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Bridging the gap: timber-hybrid structures as a pathway for circularity in the building sector

LCA Webinar

Polimi LCA Network - Junior Researchers Group

15.01.2026 | **Laura Corti**

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Outline of the presentation

- Motivation: why the building sector?
- Current use of bio-based materials and nowadays challenges
- Research objectives
- Methodological framework
- Structural design as an aid for material reuse
- CDDR approach
- Conclusions and future developments

Motivation: why the building sector?

34%

of global GHG emissions*

32%

of global energy consumption*

Cement production is responsible for 8% of global GHG emissions

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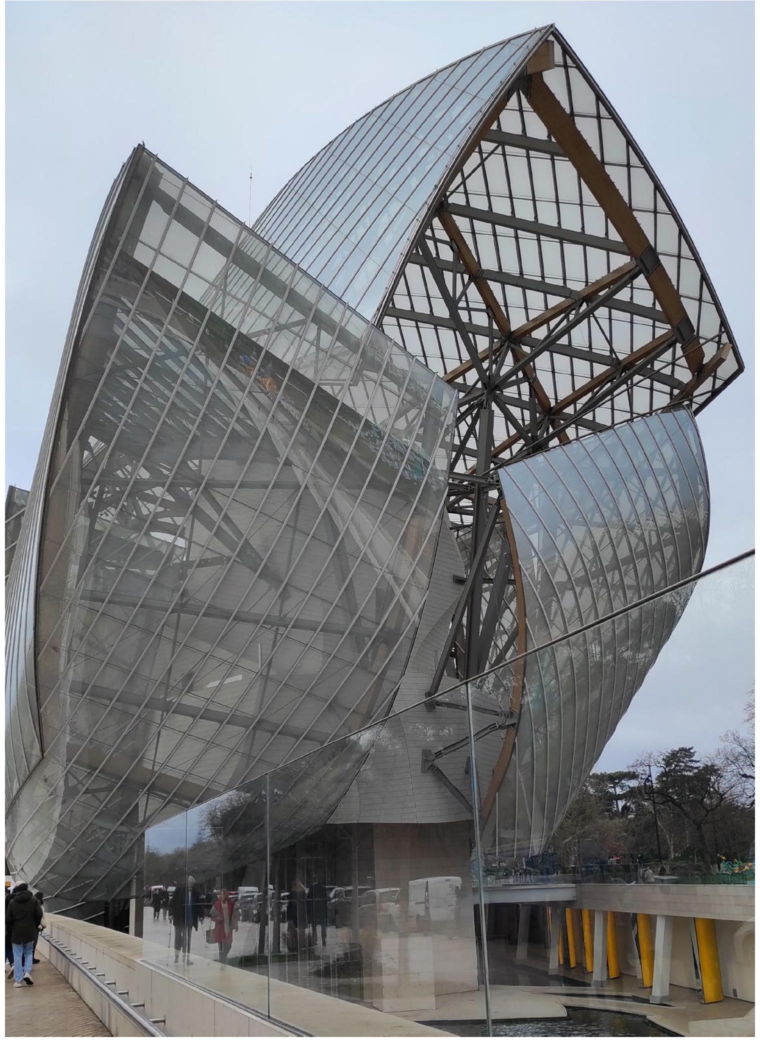
- Optimization of traditional materials
- Innovative 'bio-based' materials solutions

