



A presentation on UCD's prototype platform for MMC design, enabling more coordinated, repeatable and efficient design workflows

Oliver Kinnane. Head of School Architecture, Planning and Environmental Policy, UCD

The cover of the research paper is dark blue. At the top right, there is a white circular logo with a stylized 'a' and the 'BUILDINGS & CITIES' logo. The title 'Understanding the embodied carbon credentials of modern methods of construction' is written in white. Below the title, the authors' names are listed in white: RICHARD O'HEGARTY, AISLINN MCCARTHY, JACK O'HAGAN, THANAT THANAPORNPAKORN SIN, SAMAR RAFFOUL, and OLIVER KINNANE. The 'RESEARCH' label is in white. The 'Ju|ubiquity press' logo is in white. The abstract text is in a smaller white font. The 'POLICY RELEVANCE' section is in a smaller white font. The 'CORRESPONDING AUTHOR' and 'KEYWORDS' sections are in a smaller white font. The 'TO CITE THIS ARTICLE' section is in a smaller white font.

Understanding the embodied carbon credentials of modern methods of construction

RESEARCH

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**Author affiliations can be found in the back matter of this article*

ABSTRACT

This study assesses the embodied carbon credentials of modern methods of construction (MMC) by conducting a critical literature review and synthesis of the findings. While several studies have reviewed the broader impacts of MMC, no other study to date has comprehensively reviewed the embodied carbon credentials of this construction typology. Since MMC is not an internationally recognised term, the assessment is inclusive of other terminology used in different parts of the world – e.g. prefabrication, off-site construction and industrialised construction. The study captures 250 separate studies and distils these to a final sample set of 41 studies and a total of 82 case study comparisons. Although a general perception exists that the adoption of MMC results in embodied carbon savings, the evidence to support this claim is not robust. The results from individual case studies range significantly in both direction and magnitude, and, in the absence of a critical review, considerably different conclusions can be drawn. Upon critique and synthesis of the published studies, it is found that the adoption of MMC has no significant positive, or negative, impact on the embodied carbon of a building.

POLICY RELEVANCE

MMC have been widely cited as the answer to housing shortages and productivity issues in the construction industry more broadly. They have subsequently attracted political attention and implementation in many regions. Embodied carbon is another topic of continued debate in built environment policy. There is a somewhat hopeful assumption that the adoption of MMC will reduce embodied carbon. But, to date, the evidence to arrive at that assumption has been inconsistent. The literature that compares MMC with traditional construction varies considerably. It is found that there is no broad link between MMC and reduced embodied carbon. Reducing the embodied carbon of buildings requires assessment on a case-by-case basis.

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KEYWORDS:
modern methods of construction (MMC); embodied carbon; life cycle analysis; environmental impacts; prefabrication; buildings; construction industry

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A Decision-Support Tool

Enabling MMC adoption for a resilient, smart and green Irish construction sector

04 March 2026

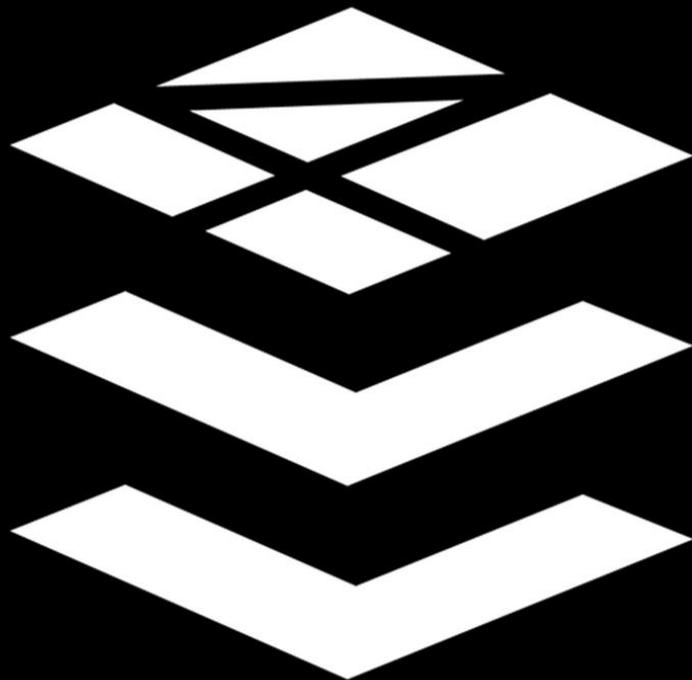
Samar Raffoul, PI
College of Engineering and Architecture

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Department of Housing, Local Government and Heritage

Rodhlann Mossop
School of Architecture, Planning and Environmental Policy

PLATFORM
MMC



The Challenge(s)

Ireland's housing crisis is the single biggest concern to the Irish people¹

Housing targets not being met

We need to **double** current annual housing delivery to meet targets (60k)

“An existential threat to Ireland's economic competitiveness”²

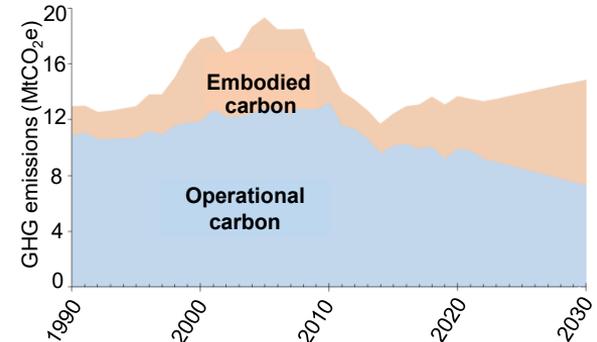
“30% of international recruits who accepted positions cancelled after researching housing market”³

Record homelessness in 2025⁴, huge class divide⁵

Acute labour challenges with shortfalls of >77,000⁶

Carbon obligations are not being met

Gains in OC reduction would be negated by rising EC from planned housing⁷.



Adapted from O'Hegarty & Kinnane, 2023⁷

A construction sector that cannot meet societal needs

Ireland expected to pay **€8 – 28bn** in carbon credits in 2030⁸.

The Specific Challenge

We need more MMC adoption, digitisation and holistic data-driven decision-making

The Irish construction sector is predominantly SMEs
~93% employ less than 6 people (2023)⁹

Initiative 17 December 2025

European Strategy for Housing Construction

The European Strategy for Housing Construction complements the Affordable Housing Initiative while aligning with the European Green Bauhaus.

This initiative addresses:

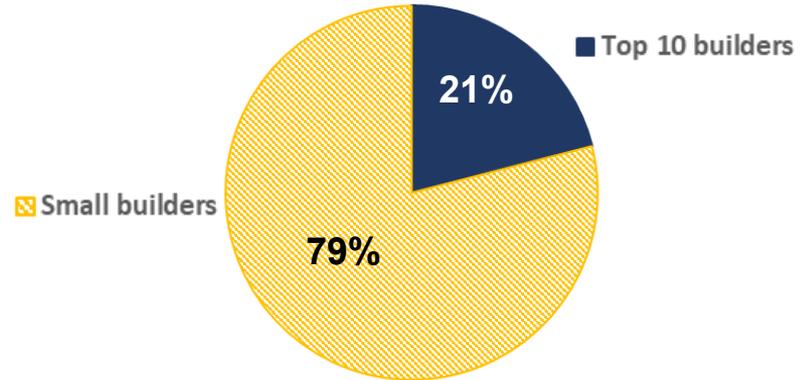
- Rising housing costs
- Limited housing supply
- Inefficiencies in the construction sector

To meet these challenges, the strategy promotes modern building methods such as:

- Modular and prefabricated construction
- Circular economy principles
- Energy-efficient technologies

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- Modular and prefabricated construction
- Circular economy principles
- Energy-efficient technologies



