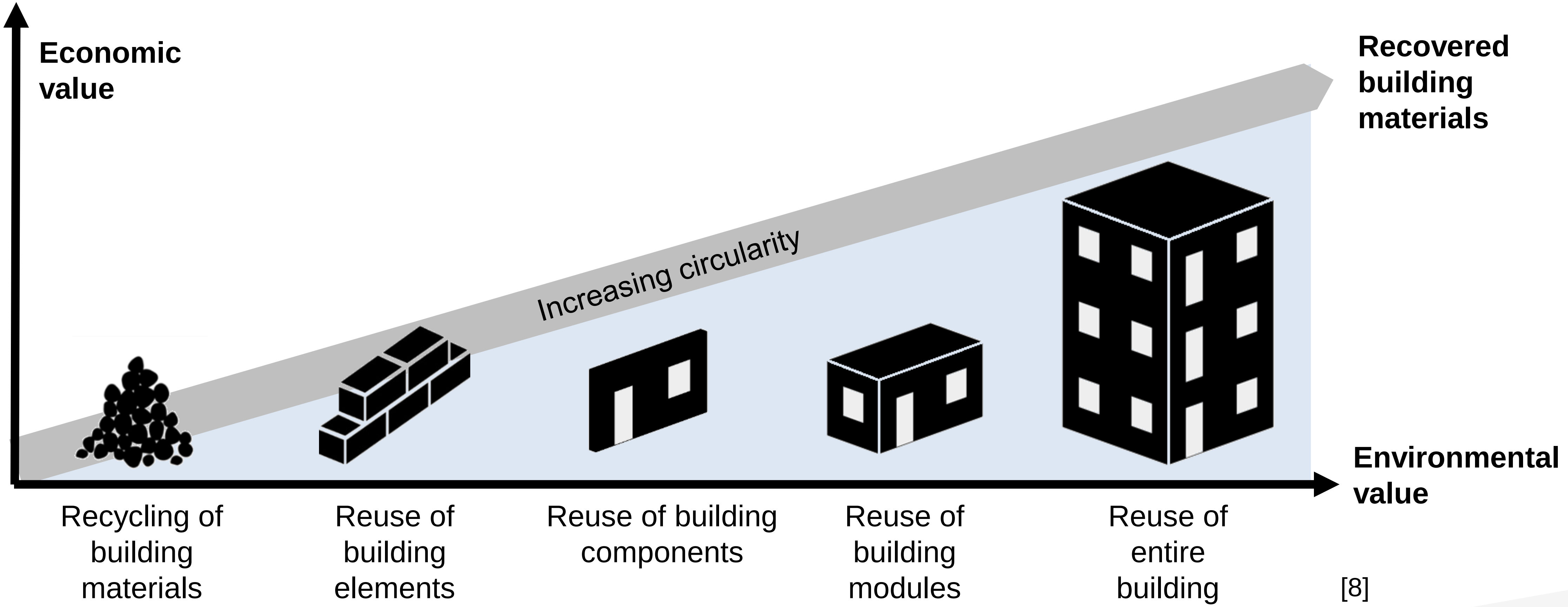
Goal: develop a design decision support to help building designers select circular economy strategies

Aim: improving environmental performance of buildings

Study: the link between circular economy strategies and the environmental performance of building typologies



Our starting point
- Where is the value?



