CROSS LAMINATED TIMBER VS CONCRETE – A COMPARATIVE LIFE CYCLE ASSESSMENT OF A RESIDENTIAL CASE STUDY BUILDING IN IRELAND

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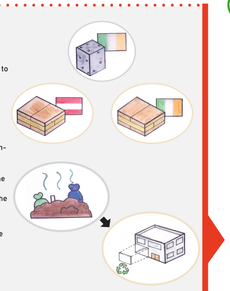
1 INTRODUCTION

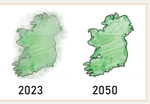
OBJECTIVES

1. Construct a **BIM model** of a case study apartment block to represent three construction types;
   - Existing – Cast in-place concrete.
   - Proposed – CLT sourced from Austria.
   - Proposed – CLT hypothetically sourced from Ireland.
2. Conduct **Life Cycle Assessments** (LCA) of the three construction types.
3. Demonstrate techniques to increase the **circularity** of the mass timber buildings at the **end-of-life stage** and calculate the difference this will have on the LCA result of the Irish CLT design option.
4. Determine a **hierarchy** of the design options showing the highest to lowest environmental impact.



MOTIVATION

- Climate Action Plan 2021 commits Ireland to a target of net-zero greenhouse emissions by 2050.
- Ireland's construction sector is the joint highest emitting industry at 37% of the country's CO_2 emissions.
- Housing for All Plan 2021 states that 300,000 new homes by 2030.
- Concrete is the most wideley used building material, producing 410 kg of CO_2/m^3.
- Mass timber products such as CLT underutilised in Ireland despite producing -632 kg of CO_2/m^3.
- Data on how much CO_2 is to be saved through the use of CLT over concrete is limited in an Irish context.

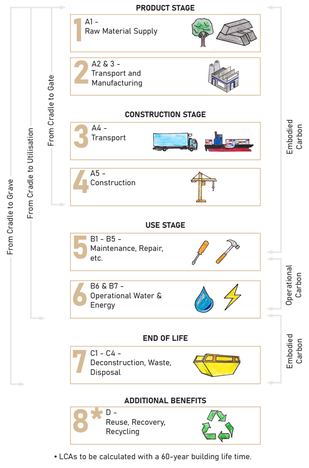


EXCLUDED FROM SCOPE

- Fire requirements.
- Impact of Austrian & Irish timber on structural sizes.
- Cost differences related to substitution of concrete with CLT

2 METHODOLOGY

LIFE CYCLE ASSESSMENTS



• LCAs to be calculated with a 60-year building life time.

LCA SOFTWARES

	Ecochain Mobius	GaBi	OneClickLCA	OpenLCA	SimaPro	Tally
Ease of Use	Easy	Moderate to Difficult	Moderate to Difficult	Moderate to Difficult	Moderate to Difficult	Moderate
Tutorials	Yes	Yes	Yes	Yes	Yes	Yes
Free Trial	Yes, 14-day	Yes, 30-day	Yes, 14-day	Free Software	No, but demo version available	Yes, 10-day
Cloud-Based	Yes	No	Yes	No	No	No
Revit Integration	No	No	Yes	No	No	Yes

ONE CLICK LCA CARBON HEROES BENCHMARKING

Benchmarks for different building types:

- Apartment Building
- Office
- Educational
- Warehouse
- Hotel
- Retail
- Hospital
- Industrial
- Other buildings

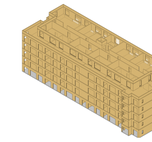
Benchmarks for regions or countries

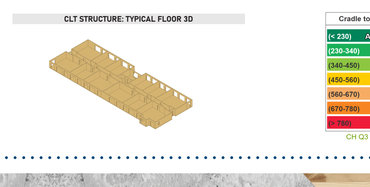
CASE STUDY BUILDING

The case study building is a five storey apartment block based in Rathfarnham, South Dublin.

2016 Census showed that apartments are the fastest growing accommodation type, increase of 11.4% between 2011 and 2016.

Over 200,000 occupied apartments in Ireland.





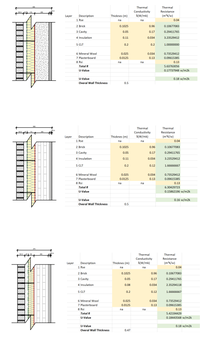
GROUND FLOOR PLAN - SCALE: 1:200

TYPICAL FLOOR PLAN - SCALE: 1:200

TOP FLOOR PLAN - SCALE: 1:200

BUILDING SECTION - SCALE: 1:20

U-VALUE COMPARISON



CLT's superior thermal performance in comparison to concrete allows for a 30mm reduction of insulation throughout the building.

