Chair of Timber Structures and Building Construction
Department of Civil, Geo and Environmental Engineering
Technical University Munich

Open Innovation Testbed for Bio-based Construction Products for Envelopes of nearly Zero Energy Buildings

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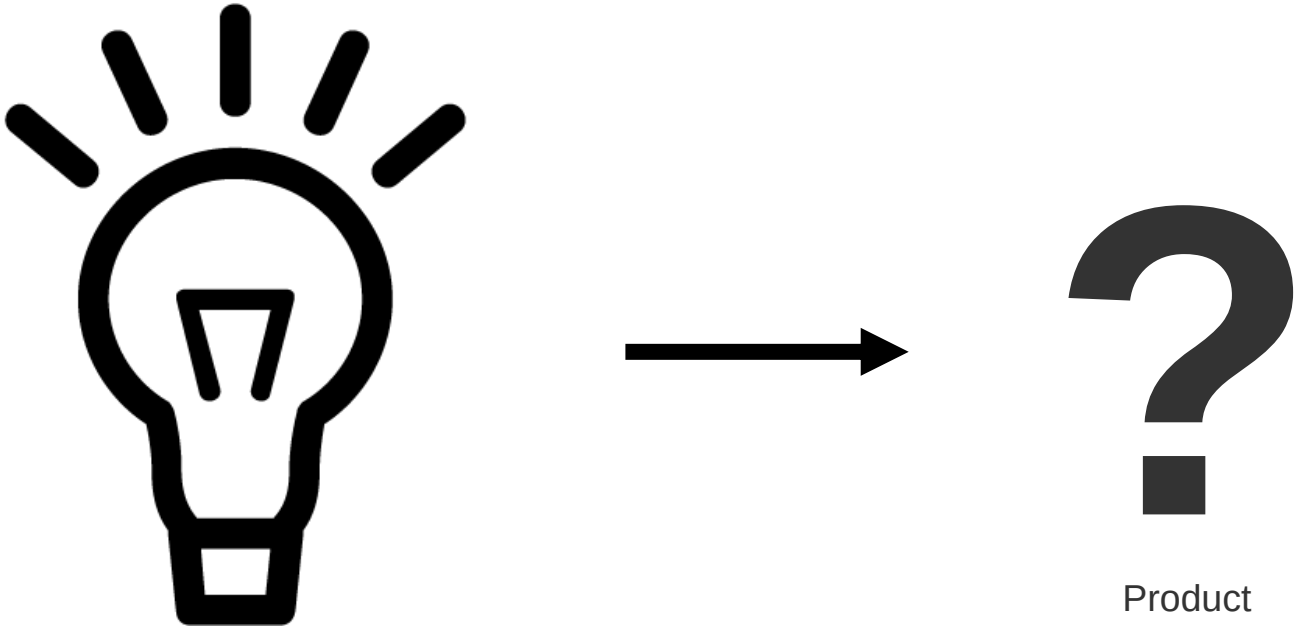
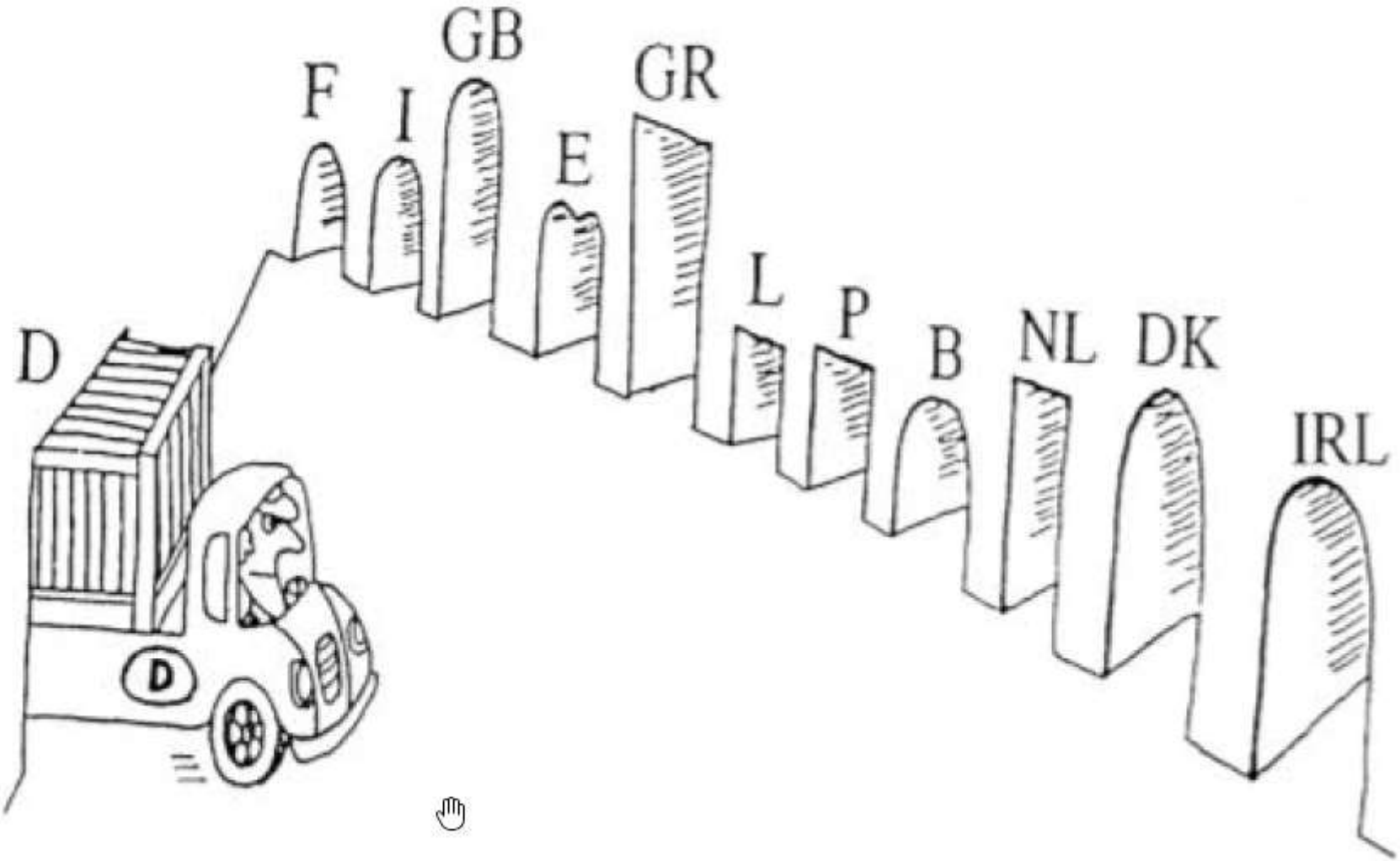
Overview

- large-scale deployment of these buildings relies on **marketable, affordable, flexible**, on demand material-based solutions for energy and resource efficient buildings
- bring laboratory-based solutions into a **replicable level and up-scale** them to solutions attractive and profitable for real applications
- **act on real building envelopes** through actions **in testbeds & living labs** that would create profound economic, social and environmental impacts
- **deep and accurate material insight** using digital twins complemented with development expertise by
  - non-destructive testing
  - advanced finite volume modelling methods
  - digital materials characterization
  - cutting-edge virtual prototyping
  - pilot lines for additive manufacturing, robotic assembly and industrial production

