A new taxonomy of skills for a more sustainable construction sector
Life cycle assessment – process, case study, future direction

10th April, The Alex Hotel

Joseph Little
Head of Construction & Building Performance
Technological University Dublin

A new taxonomy of skills for a more sustainable construction sector
Life cycle assessment – process, case study, future direction

Agenda

1. Managing carbon

1. Data / calculation tool

2. Results and findings

3. Comparisons

4. Summing up

5. Evolution of LCA

Drawing from insights of Sara Carrigan, Paul Lally (Class of 2024 MSc BPEED) and lecturer Alberta Congeduti, TU Dublin

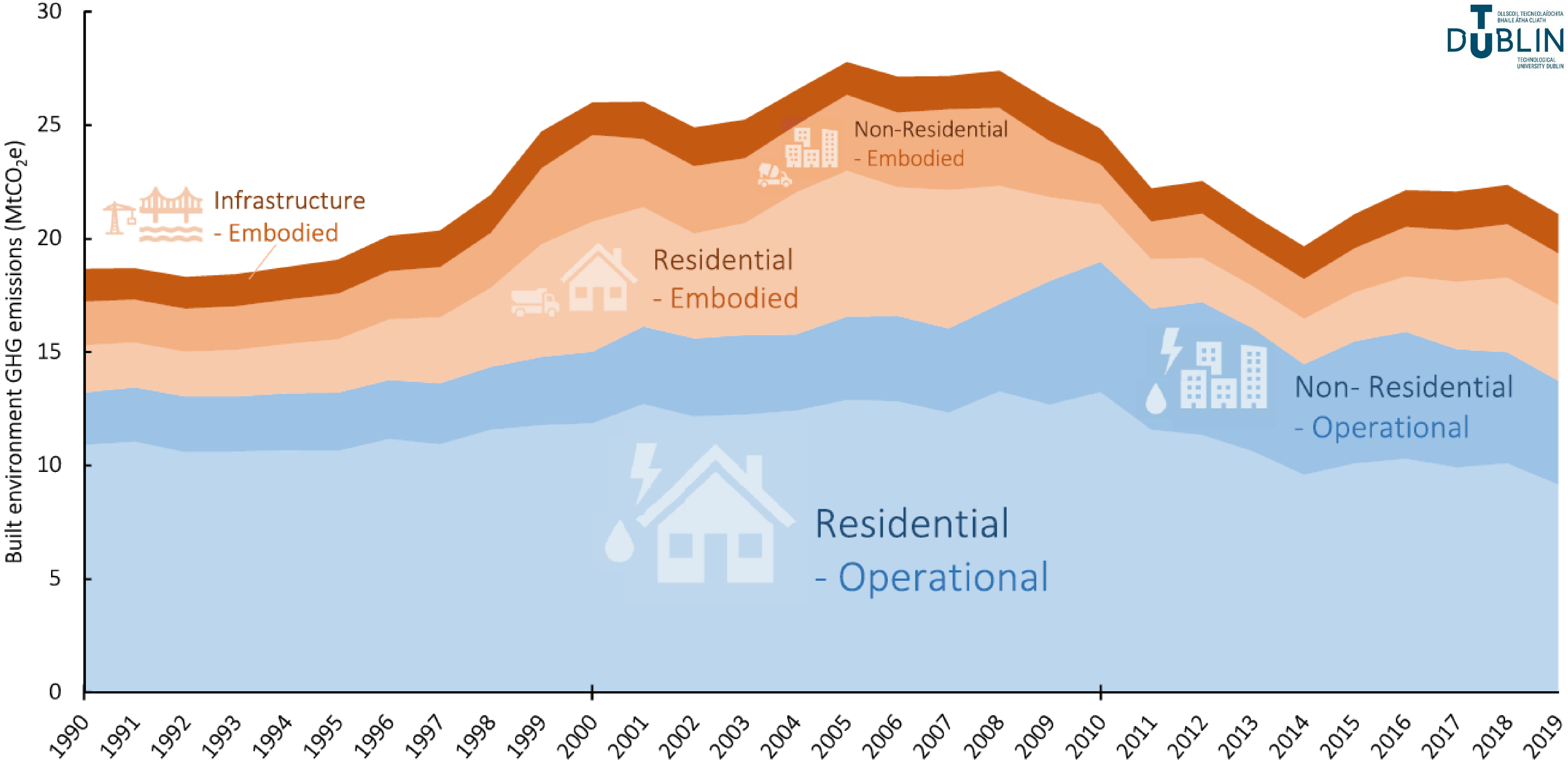
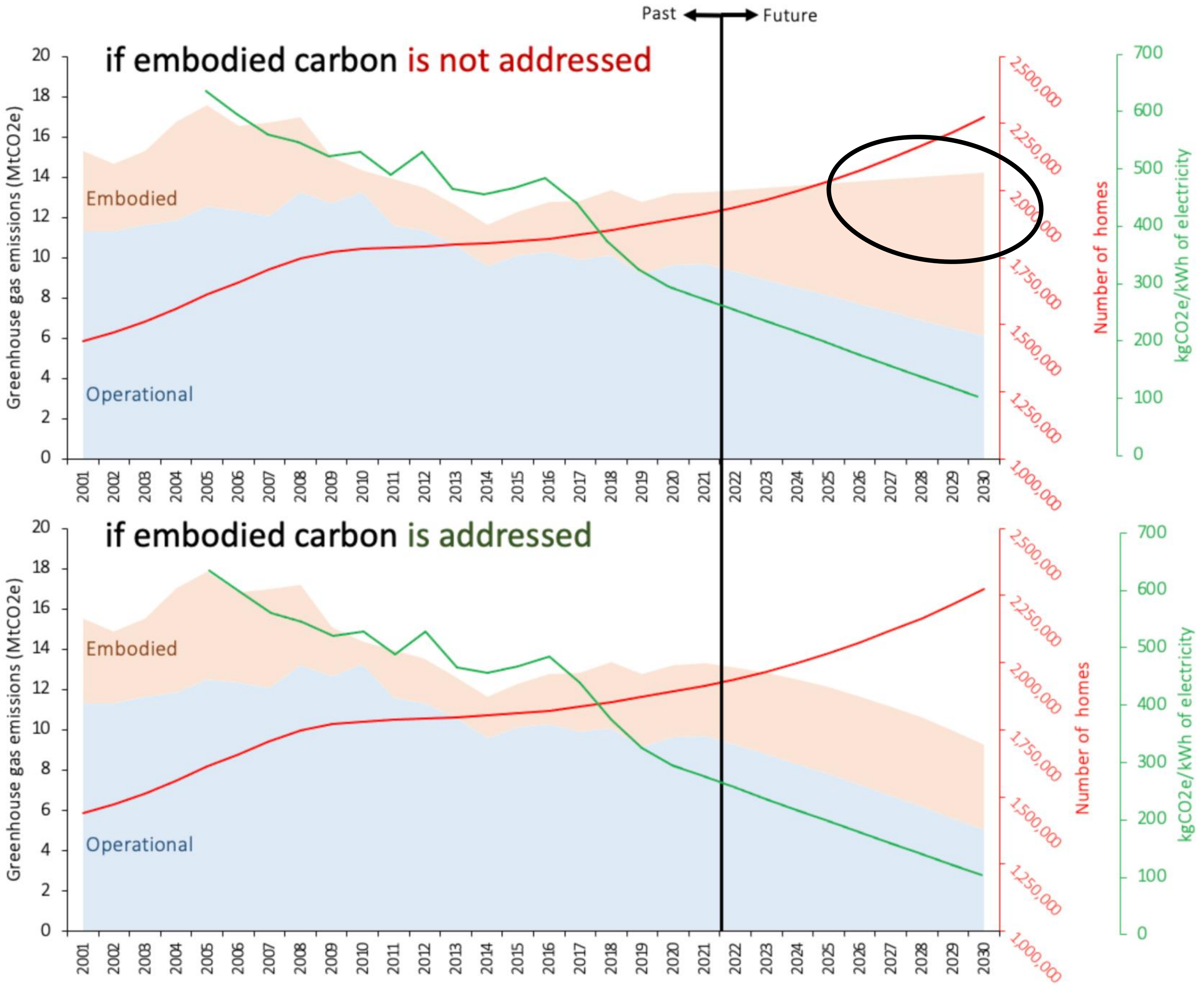


Fig. 16. Ireland's whole life carbon emissions categorised by asset-group.

R. O'Hegarty, S. Wall, and O. Kinnane, (2022).



- Top scenario: does not address embodied carbon.
- Savings in carbon emissions by improving our buildings will be offset by the addition of emissions embodied in the materials used to build new ones and upgrade the current ones.
- Bottom scenario: carbon footprint of building and construction reduced by 50% and 1/4 of new buildings are added to the current stock by repurposing vacant buildings.

R. O'Hegarty, S. Wall, and O. Kinnane, (2023). 'Whole Life Carbon In Construction and in the Built Environment in Ireland

1. Introduction

What is a life cycle analysis?