MATERIAL TRANSPORTATION COMPARISON

(A) CONCRETE TRANSPORTATION

- 6 min
- 3.7 km
- Truck

(B) CLT TRANSPORTATION (NORWAY)

Norway to England
- 25 h
- 2182 km
- Truck

England to Ireland
- 8h
- 230 km
- Container Ship

Dublin Port to Site
- 30 min
- 32.8 km
- Truck

(C) CLT TRANSPORTATION (AUSTRIA)

Austria to England
- 19 h 30 min
- 1770 km
- Truck

England to Ireland
- 8h
- 230 km
- Container Ship

Dublin Port to Site
- 30 min
- 32.8 km
- Truck

(D) CLT TRANSPORTATION (IRELAND)

- 3 h 52 min.
- 328 km
- Truck

3 RESULTS

TESTING: CONCRETE LCA

CONCRETE STRUCTURE: INFORMATION

- 200mm cast in-place reinforced concrete floor slabs.
- 200mm cast in-place reinforced concrete walls.
- 150mm cast in-place reinforced concrete top floor walls.

CONCRETE STRUCTURE: FULL 3D

CONCRETE STRUCTURE: TYPICAL FLOOR 3D

LCA RESULTS

2,574,295 kg CO_2eq is produced during the lifetime of this building.

Production stage equates to **86%** of the building's global warming potential while the end-of-life stage equals **9%**

Concrete causes **58%** of the building's material CO_2eq emissions.

Metals cause **27%** of the buildings material CO_2eq emissions (this includes concrete reinforcement).

Embodied carbon benchmark

Cradle to grave (A1-A4, B4-B5, C1-C4)	kg CO_2e/m²
(< 230) A	
(230-340) B	
(340-450) C	
(450-560) D	628
(560-670) E	
(670-780) F	
(> 780) G	

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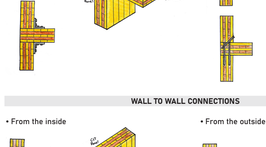
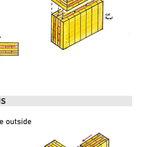
4 CONCLUSIONS

COMPARISON OF RESULTS

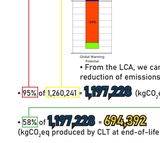
LCA STAGES



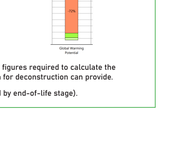
- With concrete, the product stage is the highest emitting stage. This stage's emissions become negligible with the use of CLT due to timber's sequestered carbon properties.
- The end-of-life stage is the highest emitting stage for the CLT buildings.
- Construction with CLT sourced from Austria has the highest transportation emissions.



- Concrete has the lowest transportation emissions due to the vast amount of concrete manufacturers in Ireland, allowing for local producers to be selected.
- CLT from Ireland has higher transportation emissions than concrete due to the location of the hypothetical manufacturer. With a local manufacturer emissions can be equal or even less than concrete.



GLOBAL WARMING POTENTIAL



- Switching to CLT construction reduces the building's global warming potential by **at least 50%** and a further **~100,000 kg CO_2eq** through the use of Irish timber.
- If the 63.5% of CLT that is to be sent to landfill in the CLT (Ireland) design option were to be reclaimed at the end of the building's lifetime, then a further **~440,000 kg CO_2eq** would be saved.

CARBON HEROES BENCHMARKS

Concrete

Embodied carbon benchmark

Cradle to grave (A1-A4, B4-B5, C1-C4)	kg CO_2e/m²
(< 230) A	
(230-340) B	
(340-450) C	
(450-560) D	628
(560-670) E	
(670-780) F	
(> 780) G	

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- The concrete building gets a score of 628 or an **E** rating.

Poor

CLT (Austria)

Embodied carbon benchmark

Cradle to grave (A1-A4, B4-B5, C1-C4)	kg CO_2e/m²
(< 230) A	
(230-340) B	
(340-450) C	328
(450-560) D	
(560-670) E	
(670-780) F	
(> 780) G	

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- Replacing concrete with CLT results in the building receiving score of 328, which is a **B** rating.