Marketable solutions

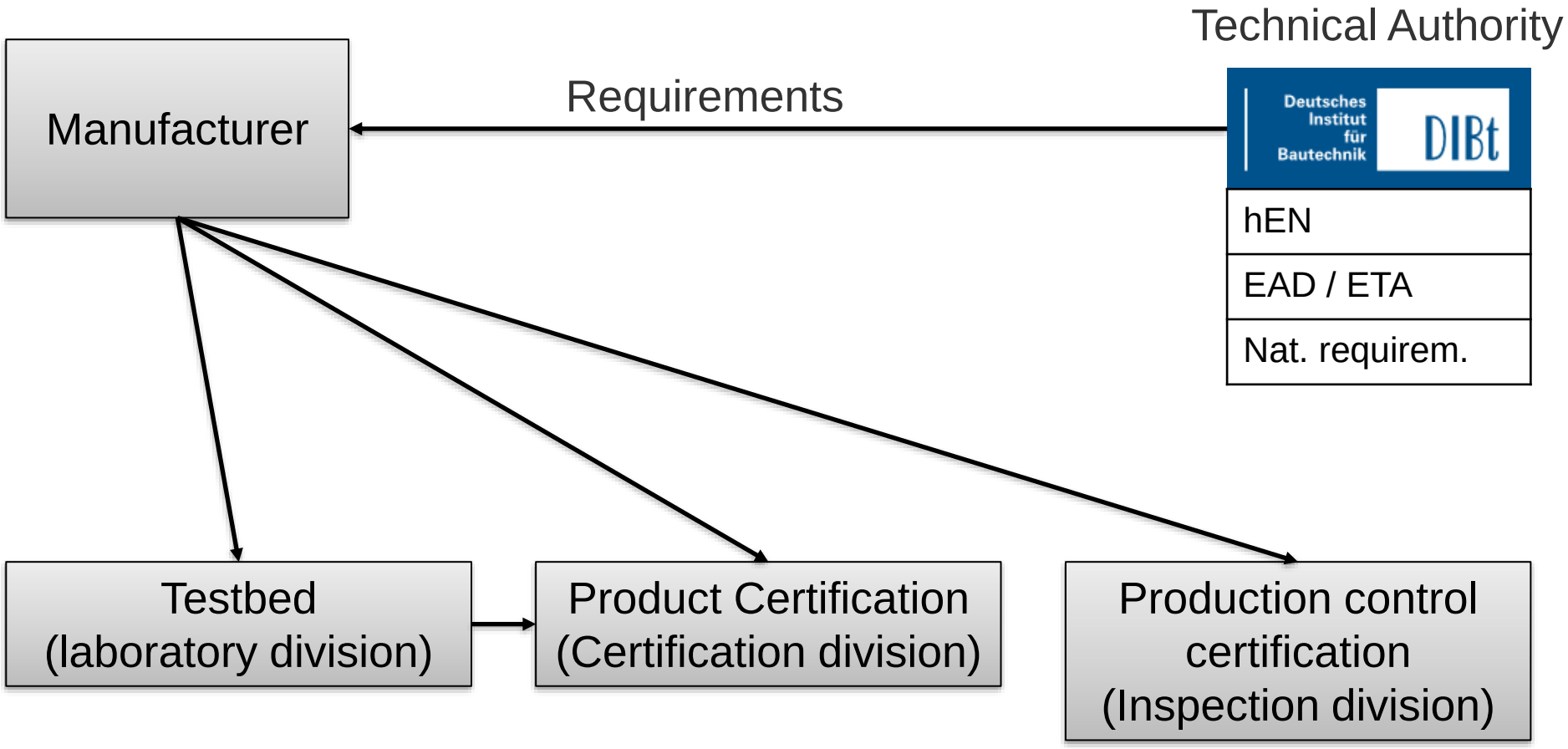


Single Market Problem



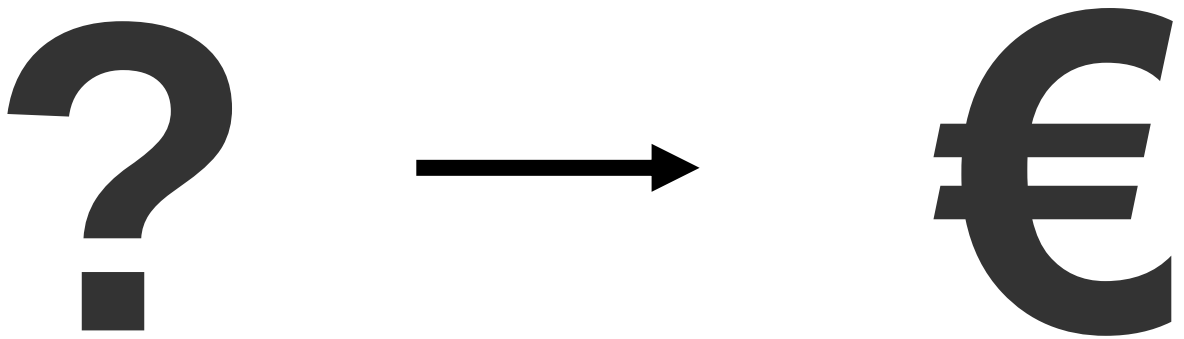
Sample to Product

with CPR conformity



Marketable solutions

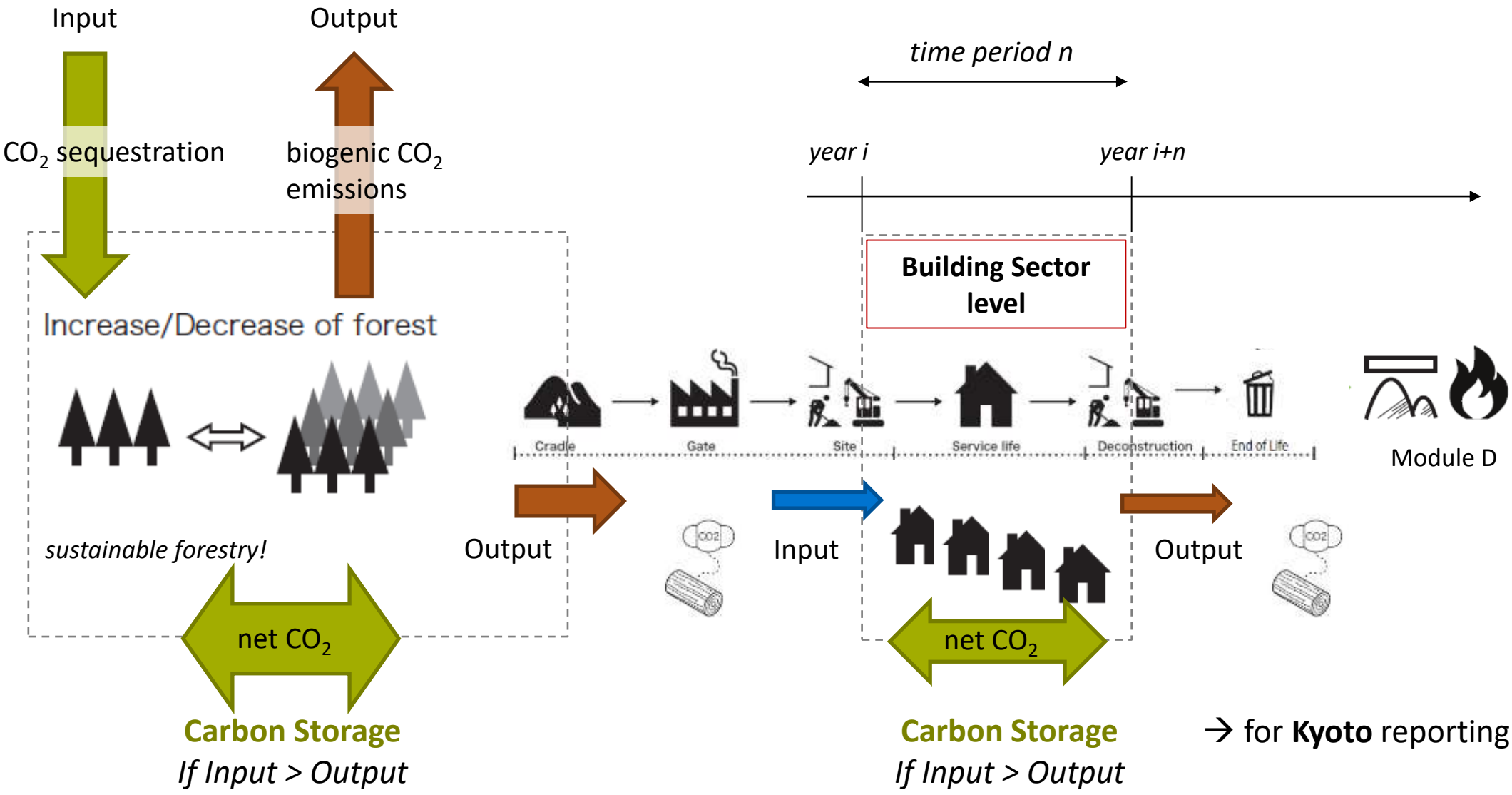
Replicable and upsalable



Product

Bio-based materials

CARBON STORAGE in forestry and (timber) construction sector



Methods for Product Peformance

Understand product properties

„natural product“

