UPFRONT CARBON IN THE BUILT ENVIRONMENT

A discussion paper on upfront carbon standards, measurement methods, benchmarking and resources for construction materials, buildings and infrastructure prepared by MECLA.

MECLA

October 2022

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COLLABORATION FOR CHANGE

Glossary

ABS	Australian Bureau of Statistics
AUSLCI	Australian National Life Cycle Inventory Database
BAU	Business as usual
CO2e	Carbon dioxide equivalent
EN	European Standard
EPD	Environmental product declaration
EPiC	Environmental Performance in Construction database
ESG	Environmental, Social and Governance
GFA	Gross floor area
GHG	Green house gas
GWP	Global warming potential
HLCA	Hybrid life cycle assssment
ICMS	International Cost Management Standard
IE Lab	Industrial Ecology
IOLCA	Input-output life cycle assssment
ISO	International Organization for Standardisation
LCA	Life cycle assessment
LCI	Life cycle indicator
MECLA	Materials & Embodied Carbon Leaders Alliance
NLA	Net lettable area
PAS	Publicly Available Specification
PCG	Project Control Group
PLCA	Process life cycle assessment
RICS	Royal Institution of Chartered Surveyors
TN	Technical Report
TS	Technical Specifications
WG2	Working Group 2

Executive Summary

Members of the Materials Embodied Carbon Leaders' Alliance (MECLA) Working Group 2 were tasked with authoring a discussion paper that documented the state-of-play on upfront embodied carbon standards, measurement, benchmarking and resources for construction materials, buildings and infrastructure. The scope of the exercise was limited to upfront carbon and the single impact indicator, Global Warming Potential (GWP) in kg CO2-e. This paper does not make recommendations. It is a snapshot of information at a point in time and a mechanism to seek feedback from industry stakeholders to inform future work directions.

- **Standards:** Identify and map the hierarchy and relationship
- **Quantification:** Identify methods and their application in scale and design stage
- **Comparable units:** Consider functional or declared units as they apply to user needs at each scale
- **Benchmarking:** Identify different approaches to benchmarking using averages at scale
- **Tools and Data:** Compile a list of embodied carbon calculation tools and data sources
- **Survey:** Seek feedback by an industry survey

NABERS – Embodied Carbon

NABERS is currently working on the technical development of a framework to assess the upfront carbon rating of buildings. This is expected to include a the scope of what will be included in the assessment, the calculation method to quantify the emissions of building materials, and the approach to a certification process consistent with other existing NABERS certifications. The core technical elements of the NABERS framework are expected to be released for public consultation later in 2022.

The NABERS framework is focusing on the specific issue of comparing and reducing the upfront carbon of whole buildings and how this should be structured to support accurate benchmarking of outcomes.

There is cross over between NABERS work and the content of this WG2 discussion paper - both informing the other. NABERS and GreenStar technical members have participated in this working group.

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Discussion Paper: Incorporating feedback themes and updated approach

The discussion paper has undergone two rounds of feedback and updates within the MECLA Working Group 2 and a final review by the MECLA Project Control Group.

Section	Key feedback themes	How feedback was addressed
Overall paper structure	Scope and intention of document need to be made clearer. More detail needs to be provided to explain each section. Make easier for a non expert LCA-practitioner/ non academics etc to read.	Discussion paper has been updated to make the purpose for each section clearer and better explain the diagrams and tables. Purpose of the document has been clearly stated as a 'state of play' review for information and education. Wording has been updated to make easier for non-practitioners to understand. The conclusion of each section includes questions on possible areas of future focus for MECLA.
Standards	Revise structure to represent hierarchy of application of standards (materials/buildings/infrastructure), consider relationship between standards to ensure consistent assessment of their application.	Hierarchy structure has been revised to reflect Product/material -> Asset level (Buildings/infra)->Organisational GHG reporting. Assessment of standards against the Environmental assessment and carbon accounting was reviewed and updated for consistency.
Declared / Functional Units	Mostly minor suggestions to change units and/or categories for some materials/ buildings/ infrastructure, questions seeking clarification between the use of "declared unit" and "functional unit"	Purpose slide added to make the intent of the section clearer. Suggested new product types have been added – noting this list is not exhaustive. Infrastructure section is still work in progress and for industry input as part of the survey.
Quantification Methods	Majority concern that limitations of the methods were not balanced and needed additional supporting evidence. Concern of the promotion of one methodology.	Whole revision of this section has been made taking account the feedback. Language reframed and additional references provided for all methods. Efforts made to distinguish methods at material / building / infrastructure scale as well as use across the design and construction delivery phases (i.e from feasibility to "as-built").
Benchmarking Methods	Further explanation needed to address the intent of the graphs as this was not clear.	Section revised to try and assist comprehension at material and building scales.
Calculation Tool and Data Inventories	Suggestions of additional tools and data inventories that should be included. Section to be completed.	Suggested tools and data inventories have been added and the section further completed to provide greater detail for each tool/data inventory.