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Findings

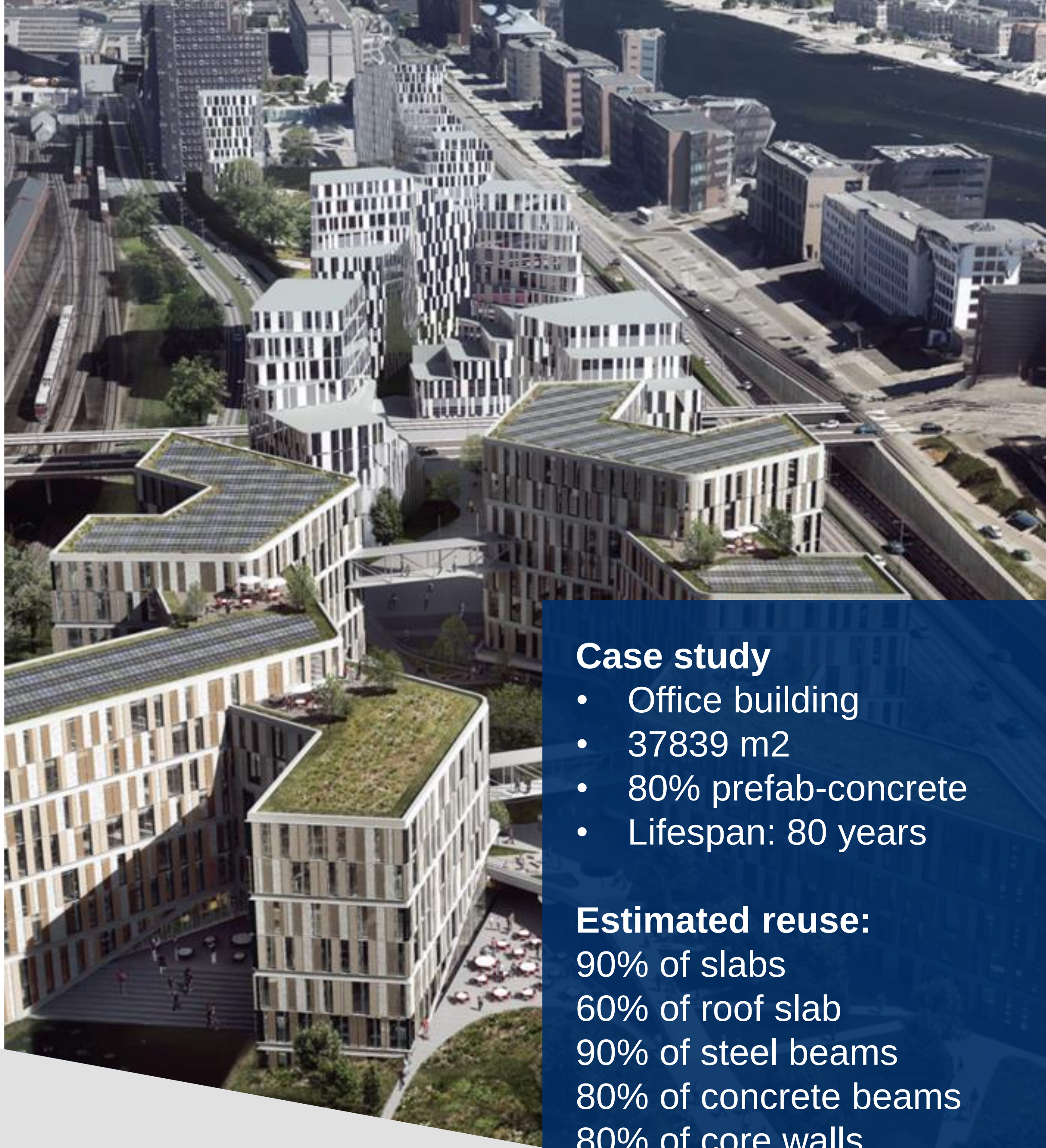
Our first take

Construction

-860.000.000 DKK

Demolition	**Disassembly**
Selective demolition	Relocation
Down-cycling	Reuse
-16.000.000 DKK	**35.000.000 DKK**

www.buildingacircularfuture.com



Case study

- Office building
- 37839 m2
- 80% prefab-concrete
- Lifespan: 80 years

Estimated reuse:

90% of slabs
60% of roof slab
90% of steel beams
80% of concrete beams
80% of core walls
90% of concrete columns

Life cycle assessment
Building components

EN 15978
openLCA 1.4
Ecoinvent 3.2 database

CO_2

		Environmental impacts					Resource use impacts		Toxicology impacts				
Reusable components	Use cycles	Impact saving [%]											Weighted impact savings [%]
		GWP	ODP	POCP	AP	EP	ADPe	ADPf	FAETP	HTP	MAETP	TETP	
Floor slabs	2	45	46	45	45	46	46	46	46	43	44	45	45
	3	60	61	60	60	60	60	61	61	59	60	60	60
Core walls	2	36	32	27	30	28	11	32	13	20	18	7	23
	3	50	47	43	46	44	31	47	31	38	37	28	40
Roof slabs	2	31	32	34	33	33	43	32	43	39	38	51	37
	3	41	42	44	46	44	53	42	53	47	48	62	47
Columns	2	41	32	37	38	37	28	38	29	32	32	29	34
	3	57	54	55	55	55	48	56	49	51	51	49	53
Beams	2	25	28	34	31	34	42	31	41	39	40	43	35
	3	33	38	46	42	45	56	42	55	52	53	58	47

50-60
40-50
30-40
20-30
10-20
0-10
<0

Note: Weighted impact savings are calculated as the average impact savings of each reusable component compared to no reuse using equal weighting factors for each environmental impact category assessed, this includes: GWP, ODP, POCP, AP, EP, ADPe, ADPf, FAETP, MAETP, HTP and TETP.

[9]

Life cycle assessment
Building level

EN 15978
openLCA 1.4
Ecoinvent 3.2 database

CO_2

Environmental impacts | Resource use impacts | Toxicology impacts

Building scenario	Use cycles	Impact saving [%]											Average [%]
		GWP	ODP	POCP	AP	EP	ADPe	ADPf	FAETP	HTP	MAETP	TETP	
DFD	2	15	8	7	7	8	0.3	10	7	5	6	17	8.2
	3	21	14	9	10	11	0.6	14	11	8	9	13	11.0

Optimisation of one sub-component may not benefit the overall buildings environmental performance!