*according to *Global Status Report for Buildings and Construction 2024-2025*

Current use of bio-based materials and nowadays challenges

Traditional timber buildings

Current use of bio-based materials and nowadays challenges

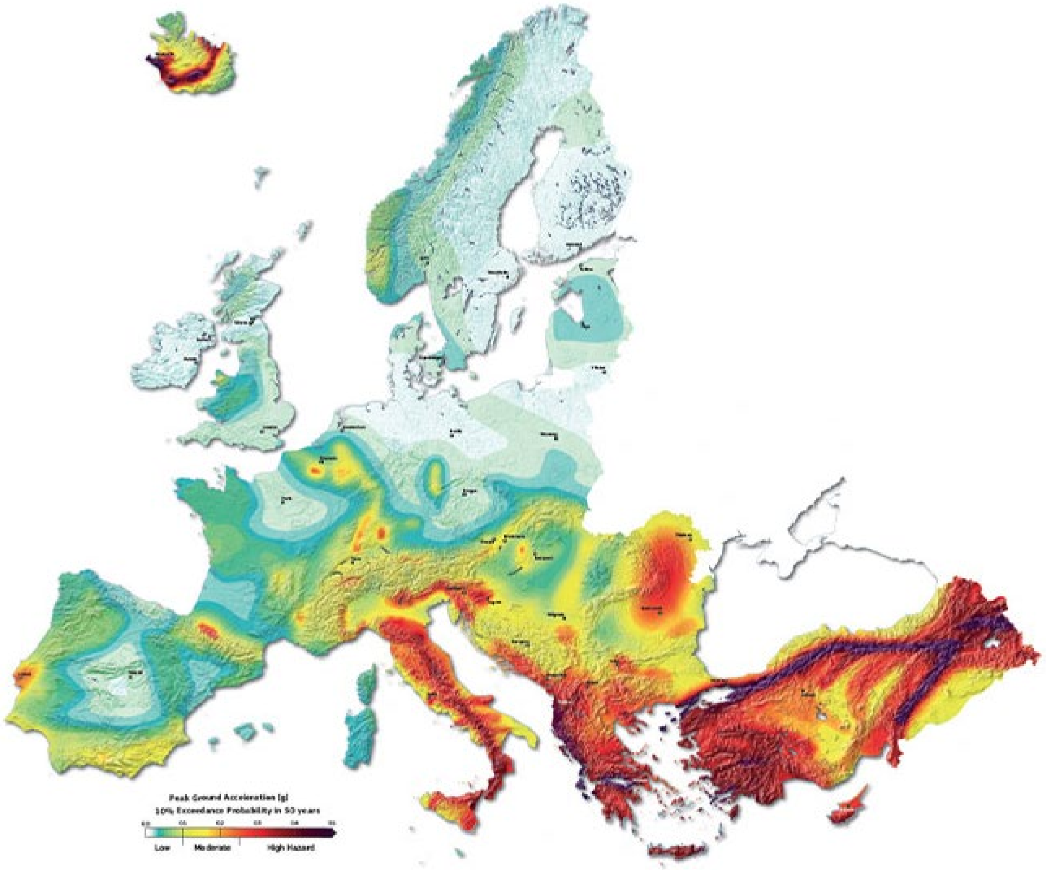


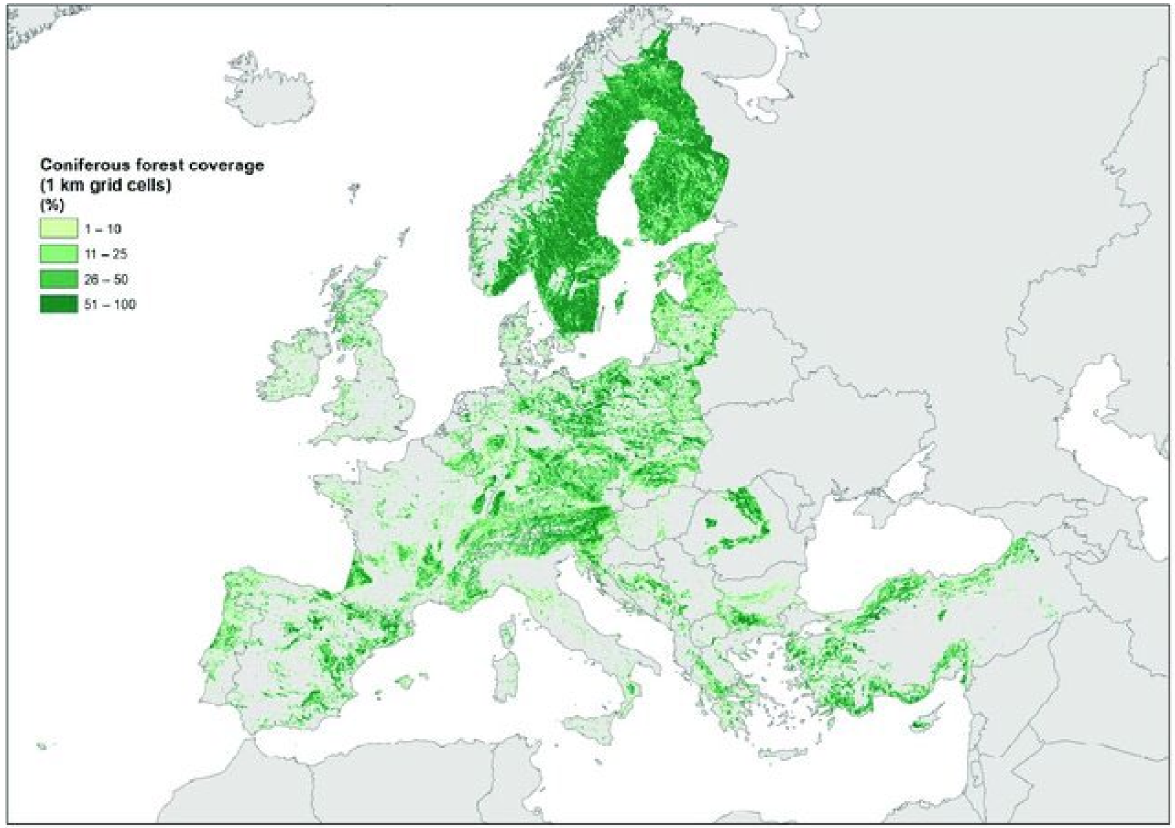
Engineered Timber Products – ETPs

- High prefabrication level
- High strength-to-weight ratio
- Renewable origin
- Proneness to composite and hybrid members and buildings

Current use of bio-based materials and nowadays challenges

Compatibility of timber structural systems with high-rise buildings in high seismicity regions





Current use of bio-based materials and nowadays challenges

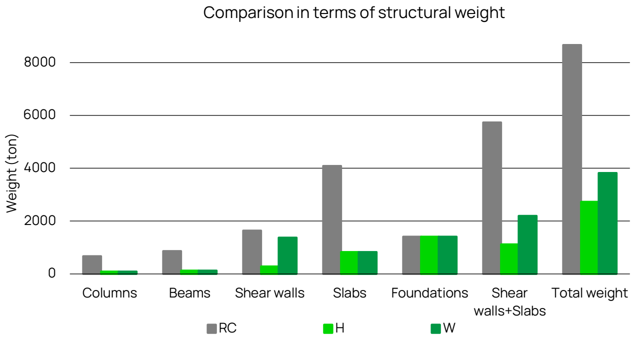
Reuse of timber members as desirable End-of-Life scenario

Research objectives

- Perform comparative LCA analysis of timber-hybrid and traditional structural systems
- Analysis of current End-of-Life scenarios for structural timber in Europe
- Investigate reuse as a currently neglected option
- Link structural performance with environmental sustainability