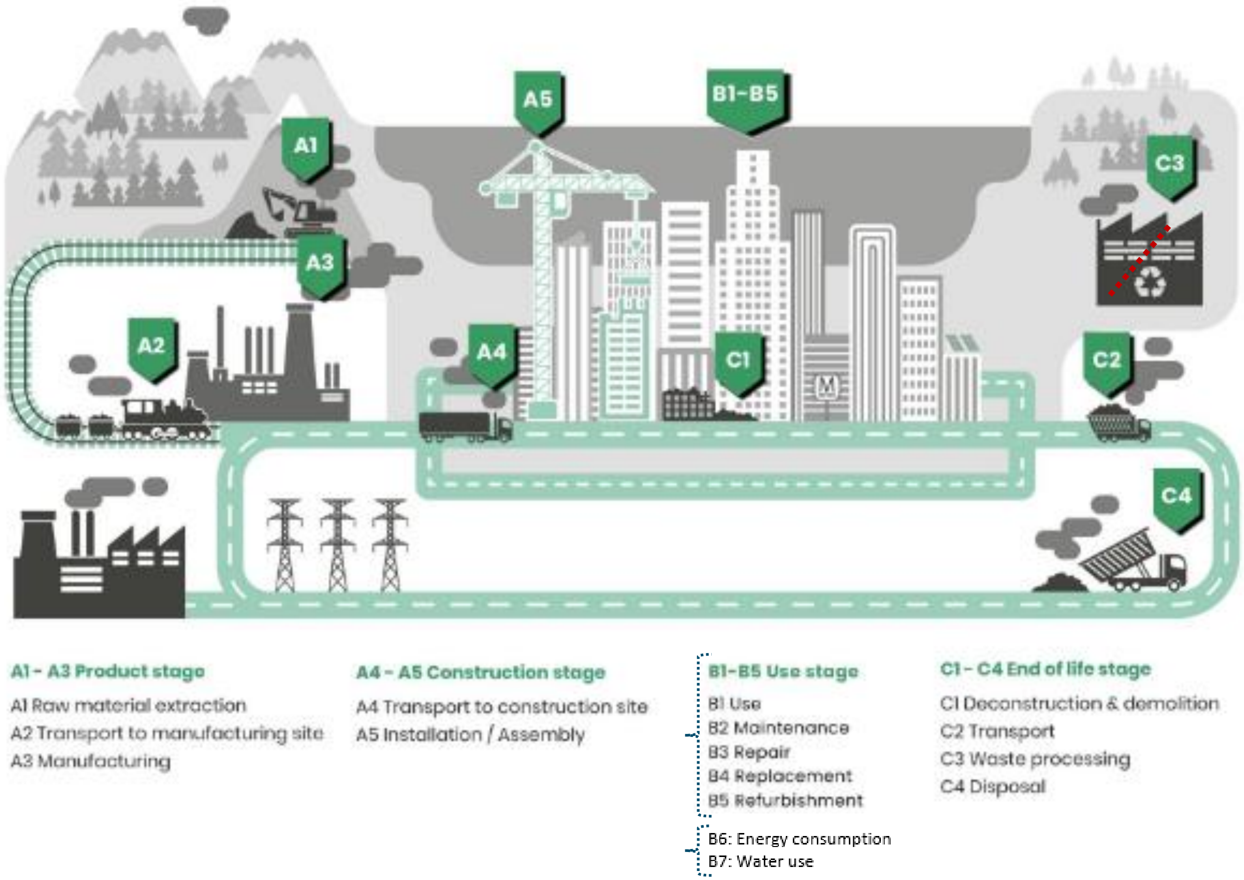
- **A methodology used to evaluate the environmental impact of a product or product system**
- **A full LCA in construction will evaluate a buildings:**
  - **Construction methods**
  - **Materials used**
  - **Waste and pollutants produced**
  - **Energy use across its whole life cycle**
- **Scenario based and can include assumptions when data is not known**
- **Key standard: EN 15978**
  - **Assesses the building products and materials in a system**

Life Cycle Assessment (LCA)
Source: One Click LCA

1. Introduction. *Continued*

Life cycle stages considered

- **Modular approach to impact assessment**
- **4 key stages commonly referred to as 'Cradle to Grave'**
- **Operational energy relates to stage B6 and covers impacts from energy use during a buildings lifetime**
- **Embodied energy/embodied carbon relates collectively to impacts from all other stages**



LCA in the construction life cycle, Source: One Click LCA

1. Introduction. *Continued*

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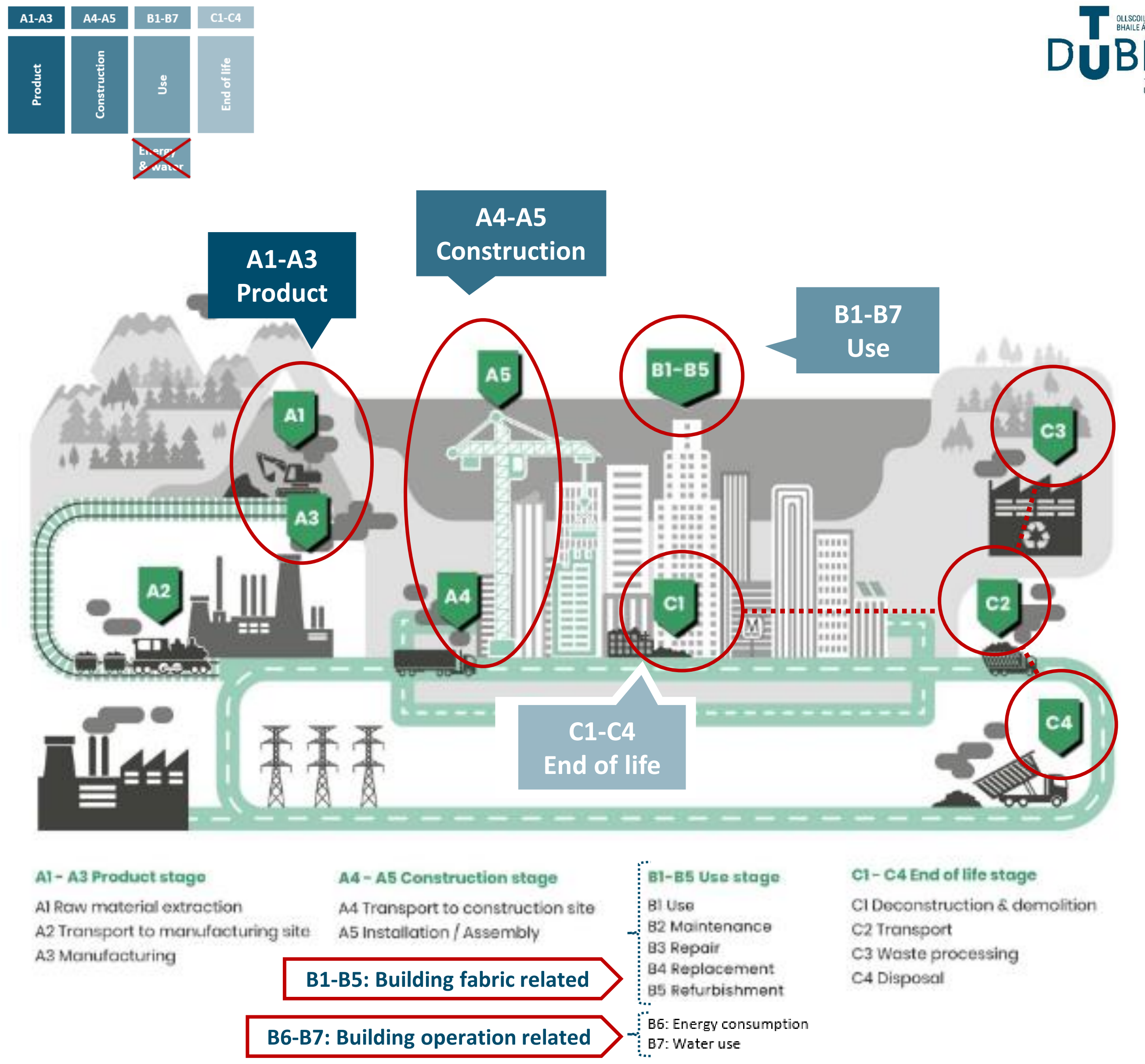

LCA in the construction life cycle, Source: One Click LCA

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1. Introduction. *Continued*

Environmental impact indicators considered

- **Global Warming Potential (GWP) $kgCO_2e$**
- Acidification potential (ADP) $kgSO_2e$
- Eutrophication potential (EP) $kgPO_4e$
- Ozone depletion potential (ODP) $kgCFC_{11}e$
- Formation of ozone of lower atmosphere (POCP) kgC_2H_4e
- Primary energy (Mj)
- Biogenic carbon storage $kgCO_2e$ bio

- Measures Carbon Dioxide (CO2) and greenhouse gas (GHG) emissions
- Aka *'carbon footprint'*