- Harvested and processed
- given micro structure
- „inherent“ properties
- single material

Improve product properties

„classic product“

- „traditional“ processed
- „micro“ structure in relation to processing
- „characteristic“ properties
- „plain“ material

Design product properties

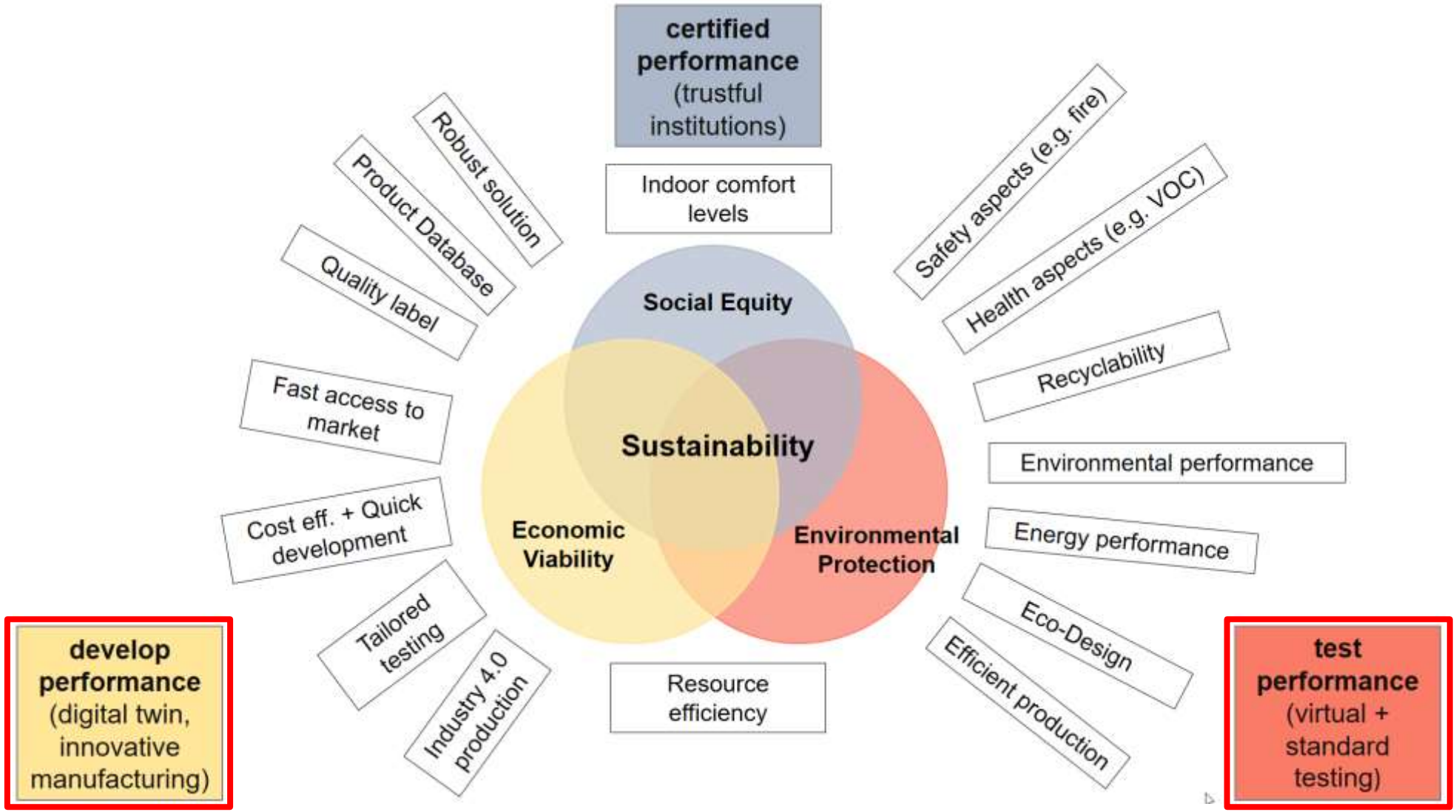
„functional product“

- „additive“ manufactured
- free form & micro structure
- „infinite“ range of properties
- „multi“-materials