CDDR approach

Concentrated Damage, Demountability, Reusability



Methodological framework

- LCA performed according to Environmental Footprint method (v. 3.1) with SimaPro software (v 9.6.1), considering Ecoinvent database (v 3.11)
- Consistency with ISO 14044 and EN 15804 standards
- Biogenic carbon stored in timber is considered with "–1 in / +1 out" rule according to the ISO 21930 standard
- Current and target End-of-Life scenarios for timber are designed according to existing literature evidences
- Buildings are designed according to latest versions of Eurocodes
- Experimental tests are carried out according to EN 26891 and EN 12512

Building level ↔ **Members level** ↔ **Connections detail level**

Baseline LCA analysis | EOL scenario | Demountability

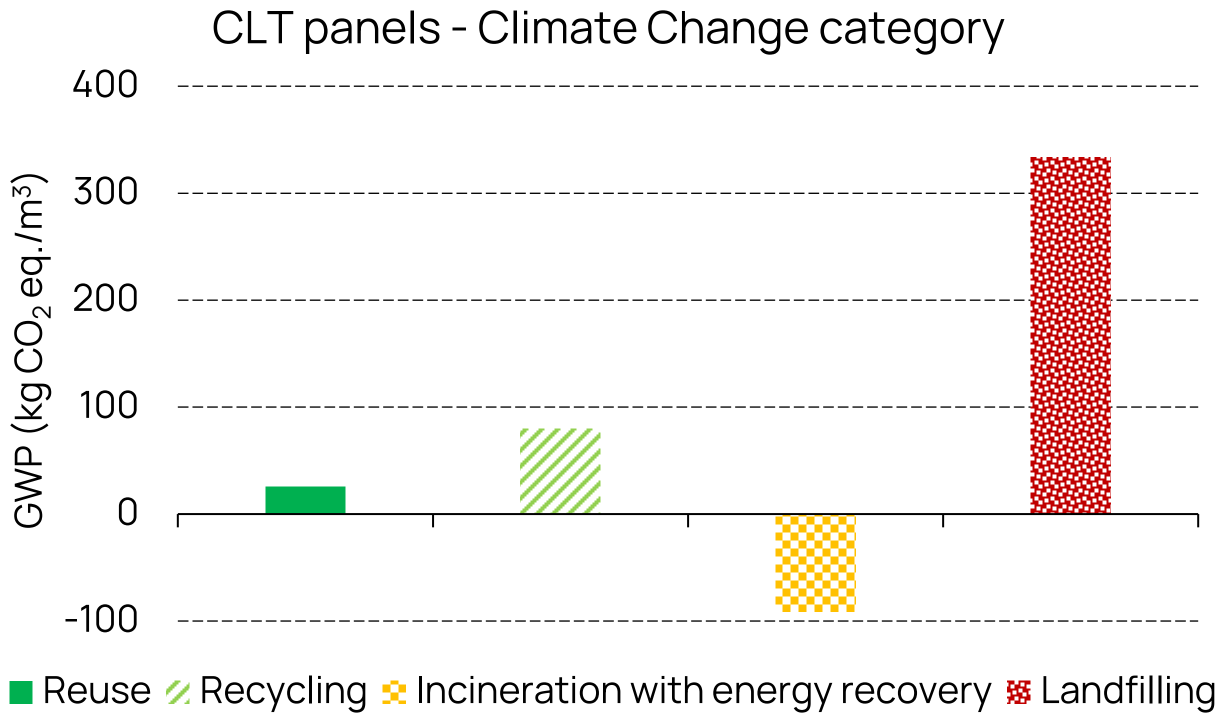
Methodological framework - Current and target End-of-Life scenarios for timber

1. Current and target practices for structural timber at the end of building's service life

Literature review of existing EPDs of Cross Laminated Timber (CLT) products

EPD info	#	C1-C4 stages (End-of-Life)
Stora Enso, Finland	1	4 scenarios are included: 100% recyclying, 100% reuse, 100% incineration with energy recovery, 100% landfilling
KLH, Austria	2	• Scenario 1: 100% incineration with energy recovery. • Scenario 2: 100% reuse.
Financiera Maderera S.A., Spain	3	A recycling ratio of 80,4%, energy recovery ratio of 6,1%, incineration ratio of 12,0% and a landfilled ratio of 1,5% is considered in accordance with the publication of the H2020 project.
Egoin S.A., Spain	7	100% recycling scenario
HASSLACHER, Austria	11	100% of the solid waste is delivered to a power plant (efficiency 61%) to be used as secondary fuel. Plant-specific characteristic values correspond to a European average scenario (EU28).
Södra, Sweden	16	100% of the product is intended for energy recovery and it substitutes fuel in a district heating plant

- LCA analysis (functional unit=1 m^3 of CLT)
- 4 different EOL scenarios



Methodological framework - Current and target End-of-Life scenarios for timber

1. Current and target practices for structural timber at the end of building's service life

Current average European scenario for structural timber EOL:

- Recycling (50%)
- Incineration with energy recovery (30%)
- Landfilling (20%)