% housing constructed in 2023⁹

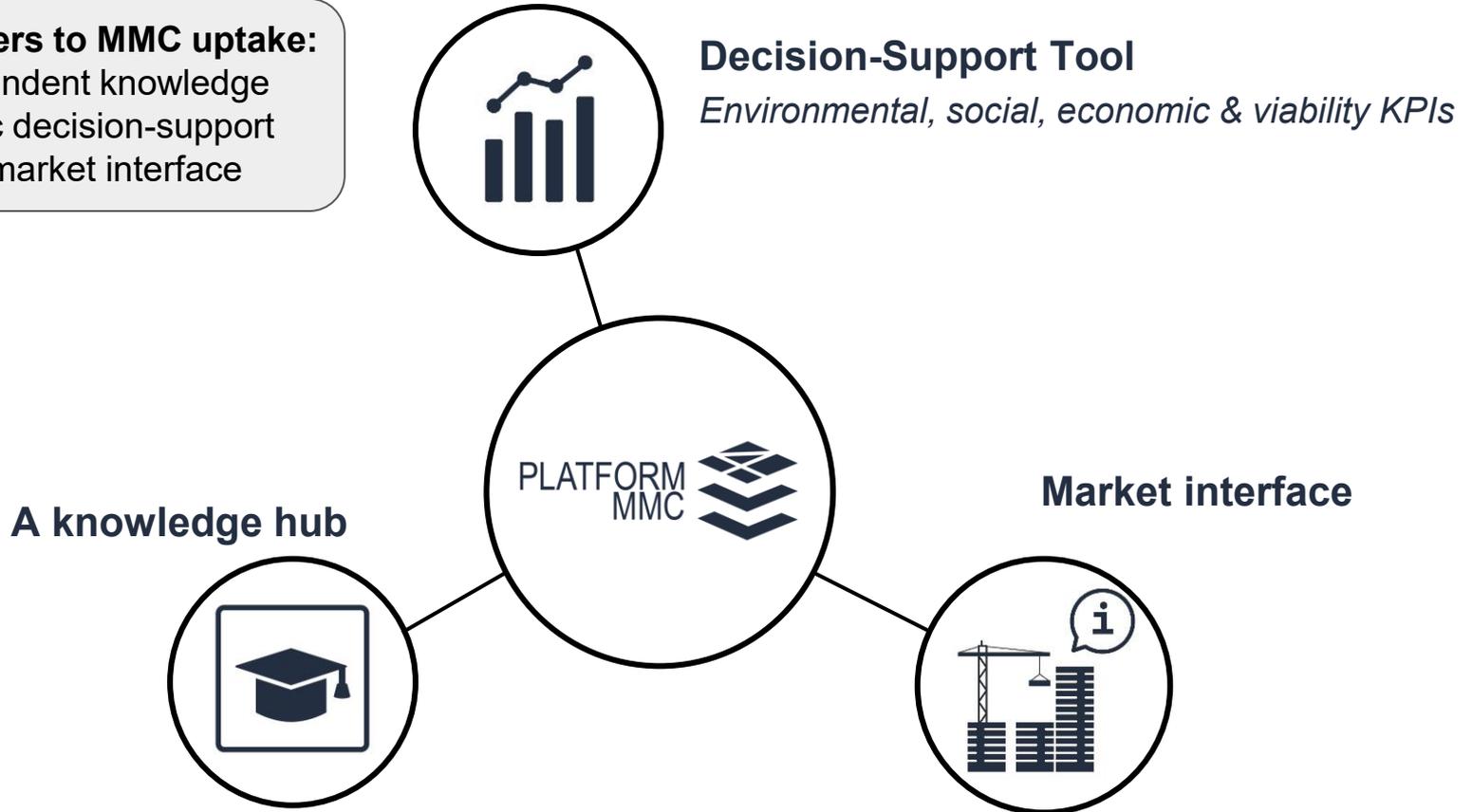
Only 7% of Irish firms regard MMC as their main activity (EY, 2023)¹⁰

Our Solution

A centralised digital service integrating three features

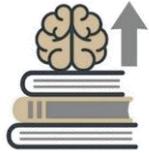
Three key barriers to MMC uptake:

- Lack of independent knowledge
- Lack of holistic decision-support
- Absence of a market interface

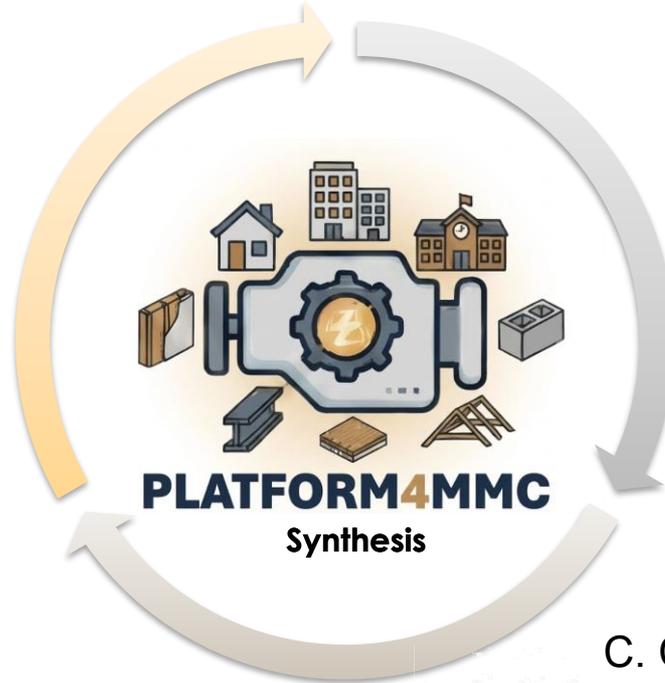


We have achieved a lot in Grow Phase

A. Knowledge
development



B. Prototype
development



C. Commercial
evaluation



Underpinned by extensive stakeholder validation, co-creation and iterative refinements

Grow Phase Achievements

B. Prototype development and validation

Robust prototype deployed in November

Tested by 42 stakeholders over 2 weeks

Excellent feedback - 30% response rate

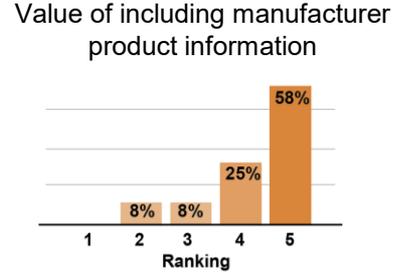
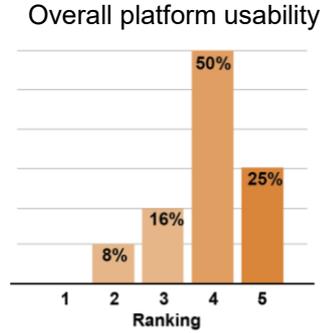
Validation of commercial model

Technology and data architecture in place

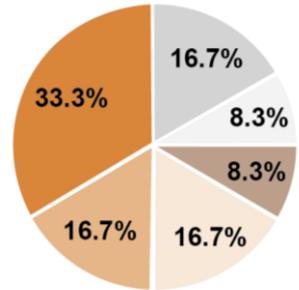
'The Decision-Support Tool is the most useful element of the platform – there is simply nothing else like it in the market!'

- Industry representative

(Appendix 1a)



Pricing Model Validation



- Free access with premium paid options
- Institutional license
- SaaS
- Pay per use
- Yes, if the product is comprehensive
- Other

Software team



Dr. S Raffoul
(UCD)



Dr. G. Dede
(UCD)



J. Cassey
(Granite; Developer)



T. Flynn
(Granite; UX/UI)



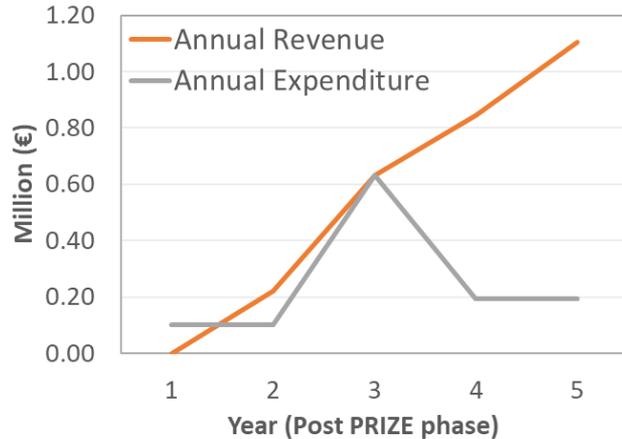
G. Corcoran
(Granite)

--- External expert consultants

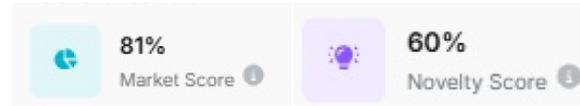
Grow Phase Achievements

C. Commercial assessment

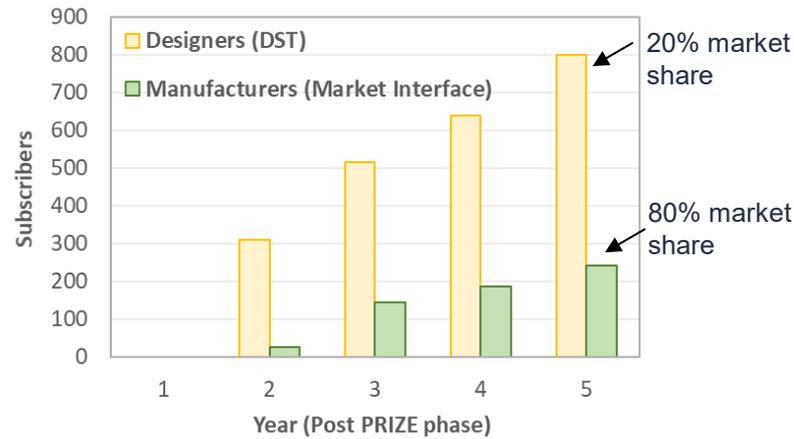
- A commercial two-tiered revenue model
- Value proposition validation
- Spin-out to commercialise IP at end of Prize



Cash Flow Forecasts



Outputs from Tradespace
(NovaUCD – UCD’s hub for innovation & startups)



Subscriber volume and market share

Commercial team



Dr. S Raffoul
(UCD)



Dr. O Kinnane
(UCD)