Virtual Prototype – Digital Twin Material

Product performance

Optimisation taks



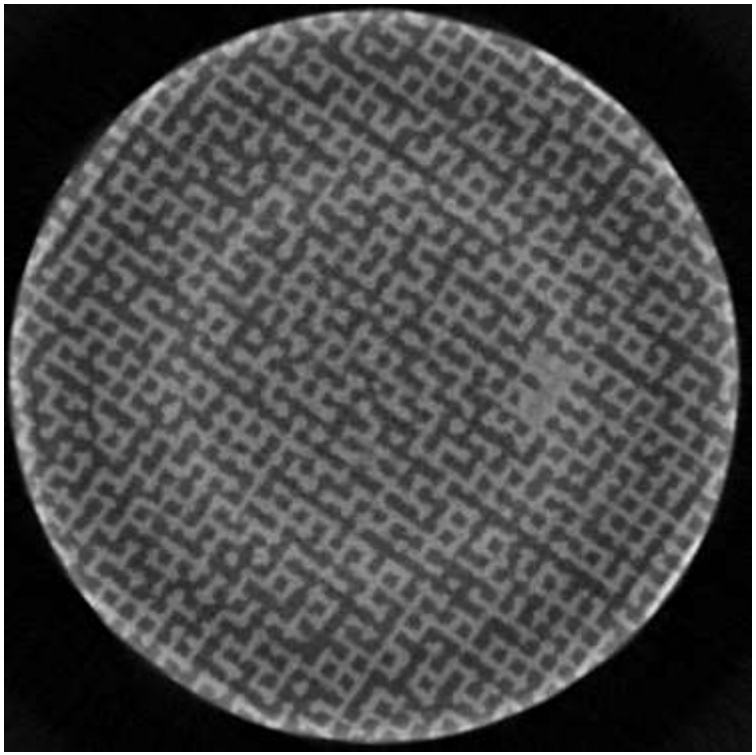
Material insight

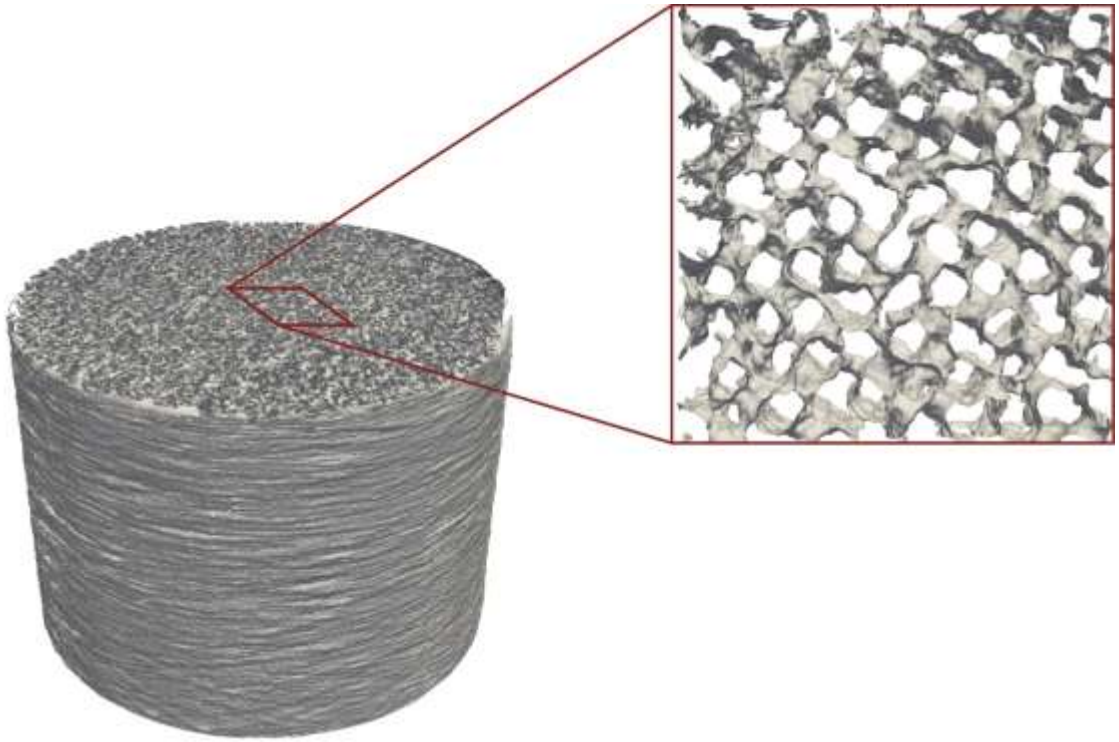
Material insight

Destructive testing

Material insight

Non-destructive CT-scanning

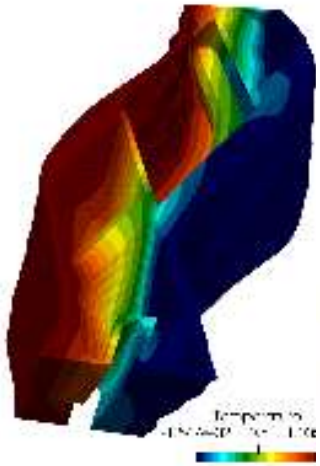
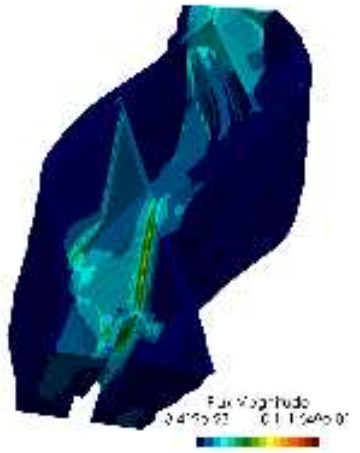




Source: TUM CMS

Material insight

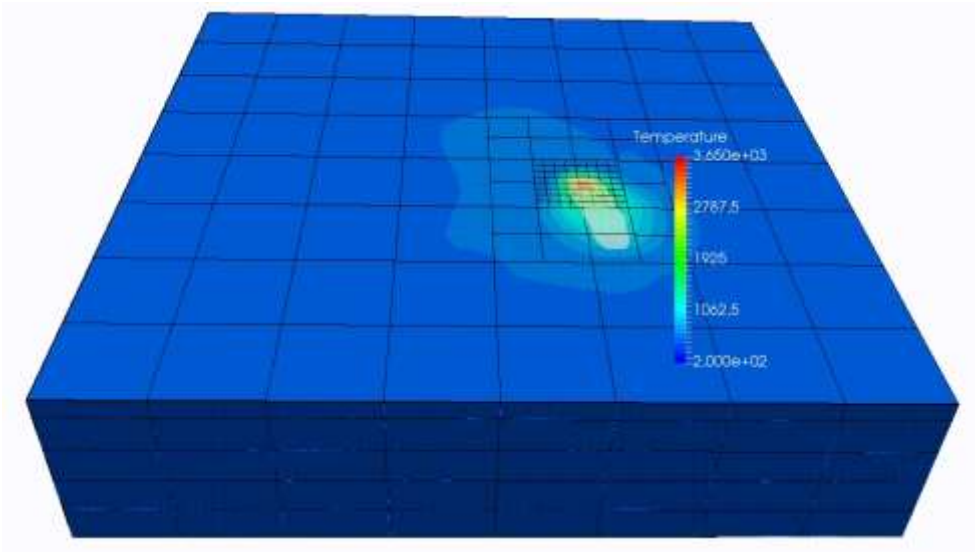
Finite Cell Simulation

Façade element	Computerized geometry	Embedded computational grid	Temperature and flux magnitude on structure
			 