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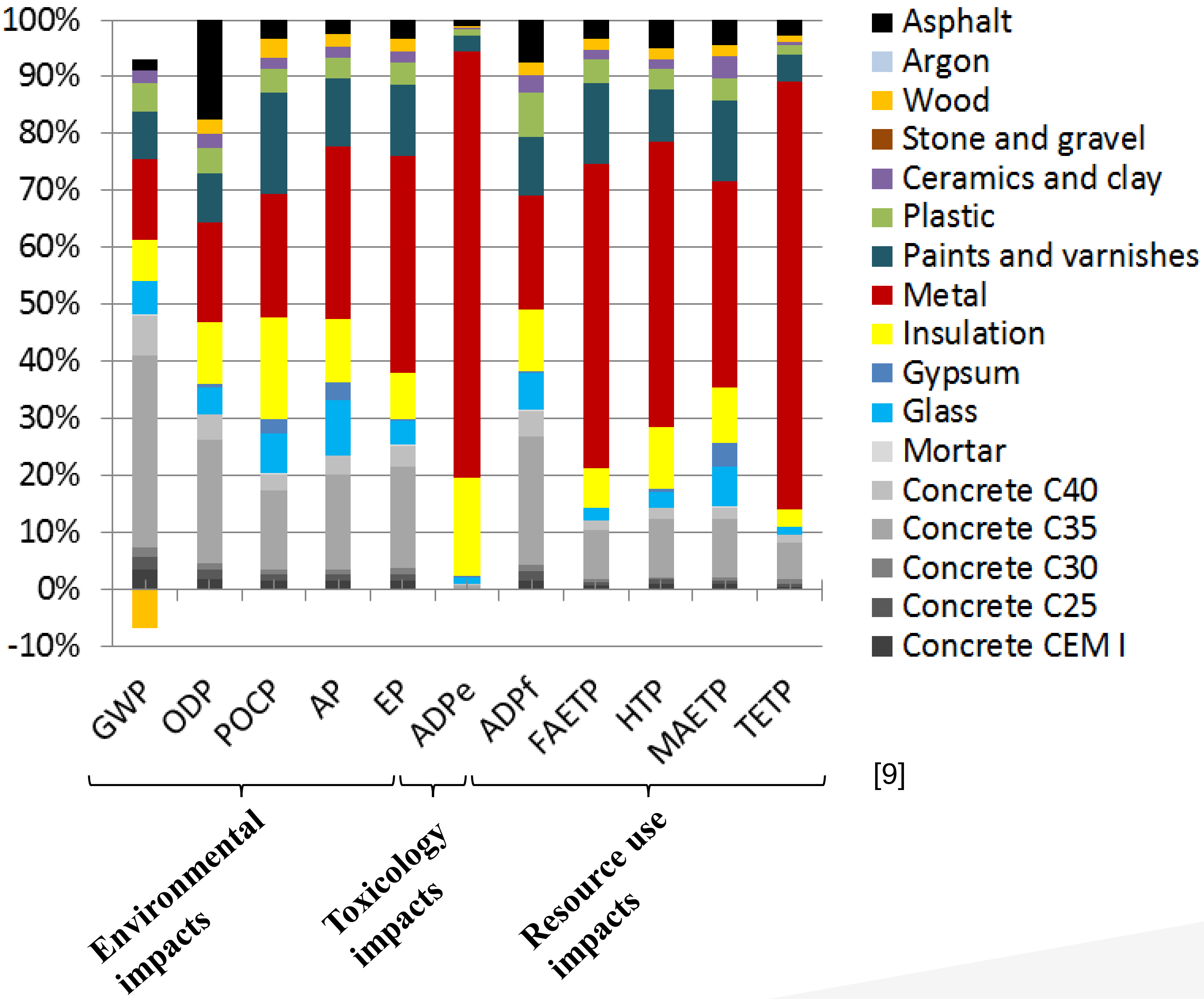
Findings

- Snaps-shots don't give us the full picture!
- The building material composition is a determining factor!
- Materials perform unevenly across the environmental impact categories
- We need to understand the interdependancies of our buildings material composition better
- Although all buildings are unique the same resources are used