Global Warming Potential, Source: TU Dublin

1. Introduction. *Continued*

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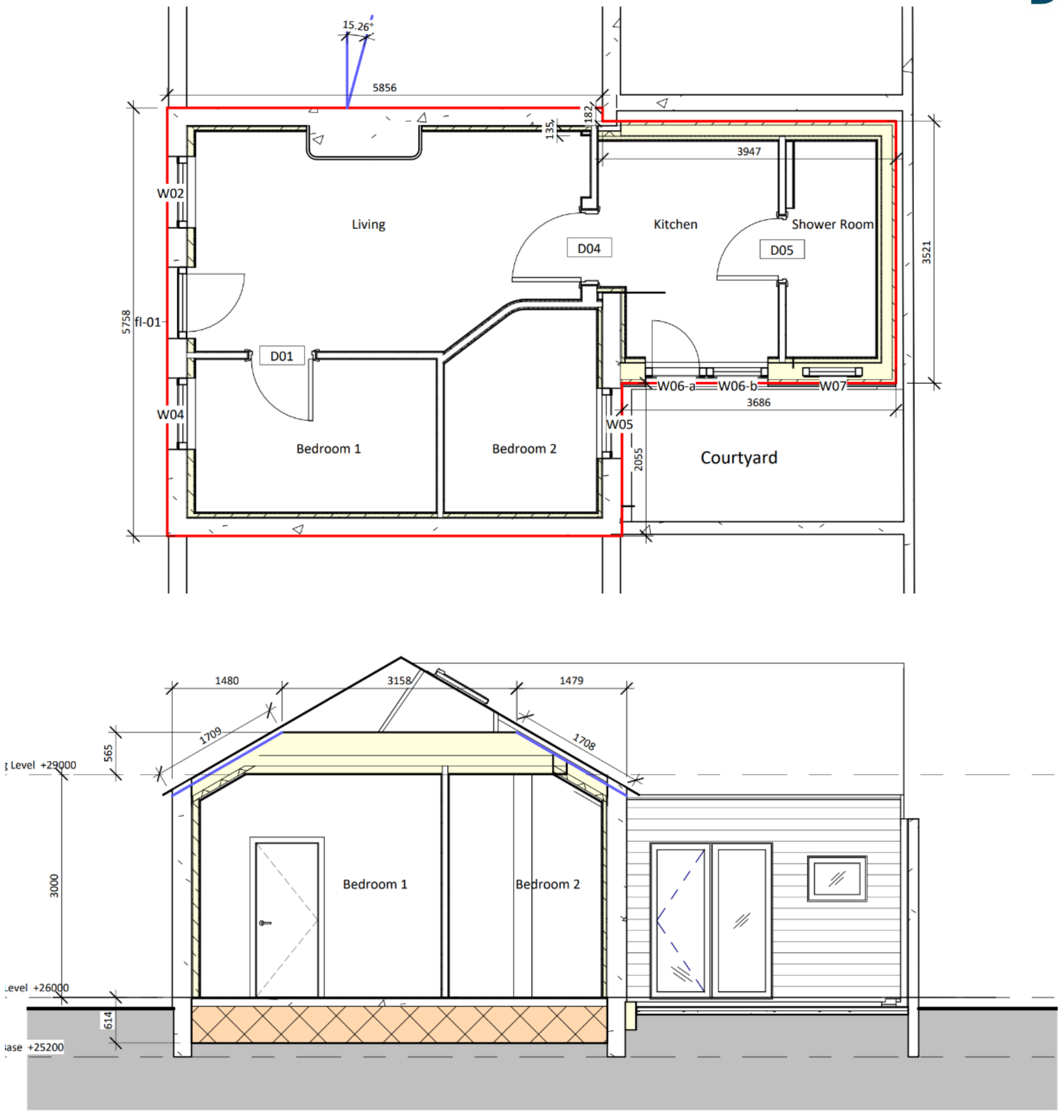
Global Warming Potential, Source: TU Dublin

- Measures the potential for embodied carbon to be stored ex. In wood
- Aka *'carbon storage'*

2. Data / calculation tool

- **As built drawings and specifications**
- **Material quantities drawn from BIM model**
- **PHPP model**
  - **Energy consumption**
  - **Water consumption**
  - **Post occupancy data not available**
- **Assumptions included cover:**
  - **Transport distances**
  - **Construction site operations**
  - **End of life scenarios**
- **Tool: One Click LCA**
  - **Work in progress**
  - **Transportation distances/material manufacturing - Ireland**



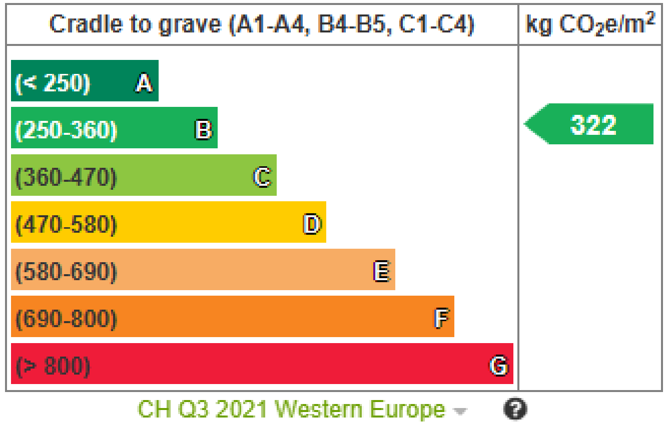
IM model output
Source: Wayne Morehead Architects

3. Results and findings

Embodied carbon results at a glance

- **Benchmarking**
  - **Comparison to a nationally averaged equivalent building - scores well**
  - **Only certain stages are considered**
  - **Variability in other stages prohibit direct comparison**
- **Results by life cycle stage**
  - **Product (A1-A3) dominant – as expected**
  - **Transport (A4) 1% - low due to local material sourcing**
- **Results by structural element**
  - **Horizontal structures 45% - dominate**
  - **Vertical structures 22% - retention of existing elements contribute to low emissions**

Benchmarking



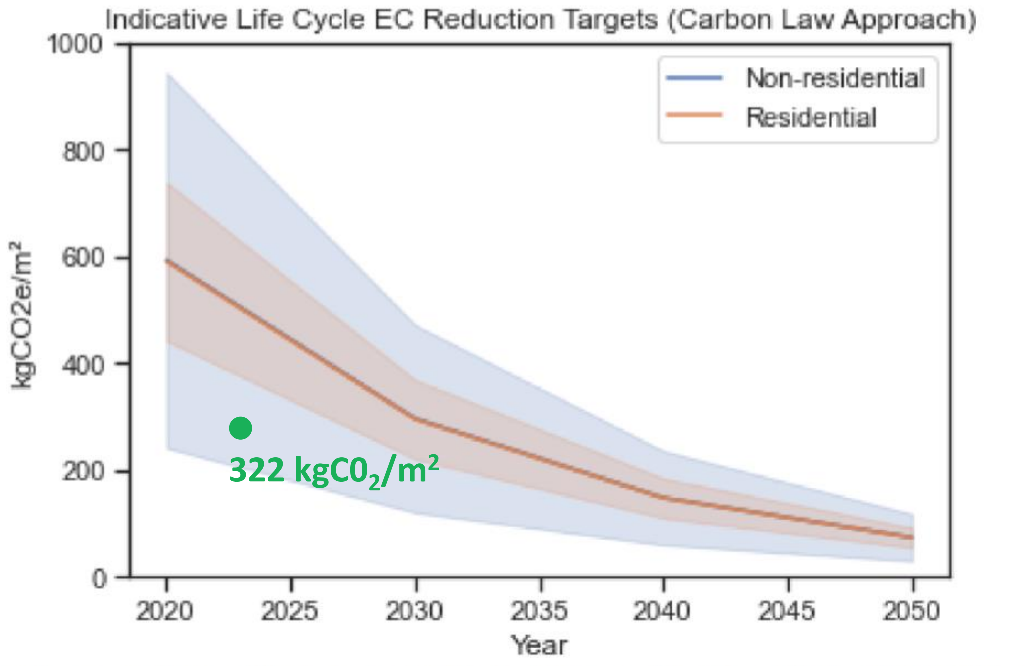


Figure 5 - Indicative reduction targets for full life cycle embodied carbon emission [kgCO2e/m²] of residential and non-residential buildings, respectively (from Ref.[23]).

M. Röck et al., (2022)

3. Results and findings. *Continued*

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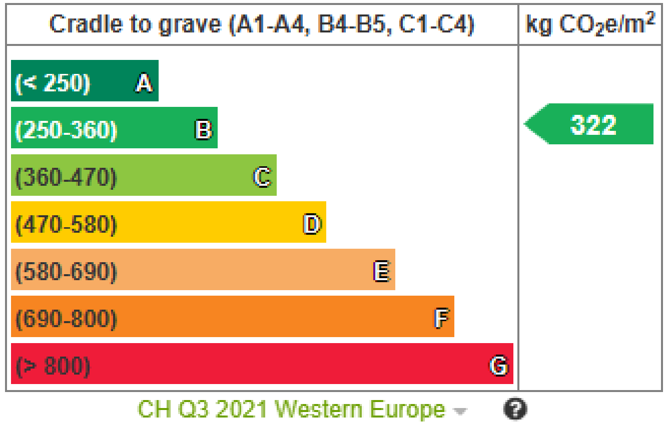
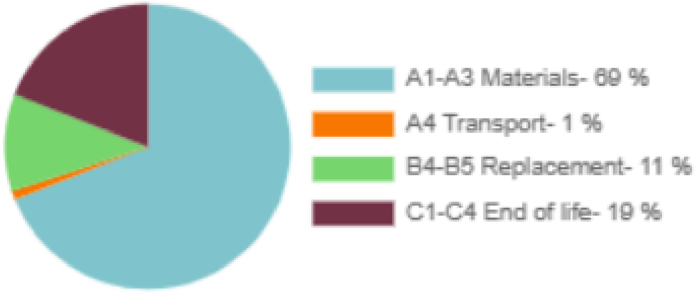


Life cycle stage



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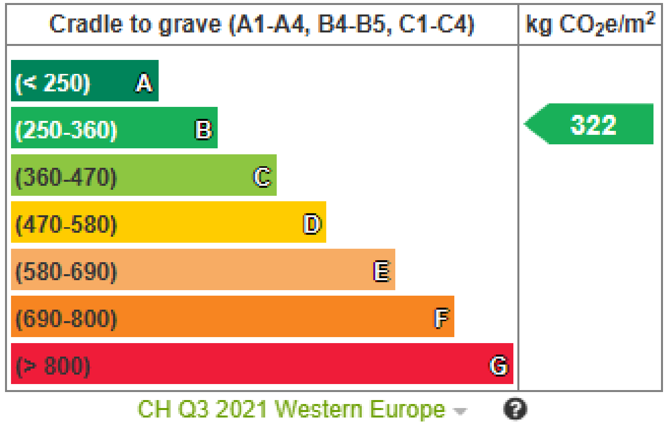