H. Hayden
(TTO; Nova)



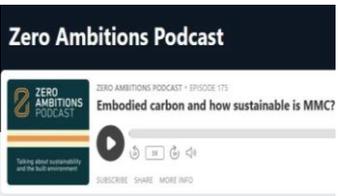
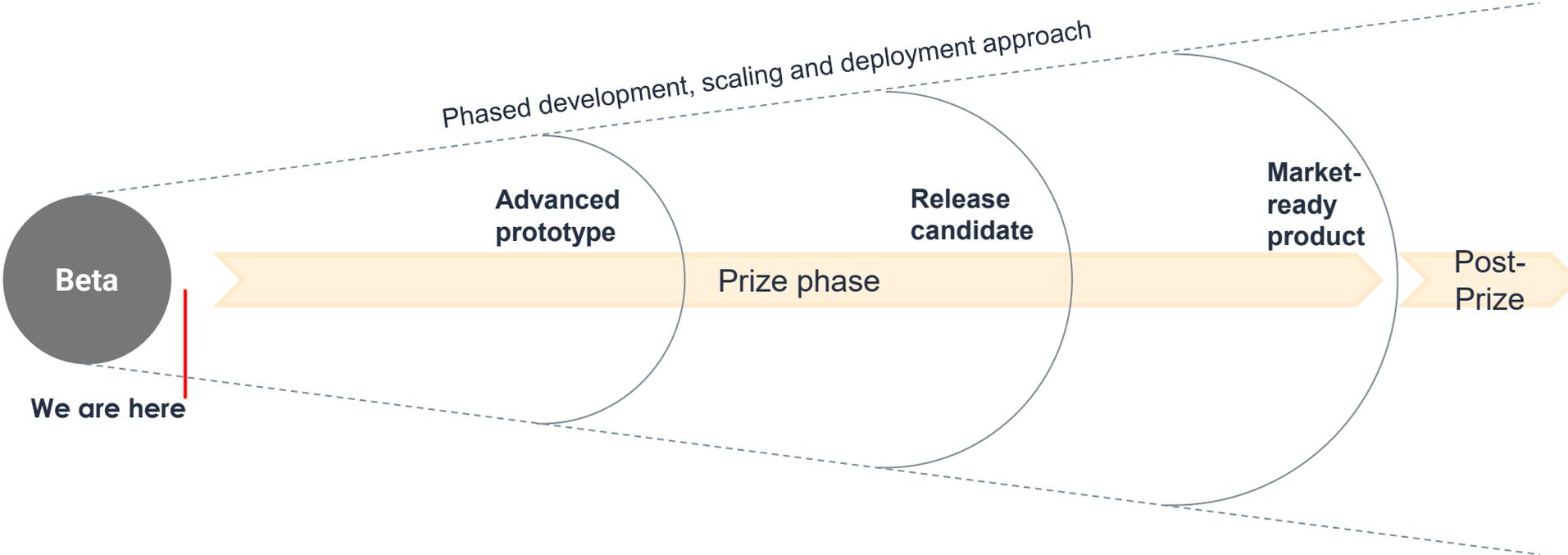
B. Maguire
(Business consultant
BMBC)

--- External expert consultants

A sustainable, profitable, scalable revenue model

We know what we need to do

Prize and beyond



Short-Medium term

Long term

Concluding remarks

- The construction industry needs to **double** annual housing delivery while meeting evolving climate & ESG **targets**.
- This requires greater MMC uptake, digitisation and holistic decision-support
- SME-dominated construction sector with limited innovation capacity requires support

Our **centralised, user-friendly, impartial** decision-support tool is crucial to assess, compare and select responsible MMC solutions enabling its higher uptake

Impact

- Speed up MMC uptake and housing delivery
- Facilitate compliance reporting & transparency
- Address labour challenges
- Improve supply-chain coordination

Transformational systemic change in construction across multiple sectors

- Digital and green transition
- Holistic triple-bottom-line decision-making
- A more resilient construction sector
- Broad policy and societal impacts



Understanding the embodied carbon credentials of modern methods of construction

RESEARCH

ju[ubiquity press

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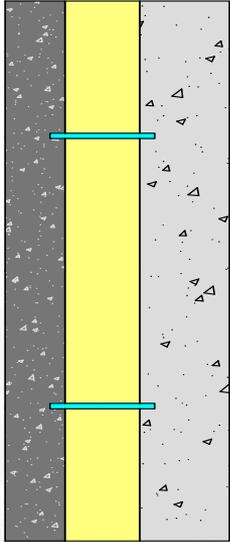
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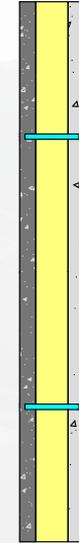
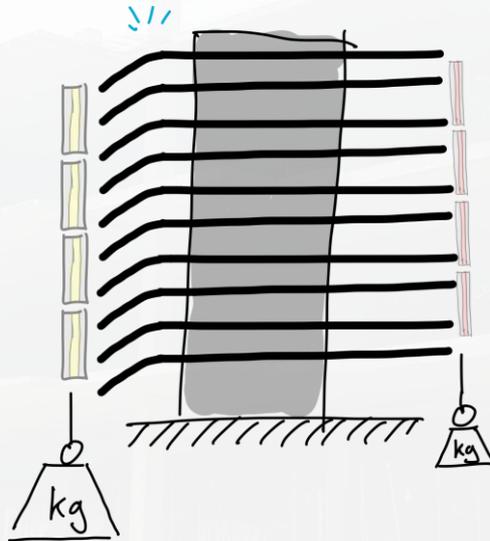
O'Hegarty, R., McCarthy, A., O'Hagan, J., Thanapornpakornsin, T., Raffoul, S., & Kinnane, O. (2023). Understanding the embodied carbon credentials of modern methods of construction. *Buildings and Cities*, 6(1), pp. 70–89. DOI: <https://doi.org/10.5334/bc.515>

Can MMC be a more sustainable solution?

- 2D Concrete panels - UCD Research - - from 2018 -



Standard concrete sandwich panel section



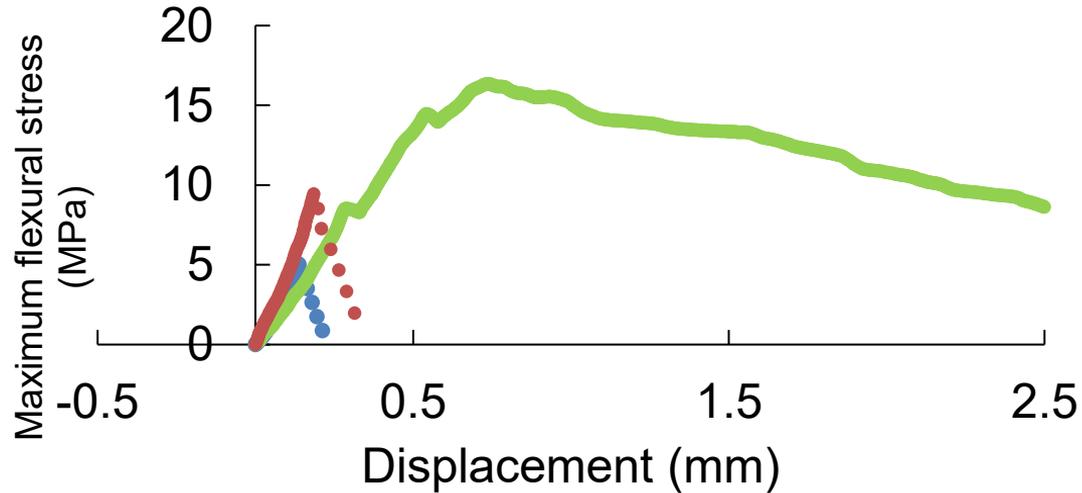
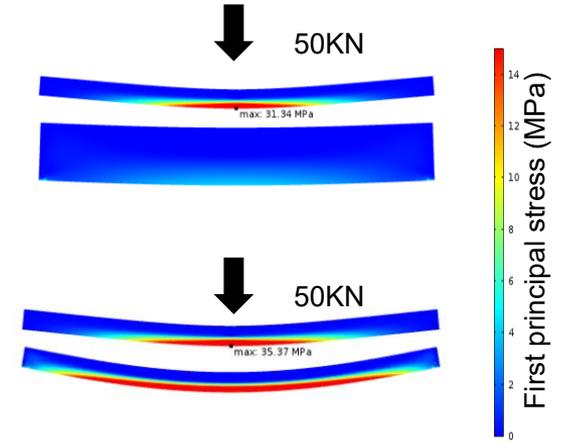
Proposed concrete sandwich panel section

-  1. Exterior Wythe concrete
-  2. Interior Wythe
-  3. Insulation
-  4. Wythe Connectors

Can we maintain the benefits while reducing the size?