Purpose of this Paper

This document is not exhaustive, nor a technical research paper intended for peer review journal publication. This paper has been produced by MECLA Working Group 2 (WG2). WG2 has had **to balance simplicity and technicality** to deliver an output which a reader might reasonably consume within a limited timeframe. WG2 was divided into 4 sub-groups each tackling a core element. As such **each chapter attempts to be self-contained - but should be considered ultimately as a whole.**

It is generally acknowledged that significant **technical complexity exists which can be a barrier to adoption and engagement** across the broad variety of industry stakeholders. The document has been reviewed by WG2 members (a full list of those in WG2 is below). **This document makes no recommendations**, rather, **it is a presentation of information and a platform to seek feedback via survey** to a variety of questions. The results of the survey, it is hoped will **inform MECLA and industry and government on important issues and activities to further pursue** towards its overall goals and objectives. WG2 hopes that your responses will increase our collective understanding of the means to reducing barriers to action, and industry's desire to take practical action at the greatest possible speed.

The goal of WG2 has been to construct a document which is broadly accessible to the average industry stakeholder as a priority, rather than being a deep LCA technical paper for LCA practitioners. We have **structured the document to broadly align with ISO 14044** to assist the reader to gain an appreciation of the issues as well as the dependencies between them. We also attempt to **make clear that the scope of the document is for "upfront embodied carbon" for materials (A1-A3); a building (A1-A5) and infrastructure (A1-A5).** The paper opens with a section on the **variety of prevailing Standards** and tries to **distinguish "carbon" from "broad LCA".** Next, a **"methods" section provides an overview of the options for calculation** and how these can be used to achieve a study goal /use. It has been a challenge to try to deal with methodology as it pertains to **"Life Cycle Inventory" (LCI)** and **"Life Cycle Assessment" (LCA).** A section on **"units" of measure** is next - the main goal here is to seek input from the industry as to what would be most useful and practical at the "material selection / comparison" task. Then follows a section on **"benchmarking / comparison" of materials and buildings** - a selection of **approaches used across the world is presented** - with input sought on what stakeholders find useful and instructive. The final section is a compilation of **calculation tools and data sources** which may assist but is not meant to be taken as finite. **Other sources are welcomed.**

Declaration of Commercial Interests

The members of WG2 are listed below alongside the declaration of interests aligned with the MECLA Governance Framework. Four sub-task groups were created to assist with each chapter of the report. The leaders of each of those sub-task groups are highlighted in BOLD.

Name	Organisation	Statements of Commercial Interest
Adam Jones	XLam	Technical Manager for XLam (development of mass timber products GLT/CLT)
Aidan Mullan	Interface	Sustainability Manager, Interface. Interface manufactures carbon neutral modular carpet in Australia and is a supplier of carbon neutral resilient flooring. Want to see an agreed, standardised, reference database to guide selection of low embodied carbon (A1-A3) building materials and product.
Andrew Wheeler	ABES	
Anna Schlunke	Planning NSW	BASIX Senior Technical Operations Officer at NSW Department of Planning and Environment
Anthony Lieberman	AIQS	Feasibility, development, and distribution of information, guidance, and standards on the quantification and benchmarking of embodied carbon for quantity surveying professionals practicing in Australia.
Barbara Nebel	thinkstep-anz	Provision of consulting services on embodied carbon of buildings and materials, Life Cycle Assessment and development of EPDs for clients
Brendan Liveris	Hanson	National Sustainability Manager, Hanson Australia (including Alex Fraser Group, Hymix, Pioneer North Qld), Construction materials supplier.
Brett Pollard	Hassell	Sustainability Leader. Provision of multidisciplinary design services to clients.
Caroline Noller	Footprint Company	WG2 Co-Chair. CEO Footprint Company. Developer of WOL carbon footprint calculators for buildings and materials carbon information (GreenBook)
Chris Jones	Boral	Technical Sales Manager. Concrete suppliers
Darryl Stuckey	Lendlease	Senior Manager, Sustainability Transformation
David Bell	InfraBuild	Manager Sustainability & Insight, InfraBuild Steel. Scrap Recycling, manufacturing, processing and distribution of reinforcing and structural steel products.
David Law	Aurecon	Provision of consulting services of structural engineering design to clients
Deepali Ghadge	Pangolin Associates	Carbon and Energy Consultant, LCA practitioner
Elizabeth Cuan	Edge Environment	Senior Consultant, Edge Environment
George Sfinas	Standards Australia	WG2 Sub task Lead. Development of Australian and adoption of International Standards
Guy Manthel	Knauf	Technical Product Manager Knauf.
Jacqui Bonnitcha	Lendlease	WG2 Sub task Lead. Manager, Sustainable Futures an internal technical sustainability advisory unit for Lendlease businesses.
James Bedford		
James Endean	Pangolin Associates	Senior Carbon and Energy Consultant. Provide advisory services on organisational, product and building greenhouse gas emissions.
James Mortensen	Slattery	Carbon Planning Lead. Provision of consulting services on upfront embodied carbon to clients.
Jarrod Parker	GHD	Provision of consulting services on embodied carbon to clients.
Jason Nairn	CCAA	Director-Research and Technical Services for CCAA peak industry body (not for profit).
Jocelyn Chiew	City of Melbourne	Director City Design, City of Melbourne
Joel Clayton	CCAA	National Sustainability Manager for CCAA peak industry body (not for profit).