Source: TUM CMS

Material insight

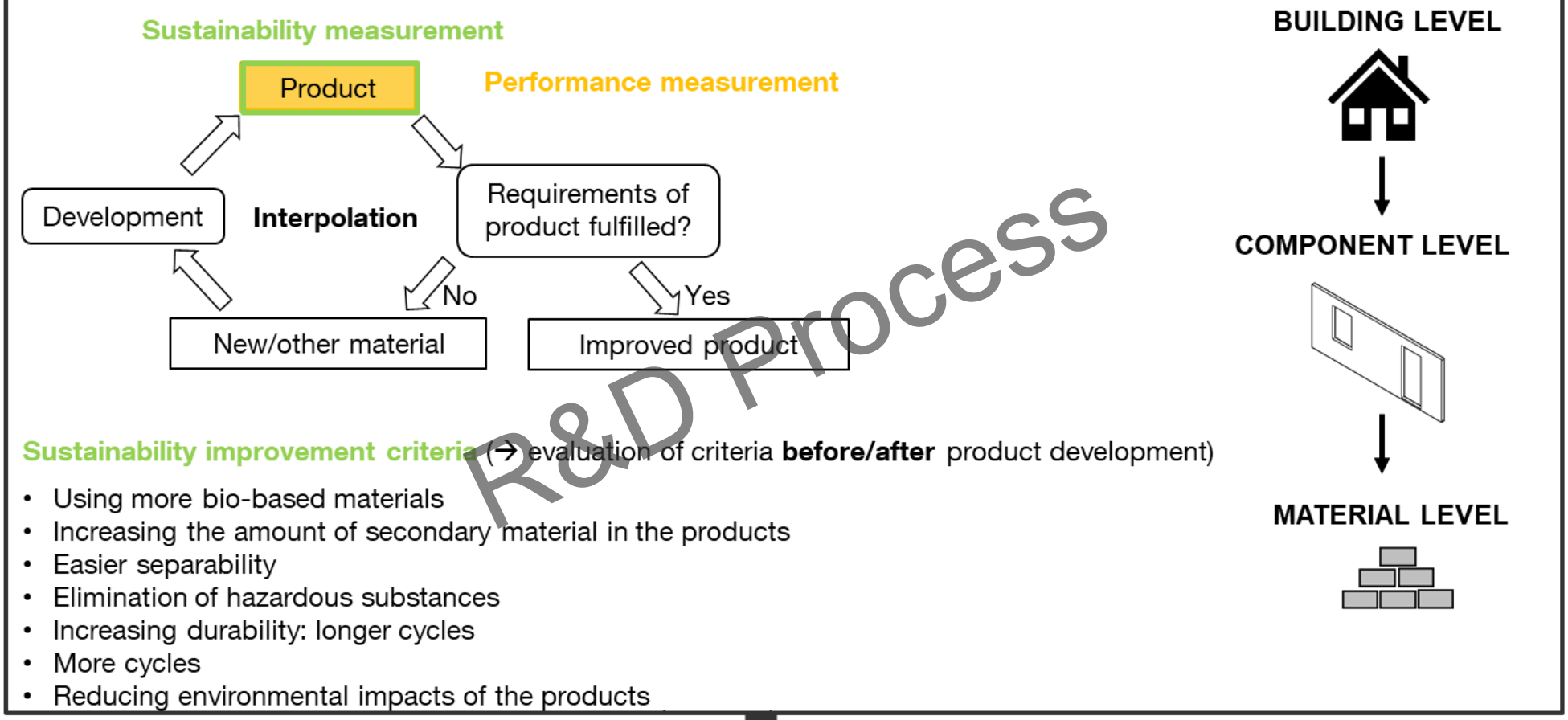
Simulation (additive) manufacturing



TUM HBB & TUM CMS

Circularity

IMPROVEMENT OF ENVIRONMENTAL PERFORMANCE OF PRODUCTS TROUGH SUSTAINABILITY MEASUREMENT



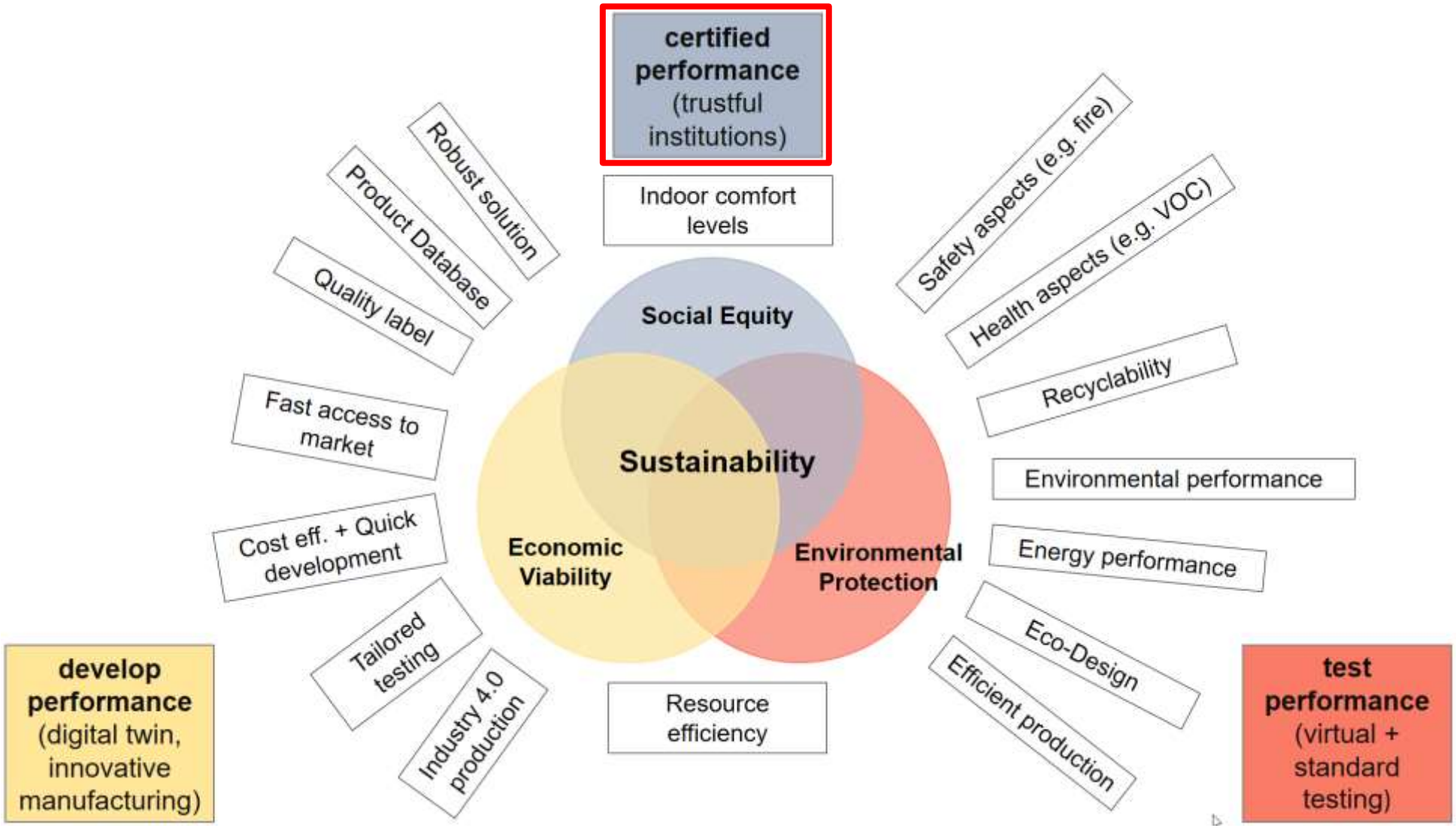
Sustainability improvement criteria (→ evaluation of criteria **before/after** product development)

- Using more bio-based materials
- Increasing the amount of secondary material in the products
- Easier separability
- Elimination of hazardous substances
- Increasing durability: longer cycles
- More cycles
- Reducing environmental impacts of the products