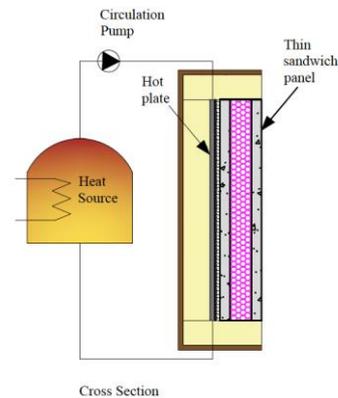
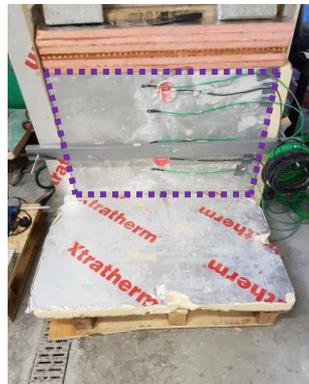
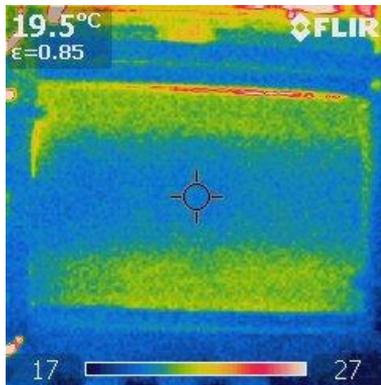
Structural



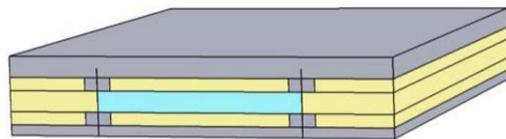
- Normal concrete
- High performance concrete
- High performance fibre reinforced concrete

Thermal

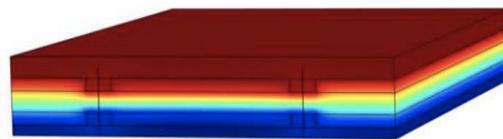
Experimental



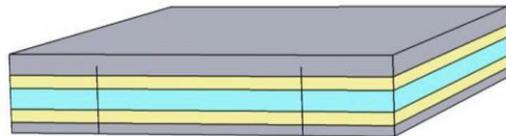
Finite element modelling



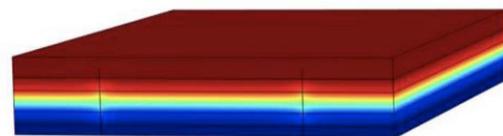
Test panel:



$$U_{av} = 0.324 \text{ W}\cdot\text{m}^{-2}\cdot\text{K}^{-1}$$



Optimised panel:



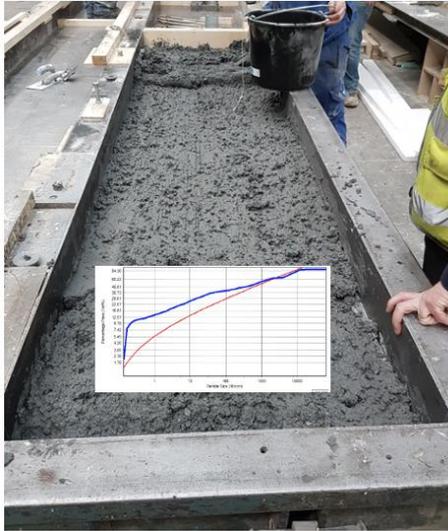
$$U_{av} = 0.133 \text{ W}\cdot\text{m}^{-2}\cdot\text{K}^{-1}$$

45 °C

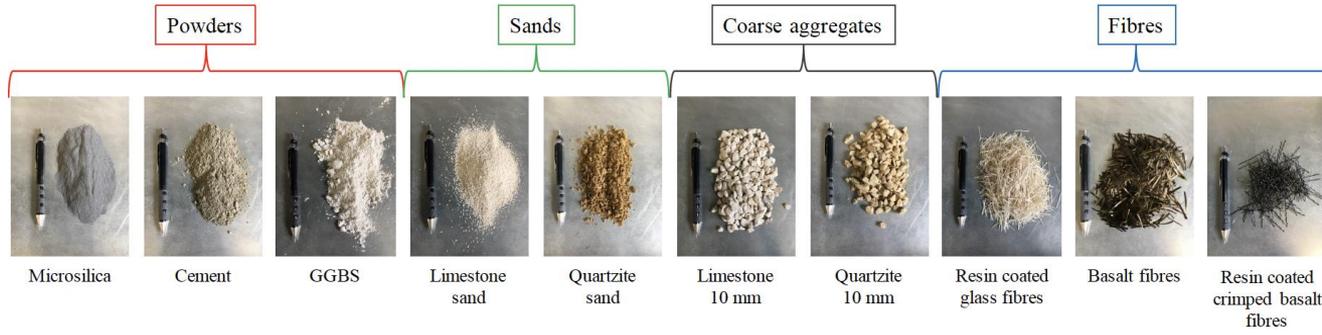
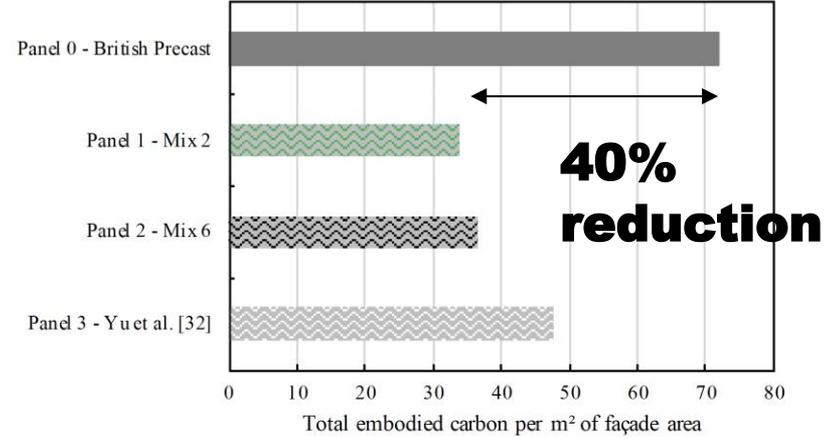
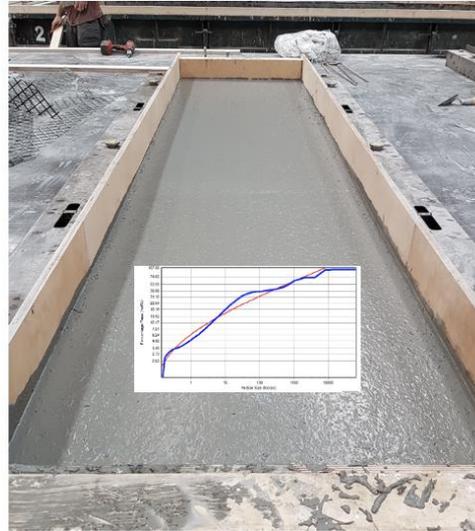
20 °C

Materials + embodied carbon

Mix iteration 4



Mix iteration 16



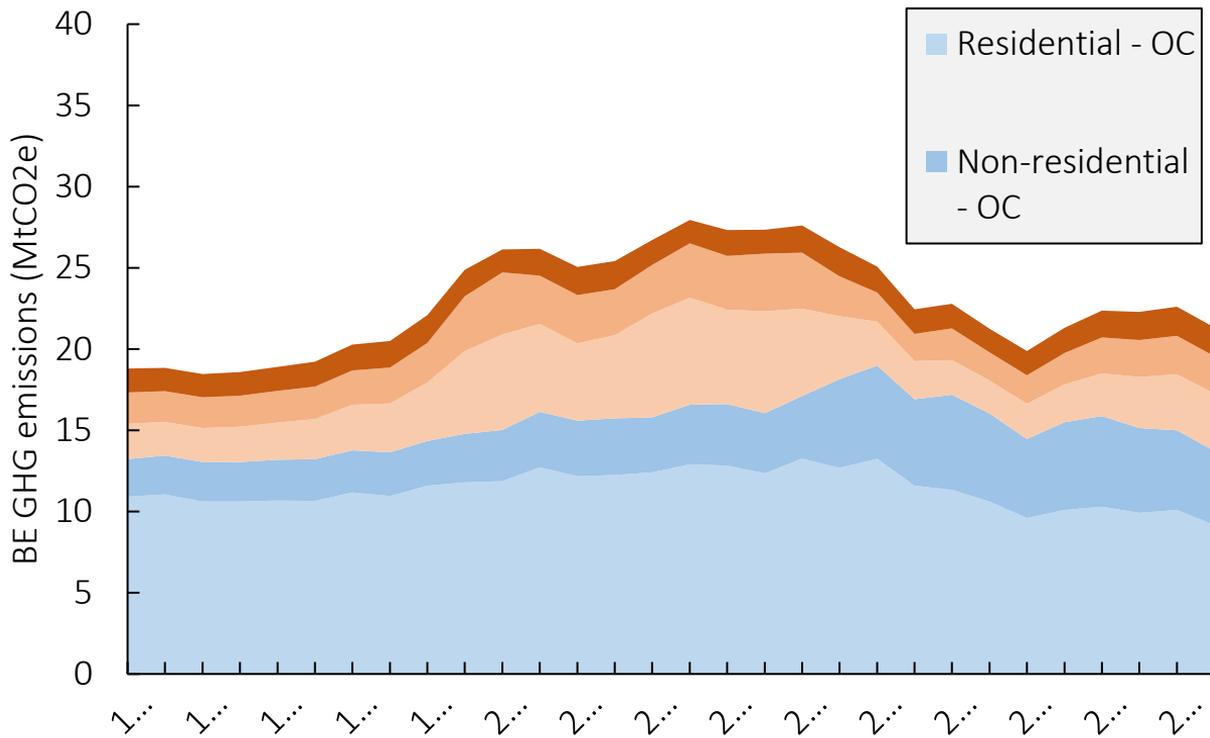
Can MMC be a more sustainable solution?

Yes

Is it?

?

The built environment's GHG emissions



Building and Environment 126 (2022) 109730

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Whole life carbon quantification of the built environment: Case study Ireland

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^b UCD Energy Institute, University College Dublin, Ireland

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A B S T R A C T

The built environment continues to grow rapidly and is currently estimated to account for 36–38% of all Greenhouse Gas (GHG) emissions globally. Continuing at a business as usual trajectory will see global annual increases in GHG emissions as a result of unsustainable urban growth. Some past studies have quantified national GHG emissions associated with the built environment but, to date, no national framework for GHG emissions accounting of the built environment exists. This study presents a robust methodology for estimating GHG emissions associated with the built environment using Ireland as a case study. Taking a Whole Life Carbon (WLC) perspective it quantifies both operational and embodied emissions. One single method is used to operational emission quantification, by which well-documented data exist. For embodied emissions two methods are applied: 1) Material-based emissions are calculated using the Commodity Accounting Method (CAM) and 2) National-level emissions are quantified using measured floor area and other construction-related data (the National Inventory Method¹). GHG Accounting agreements between the methods is observed which enables robust conclusions to be drawn. ~37% of all built GHG emissions are attributed to the built environment while ~12% of these emissions are embedded in the production of the raw materials, the transport of materials and the construction and demolition of buildings and infrastructure.