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Name	Organisation	Statements of Commercial Interest
Jorge Chapa	GBCA	Rating new construction through Green Star
Kalpesh Patel	Stockland	Sustainable Projects Manager Communities, Group Sustainability at Stockland (National Real Estate Developer)
Lachlan Ramsey	AECOM	Provision of consulting services on embodied carbon to clients.
Laszlo Peter	KPMG	Head of Blockchain Services Asia Pacific
Laura Guccione	BlueScope	Senior Sustainability Technical Advisor for BlueScope, a provider of steel products, systems and technologies.
Lauren Howe	Arup	WG2 Co-Chair. Provision of consulting services on embodied carbon to clients.
Lucy Marsland	Atelier Ten	Provision of consulting services on embodied carbon to clients.
Maryia Perthen	eTool	Director and BDM at eTool - LCA software provider
Mehdi Robati	Lendlease & Researcher	Senior sustainability consultant at Lendlease and an active Researcher in the fields of Low-Carbon building and Carbon Value Engineering.
Melissa Gaspari	Andefena	Associate provision of consulting services regarding emissions including embodied carbon
Melita Jazbec	Institute for Sustainable Futures, UTS	Senior research consultant at Institute for Sustainable Futures at UTS. Research area and consultancy services in circular economy
Rob Campbell	eTool	Services Team leader at eTool. eTool is LCA software provider
Rodrigo Martinez	Pathzero	Sustainability Consultant at Pathzero. Other interests in relation to the subject matter of WG2 on measuring Embodied Carbon: providing sustainability advice and consultancy to companies to drive best carbon accounting practices in the asset management sector
Sadeq Zaman	Department of Planning and Environment (NSW)	Provision of technical services in water infrastructure projects and assessment of major planning proposals (state significant development and state significant infrastructure in the Sydney Region under the EP&A Act)
Steve Mitchell	EPD Australasia, thinkstep-anz	Chair, EPD Australasia Ltd - operating an ISO 14025 / EN 15804 compliant (process LCA-based) Environmental Product Declaration Programme on a commercial basis; Principal Consultant with thinkstep-anz - provision of life cycle assessment and related services such as verified EPDs (including embodied carbon) for clients.
Supratik Ghosh	NABERS	NABERS Sector Expansion Lead developing the embodied carbon initiative
Toktam Tabrizi	Atelier Ten	Provision of consulting services on embodied carbon to clients.
Tyrel Momberg	ISC	Rating Infrastructure projects through IS Ratings. ISC owns and manages the Infrastructure Sustainability Materials Calculator (used within IS submissions).
Yusi LI	GHD	Provision of consulting services on embodied carbon to clients.

SECTION 1

BACKGROUND

Purpose of the MECLA Alliance

This collaboration of organisations comes together to drive reductions in embodied carbon in the building and construction industry. We seek to align with the Paris Agreement targets and principles of the circular economy and recognise that the building and construction sector is a complex ecosystem.

We will do this by:

- **Demonstrating the demand** and activating the supply of materials which meet the needs of net zero carbon goals.
- **Defining a best practice embodied carbon evaluation framework**
- **Knowledge sharing** through best practice education, case studies, myth-busting, demonstrations, and supporting innovation in materials and processes as part of a pre-competitive approach.
- **Developing common language** for design specifications, procurement guidelines and tendering criteria as standard practice for government agencies and companies.
- Helping to manage industry's **climate transition risks, risks associated with adopting innovative materials** and the required skills development.
- **Supporting materials** such as steel, cement and concrete, and aluminium **to reduce their carbon intensity** and giving **visibility to other low carbon and innovative materials incl Services/Systems** in the built environment.

COLLABORATION FOR CHANGE

MECLA Founding Members

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AECOM
Australian Institute of Landscape Architects
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Australian Ethical
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BINGO INDUSTRIES
BlueScope
BMT
BORAL
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BuildFit
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MOTT MACDONALD
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Objective and Background

Introduction

The objective of MECLA Working Group 2 (WG2) – is to contribute to the construction industry's understanding and application of the types of quantification and benchmarking approaches for upfront carbon performance at relevant scales. This area is known for its technical complexity and so WG2 have tried to provide a state-of-play as well as areas for further / future work, in a "plain-English" style with the aim of supporting engagement and comprehension by both practitioners and non-technical industry stakeholders. A key issue is how to overcome the complexity which has been a key barrier to progress.

This paper summarises the research findings and seeks input and feedback from stakeholders to assist with further work for MECLA.

What is apparent by the information presented and questions asked, is that embodied carbon is a very complex issue that would benefit from significant further research and development investment to reduce complexity, increase consistency and comparability and thus aid the transformation of the construction sector to net zero track by 2040.

Document Structure

This discussion paper is divided into five sections:

- Section 1: Identify and map the hierarchy and relationship of related embodied carbon "Standards"
- Section 2: Quantification methods and their application in scale and design stage
- Section 3: Considers Functional / Declared Units as they apply to User needs at each scale
- Section 4: Approaches to empirical benchmarking (establishing average) at scales
- Section 5: Compilation of a list of a) embodied carbon calculation tools and b) Data sources

In addition to the discussion paper there is a survey to provide feedback. In each section there is a summary page with the survey questions presented.

Scales and Scope of Assessment

The diagram attempts to define the specific scope of this paper as "upfront carbon" in the context of a) individual materials b) the whole building and c) infrastructure scales. Which recognises that there are differing "technical needs and methods" applicable for embodied carbon at each of these scales and across the project/ asset life cycle.

This Scope was agreed by MECLA PCG and is the focus of Working Group 2 consideration and research.