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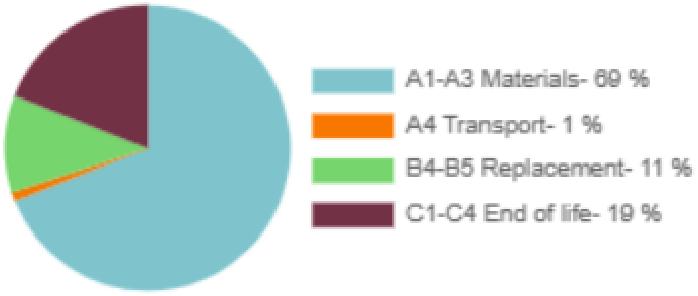
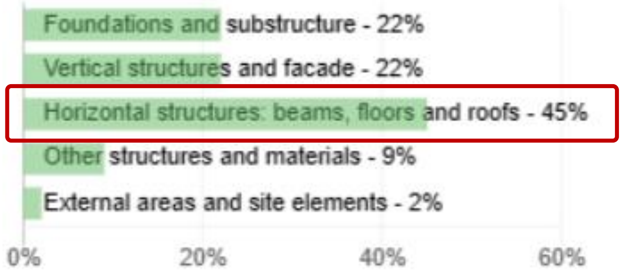


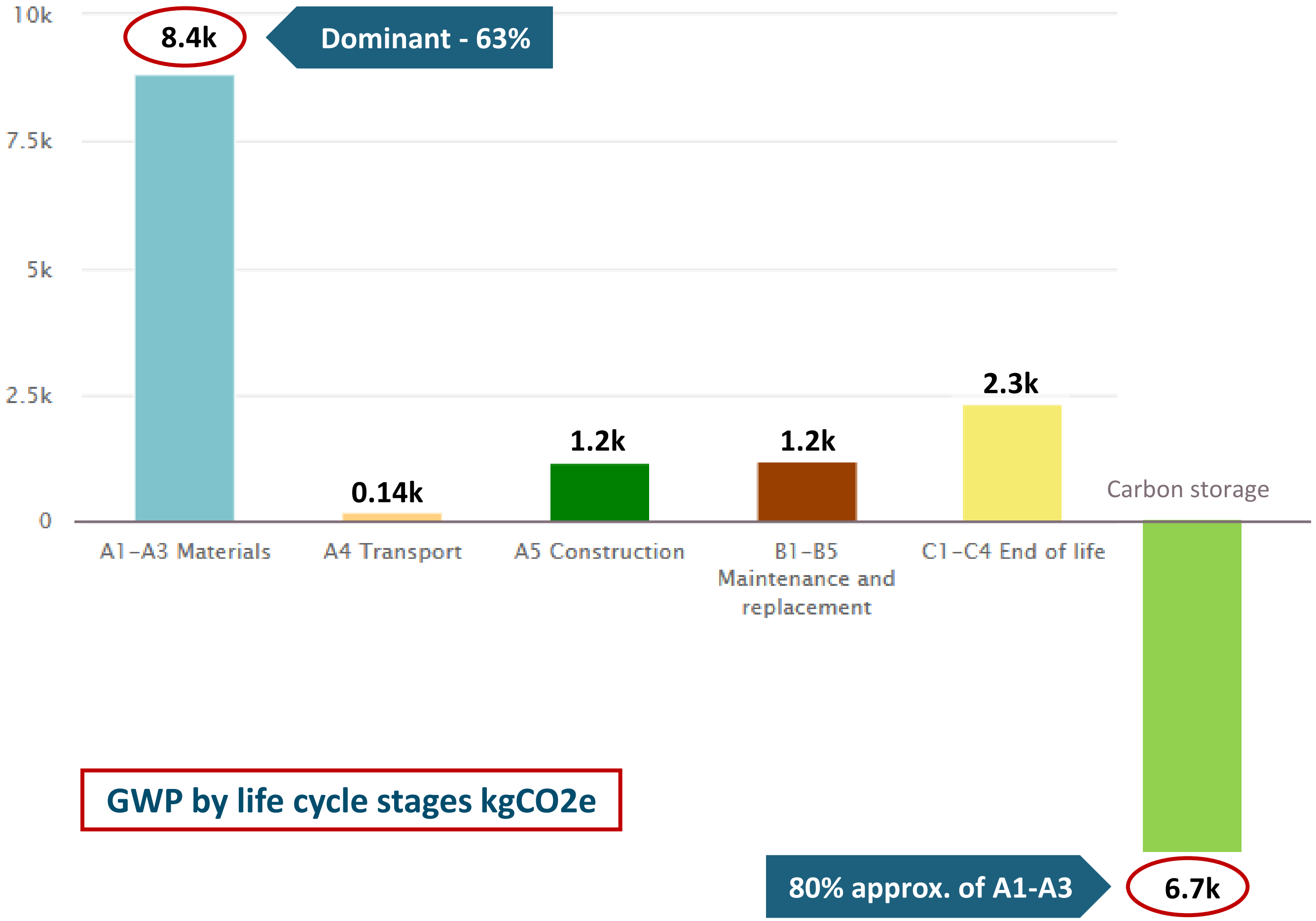
Structural element



3. Results and findings. *Continued*

Embodied carbon results by life cycle stage (excl. B6)

- **Product stage (A1-A3)**
  - **Dominant stage - 63% approx. of total embodied carbon emissions**
- **Carbon storage**
  - **Provides 80% approx. offset against product stage (A1-A3) emissions**
- **Operational energy (B6)**
  - **Dominant stage - 25x approx. on product stage (A1-A3)**
  - **Scale of magnitude amplified by:**
    - **Low carbon material selection**
    - **No renewables yet**



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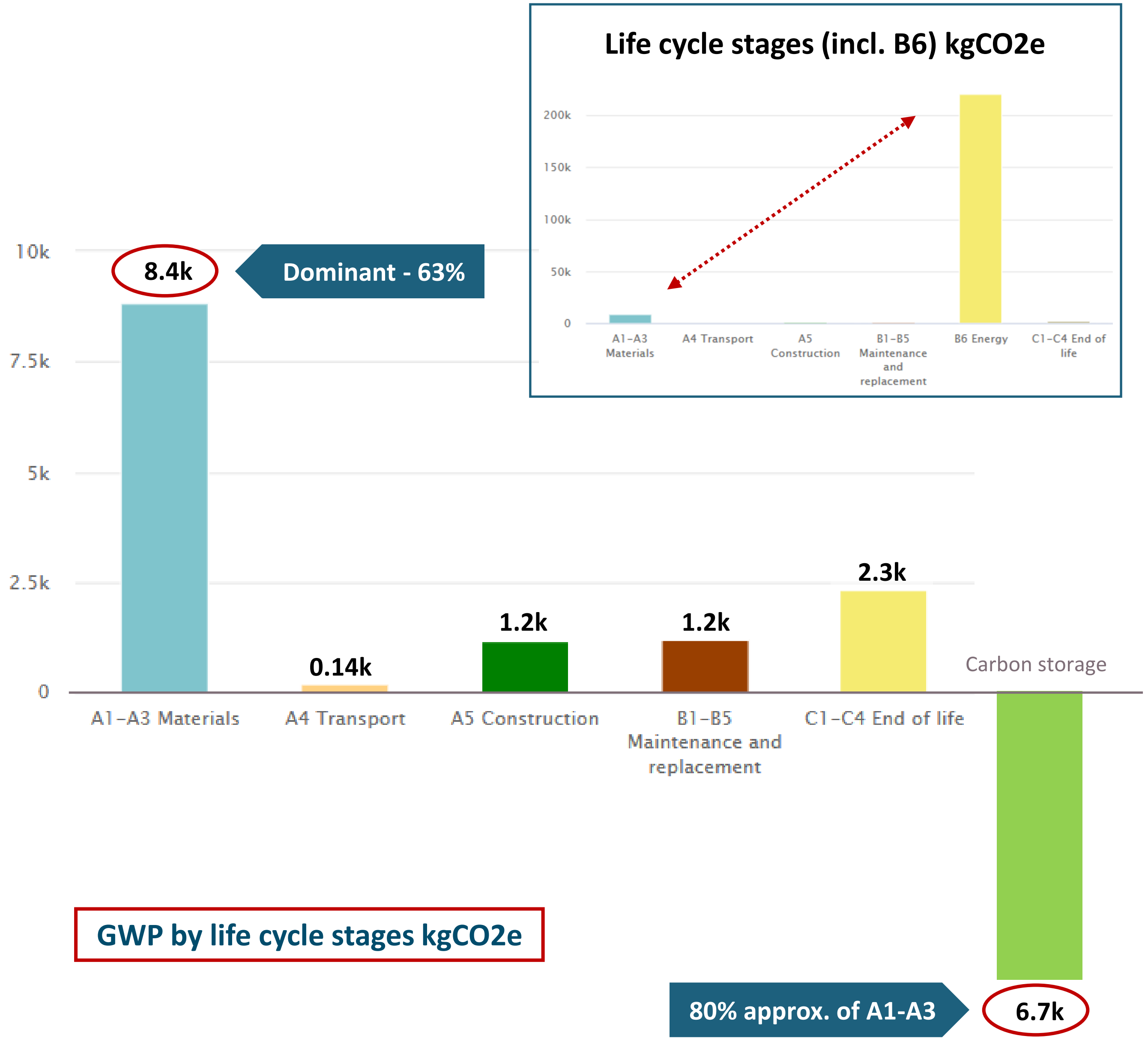
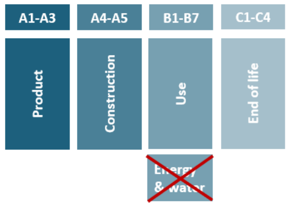
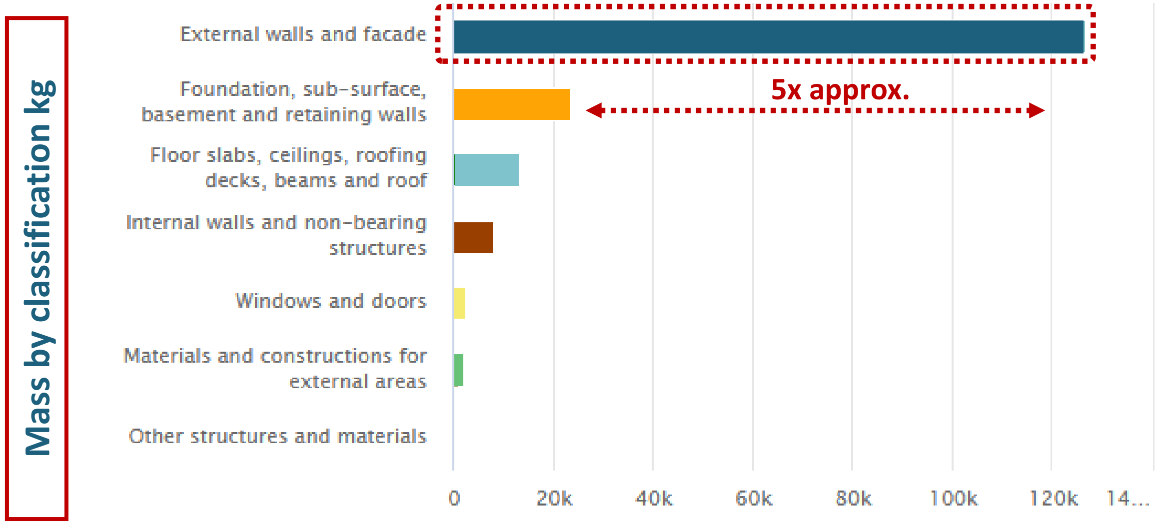