1. Introduction

Without 'immediate and deep' emissions reductions from all sectors, global warming will rise above 1.5 °C and potentially above 2 °C (1). The sectors responsible for these emissions, as defined in the IPCC (The Intergovernmental Panel on Climate Change) national greenhouse gas inventory guidelines, are Energy, Industrial Processes, Agriculture, Waste and LULU (Land Use, Land-Use Change and Forestry) (1, 2). From a national emissions accounting perspective, the framework is complex and enables comparisons across sectors. However, when the sector of interest is outside this taxonomy, retrospective accounting is required. A 'Built Environment' (BE) sector², which aggregates emissions from the construction and operation of buildings and infrastructure, is one such cross-sector setting. To set policies specific to the built environment knowledge of its Whole Life Carbon impact is required.

This is indeed particularly important as the BE is exhibiting increasing activity, and is being targeted with a range of policies focused on emissions decarbonisation. The BE is commonly thought to account for approximately 40% of all anthropogenic Greenhouse Gas (GHG) emissions. However, this figure varies widely across studies, owing to differences in defining the scope of the built environment and the use of methods or unpublished methodologies.

This paper aims to address some of the challenges associated with quantifying the impact of the built environment, using Ireland as a national case study. Aligning with the focus on Whole Life Carbon (WLC) quantification, in initiatives such as the EU Level(s) framework, both operational and embodied related emissions are captured. An overview of past studies is first presented in Section 2 which discusses the scope and definitions of the built environment and analyses relevant numbers on BE-related GHG emissions (BE-GHG). Section 3 presents the area of this work, it describes two novel methodologies for quantifying BE-GHG emissions defined here as:

1. the Commodity Accounting Method (CAM) which reports GHG emissions by material type and life cycle stage using both production-based (regarding international trade) and consumption-based methods (including imports and exporting exports), and

2. the Sector Inventory Method (SIM) which specifies and estimates emissions from different user groups (residential buildings, non-residential buildings and infrastructure) using national construction figures and average carbon emission intensities.

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E-mail addresses: richard.ohegarty@ucd.ie (R. O'Hegarty), oliver.kinsane@ucd.ie (O. Kinsane).

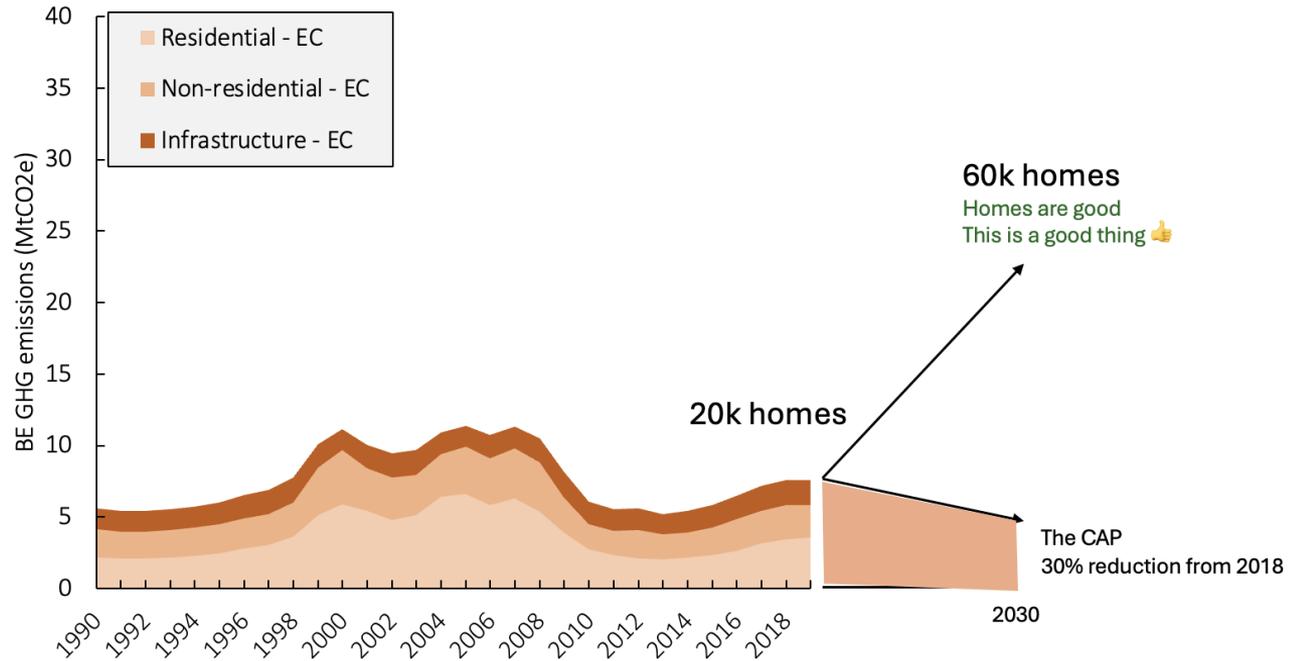
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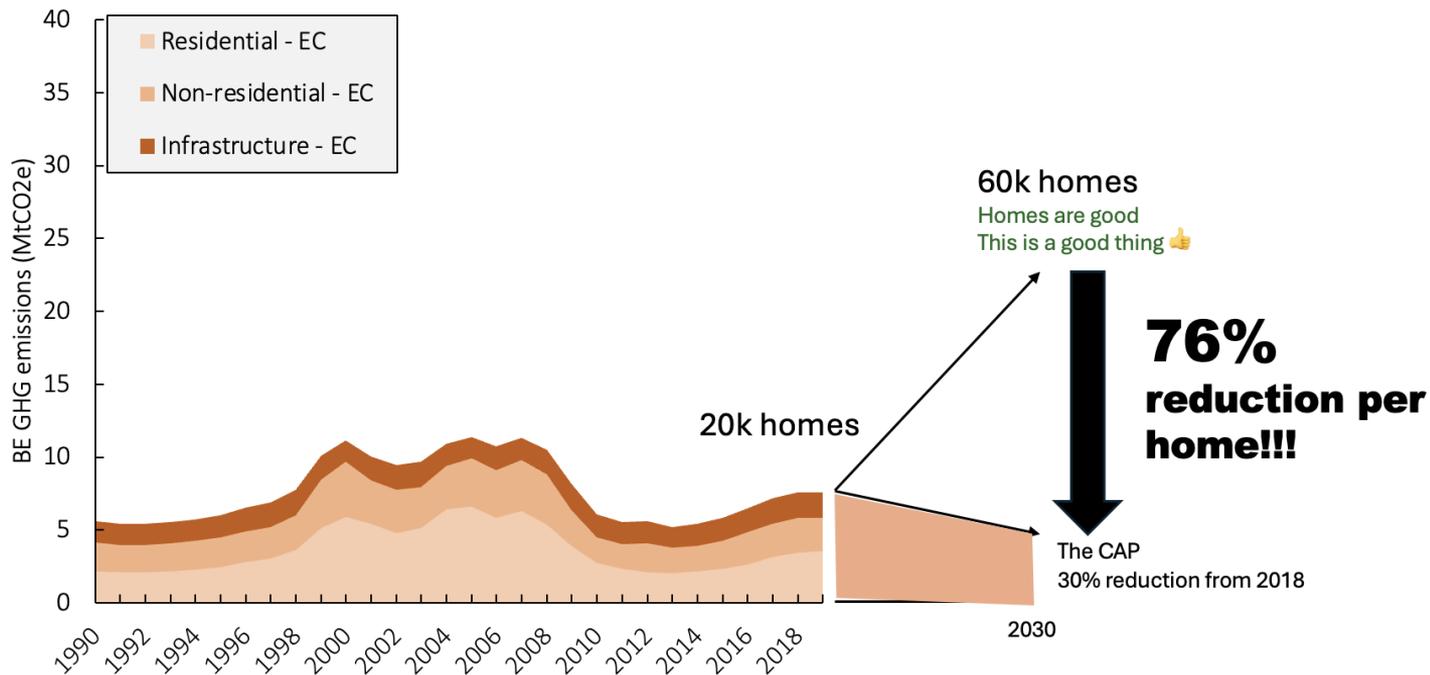
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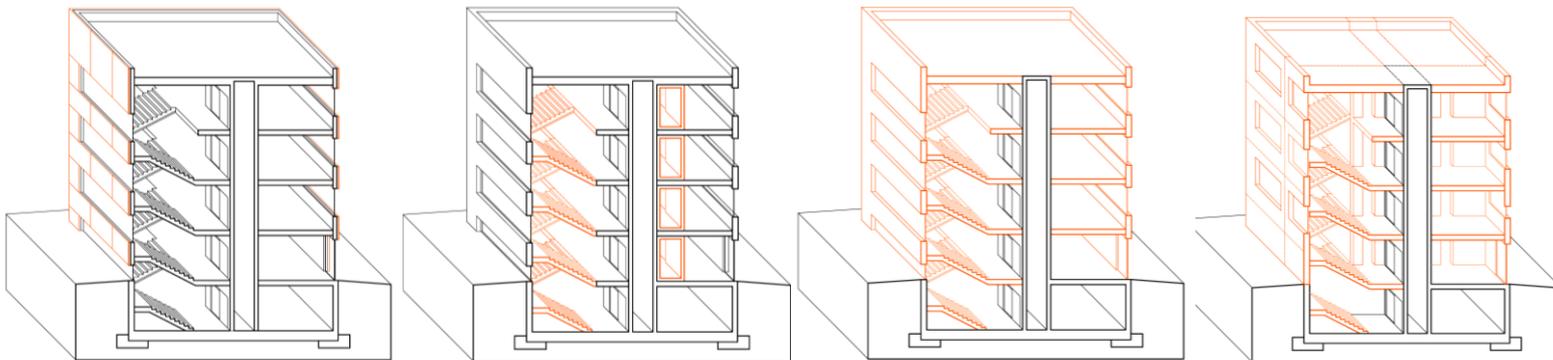
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Embodied carbon baseline