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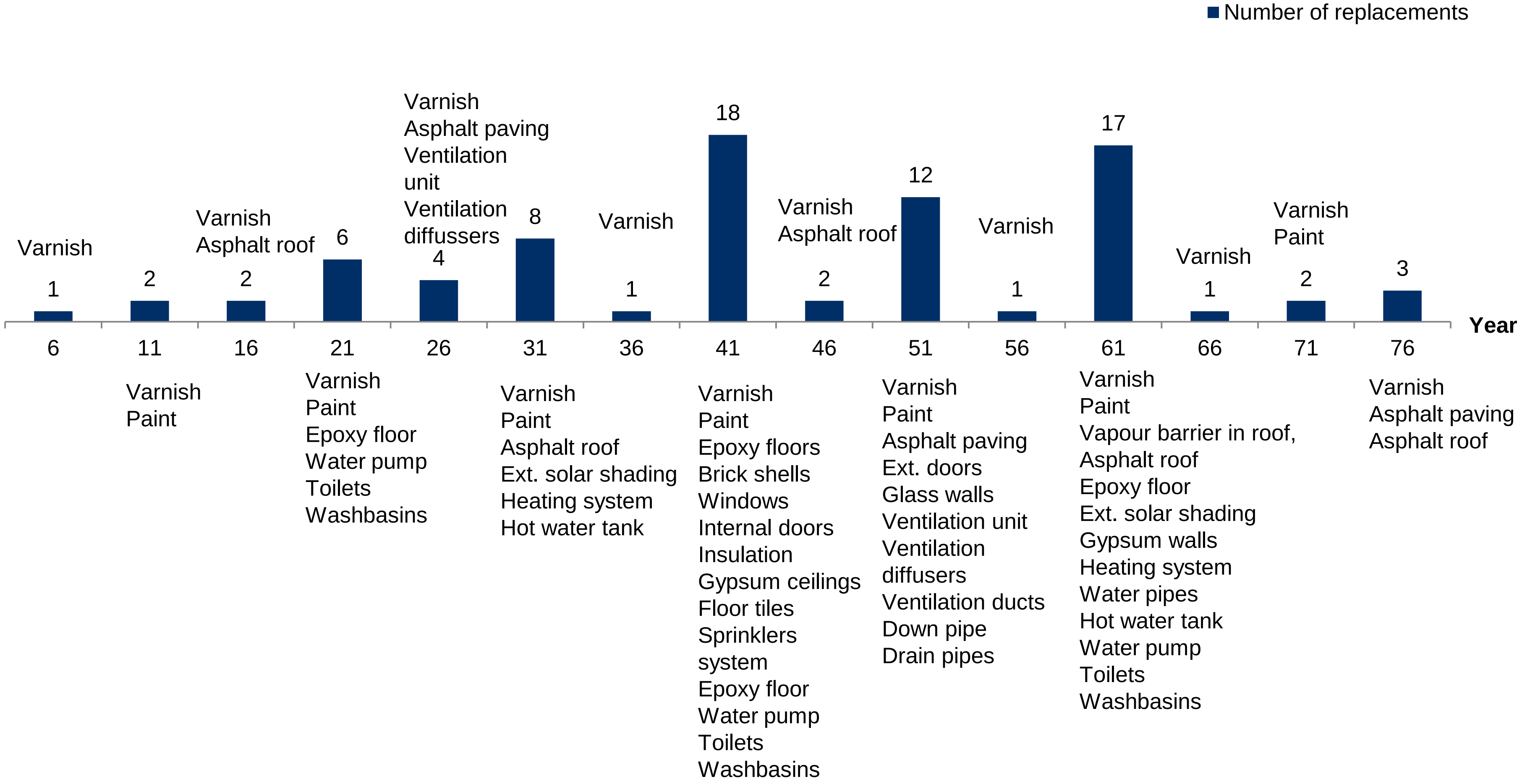
The building metabolism