3. Results and findings. *Continued*



Embodied carbon results by classification (excl. B6)

- **Materials and products broadly ‘classified’ as foundations, vertical structure, finishes…**
- **Mass by classification**
  - **External walls and façade - greatest mass of use**
- **GWP by classification**
  - **Low impact relative to high mass of use**
  - **Reuse of existing walls**
- **Reuse of existing materials**
  - **No product stage emissions (A1-A3)**
  - **No construction emissions (A4-A5)**



3. Results and findings. *Continued*

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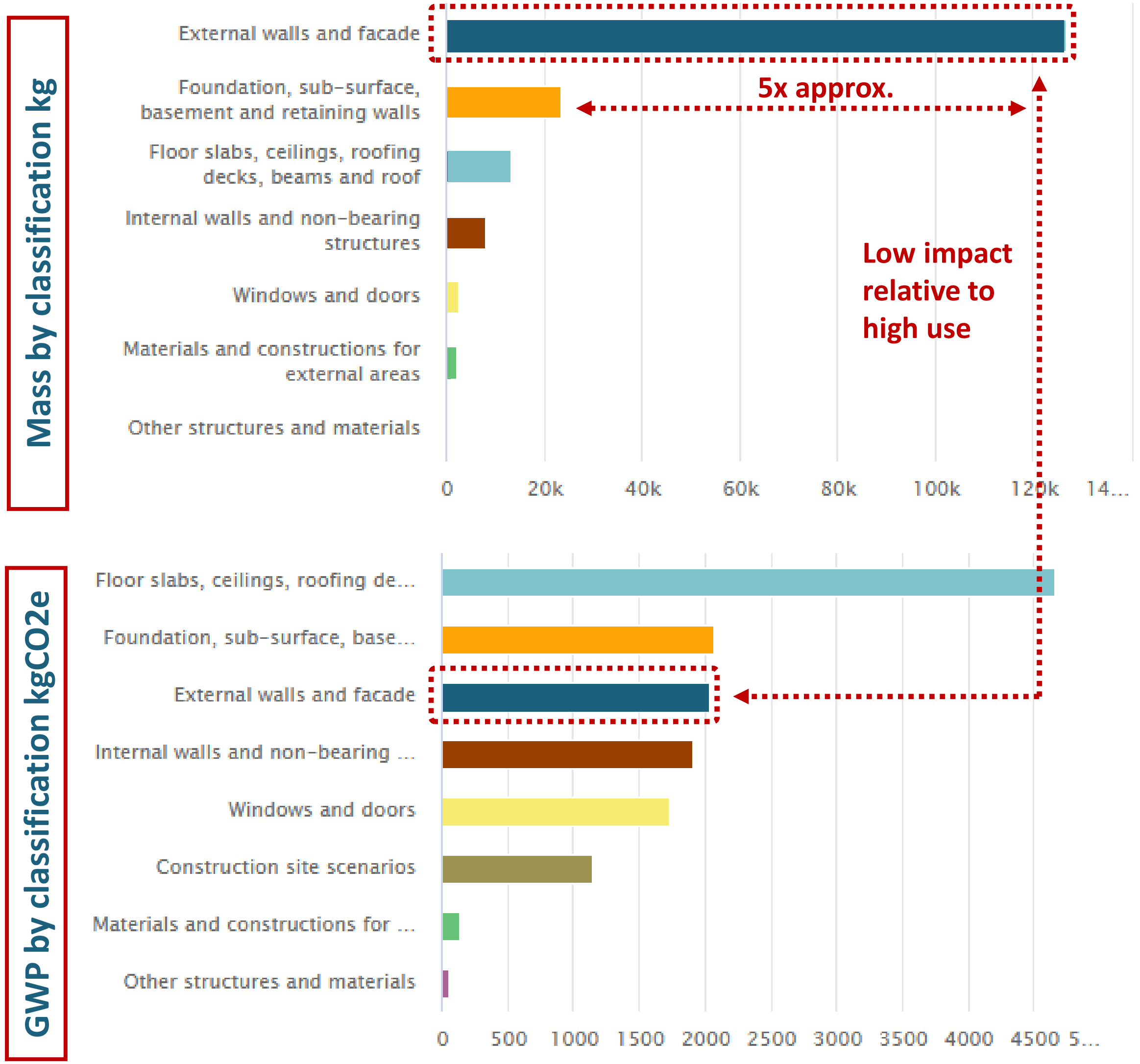
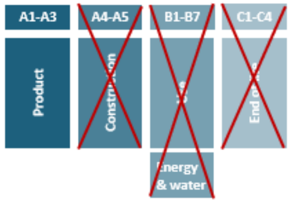


3. Results and findings. *Continued*



Embodied carbon results by most contributing materials (A1-A3)

- Floor adhesive
  - High mass of use
  - High emissions per m3
  - Hotspot
- Cellular glass aggregate
  - High mass of use
  - Low emissions per m3
  - Target
- Hotspotting
  - Useful at early design stage
  - Target - no red clouds - not always possible!

Most contributing materials (Global warming)

No.	Resource	Cradle to gate impacts (A1-A3)
1.	Fibre cement slates, 10.6 mm, 20.67 kg/m2, 1950 kg/m3	1,1 tonnes CO_2e
	Hotspot: SMP-Parquet adhesive, PAR 360: 1790 kg/m3, PAR 365: 1750 kg/m3, Silane modified polymers - based	0,87 tonnes CO_2e
	Target: Cellular glass aggregate, 10-60 mm, loose bulk density 180 kg/m3	0,85 tonnes CO_2e
4.	Ready-mix concrete, normal-strength, generic, C30/37 (4400/5400 PSI), 10% (typical) recycled binders in cement (300 kg/m3 / 18.72 lbs/ft3)	0,8 tonnes CO_2e
5.	NHL (natural hydraulic lime) based floor screed, 1900 kg/m3	0,61 tonnes CO_2e
6.	PIR insulation board, with foil facing, R = 0.91 m2K/W (20 mm), L = 0.022 W/mK, 20 mm, Lambda=0.022 W/(m.K)	0,54 tonnes CO_2e
7.	Wood fiber insulation boards,	0,42 tonnes CO_2e
8.	Gypsum plaster board, 12.5 mm, 9.5 kg/m2, 760 kg/m3, 0.19 w/mK, Fire class: A2-s1	0,33 tonnes CO_2e

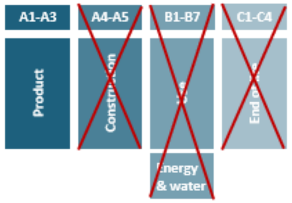
4. Comparisons

What happens when:

- **Material swap: 'Circular' insulation materials are replaced with mainstream equivalents?**
  - 'Daemstatt' cellulose to mineral wool
  - 'Pavadry' woodfibre to PIR
  - 'Pavatextil' recycled cotton to mineral wool
- **Rebuild: The existing concrete walls and footings are rebuilt?**