Embodied carbon baseline





“For the purpose of this work, the term “MMC building” herein refers to all buildings that use a form of off-site construction (e.g. MMC, OSM, PFC, etc.) that is consistent with the UK definition of **MMC categories 1, 2, 3 and 5.**”

Table 1. Table of related terms used to describe non-conventional construction (Adapted from (Ayinla et al., 2019; Sánchez-Garrido et al., 2023b)).

Terminology	Acronym	Countries
Modern Methods of Construction	MMC	UK, Ireland, Spain
Off-Site Manufacturing	OSM	Australia
Industrialized Building System	ISB	Malaysia, Thailand
Prefabrication, Preassembly, Modularization, Off-site Fabrication	PPMOF	US
Off-Site Construction	OSC	China
Prefabricated Prefinished Volumetric Construction	PPVC	Singapore
Modular Integrated Construction	MIC	Hong Kong
Off-Site Production	OSP	Germany
Industrialised Construction	-	Sweden, Finland, Denmark
Industrialised Housing	-	Netherlands
Prefabricated Housing	-	Japan, Philippines
Modular Construction	-	Canada

International academic study

Start



Scopus

Search: Abstract OR Title OR Keywords

Search for: { modern-methods-of-construction OR prefabricated-construction OR offsite-construction OR prefabricated-buildings OR mmc OR OSM OR industrialized-building-system OR preassembly OR prefabricated-building OR prefabricated-home OR prefabricated-housing OR modular-construction OR industrialized-construction OR modular-integrated-construction } AND { life-cycle-analysis OR embodied-carbon OR global-warming-potential OR embodied-greenhouse-gas-emissions OR life-cycle-assessment OR whole-life-carbon OR carbon-footprint OR global-warming-potential }

Articles from initial search

n = 250

Stage 1

Initial filtering

Discarded based on a manual review of relevance.

n = 184

Articles after initial screening

n = 66

Stage 2

Further filtering

Relevant but inadequate quantitative data

n = 36

Snowballing

Additional relevant articles not captured in meta search

n = 11

Articles selected for case study analysis

Expanded scope based on references within meta search

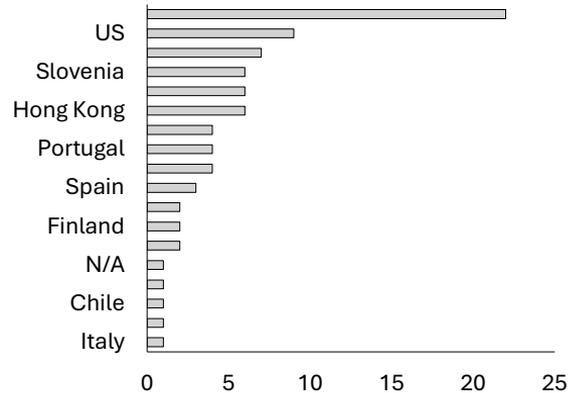
n = 41

Stage 3

Systematic review



Geographical location (count)



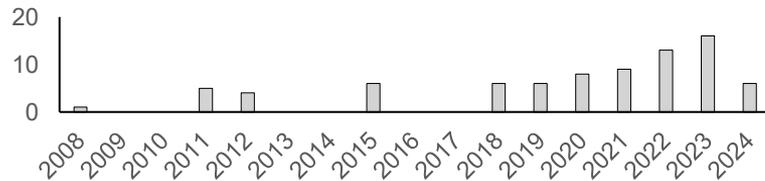
Building function

87% Residential buildings

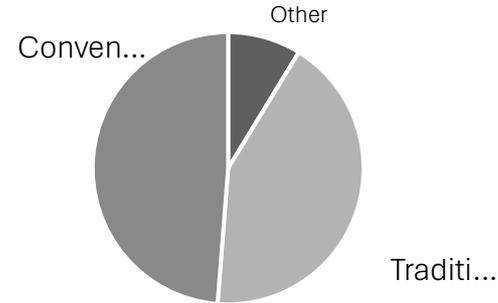
The remaining case studies were a mixture of schools, education buildings, offices or other public buildings.



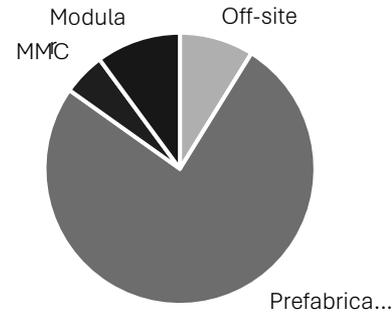
Publication year (count)



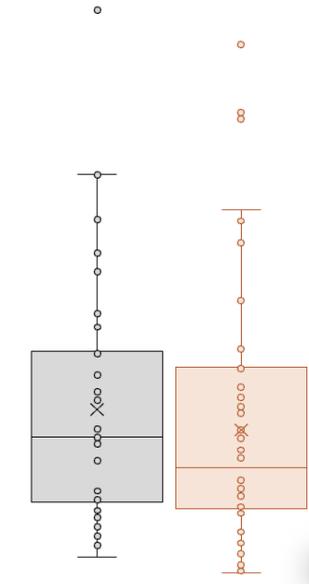
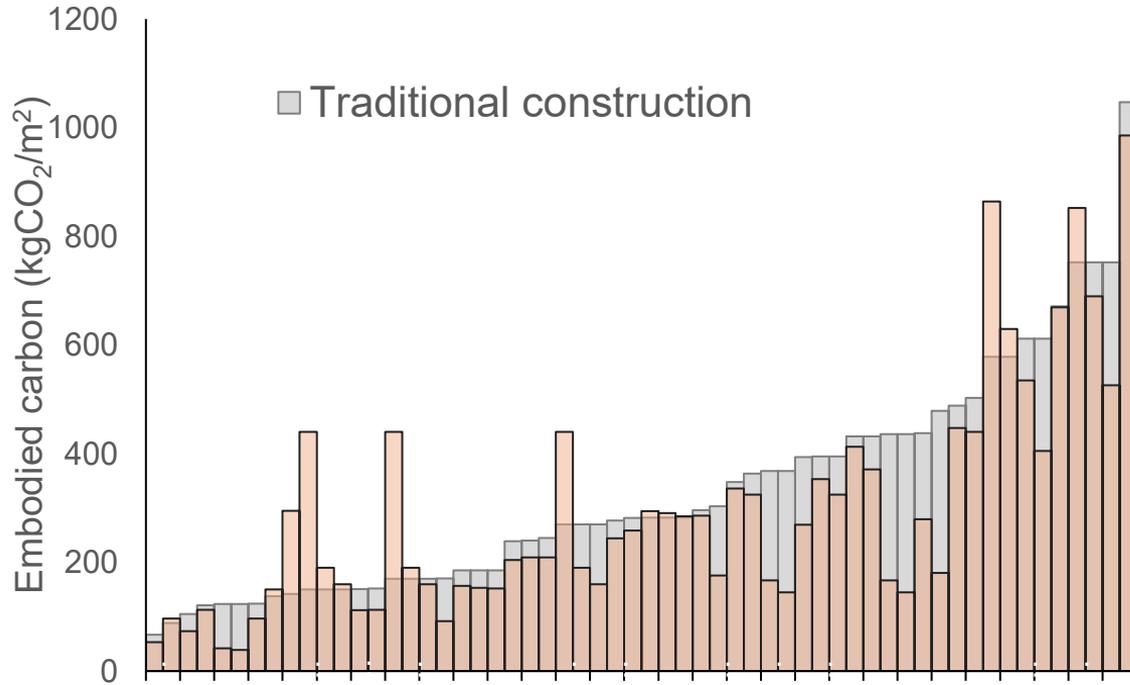
Terminology used for **non-MMC** case study (n = 82)



Terminology used for **MMC** case study (n = 82)