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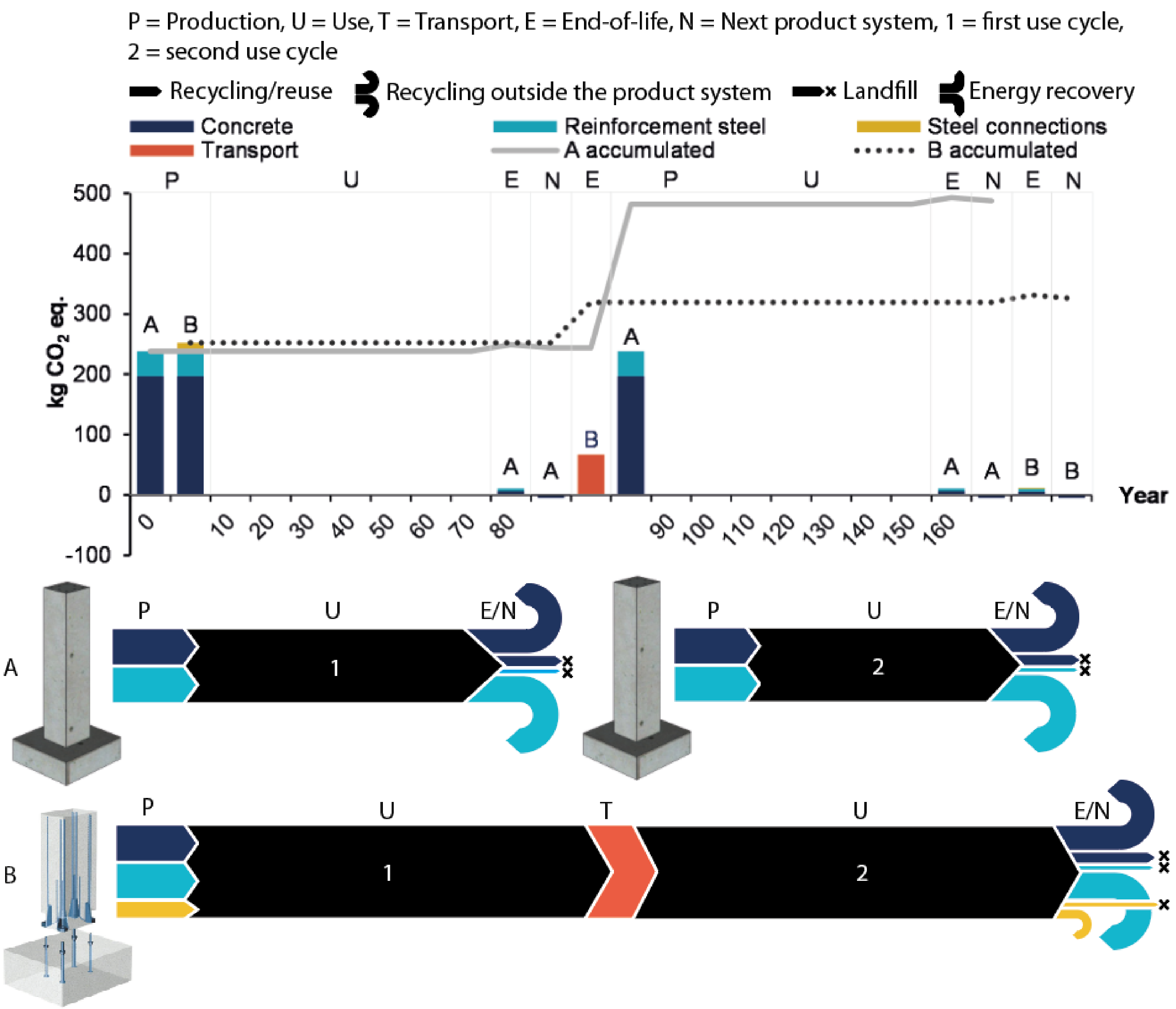
School

Hospital

Office

Residential



From research to practice

Educating the industry

To have a dialog we need common knowledge.

The environmental impact and material flow difference over time between linear and circular building components

LCA method development:
How do we best calculate the environmental benefits of CE in buildings?

How do we communicate scientific results into industry practice?

From research to practice
Design and engineering strategies

- Different ways of achieving CE: How is CE being used in building design?
- Ranked according to the strategies most used
- Intuition based
- Studies suggest to create new design strategies through a combination of several CE design strategies to reduce environmental impacts and create value for the construction sector
- The individual strategies can enable or enhance other strategies

1	Design for assembly/disassembly
2	Design for material selection/substitution
3	Design for adaptability and flexibility
4	Design in modularity
5	Design for secondary materials
6	Design for product-service-systems
7	Design for prefabrication
8	Design for standardization
9	Design for optimized shapes/dimensions
10	Design for durability
11	Design for material optimisation
12	Design for material passport
13	Design for accessibility
14	Design reusing existing building/components/materials
15	Design using BIM
16	Design in layers
17	Design for material storage
18	Design for symbiosis
19	Design out secondary finishes
20	Design for use

 17

Circle House

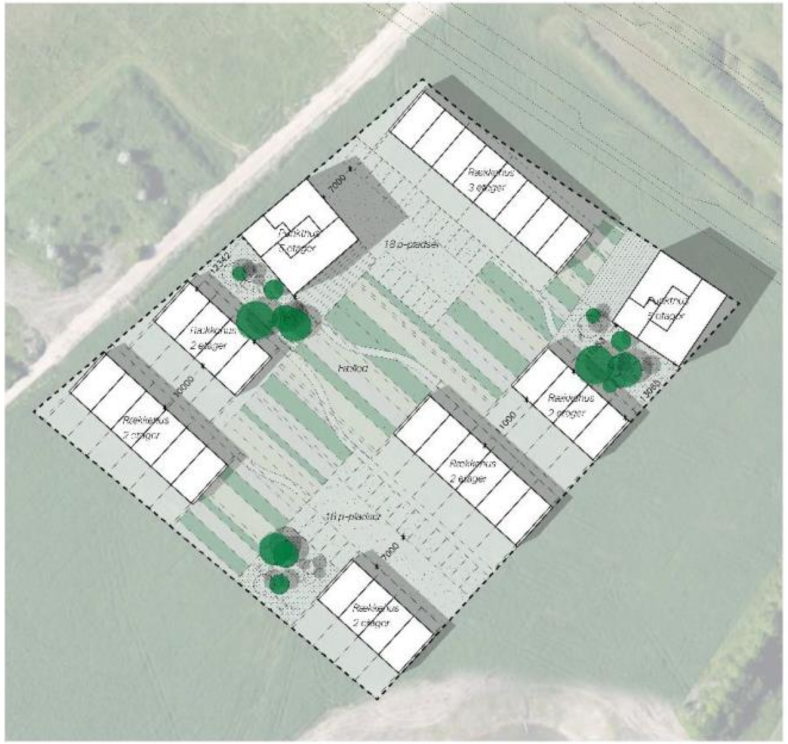
Stakeholder goal
60 social housing residents design for easy operation and maintenance