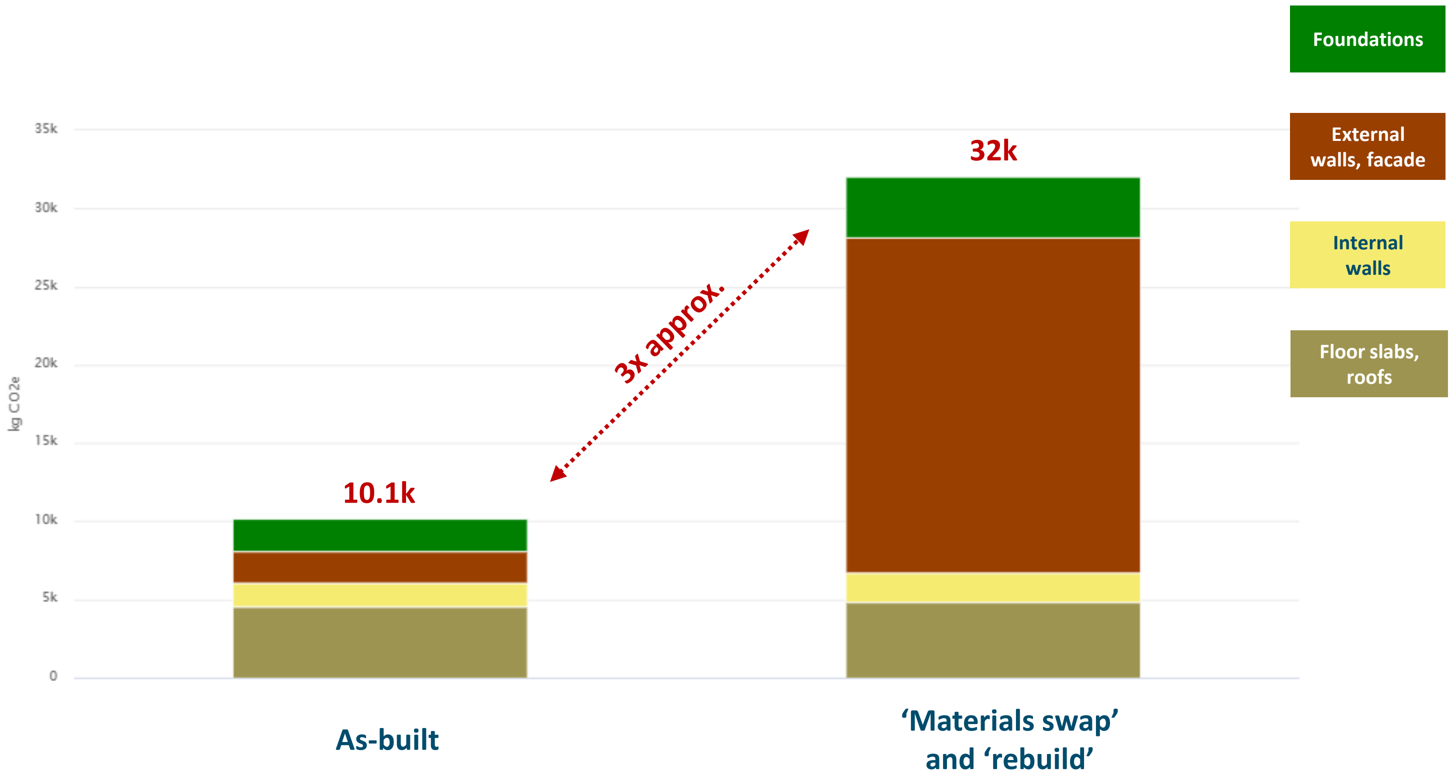
Life Cycle Analysis (EN15978)

4. Comparisons. *Continued*



Analysis focus: Product stage (A1-A3)

- **Total emission increase: 3x approx. on as-built**
- **68% saving on emissions against a 'mainstream' build**
- **Emission increase by element:**
  - **Foundations: 86%**
  - **External walls, façade: 10x**
  - **Internal walls: 26%**
  - **Floor slabs, roofs: 6%**
- **Carbon storage: 27% decrease**



GWP by elements kgCO2e

4. Comparisons. *Continued*

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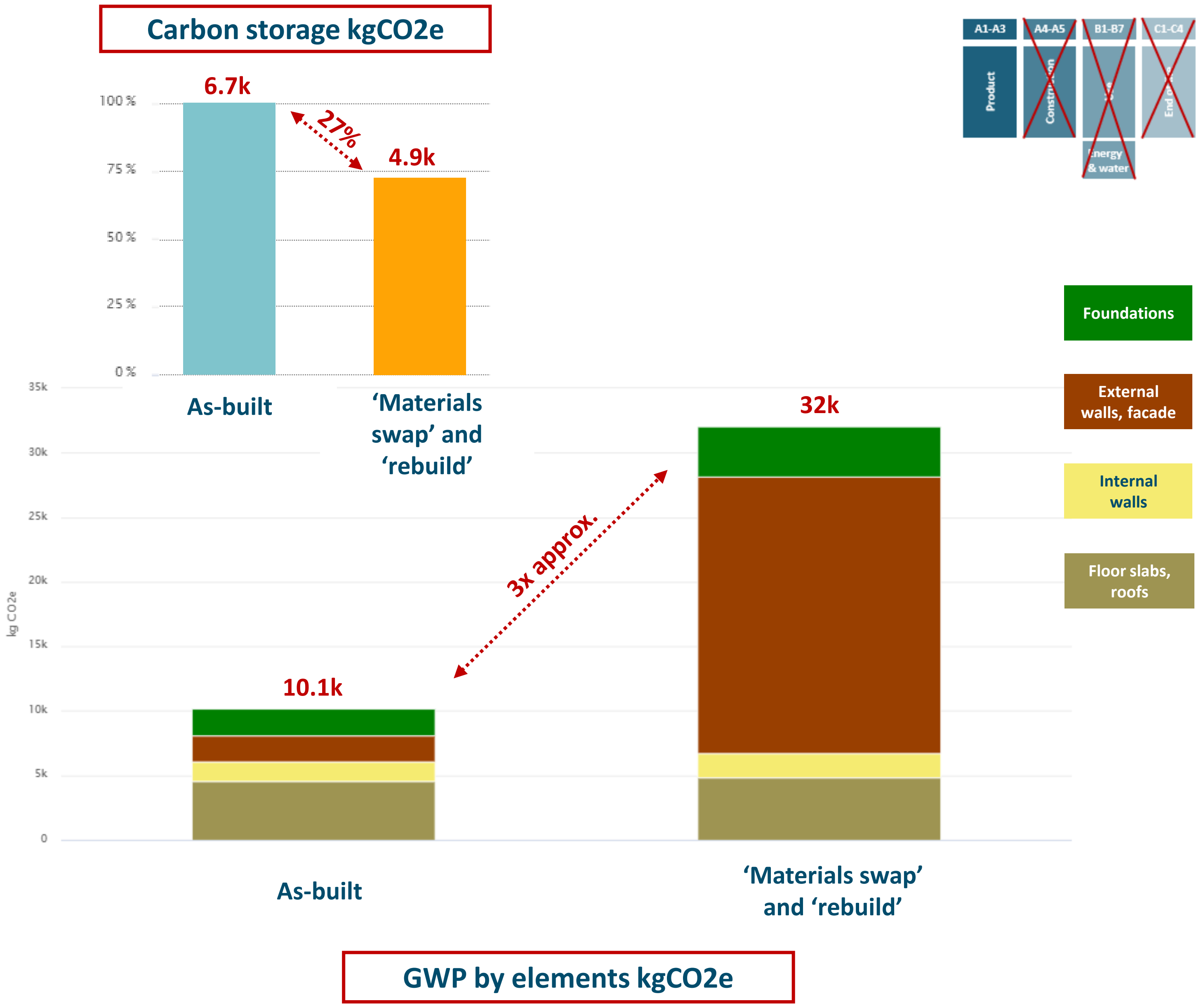

5. Summing up

LCA analysis shows:

- **Transport - local material supply**
- **Carbon storage potential - increases with wood based materials**
- **Reuse wherever possible - avoid product (A1-A3) and construction (A4-A5) stage emissions**
- **Target low embodied carbon materials for high mass of use**
- **LCA at early design stage will identify 'hotspots', facilitate better material selection and set targets**
- **Reducing embodied carbon emission will reduce other impacts**

Life cycle assessment, EN 15978 – All impact categories

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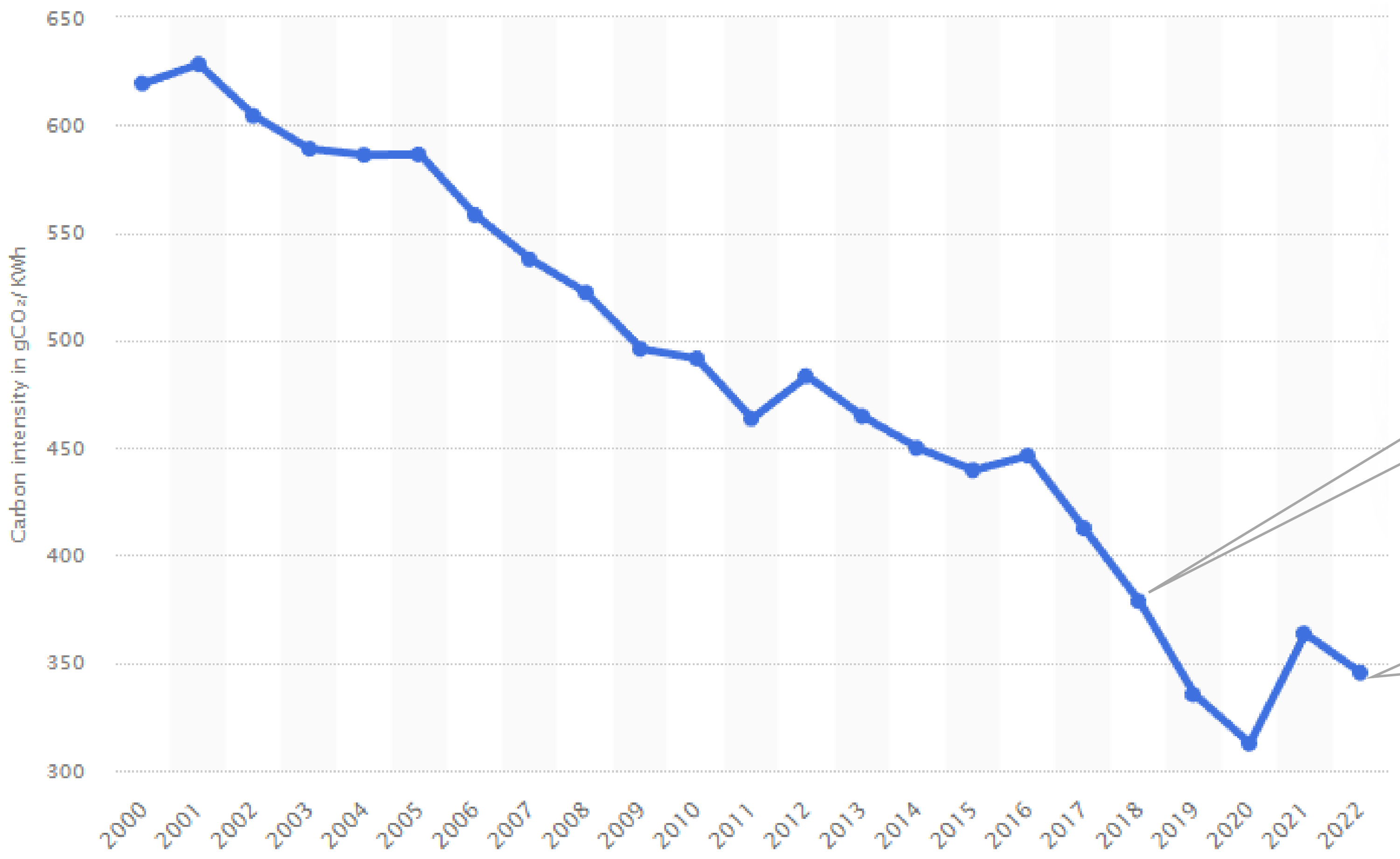