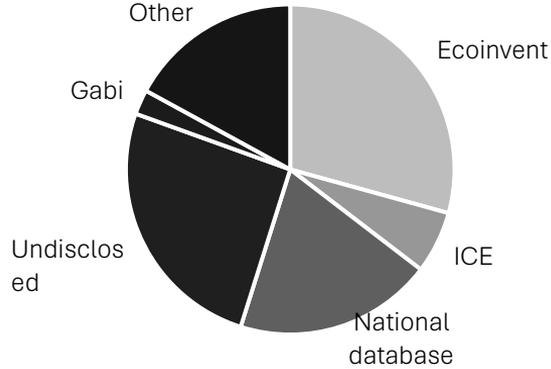


Data spread

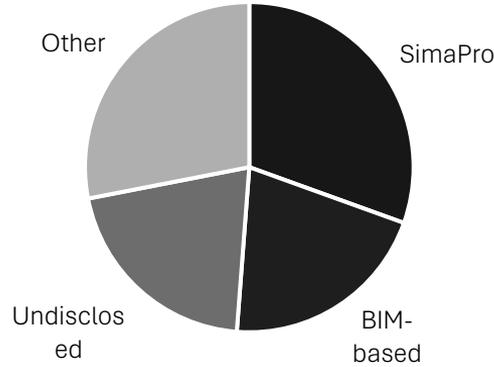


Results – Absolute Values

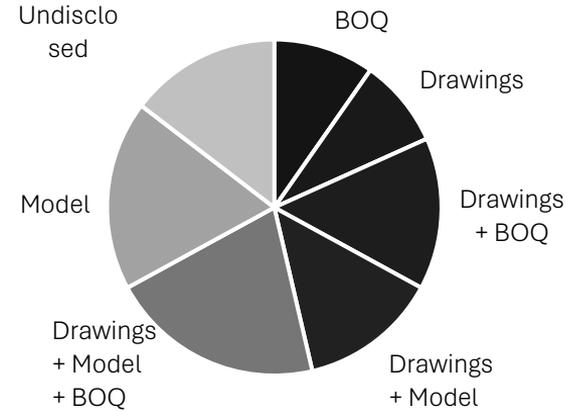
Carbon intensity database



LCA tool



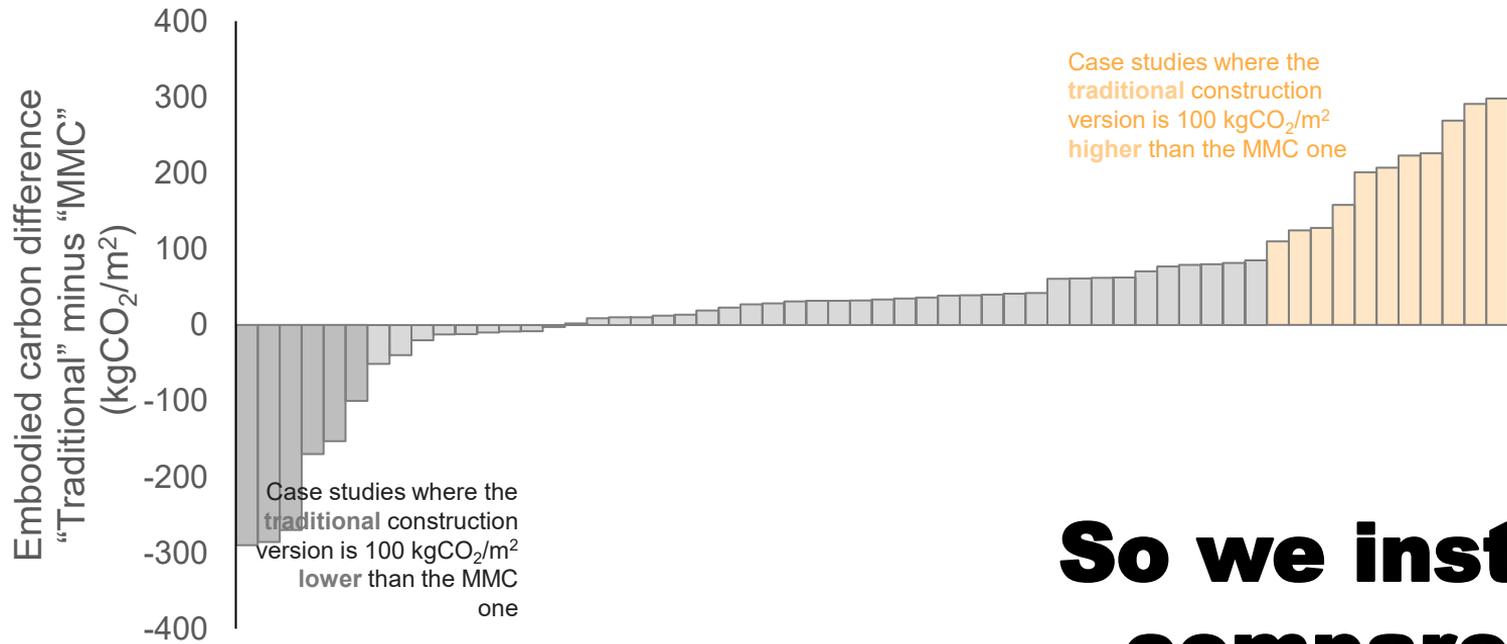
Material quantity source



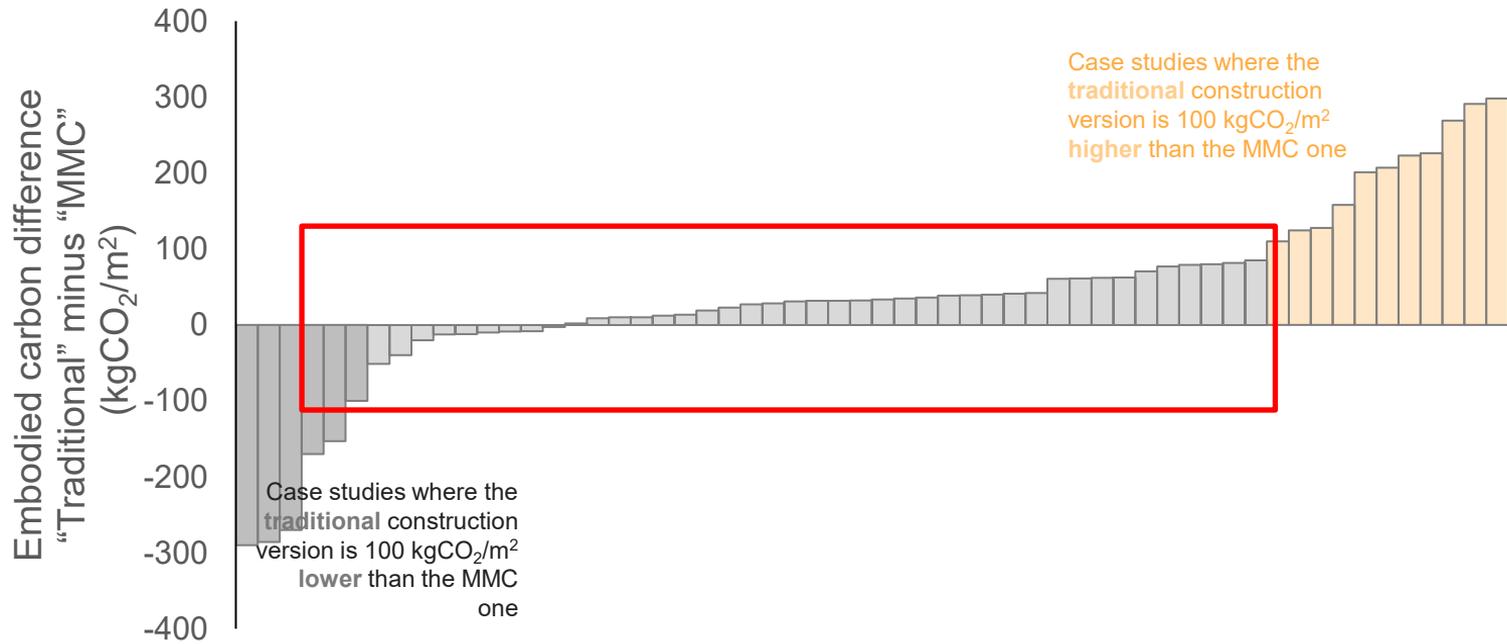
LCA scope

Study reference	Data included in quantitative analysis				Structure	Skin (Façade and roof)	Partitions and finishes	MEP/Services	General description provided in the study
	A1 - A3 (Product)	A4 (Transport to site)	A5 (Construction)	B (Use)					
(Akan and Popovic-Larsen, 2012)	x	x	x						Traditional vs cold-form steel skeleton with cast in situ
(Ayn et al., 2012)	x	x	x		x	x	x		Conventional concrete vs prefabricated modular steel
(Ayn et al., 2012)	x	x	x		x	x	x		Conventional concrete vs prefabricated modular timber
(Bakalbah and Sher, 2021)	x	x	x	x	x	x	x		On-site concrete vs individual panel system
(Bakalbah and Sher, 2021)	x	x	x	x	x	x	x		On-site concrete vs prefabricated prefinished volumetric construction
(Cai et al., 2020)	x	x	x	x	x	x	x		Cast in place vs prefabricated light-steel
(Cao et al., 2015)	x	x	x	x	x				Cast in-situ vs precast concrete
(Chakraborty, 2022)	x	x	x	x	x				Timber-concrete building vs existing-concrete building
(Dehnavi et al., 2023)	x	x			x	x	x		Cast in-situ structure vs precast concrete structure
(Dong et al., 2019)	x	x	x		x	x	x		Cast in-situ apartment a and h vs precast concrete apartments
(Dong et al., 2019)	x	x	x		x				Cast in-situ facade group vs precast concrete facade group
(Dong et al., 2019)	x	x	x		x				Precast concrete facade element vs cast in-situ façade element
(Dui et al., 2019a)	x	x	x		x	x	x		Traditional vs prefab scenario
(Dui et al., 2019a)	x	x	x		x	x	x		Traditional vs prefab scenario
(Dui et al., 2019a)	x	x	x		x	x	x		Traditional vs prefab scenario
(Fahnestock, 2016)	x				x				Concrete vs volumetric modular
(Fazio et al., 2024)	x				x	x	x		Concrete vs cross-laminated timber and glulam columns
(Gao et al., 2024)	x	x	x		x				Cast-in-place concrete building materials case b vs prefabricated component case a
(Gier and Horvath, 2020)	x	x	x		x	x	x		Timber traditional (2 stories) vs steel container modular
(Gier and Horvath, 2020)	x	x	x		x	x	x		Timber traditional (2 stories) vs timber modular
(Gier and Horvath, 2020)	x	x	x		x	x	x		Timber traditional (2 stories) vs steel modular
(Gier and Horvath, 2020)	x	x	x		x	x	x		Timber traditional (3 stories) vs steel container modular
(Gier and Horvath, 2020)	x	x	x		x	x	x		Timber traditional (3 stories) vs timber modular
(Gier and Horvath, 2020)	x	x	x		x	x	x		Timber traditional (3 stories) vs steel modular