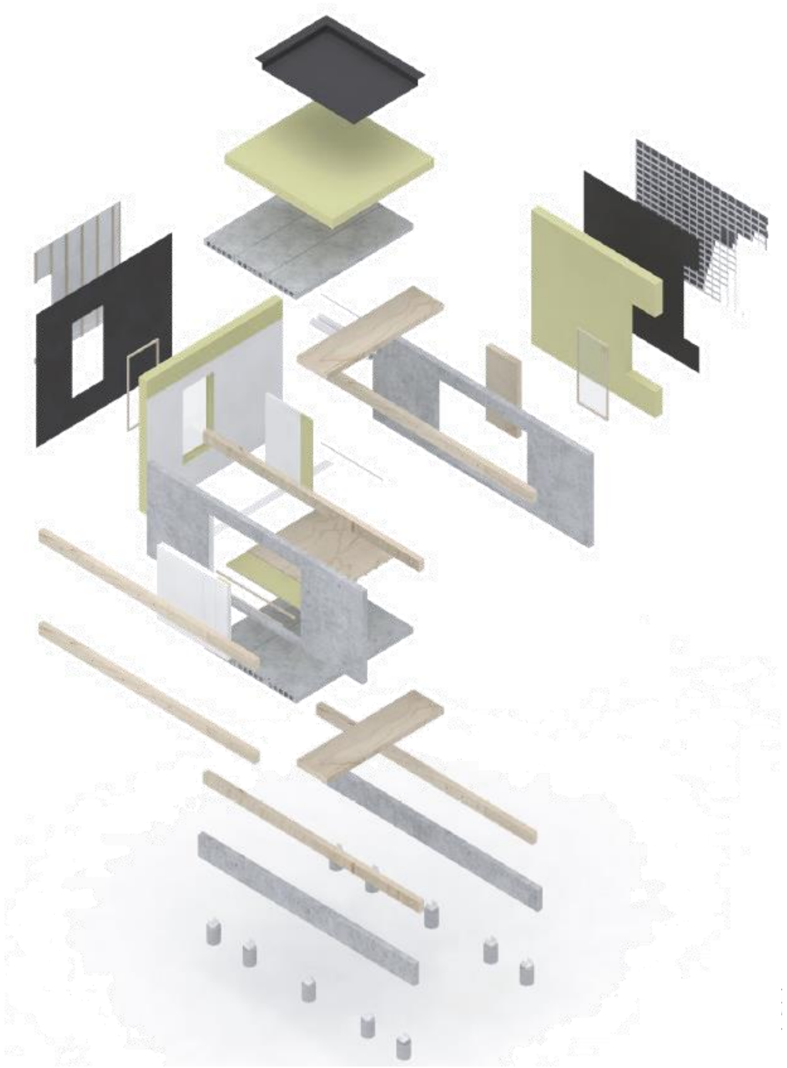
Alignment

Sustainability goal
90% of the materials can be reused or recycled without loss of value