A single impact indicator = Global Warming Potential (GWP) Carbon (in kg CO2-e)

LCA (ISO 14044) is generally broken into 4 main "stages" known as A,B,C & D and described in EN 15978 and 15804. Stage "A" pertains to the upfront "cradle-to-gate" processes and impacts of a product system. In this document, to assist comparability - materials are considered A1-A3 (cradle to final production gate) and buildings/infrastructure extended to include A4 and A5 - to final installation at practical completion.

A1-A3 at the basic material and assembly level.
A1-A5 at the building and infrastructure level.

Note this paper only considers upfront carbon and does not consider in-use (B1-B5); end of life (C1-C4) or D. We recognise the need to balance the whole of life issues – as an initial priority MECLA is looking to address A1-A5.

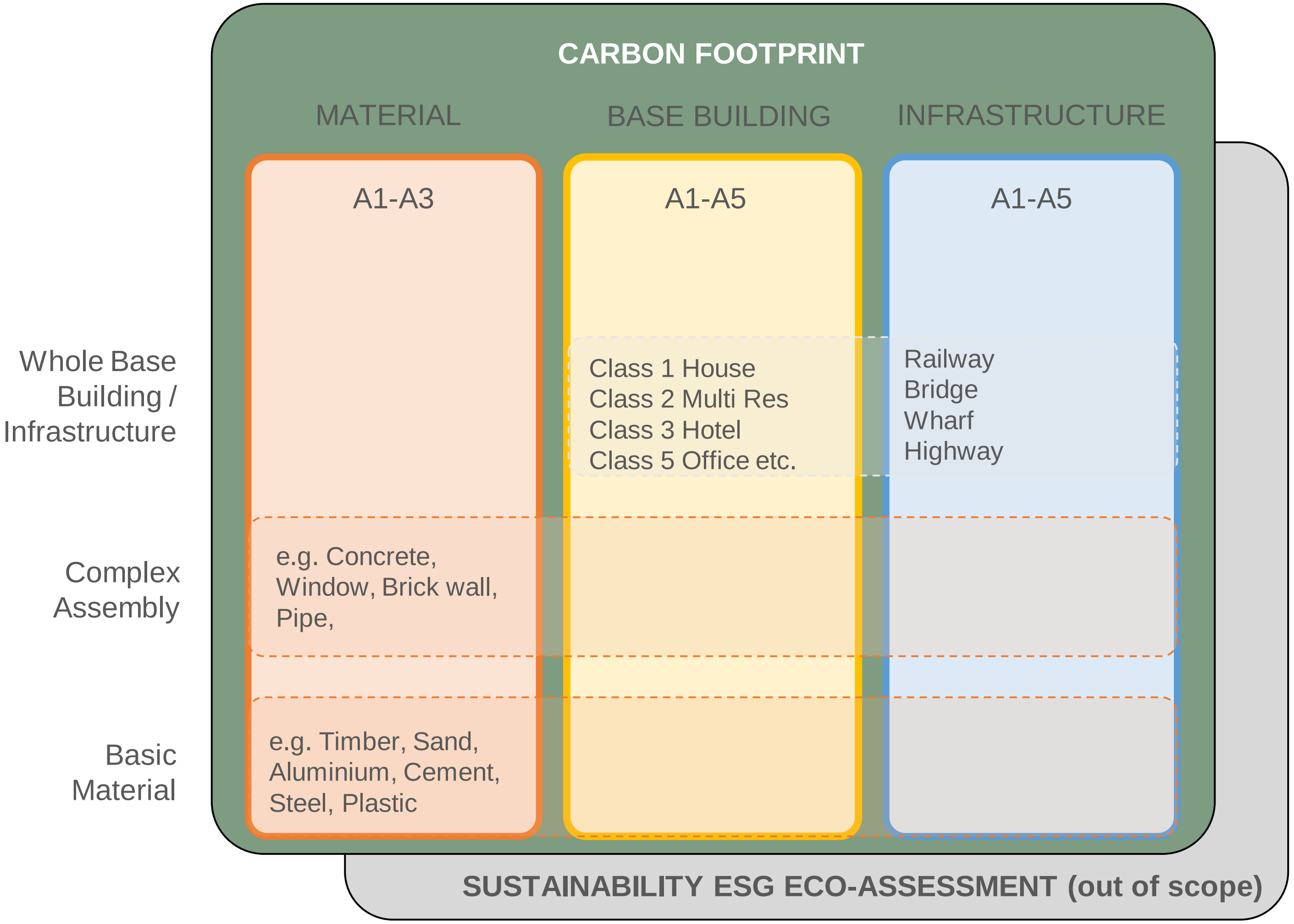


Figure 1: Scales and Scope of Assessment

SECTION 2

EXISTING STANDARDS RELATED TO EMBODIED CARBON

Standards - Purpose

This section summarises the results of an extensive scan to identify and map standards related to embodied carbon. The following process was undertaken to identify and map the hierarchy and relationship of embodied carbon standards:

1. Identify and list current ISO and other Standards related to embodied carbon evaluation / benchmarking;
2. Identify and consider all other property industry normative standards and approaches to measurement which could be adopted;
3. Map the relationship amongst these;
4. Consider each **scale** "product, building, infrastructure";
5. Consider **type** of standard "broader environment & carbon accounting" separately.

The objective was to identify and map the relationships amongst the various standards and highlight complexity / overlap and coverage.