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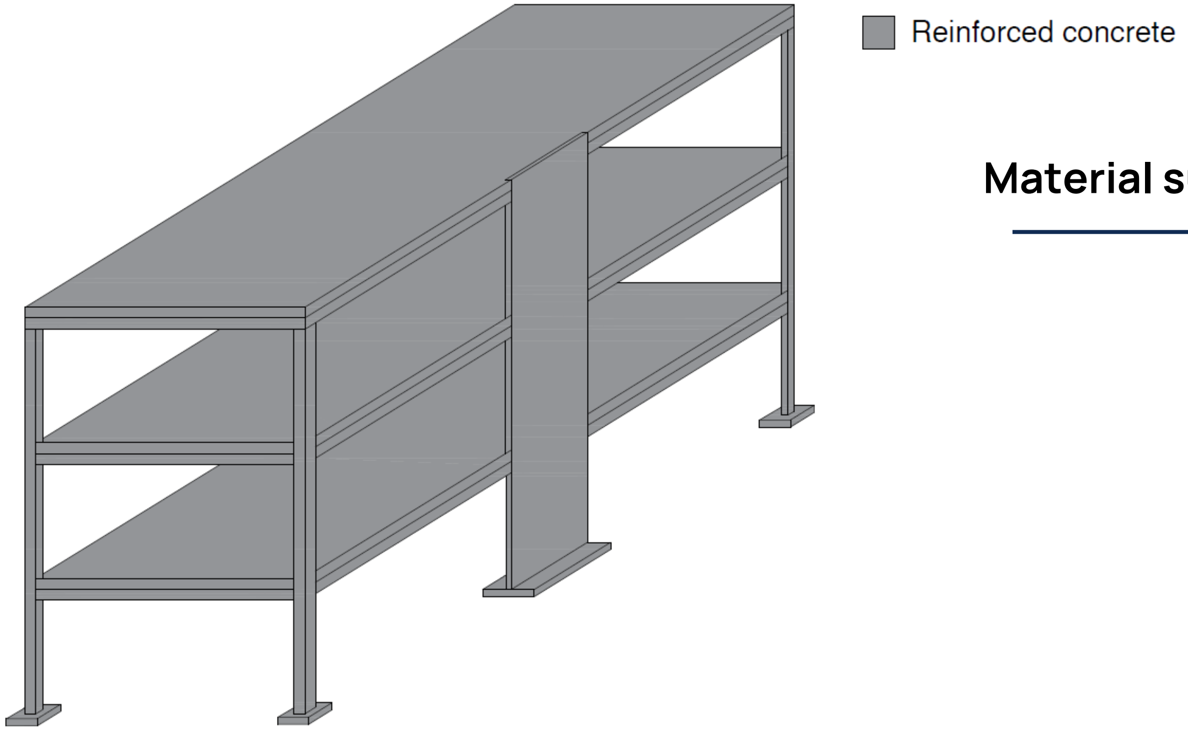
Target average European scenario for structural timber EOL:

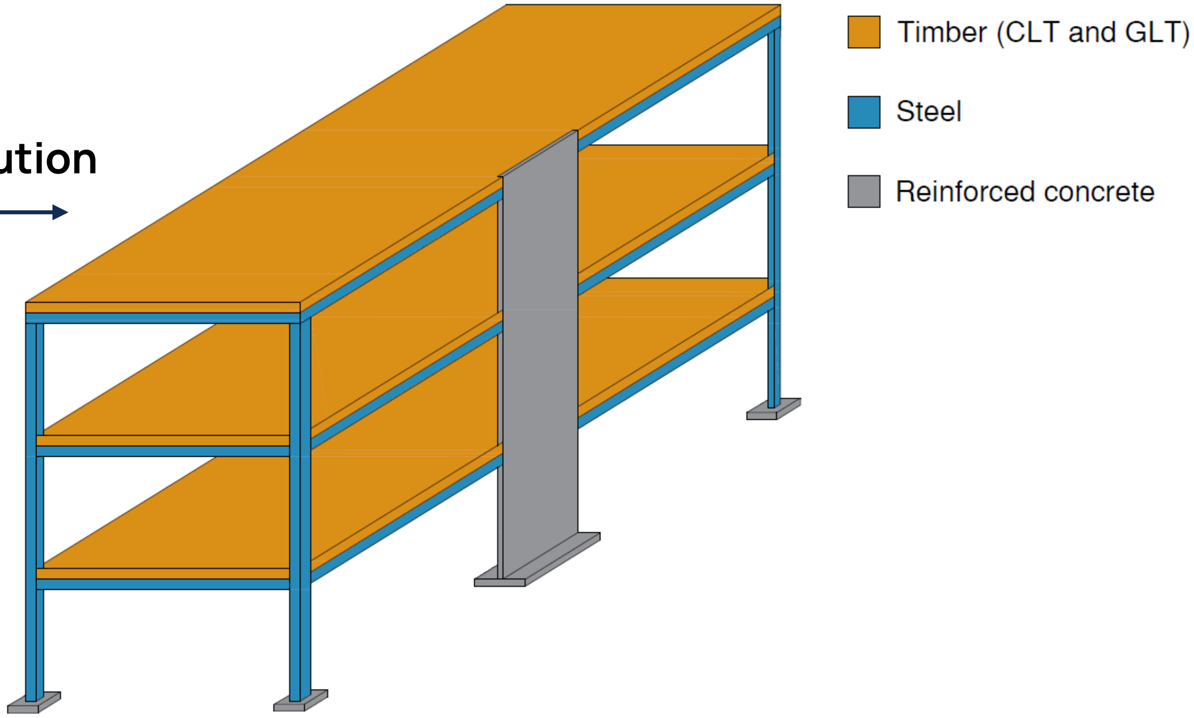
- Reuse (50%)
- Recycling(40%)
- Incineration with energy recovery (10%)