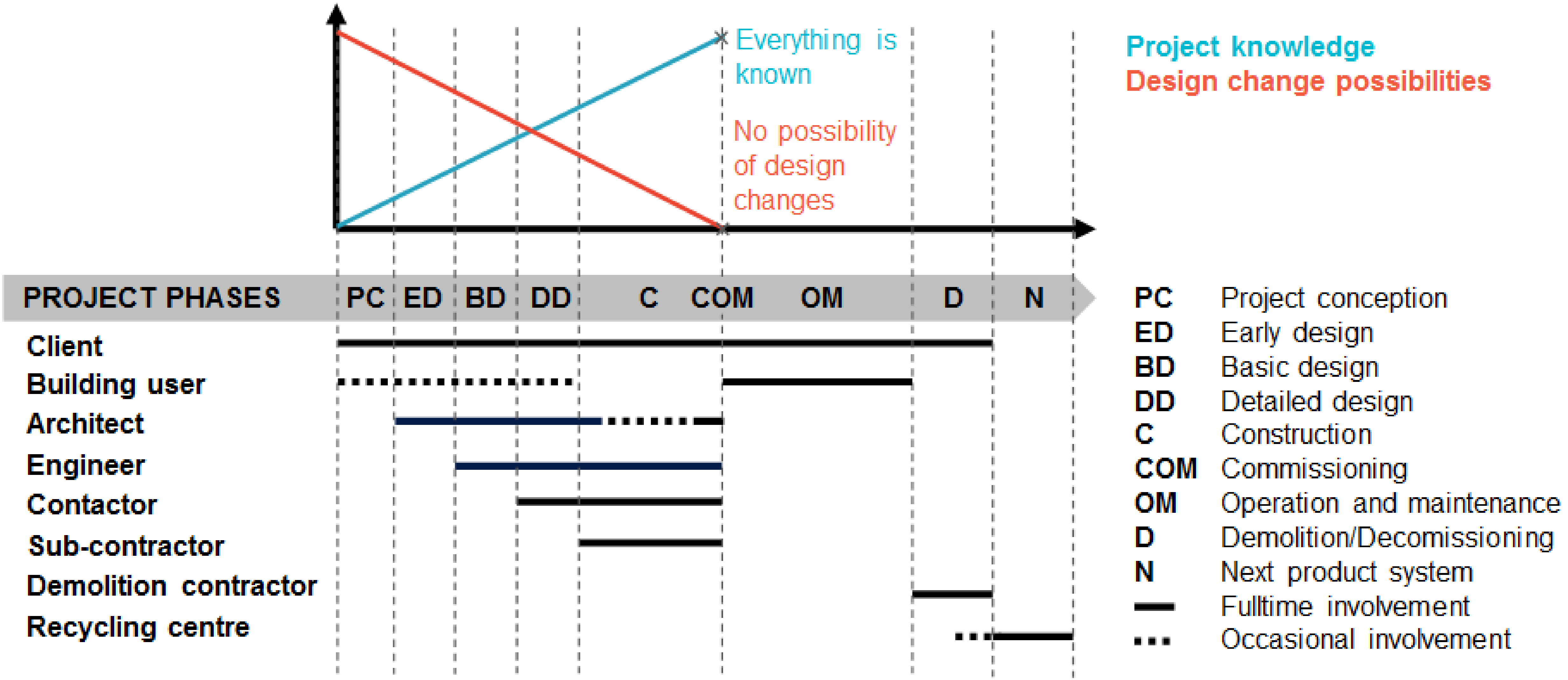






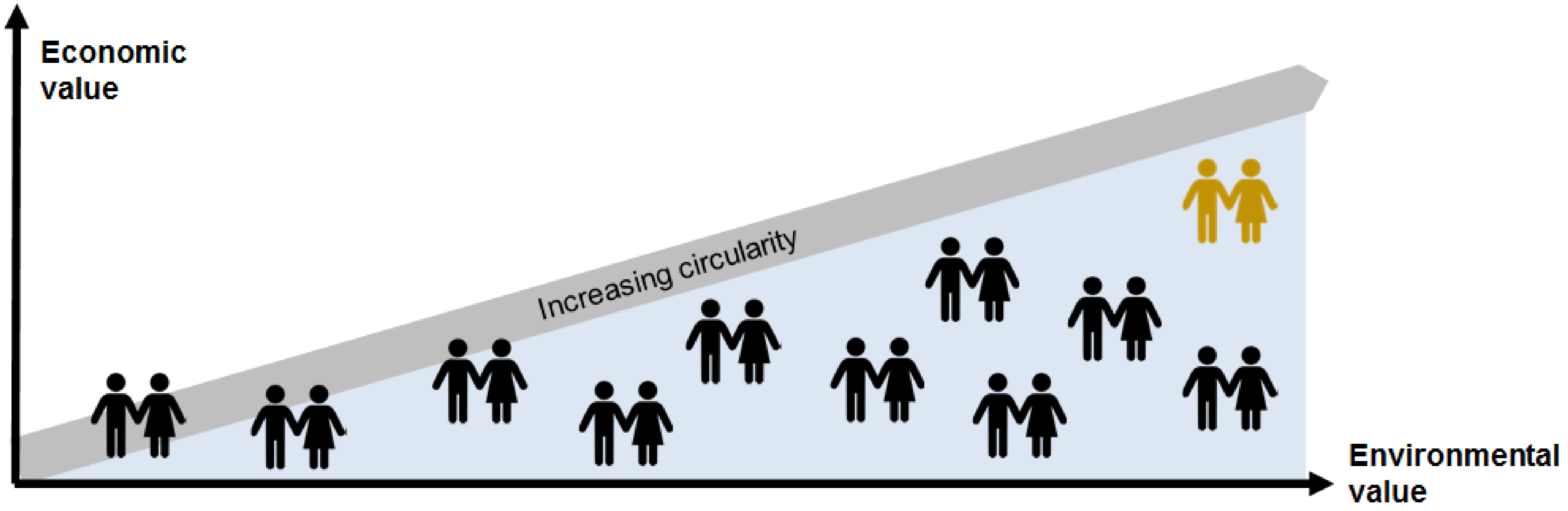


1	Design for assembly/disassembly	x
2	Design for material selection/substitution	x
3	Design for adaptability and flexibility	x
4	Design in modularity	x
5	Design for secondary materials	x
6	Design for product-service-systems	x
7	Design for prefabrication	x
8	Design for standardization	x
9	Design for optimized shapes/dimensions	
10	Design for durability	x
11	Design for material optimisation	x
12	Design for material passport	x
13	Design for accessibility	x
14	Design reusing existing building/components/materials	
15	Design using BIM	
16	Design in layers	
17	Design for material storage	
18	Design for symbiosis	
19	Design out secondary finishes	x
20	Design for use	


Everything is known
No possibility of design changes
Project knowledge
Design change possibilities
PROJECT PHASES
PC
ED
BD
DD
C
COM
OM
D
N
Client
Building user
Architect
Engineer
Contactor
Sub-contractor
Demolition contractor
Recycling centre
PC Project conception
ED Early design