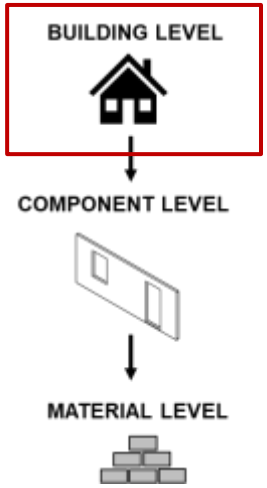
Reommendations for industry

Product performance

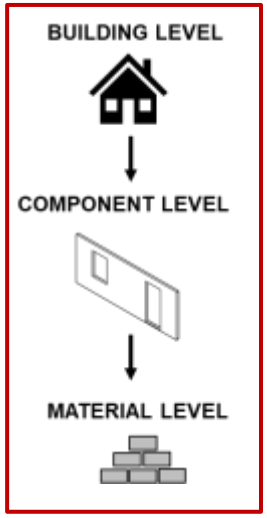
Optimisation taks



Circularity – Building level

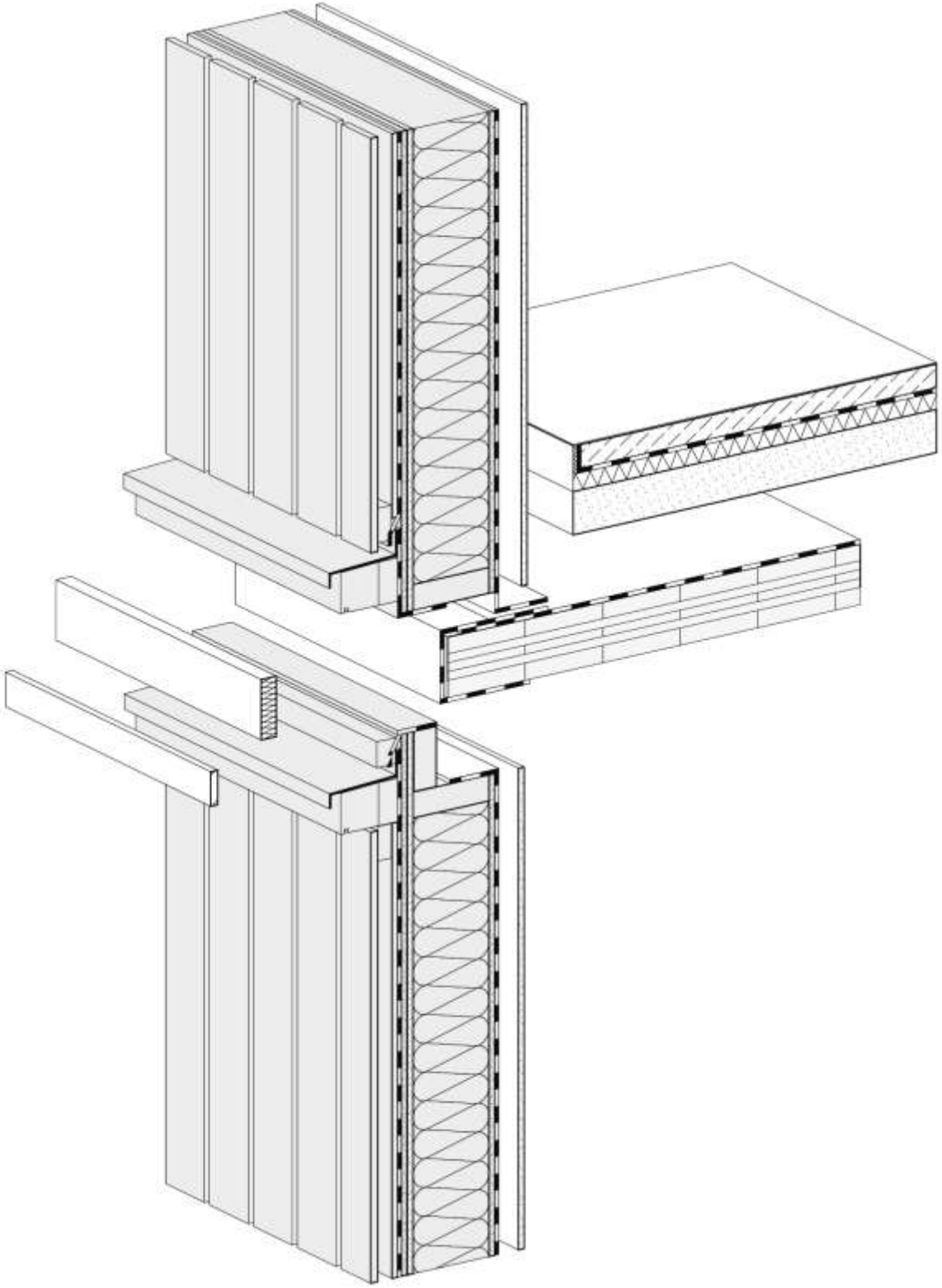


Circularity performance




dataholz.eu
Ökobilanzielle Berechnung* der Umweltauswirkungen und des Ressour
Bauteilnummer
AWTH04a-08
Bauteilbezeichnung
Außenwand Holzständer
Ökobilanzierung | Berechnung nach DIN EN 15804 & 15978 bz
Baustoffangaben zur Konstruktion, Schu
Ökologische Bewertung des
Lebenszyklus
PEI
*berechnet durch d

Wahl der K
Konstruktio
Holzrahm
Holzmass
Wärmeschutz
U ≤0,15 W
U 0,16–0,
U ≥0,21 W
Fassade Holz
hinterlüft
Fassade
nicht hint
Fassade
Schallschutz
R_w ≤43 dB
R_w 44–47
R_w 48–57
R_w ≥58 dB

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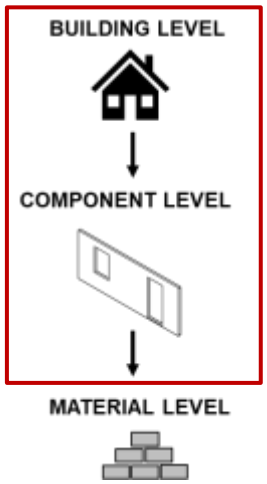
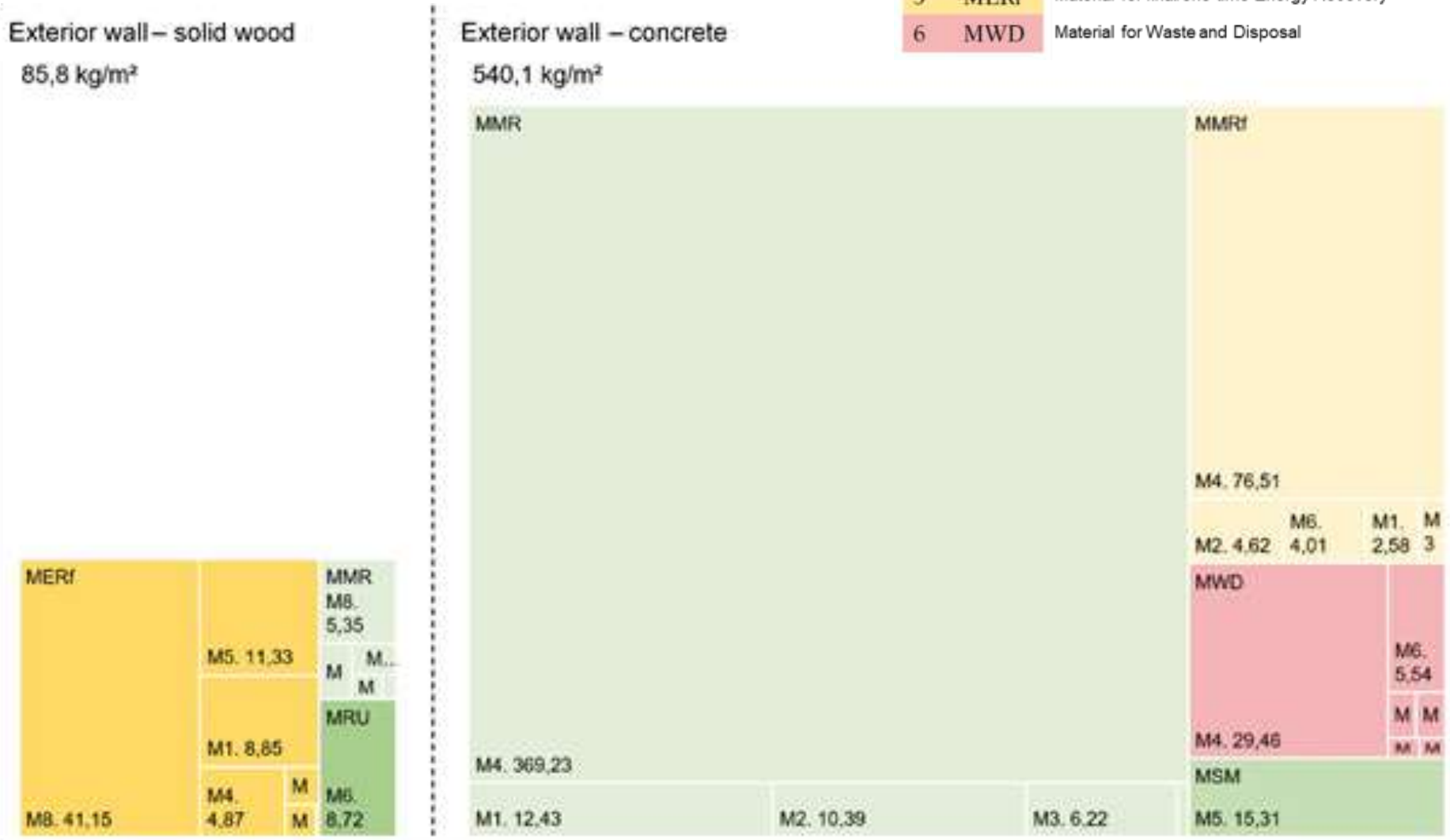
Circularity performance