2. Reuse scenario implies minimum damage of structural members and easy demountability

Structural design as an aid for material reuse

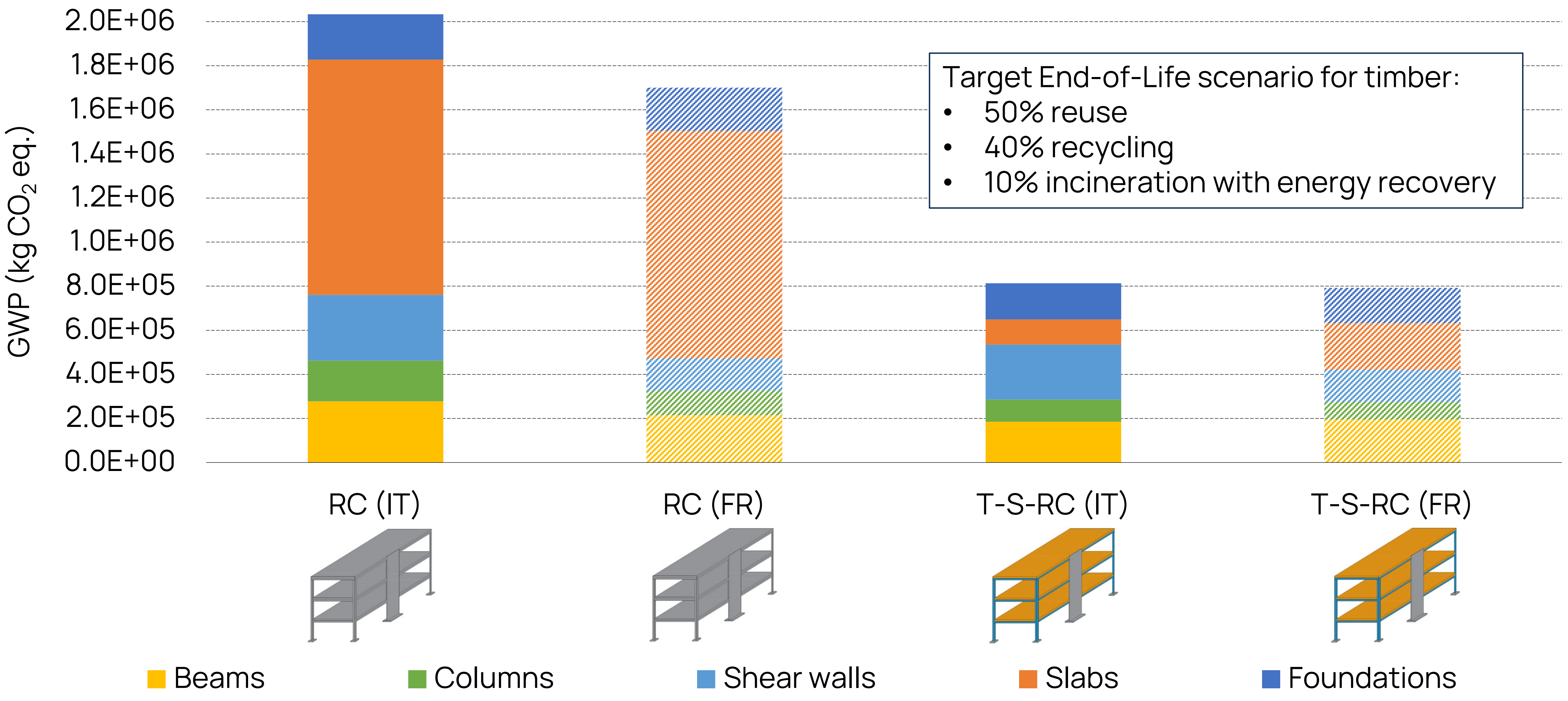


Material substitution →



- Equivalent multistorey residential buildings designed in Milan and in Paris
- National annexes of Eurocode 8 are considered

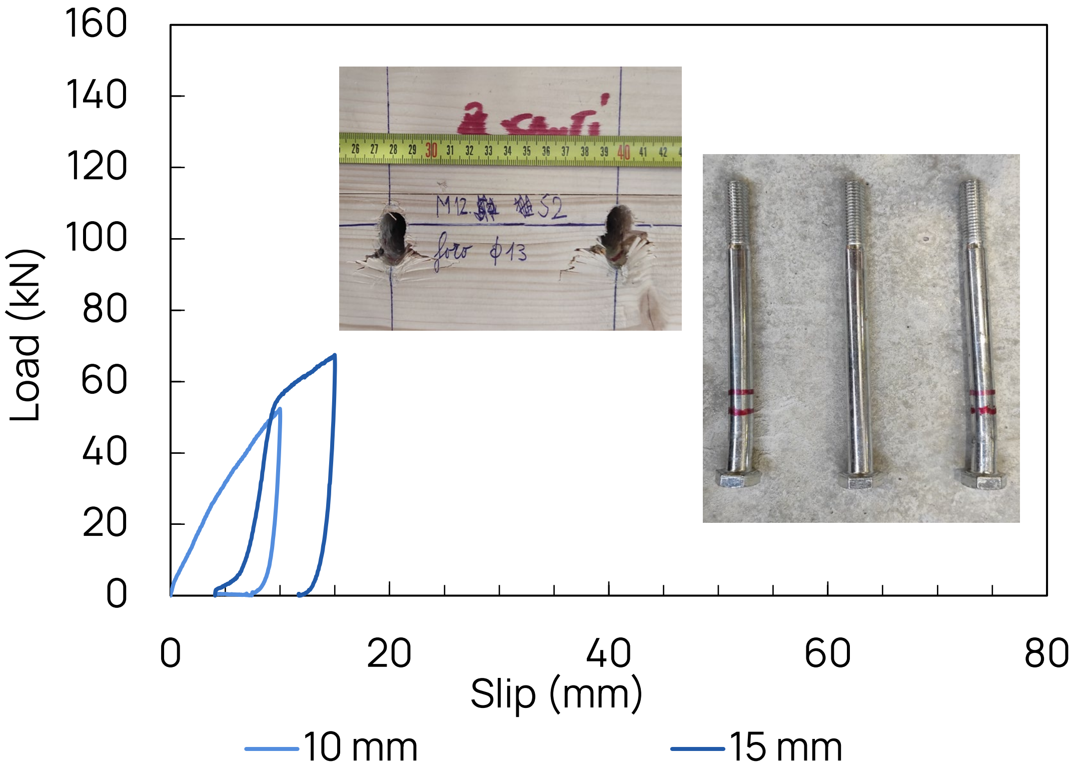
Structural design as an aid for material reuse