Over 150 standards were identified. These were subsequently reduced and synthesized to arrive at a core groups of "standards" most closely aligned and relevant to "embodied carbon" at material / building and infrastructure scale.

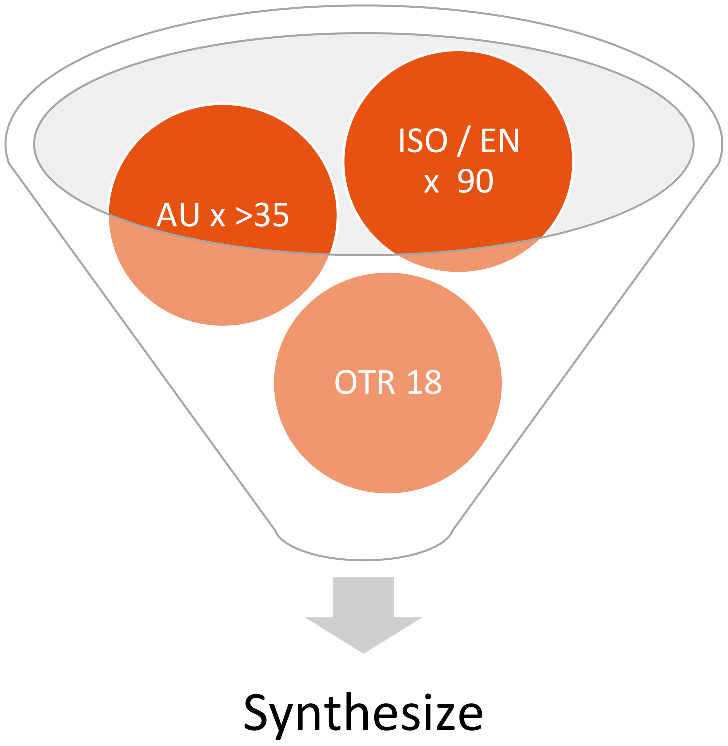


Figure 2: Number of standards reviewed

Note on terminology used:

Scales: Material, Building, Infrastructure (organisation was identified but is not a focus of this paper).

Type: Broader sustainability/environmental impact standards and specific carbon accounting/management standards.

Standards - Findings

Over 143 standards were identified (many with multiple variants and editions). Considerable effort was required to map the relationships and precedent amongst the standards. These were subsequently reduced and synthesized to arrive at a core groups of "standards" most closely aligned and relevant tosingle impact point, "embodied carbon" at material / building and infrastructure scale.

Hierarchy:

The hierarchy of standards (on the following page) was assessed via the three scales referenced in the earlier slide in ascending order: material/product, building, and infrastructure.

A fourth scale was also identified of organisational /business emissions reporting however is not in scope of the paper.

The hierarchy on the following page shows the relationship amongst these.

Table 1 does not contain an exhaustive list of standards. Rather, it gives an insight into the extent of standards that apply to the four scales. Note that some of the standards can be categorised into multiple scales, depending on the scope of the standard.

A common theme in both the hierarchy of standards as well as the standards map (Table 2) was to distinguish between two types of standards: those applicable to broader environmental / sustainability impact assessment (multi-indicator standards) (e.g. EN15987) and those applicable only to single LCA indicator carbon accounting/management (single-indicator standards) (e.g. ISO14067 carbon footprint of products).

Standards Application Map:

The standards map (Table 2), identifies and maps relevant sustainability standards that relate to both types identified above as well as to the three scales. The standards range from ISO/EN standards to industry standards such as the GHG Protocol and International Cost Management Standard.

There are two main assessments in the Standards Application map.

1. Whether the standard is a single or multi-impact indicator standard i.e. carbon accounting/management OR full 'life cycle assessment broader environmental impact categories.
2. Which scale does the Standard apply to i.e. material, building and infrastructure scales.

Standard that apply are identified with a green 'Y'. Standards that do not apply are identified with a red 'N'.

Hierarchy of Standards

Table 1 presented here summarises the hierarchy of standards against the four scales. The table does not contain an exhaustive list of standards. Rather, it gives an insight into standards that apply at each scale.

		Life Cycle Assessment (ISO 14040:2006 / ISO 14044:2006)	
Scale	Scale Description	Broader environmental impact categories (multi-indicator including carbon)	Carbon Footprint (single indicator)
Products	Standards which provide requirements and guidance for quantifying/communicating the footprint of a product/material.	EN 15804:2019 ISO 14025:2006 ISO 21930:2017	GHG Protocol - Product Standard ISO 14067:2018 PAS 2050: 2011
Buildings	Standards that provide requirements and guidance for assessing the footprint of a building (base building and or fitout / whole building)	EN 15978:2011 ISO 21929-1:2011 ISO 21931-1:2010	International Cost Management Standard 3 RICS - Whole life carbon assessment for the built environment PAS 2060 ISO 14067:2018
Infrastructure	Standards that provide requirements and guidance for assessing the footprint of infrastructure (e.g. road / rail / dam / port etc)	ISO 15392:2019 ISO/TS 21929-2:2015 ISO 21931-2:2019	International Cost Management Standard 3 ISO 14064-1:2018 PAS 2080
Organisational/ Business emissions reporting	Standards that provide requirements and guidance for companies/organisations to report emissions and understand environmental footprint	ISO 14007:2019	GHG Protocol - Corporate Standard