Demolition (waste) streams

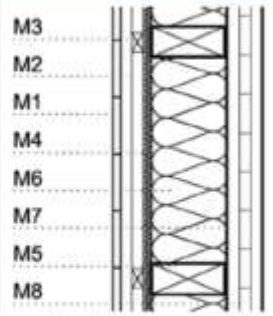
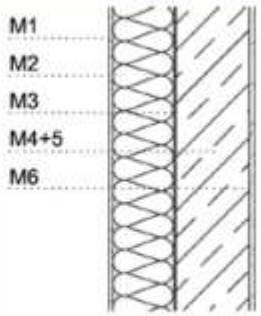




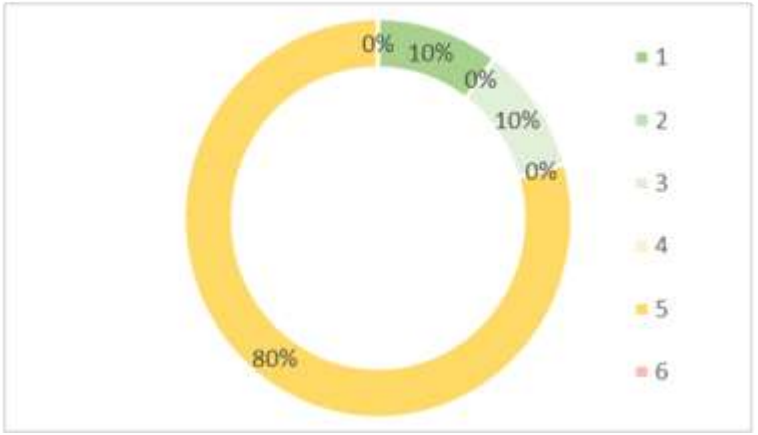
1	MRU	Material for Re-Use
2	MSM	Material for Secondary Material Use
3	MMR	Material for Material recovery
4	MMRf	Material for for final/one-time Material Recovery
5	MERf	Material for final/one-time Energy Recovery
6	MWD	Material for Waste and Disposal

Circularity performance

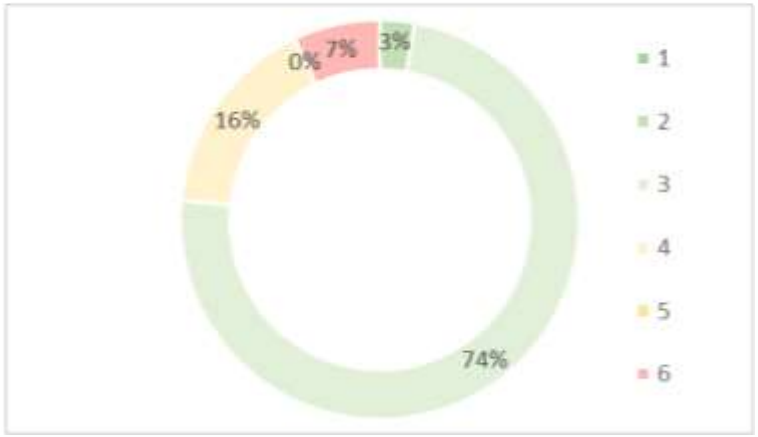
Component level model(s)

Construcion	Solid wood wall	Concrete wall
Component layers		
Total mass [kg/m²]	85,8 (100%)	540,1 (100%)
Environmental impact per m² component area (Modules A1-C4)		
GWP [kg-CO_2-Äq./m²]	24,3	84,6
PERE+PENRE [MJ/m²]	695	817
Recyclability per m² component area		
MRU Material for reuse [kg/m²]	8,7 (10%)	0,0
MSM Material for secondary material use [kg/m²]	0,0	21,0 (3%)
MMR Material for Material Recovery [kg/m²]	8,8 (10%)	393,0 (74%)
MMRf Material for final/one-time Material Recovery [kg/m²]	0,0	89,0 (16%)
MERf Material for final/one-time Energy Recovery [kg/m²]	67,4 (80%)	0,0
MWD Material for Waste and Disposal [kg/m²]	0,0	37,9 (7%)

Exterior wall – solid wood



Exterior wall – concrete



Circularity Indicators

Building level

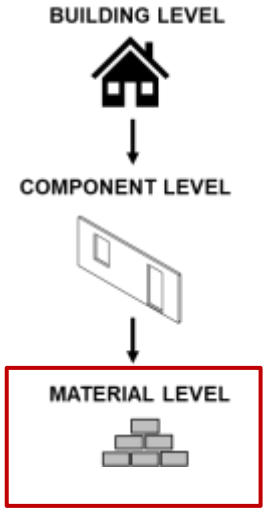
Circularity Indicators

Building level - several indicator options are available

Source: Madaster

Circularity Indicators

Material level



	Material Flow Analysis	Functional unit	Separation of circularity and other quality aspects	Building/Component/Material level
LEVEL(s)	yes	m² useful floor space/yr. or other units for 3rd level	no	Building Level
BAMB	no info.	No info.	No info.	Mixture
Madaster	yes	m³	yes	Building Level
Recycling-Tool	yes	m² (on standard product)	yes	Component level