Structural design as an aid for material reuse

Two experimental campaigns in LPM (Materials Testing Laboratory of Polimi) to support LCA analysis of the structural system

1. Monotonic and cyclic push-out tests of timber-steel hybrid joints



2. Real scale tests on timber-steel hybrid beam-to-column joints

CDDR approach

Aim: increase reuse percentage for timber EOL

1. To guarantee that structural members are reusable, **damage shall be concentrated** in specific zones of the system, previously defined during design phase
2. Building disassembly cannot create (additional) damage in the system, so that Design for Disassmebly (DfD) is a key concept to guarantee **demountability**
3. Large portions of the structural system are **reusable** if and only if two previous points are fulfilled

CDDR approach

Concentrated **D**amage, **D**emountability, **R**eusability

CDDR approach

CDDR approach

Concentrated Damage, Demountability, Reusability

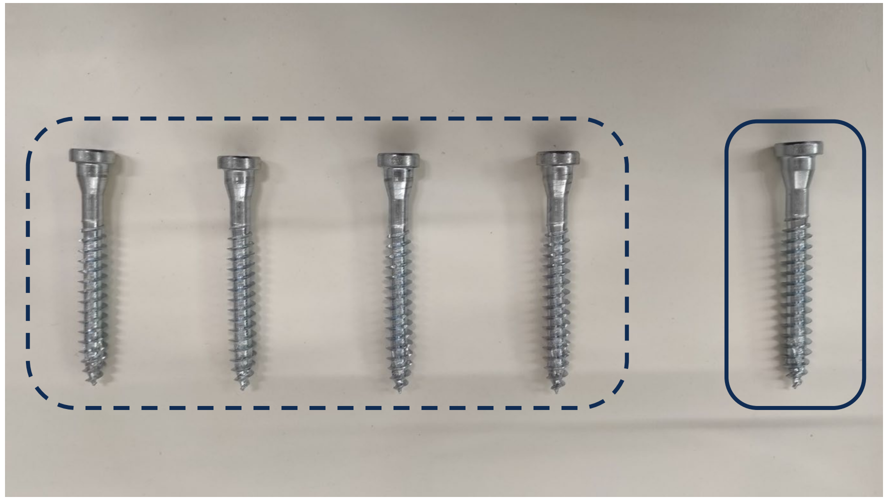
Damage is concentrated in a specific area of the specimen

CDDR approach

CDDR approach

Concentrated Damage, Demountability, Reusability

Screws removed from the specimen after the test

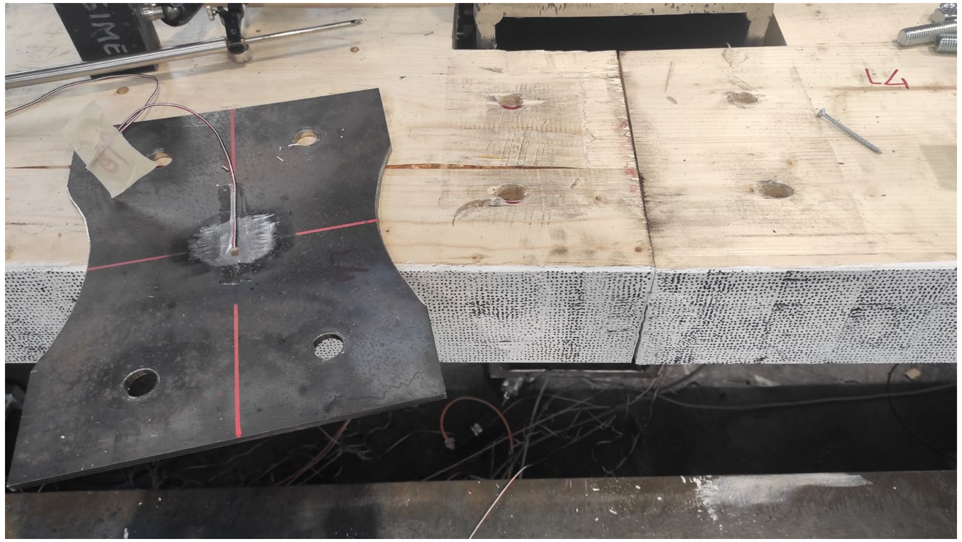


New screw

CDDR approach

CDDR approach

Concentrated Damage, Demountability, Reusability



- CLT panels are undamaged and can be reused
- Steel column is undamaged and can be reused
- Steel beams exhibit concentrated deformation in the welded steel plates, all the rest can be reused

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Target EOL scenario for timber (50% reuse) is realistic

Conclusions and future developments

- Environmental sustainability of the building sector necessarily passes from structural design choices
- Structural and environmental perspectives are expected to be considered simultaneously
- LCA analysis of timber-hybrid structural systems highlights the significantly lower impact on climate change category (≈ -50%), considering that timber landfilling is avoided
- The role of connections is minimal according to their impact on climate change, however their 'conceptual' role is prominent
- Target EOL scenario (50% of reuse) for timber can be achieved through Design for Disassembly and limitation of damages
- Biogenic carbon content in timber is currently considered in simplified terms. Dynamic LCA to assess temporal effects is scheduled

Thank you for your attention!