345.35 = 91.2% of 2018 levels = **10.1** Mt CO2e*91.2% = 9.212 Mt CO2e in 2022 (behind target)

2018: 378.64

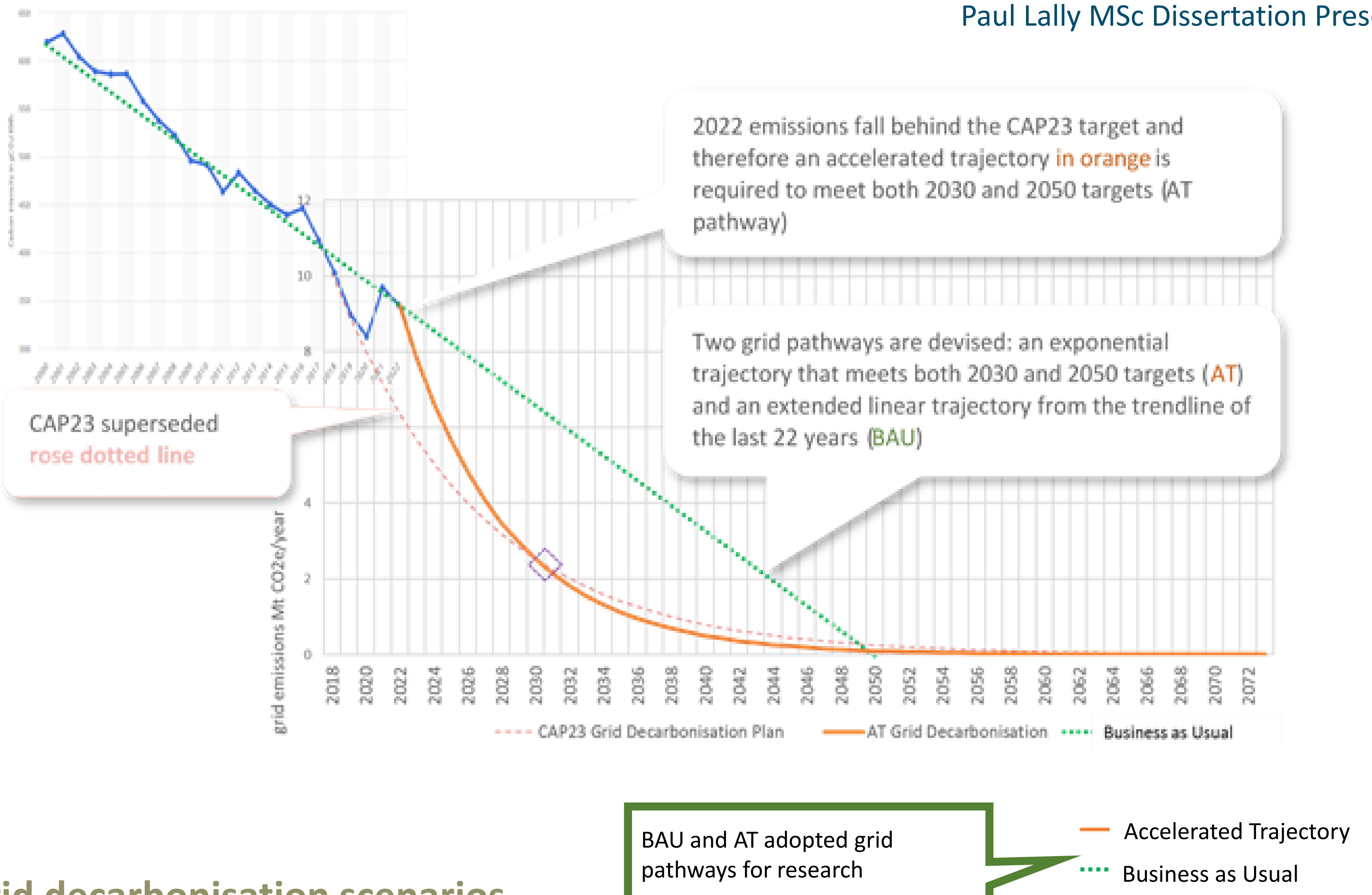
2022: 345.35

345.35 equates to total national emissions of **9.2 Mt CO2e** in 2022

These correspondences and the 22-year time axis means historical trendlines can be mapped onto following graphs

Source: https://www.statista.com/statistics/1290237/carbon-intensity-power-sector-ireland/#:~:text=In%202022%2C%20Ireland's%20power%20sector,%2FKWh)%20of%20electricity%20generated

grid decarbonisation scenarios



BAU and AT adopted grid pathways for research

2073 grid decarbonisation scenarios

To recap: DLCA accounts for time-variant decarbonisation and therefore produces more accurate GWP (generally less than the GWP produced in static LCA).

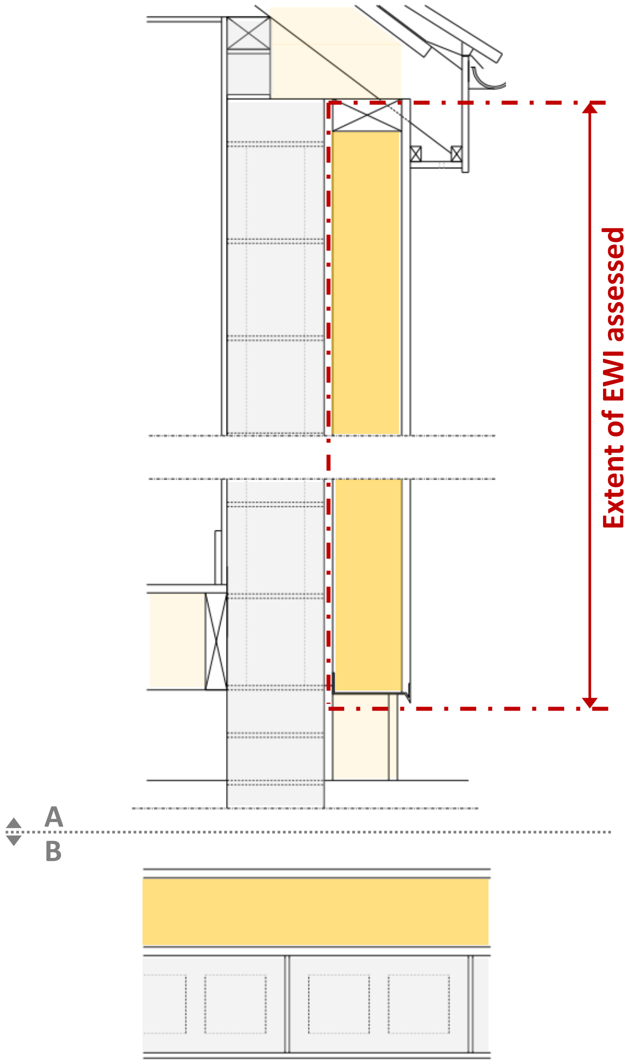
However, DLCA also demonstrates the effects of temporal delays, showing higher GWP than static LCA, which doesn't account for delayed or staged retrofits.

These conclusions are of interest to the standardisation of LCA, the EPBD targeting of renovations and the accuracy of GWP life cycle assessment procedures.

Sara Carrigan MSc Dissertation Presentation

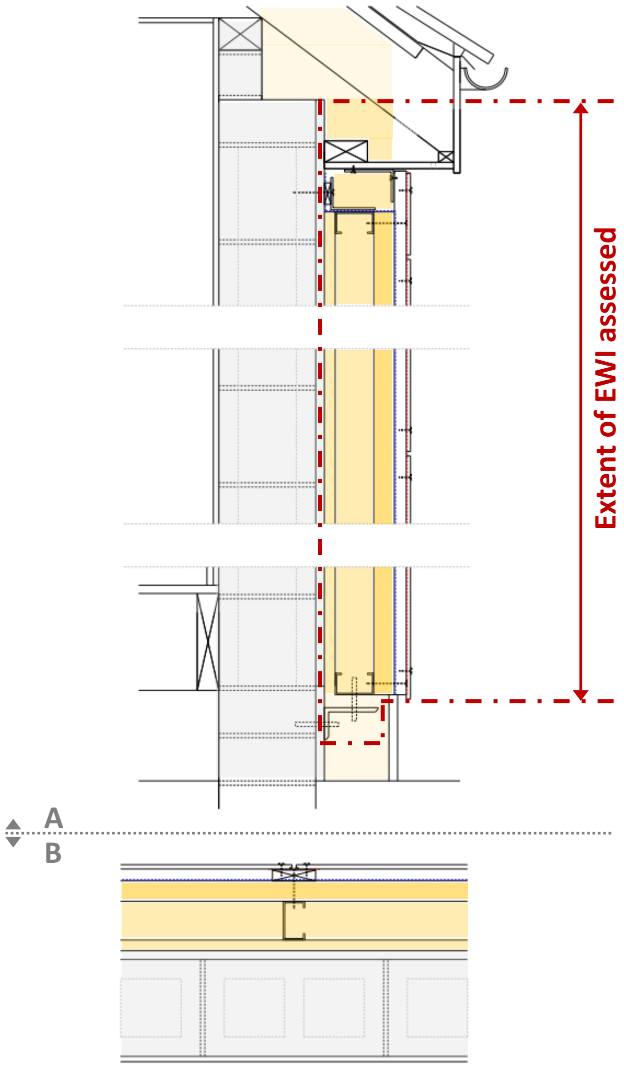
EWI retrofit strategies

- **Three variants** of the A2 retrofit
- **EWI strategies -** 0.18 W/m^{2}K
- **EWI 1:** Conventional, low-cost solution - EPS in a bonded ETICS approach
- **EWI 2:** Low embodied carbon alternative - Woodfibre in a bonded ETICS approach
- **EWI 3:** Enhanced version of EWI 2 - Woodfibre in a DfD assembly