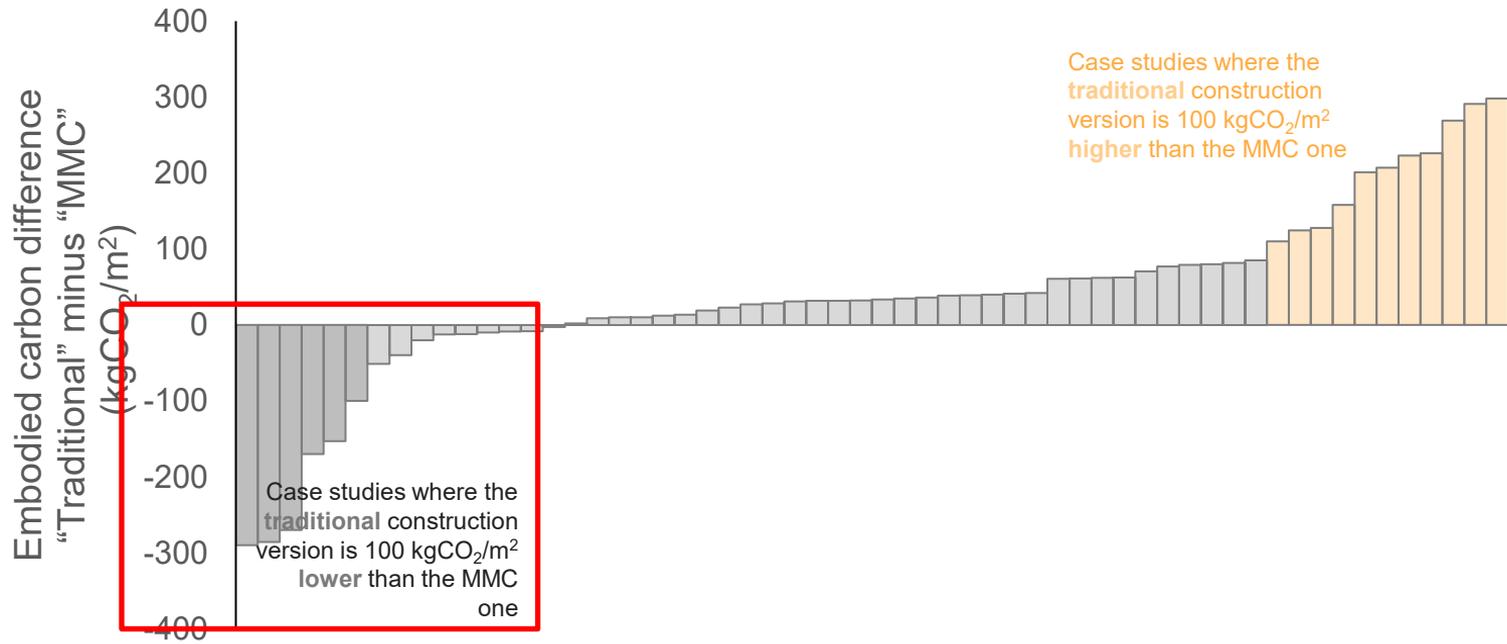
The LCA results are not comparable across studies



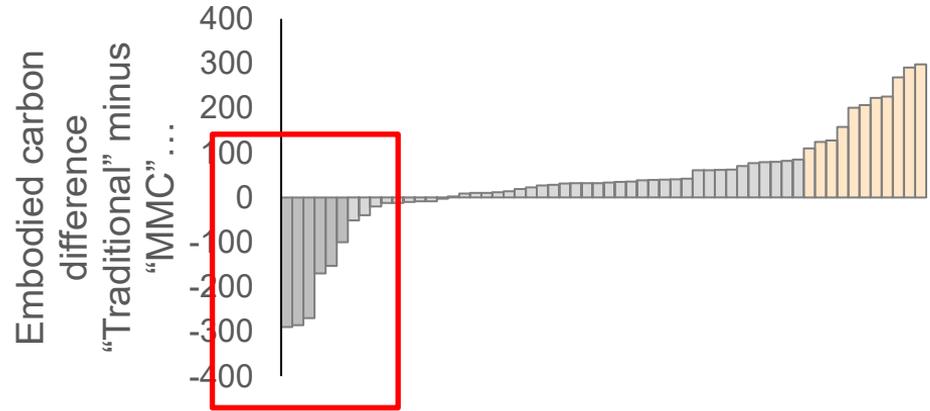
**So we instead
compare the
differences within
individual studies**



Mostly negligible



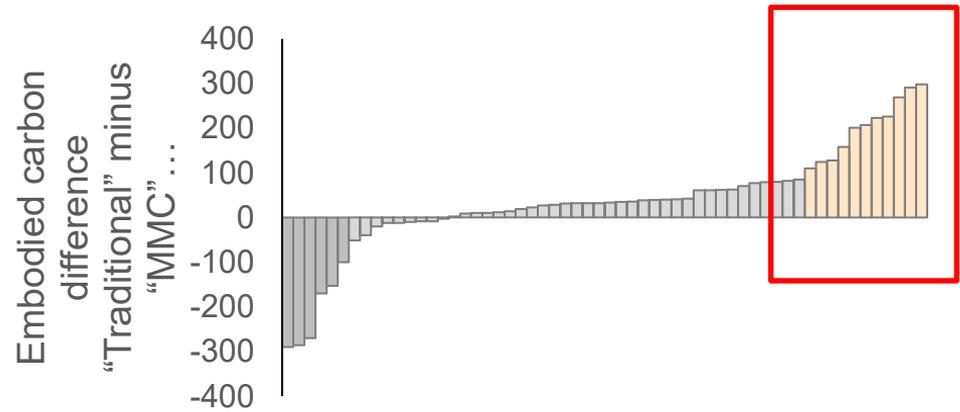
Some pro "traditional"



Mostly modular comparisons

Rationale for higher embodied carbon in MMC:

- Greater variety of structural loads e.g. transport + lifting
- Sub optimal design options at building level
- Shipping container modules particularly high carbon



Primary reasons for lower embodied carbon in MMC:

- Waste reduction
- Timber vs concrete
- Note. Some assumption bias



A presentation on UCD's prototype platform for MMC design, enabling more coordinated, repeatable and efficient design workflows

Oliver Kinnane. Head of School Architecture, Planning and Environmental Policy, UCD

Understanding the embodied carbon credentials of modern methods of construction

RICHARD O'HEGARTY ● **THANAT THANAPORNPAKORN SIN** ●
AISLINN MCCARTHY ● **SAMAR RAFFOUL** ●
JACK O'HAGAN ● **OLIVER KINNANE** ●

**Author affiliations can be found in the back matter of this article*

ABSTRACT

This study assesses the embodied carbon credentials of modern methods of construction (MMC) by conducting a critical literature review and synthesis of the findings. While several studies have reviewed the broader impacts of MMC, no other study to date has comprehensively reviewed the embodied carbon credentials of this construction typology. Since MMC is not an internationally recognised term, the assessment is inclusive of other terminology used in different parts of the world – e.g. prefabrication, off-site construction and industrialised construction. The study captures 250 separate studies and distils these to a final sample set of 41 studies and a total of 82 case study comparisons. Although a general perception exists that the adoption of MMC results in embodied carbon savings, the evidence to support this claim is not robust. The results from individual case studies range significantly in both direction and magnitude, and, in the absence of a critical review, considerably different conclusions can be drawn. Upon critique and synthesis of the published studies, it is found that the adoption of MMC has no significant positive, or negative, impact on the embodied carbon of a building.

POLICY RELEVANCE

MMC have been widely cited as the answer to housing shortages and productivity issues in the construction industry more broadly. They have subsequently attracted political attention and implementation in many regions. Embodied carbon is another topic of continued debate in built environment policy. There is a somewhat hopeful assumption that the adoption of MMC will reduce embodied carbon. But, to date, the evidence to arrive at that assumption has been inconsistent. The literature that compares MMC with traditional construction varies considerably. It is found that there is no broad link between MMC and reduced embodied carbon. Reducing the embodied carbon of buildings requires assessment on a case-by-case basis.

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KEYWORDS:
modern methods of construction (MMC); embodied carbon; life cycle analysis; environmental impacts; prefabrication; buildings; construction industry

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