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Methodological framework – LCA information/1

1. **Goal of the study**
   - Different structural systems comparison (timber-based vs. reinforced concrete structural systems)
   - Assessment of realistic End-of-Life scenarios for Engineered Timber Products
   - Assess environmental benefits of reusing timber for structural purposes
2. **Scope of the study**
   - Functional unit: 1 m^3 of CLT
   - System boundaries: Cradle to gate with options, modules C1–C4, module D and with optional modules (A1–A3 + C + D modules)
   - Cut-off rule: 1%

Methodological framework – LCA information/2

3. **Life Cycle Inventory Analysis (LCI)**
    - Primary and secondary data
    - Included inventory flows: forestry operations, transport of logs, fuels, CLT refinement, electricity and thermal energy consumption, adhesives, packaging materials, waste and by-products (chips, sawdust, bark)
    - Allocation approach: forestry impacts allocated only to roundwood
4. **Life Cycle Impact Assessment (LCIA)**
    - Indicators for mandatory impact category indicators according to EN 15804+A2: Global Warming Potential (fossil, biogenic, LULUC, total), Ozone Depletion Potential (ODP), Acidification Potential (AP), Eutrophication (freshwater, marine, terrestrial), Photochemical ozone formation (POCP), Abiotic depletion (fossil & minerals), Water deprivation potential (WDP)
    - Biogenic carbon: -750 kg CO_2 eq./m^3, according to literature data

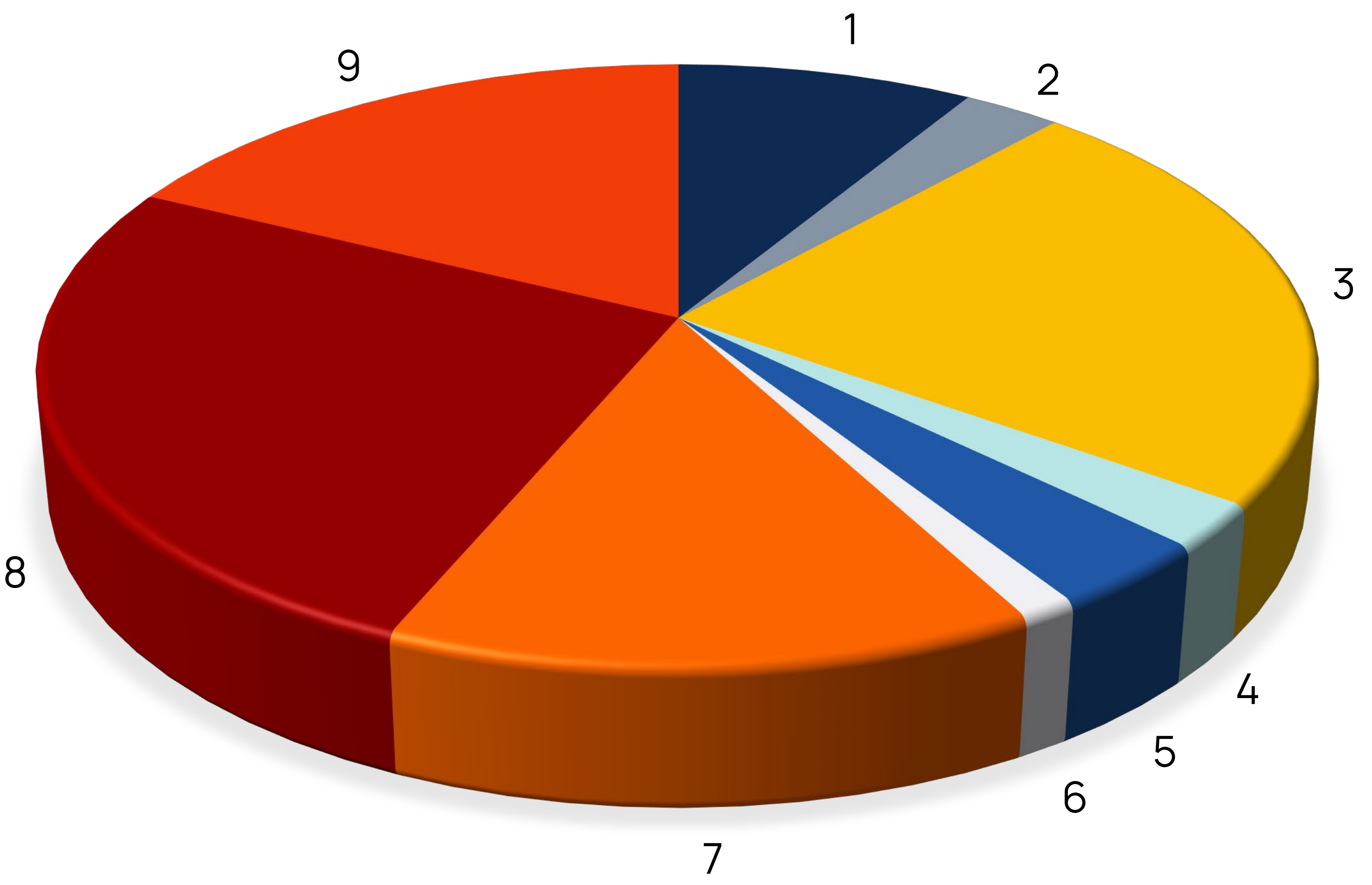
Methodological framework – LCA information/3