BD Basic design
DD Detailed design
C Construction
COM Commissioning
OM Operation and maintenance
D Demolition/Decomissioning
N Next product system
Fulltime involvement
Occasional involvement


CIRCLE HOUSE
Danmarks
Første
Cirkulære
Boligbyggeri

Teaming up desing and engineering strategies



When do we get value?

- Linking buildings environmental performance profiles with CE design strategies [10]
- For which design strategy configurations?
- For which buildings, materials, components
  (direct reuse of components or direct access to resources?)
- Low hanging fruits
- Visionary strategies

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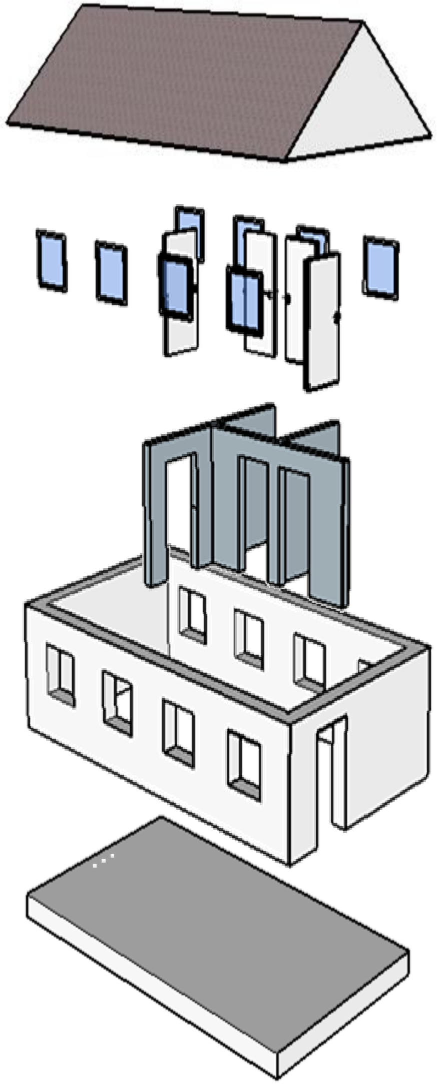
What gets measured gets done!

COMPONENTS



BUILT-IN

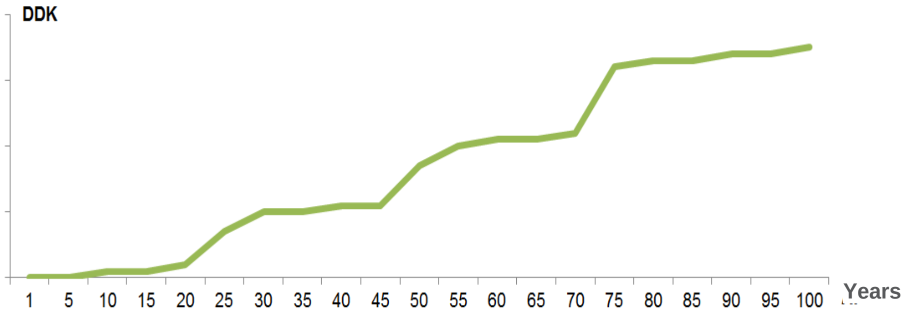
- 20% Virgin material
- 50% Recycled material
- 30% Reused material

RECOVERY

- 15% Disposal
- 50% Recycling
- 30% Reuse

TOTAL SCORE

TOTAL COST



Human health

Eco-system

Resources

It starts with you and me!

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