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

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Erhvervs PhD
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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 CO₂-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

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

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

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

Company supervisors

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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 \[1\]

![Diagram showing project phases and involvement over time](image)
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

Develop LCA method for quantifying environmental benefits of CE

Buildings environmental performance profile

Circular economy strategies

New building design strategies and tools
Our starting point - Where is the value?

- Recycling of building materials
- Reuse of building elements
- Reuse of building components
- Reuse of building modules
- Reuse of entire building

[8]
Findings
Our first take

-860,000,000 DKK

Demolition
Selective demolition
Down-cycling

Disassembly
Relocation
Reuse

-16,000,000 DKK
35,000,000 DKK

Case study
- Office building
- 37,839 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

www.buildingacircularfuture.com
# Life cycle assessment

## Building components

<table>
<thead>
<tr>
<th>Reusable components</th>
<th>Use cycles</th>
<th>Environmental impacts</th>
<th>Resource use impacts</th>
<th>Toxicology impacts</th>
<th>Impact saving [%]</th>
<th>Weighted impact savings [%]</th>
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<tbody>
<tr>
<td>Floor slabs</td>
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<td>45 46 45 45 46 46 46 46 43 44 45</td>
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<td>Core walls</td>
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<td>50 47 43 46 44 31 47 31 38 37 28</td>
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<tr>
<td>Roof slabs</td>
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<td>33 38 46 42 45 56 42 55 52 53 58</td>
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</table>

**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.
Life cycle assessment
Building level

<table>
<thead>
<tr>
<th>Building scenario</th>
<th>Use cycles</th>
<th>Impact saving [%]</th>
<th>Average [%]</th>
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<td></td>
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<td>ODP</td>
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<tr>
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</tbody>
</table>

Optimisation of one sub-component may not benefit the overall building's environmental performance!
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 interdependencies of our buildings material composition better

- Although all buildings are unique the same resources are used
The building metabolism

<table>
<thead>
<tr>
<th>Year</th>
<th>Varnish</th>
<th>Asphalt roof</th>
<th>Paint</th>
<th>Varnish</th>
<th>Asphalt paving</th>
<th>Ventilation unit</th>
<th>Ventilation diffusers</th>
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<td>71</td>
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</table>

**Number of replacements**
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
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
Project knowledge
Design change possibilities

Everything is known
No possibility of design changes

PROJECT PHASES: PC ED BD DD C COM OM D N

- **PC**: Project conception
- **ED**: Early design
- **BD**: Basic design
- **DD**: Detailed design
- **C**: Construction
- **COM**: Commissioning
- **OM**: Operation and maintenance
- **D**: Demolition/Decommissioning
- **N**: Next product system

- **Client**: Fulltime involvement
- **Building user**: Occasional involvement
- **Architect**: 
- **Engineer**: 
- **Contactor**: 
- **Sub-contractor**: 
- **Demolition contractor**: 
- **Recycling centre**: 

Graph showing the timeline and involvement of various roles in project phases.
When do we get value?

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

[10]
What gets measured gets done!

**COMPONENTS**

- 35%
- 50%
- 80%
- 70%
- 20%

**BUILT-IN**

- 30%

**RECOVERY**

- 55%

**TOTAL COST**

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

**TOTAL SCORE**

- C1

**Graphs**

- Human health
- Eco-system
- Resources

- What gets measured gets done!
It starts with you and me!
References