Table 2: Standards application map

Standard	Designation	Title	Summary	Life Cycle Assessment					
				Broader Sustainability/ESGs			Carbon Accounting & Management		
				Material	Building	Infra-structure	Material	Building	Infra-structure
International Organisation for Standardisation	ISO 14007:2019	Environmental management — Guidelines for determining environmental costs and benefits	Guidelines on determining environmental costs and benefits associated with broad environmental aspects	Y	Y	Y	N	N	N
	ISO 14025:2006	Environmental labels and declarations — Type III environmental declarations — Principles and procedures	Establishes principles, procedures for developing environmental declarations and using environmental information	Y	Y	Y	N	N	N
	ISO 14026:2017	Environmental labels and declarations — Principles, requirements and guidelines for communication of footprint information	Provides principles, requirements and guidelines for communicating the environmental footprint of products	Y	Y	Y	N	N	N
	ISO 14040:2006	Environmental management — Life cycle assessment — Principles and framework	Definition of the goal and scope of Life Cycle Assessment and Life Cycle Inventory analysis phase	Y	Y	Y	Y	Y	Y
	ISO 14044:2006	Environmental management — Life cycle assessment — Requirements and guidelines	Sets out specific requirements of Life Cycle Assessment, Life Cycle Inventory	Y	Y	Y	Y	Y	Y
	ISO 14064-1	Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals	Establishes principles and requirements for the quantification and reporting of greenhouse gas emissions and removals	N	N	N	Y	Y	Y
	ISO 14067:2018	Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification	Quantification/reporting for the carbon footprint of a product	N	N	N	Y	Y	Y
	ISO 14080:2018	Greenhouse gas management and related activities — Framework and principles for methodologies on climate actions	Provides a guideline for establishing approaches and processes to methodologies on climate change	N	N	N	Y	Y	Y
	ISO 15392:2019	Sustainability in buildings and civil engineering works — General principles	Establishes general principles for sustainability in new and existing buildings, materials, products etc.	Y	Y	Y	N	N	N
	ISO 21678:2020	Sustainability in buildings and civil engineering works — Indicators and benchmarks — Principles, requirements and guidelines	Principles, requirements and guidelines for the establishment and use of benchmarks related to environmental performance	Y	Y	Y	N	N	N

Table 2: Standards application map

Standard	Designation	Title	Summary	Life Cycle Assessment					
				Broader Sustainability/ESGs			Carbon Accounting & Management		
				Material	Building	Infra-structure	Material	Building	Infra-structure
International Organisation for Standardisation	ISO 21929-1:2011	Sustainability in building construction — Sustainability indicators — Part 1: Framework for the development of indicators and a core set of indicators for buildings	Establishes set of indicators for assessing the sustainability of design, construction, operation, maintenance, refurbishment; and end of life of buildings	Y	Y	Y	N	N	N
	ISO 21930:2017	Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services	Provides core rules around the development of an Environmental Product Declaration - builds on ISO 14025 by providing particular requirements for construction products/services	Y	N	N	N	N	N
	ISO 21931-1:2010	Sustainability in building construction — Framework for methods of assessment of the environmental performance of construction works — Part 1: Buildings	General framework for methods of assessing the environmental performance of buildings	N	Y	Y	N	N	N
	ISO 21931-2:2019	Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 2: Civil engineering works	General framework for methods of assessing the environmental , social, economic performance of civil infrastructure	N	Y	Y	N	N	N
	ISO/TS 21929-2:2015	Sustainability in building construction — Sustainability indicators — Part 2: Framework for the development of indicators for civil engineering works	Establishes set of indicators for assessing the sustainability of design, construction, operation, maintenance, refurbishment; and end of life of "civil engineering works"	N	Y	Y	N	N	N
	ISO/TR 21932	Sustainability in buildings and civil engineering works — A review of terminology	A standard of terms & definitions related to buildings and their effect on sustainability/sustainable development	Y	Y	Y	N	N	N
European Committee for Standardisation	EN 15978:2011	Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method	Calculation method to assess the environmental performance of buildings - based on Life Cycle Assessment	Y	Y	Y	N	N	N
	EN 15804:2019	Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products	Provides product category rules for environmental declarations for any construction product/service.	Y	Y	Y	N	N	N

Table 2: Standards application map

Standard	Designation	Title	Summary	Life Cycle Assessment					
				Broader Sustainability/ESGs			Carbon Accounting & Management		
				Material	Building	Infra-structure	Material	Building	Infra-structure
British Standards Institute	PAS 2050:2011	Specification for the assessment of the life cycle greenhouse gas emissions of goods and services	Sets out requirements for the assessment of greenhouse gas emissions within the life cycle of goods and services	N	N	N	Y	Y	Y
	PAS 2080:2016	Carbon management in infrastructure	Provides a common framework to assess whole life carbon in infrastructure	N	N	N	N	N	Y
Royal Institution of Chartered Surveyors	N/A	RICS - Whole life carbon assessment for the built environment	Provides a framework of carbon assessment throughout the built environment	N	N	N	Y	Y	Y
Greenhouse Gas Protocol	N/A	Greenhouse Gas Protocol - Product Life Cycle Accounting and Reporting Standard	Provides an understanding of full life cycle emissions of a product and to focus efforts on reducing greenhouse gas emissions	N	N	N	Y	Y	Y
	N/A	Greenhouse Gas Protocol - Corporate Standard	Provides requirements and guidance on preparing greenhouse gas emissions inventory	N	N	N	N	N	N
Ministry of Business, Innovation & Employment	N/A	Whole-of-Life Embodied Carbon Assessment: Technical Methodology	Sets out a methodology for assessing the embodied carbon of new buildings in New Zealand	N	N	N	N	Y	N
Other	N/A	International Cost Management Standard 3	Provides a consistent method for carbon life cycle reporting of a wide range of infrastructure projects	N	N	N	Y	Y	Y
	N/A	AIQS, Australian Cost Management Manual	Provides a uniform basis for the measurement of building works	N	N	N	Y	Y	Y