5. Life Cycle Interpretation

- A1–A3 dominate most impacts, especially energy use and emissions
- Negative GWP values occur due to biogenic carbon storage
- End-of-life scenarios significantly affect results: Incineration with energy recovery provides the largest Module D benefits. Reuse and recycling scenarios show different trade-offs.
- According to EN 15804 reuse option does not reward extended carbon storage time
- Results are scenario-dependent and choice of the scenario strongly depends on design choices

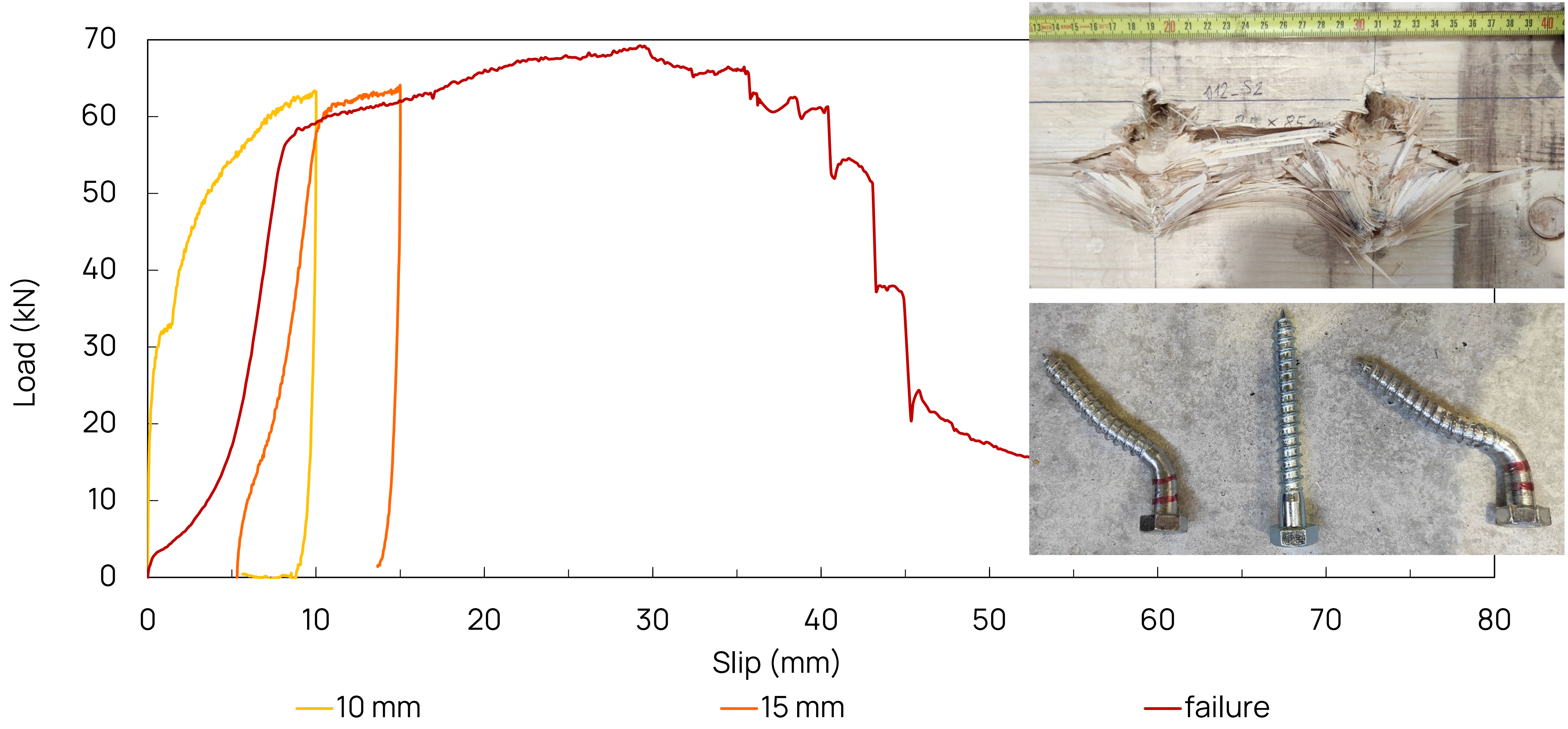
Methodological framework – LCA information/4

Characterization results of CLT manufacturing, construction phase and dismantling based on inputs and outputs (Climate Change category)



Compartment	GWP share
Source wood	8.7%
Low-sulfur diesel (Europe without Switzerland)	2.9%
Transport by lorry EURO6	**23.2%**
Polyurethane adhesive	2.4%
Flat pallet (Europe)	3.7%
Packaging film (Low density polyethylene)	1.2%
Electricity, medium voltage	**14.3%**
Heat production from hardwood chips	**25.9%**
Waste wood, untreated	**17.7%**

Structural design as an aid for material reuse



CDDR approach – connections 'conceptual' role

The role of connections is minimal according to their impact on climate change, however their 'conceptual' role is prominent

GWP of connections for ground storey CLT shear walls is 5.3% of total GWP of CLT shear walls (data calculated from a multistorey residential building used a case study).
However, reuse of CLT panels from shear walls strongly depends on connections demountability; therefore, connections have a prominent role in defying reuse percentage of CLT panels.