Very Good

CLT (Ireland)

Embodied carbon benchmark

Cradle to grave (A1-A4, B4-B5, C1-C4)	kg CO_2e/m²
(< 230) A	
(230-340) B	307
(340-450) C	
(450-560) D	
(560-670) E	
(670-780) F	
(> 780) G	

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- Replacing the CLT with Irish sourced CLT results in a score of 307, which is a **B** rating.

Very Good

CLT (Ireland) With DfD

Embodied carbon benchmark

Cradle to grave (A1-A4, B4-B5, C1-C4)	kg CO_2e/m²
(< 230) A	
(230-340) B	200
(340-450) C	
(450-560) D	
(560-670) E	
(670-780) F	
(> 780) G	

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- Implementing DfD to Irish sourced CLT building results in a score of 200, which is an **A** rating.

Excellent

TESTING: DESIGN FOR DECONSTRUCTION

With high end-of-life emissions seen in the results of the CLT buildings, the scope for CLT's end-of-life is to be explored.

End-of-Life Scope:
- 14.5% Recovered
- 22% Incinerated with energy recovery
- 63.5% Landfilled (wood product waste)

As seen, Tally's scope for CLT has only 14.5% of the timber recovered, the rest is landfilled or incinerated.

A solution to this are the methods of designing for deconstruction, which will allow for most, if not all, of the CLT to recovered/reused.

WALL TO FLOOR CONNECTIONS

- With steel L-bracket

- With only self-tapping screws

WALL TO WALL CONNECTIONS

- From the inside

- From the outside

Floor To Floor Connections

- With engineered timber jointing piece and self-tapping screws

- With only self-tapping screws

Results

- From the LCA, we can gather the figures required to calculate the reduction of emissions that design for deconstruction can provide.
- 95% of 1,260,241 - **1,197,228** ($kgCO_2eq$ produced by end-of-life stage).
- 58% of **1,197,228** - **694,392** ($kgCO_2eq$ produced by CLT at end-of-life stage).
- 63.5% of **694,392** - **440,936** (if all of the CLT sent to landfill [according to Tally] is to be reused instead, then this figure is the $kgCO_2eq$ saved).
- 1,260,241 - **440,936** = 819,303

GWP of the CLT (Ireland) building with design for deconstruction elements:

819,303 $kgCO_2eq$

TESTING: CLT LCA (IRELAND)

CLT STRUCTURE: INFORMATION

- 200mm CLT panel floors.
- 200mm CLT panel walls.
- 140mm CLT panel top floor walls.
- Ground floor remains concrete to reduce ground contact with timber. This prevents fungus, moisture, rot and insects.

CLT STRUCTURE: FULL 3D

CLT STRUCTURE: TYPICAL FLOOR 3D

LCA RESULTS

1,260,241 kg CO_2eq is produced during the lifetime of this building.

End-of-life stage equals **95%** of the buildings global warming potential. Transportation is **2%**

Concrete causes **31%** of the building's material CO_2eq emissions.

Metals cause **16%** of the buildings material CO_2eq emissions (this includes concrete reinforcement).

Embodied carbon benchmark

Cradle to grave (A1-A4, B4-B5, C1-C4)	kg CO_2e/m²
(< 230) A	
(230-340) B	
(340-450) C	
(450-560) D	307
(560-670) E	
(670-780) F	
(> 780) G	

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TESTING: CLT LCA (AUSTRIA)

CLT STRUCTURE: INFORMATION

- 200mm CLT panel floors.
- 200mm CLT panel walls.
- 140mm CLT panel top floor walls.
- Ground floor remains concrete to reduce ground contact with timber. This prevents fungus, moisture, rot and insects.

CLT STRUCTURE: FULL 3D

CLT STRUCTURE: TYPICAL FLOOR 3D

LCA RESULTS

1,244,287 kg CO_2eq is produced during the lifetime of this building.

End-of-life stage equals **89%** of the buildings global warming potential. Transportation is **6%**

Concrete causes **31%** of the building's material CO_2eq emissions.

Metals cause **16%** of the buildings material CO_2eq emissions (this includes concrete reinforcement).

Embodied carbon benchmark

Cradle to grave (A1-A4, B4-B5, C1-C4)	kg CO_2e/m²
(< 230) A	
(230-340) B	
(340-450) C	
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