Standards Summary

- The hierarchical approach of Products, Buildings, and Infrastructure is helpful in determining the standards that apply to each respective scale.
- There is substantial cross-over and complexity in relation to the standards investigated, leading to the question of the need for simplification to assist accelerated uptake including an evaluation of the cost vs benefit of increasing levels of complexity.
- Many current ISO standards were found to relate to broader 'sustainability' assessments for built environment ie. (full LCA and extended ESG impacts) and are not specific to carbon alone and these generally preclude single point impact assessment.
- ISO standards are generally broad and can be used in multiple applications. More recently, emerging 'industry' standards are targeted to specifically manage /account / assure for carbon in the built environment.

Section 2 Survey Questions
Within the context MECLA's focus on Upfront Carbon - please consider the following questions:

1. Do you think that simplification of the standards is desirable? Y/N (why)
2. Is there a role for MECLA, Standards Australia and others to lead a simplification process? Y/N If No, why? (text response)
3. Existing approach to standards seem to focus on broad 'environmental' principles. How can we best accelerate embodied carbon measurement, benchmarking and reduction standards at the different scales? (text response)
4. Does the development of 'industry standards' represent the best pathway forward? Y/N If no – why? (text response)
5. Please provide any additional comments/feedback on Section 2. (text response)

SECTION 3

QUANTIFICATION METHODS FOR EMBODIED CARBON

Methods to Quantify Embodied Carbon

The purpose of this section is to provide an overview of the **three quantification methods that can be used to calculate embodied carbon**. This is to provide further understanding to stakeholders that may be using different information across the stages of a project. Table 3 on the next page provides further discussion on the benefits and limitations associated with each and how they can be applied to different scales (material, building/infrastructure scale); as well as across the different design stages (i.e. from feasibility through early-stage design, detailed design, construction and as built).

The three quantification methods and the relationship between them is depicted in Figure 3.

Carbon Quantification Methods - Summary

Bottom-up (Process LCA: PLCA)

A detailed iterative bottom-up approach where a physical quantity of resource and energy use across a stream of "unit-processes" of production are quantified up and down stream of a given system boundary point (1,4).

Most commonly used to understand impacts of a product and produce environmental product declarations (EPDs), as well as used to model asset level (building/infrastructure).

PLCA is integrated into various sustainability rating and product declarations systems.

PLCA provides detail on the unit process impacts which are informative for developing specific improvement options.

Hybrid / Combined LCA (HLCA)

Is a method where any combination of IOLCA and PLCA approaches are applied to capitalize the respective benefits of IOLCA and PLCA and minimize their respective limitations (2,3,4).

This approach is often used at early design stages for the whole building level in an attempt to increase completeness where data is unknown. For example, RiCS Professional Statement utilises a hybrid approach at early design stage by calculating A5 as kgCO2e/£100k of project value.

RiCS / ICMS-3, 95%by $ value completeness test for "whole building" assessments.

Top-Down (Input-output LCA: IOLCA)

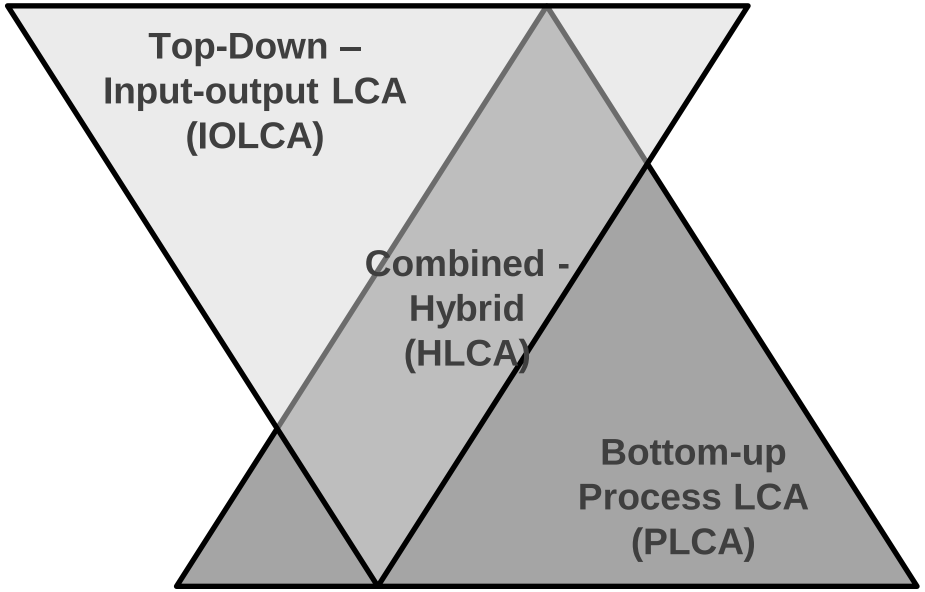
Is a method that combines macro-economic and environmental input-output data for a countries sub-sectors (2,4). In Australia, the ABS is tasked with delivering IO tables for use by industry.