MATERIAL CIRCULARITY INDICATOR (MCI , Ellen MacArthur Foundation)*

$$MCI^*_P = 1 - LFI \cdot F(X) \qquad MCI_P = \max(0, MCI^*_P)$$

Linear Flow Index — Utility Factor

INPUT
Virgin Feedstock
Unrecoverable Mass } Linear Flow Index
Utility

OUTPUT
Material Circularity Indicator MCI → material recyclability assessment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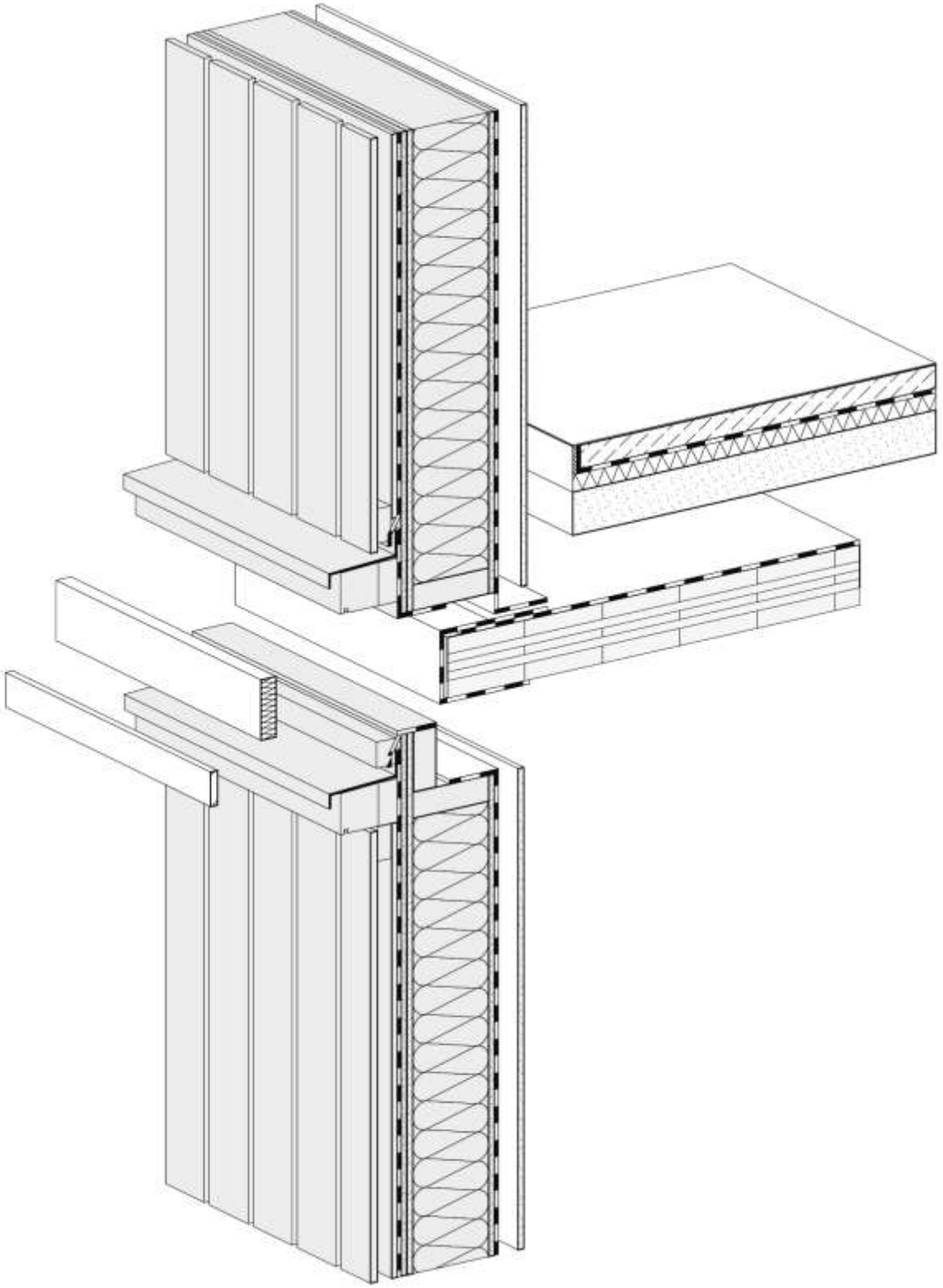


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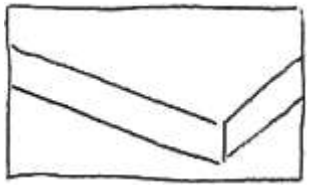
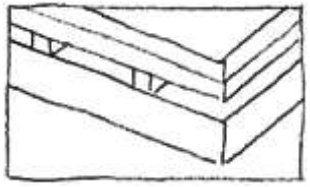
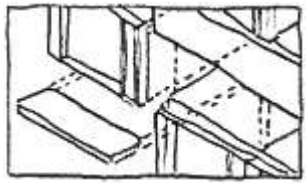
dataholz.eu – element catalogue



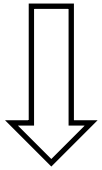
standardised
building materials



standardised
assemblies

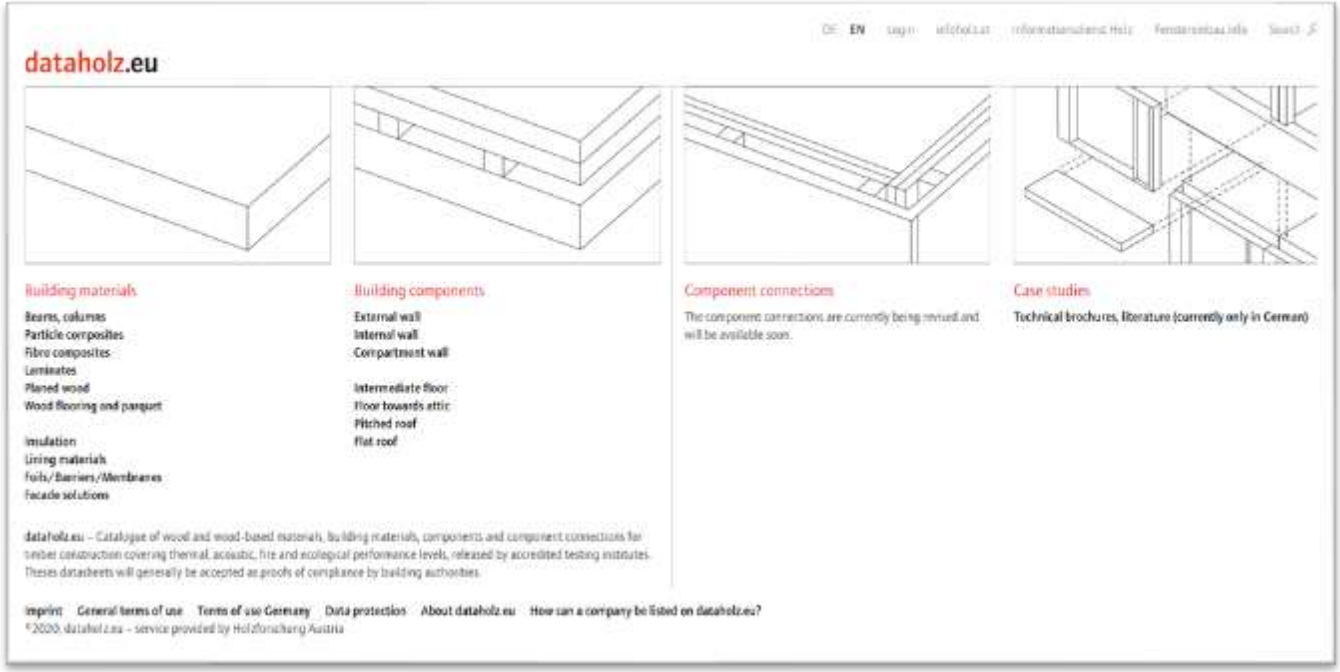


standardised
connections/details



individualised
building

web-based
best-practice examples & **data**



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End

Thank you for your attention …

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Thank you …