EWI 1: Conventional (EPS)

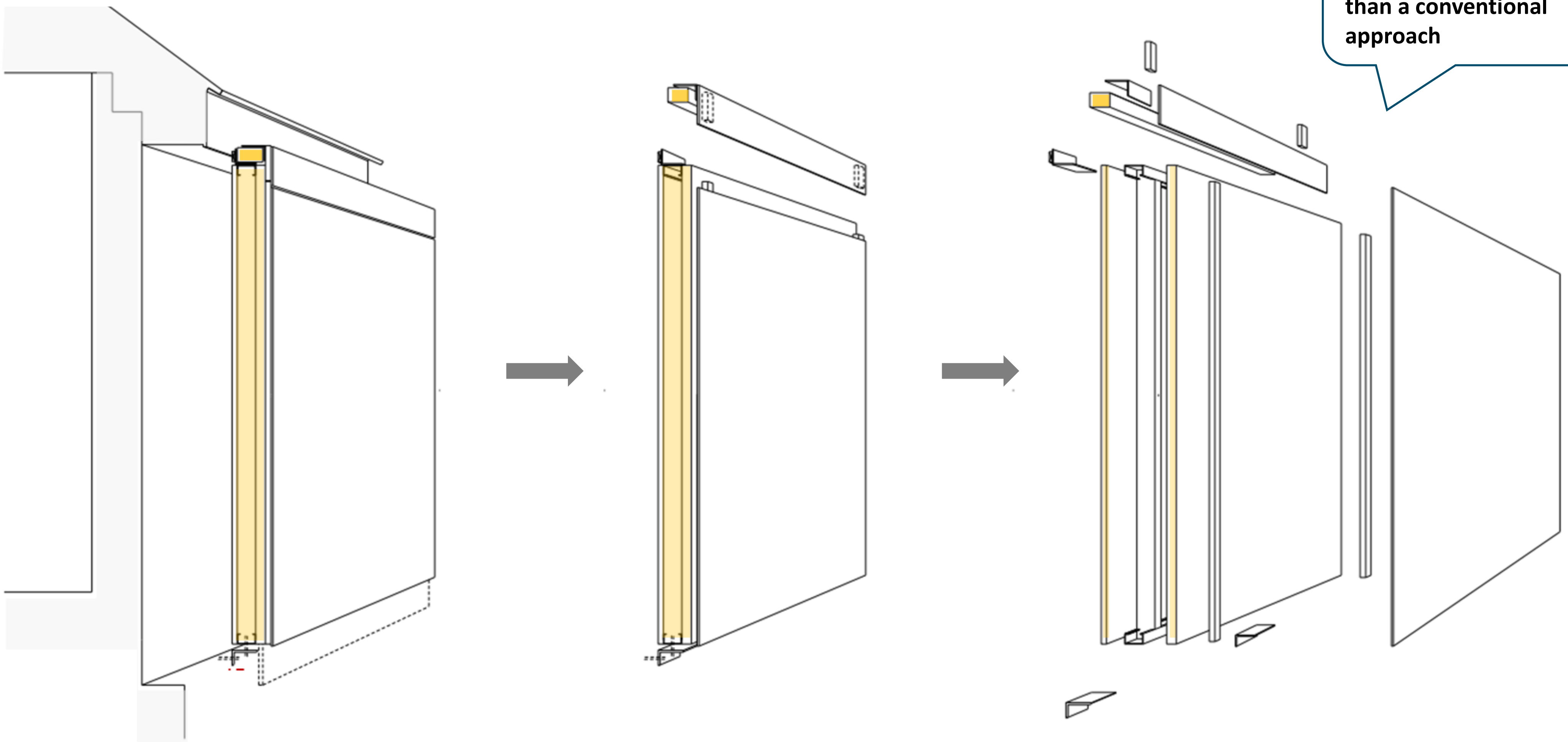
EWI 2: Low embodied carbon (Woodfibre)



EWI 3: Circular (Woodfibre in a DfD assembly)

DfD – disassembly hierarchy

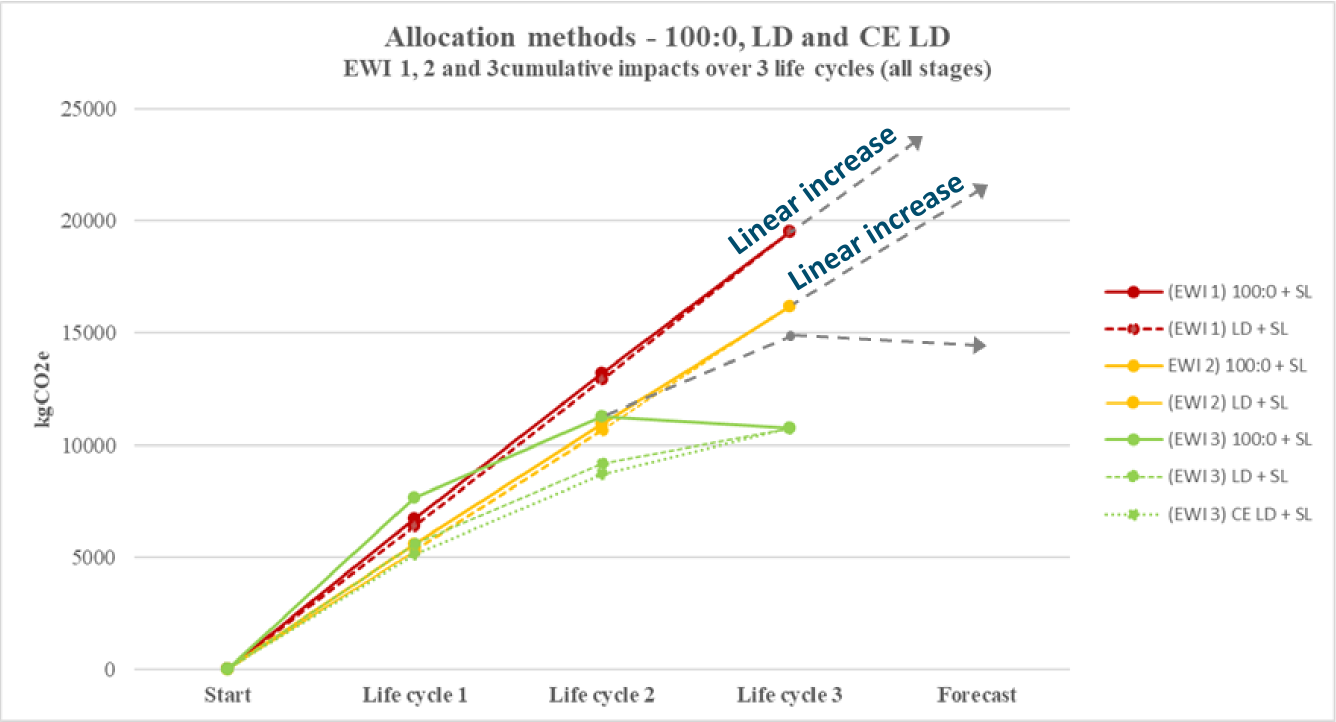
DfD requires mechanical fixings and more materials than a conventional approach



Element level **Component level** **Product level**

Allocation methods - Results. *Continued*

- **EWI 3 is best performing** when considered over multiple lives
  - **Payoff - ** range of emissions from 'conservative' to 'best case'
  - **Margin of payoff increases** in each life relative to EWI 1 and 2
- **DfD value** lies in:
  - **Avoided** production/EoL impacts
  - **Benefits** from recycling/incineration
- **EWI 1 and 2 increase linearly** – repeated production / EoL emissions



Discussion

- **Long building lifespans** creates uncertainty
  - Number of cycles
  - Future reuse/recycling scenarios
- **Designing for reuse potential** is important
- **Upfront carbon cost** of DfD is minor relative to the carbon saving from reuse

+ 15% - 45% - 108%

Summary results Multi-cycle LCA			EWI 1 Conventional			EWI 2 Low embodied carbon			EWI 3 Circular		
			Life 1	Life 2	Life 3	Life 1	Life 2	Life 3	Life 1	Life 2	Life 3
Multi cycle LCA ($kgCO_2e$)	Allocation methods	Baseline	6691	6513	6335	5570	5392	5214	7811	3746	3818
		100:O	6691	6513	6335	5570	5392	5214	7671	3605	-539
		LD	6404	6518	6618	5280	5397	5499	5609	3569	1559
		CELD							5126	3569	2043
	Van Gulck method	Baseline	6691			5570			7892		
		TF1	10340			8084			8870		
		TF2	11124			8557			8247		
		TF3	14773			11071			9225		
		EoL							7811		

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Conclusions

We don't have the carbon budget to do all we want.

We need LCA, carried out using a robust comparable methodology

We need data for Irish buildings: support IGBC's 'Indicate' project

LCA needs to evolve to take account of:

a) Decarbonising energy systems
b) Staging of retrofits
c) Design for disassembly and multiple lives

Become Indicate champions!

Contact Stephen Barrett in IGBC: stephen@igbc.ie

A new taxonomy of skills for a more sustainable construction sector
Life cycle assessment – process, case study, future direction

10th April, The Alex Hotel

Thank you

Joseph.little@tudublin.ie