Most commonly applied in macro-policy modelling. It is the main method used by GHG Protocol ; PAS 2060; Climate Active certification as "value-based" quantification methods.

Not commonly used at the individual material level, but sometimes used as an approach to background data for product level assessment and declarations.

The list of data inventories on page 49 summarise the method that each database uses.

Figure 3: Diagrammatic representation of top down and bottom up approach of calculation methods not to scale



1. Campbell, R (2022), direct correspondence.
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3. Crawford, R. H., Bontinck, P. A., Stephan, A., Wiedmann, T., & Yu, M. (2018). Hybrid life cycle inventory methods–A review. Journal of Cleaner Production, 172, 1273-1288.
4. Ward et al, (2017) Truncation error estimates in PLCA using IOLCA; Journal of Industrial Ecology, 22 (5) 10880-1091

Note: this is not an exhaustive list of references and further listing of references could be of merit

Methods to Quantify Embodied Carbon

Each quantification method and data has strengths and limitations depending on the scale and design stage. The table below describes these strengths and limitations. **It is critical to note, that none of the methods are perfect** but having an understanding of the methods is helpful to the objective of comparison and benchmarking of individual material as well as building scale. Also helps to understand which method is helpful at what stage of design. Examples are provided on the following pages to illustrate key issues. We encourage readers to review the reference in detail for further detailed discussion of methods.

Access to reliable data that is complete, accurate, reliable and accessible is a key challenge of both the LCA community and sustainability practitioners more generally.

An important issue is "**completeness**" of the physical quantities included in the declared / functional unit. At the individual material level, PCR's attempt to standardize what must be "included" in the unit of measure to improve comparability. For the building scale, ICMS and RICS have attempted to define the requirement for 95% of the building by value must be included and the "intensity" reported in both GFA and NFA area normalization.

The approach to "benchmarking" at this point in time needs to consider the level of "accuracy" possible within the needs and application of the User.
The 1% and 5% "completeness" tests for LCA within the standards should be reviewed considering the inherent limits of the methods.

Table 3: Comparison of PLCA, HLCA, IOLCA

Attribute	PLCA (bottom up)	HLCA (hybrid/combined)	IOLCA (top down)
Strengths	High detail possible which supports in-depth analysis of a specific product (1). Provides manufacturers with detail to improve performance. Comparability possible if data developed using rules based on existing standards EN 15804 and/or ISO 21930. Exclusively used in relation to ISO14025.	Attempts to maximise the strengths of PLCA and IOLCA and reducing limitations (2,3,4,5,6) Helpful to early-stage design and decision making of building assessment. Reduced speed and cost.	Level of system completeness achieved (2,3,4,5). Reduced speed and cost. Helpful at early-stage and feasibility and planning. Used by most companies in Scope 3 assessments for capital works.
Limitations	The Incompleteness possible through "cut-off" criteria for 3 or more stages upstream is estimated in the range of 2-77% (2,3,5) with an average of 50% depending on the supply chain complexity. Note this is a methodological decision. Greater time required to conduct assessments.	Limited technical development of material datasets using this approach at this time. The degree of accuracy achieved warrants further research work to determine whether this approach is helpful. Presently incorporated into the GBCA GreenStar embodied carbon calculator. Limitations in input-output sectoral resolution and difficulty in allocating sectoral impacts to specific materials – leads to dispute between PLCA and HLCA practitioners.	Lacks the level of resolution/granular detail provided by PLCA inventories. Ie. Not good for product level in-depth assessments or comparison (5). Variance between national IO methods and inter-regional production technologies contributing to variance in results (3,5). Truncation error estimates for IOLCA still occur and likely contribute to +15-90% overestimates.
Material level issues (inventory)	The use of proxy data for regionalization leading to error levels noted above (5,6). Different methods by commonly used inventories can lead to comparability problems.	Databases are limited to USA and Australia for comprehensive material level inventory data points. Methodologies not aligned when comparing between Australian products and imported products.	Can lead to over or under-estimation at the product level (5). Does not support detailed product assessment or optimisation.
Building / infrastructure level issues	Completeness of materials quantities is important for comparability (6,7). Achieving the 95% completeness by "cost" test across a whole asset as required by standards (e.g. RICS) is challenging.	As compared to PLCA can yield value 30-50% higher at the building level (2,3,8,9).	Can support feasibility/early-stage whole building assessment but may result in overstated results (7,8)

Reference and Sources

1. Campbell, R (2022), direct correspondence.
2. Crawford, et.al (2022); Resources, Conservation & Recycling,https://doi.org/10.1016/j.resconrec.2021.106058
3. Lenzen et al (2003);
4. Treloar, et.al (2002); p94 in Australia and NZ Architectural Science Association Conference proceedings.
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10. Crawford, RH., et al 2018, Establishing a comprehensive database of construction material environmental flow coefficients for Australia, https://anzasca.net/wp-content/uploads/2019/01/43-Establishing-a-comprehensive-database-of-construction-material-environmental-flow-coefficients-for-Australia.pdf

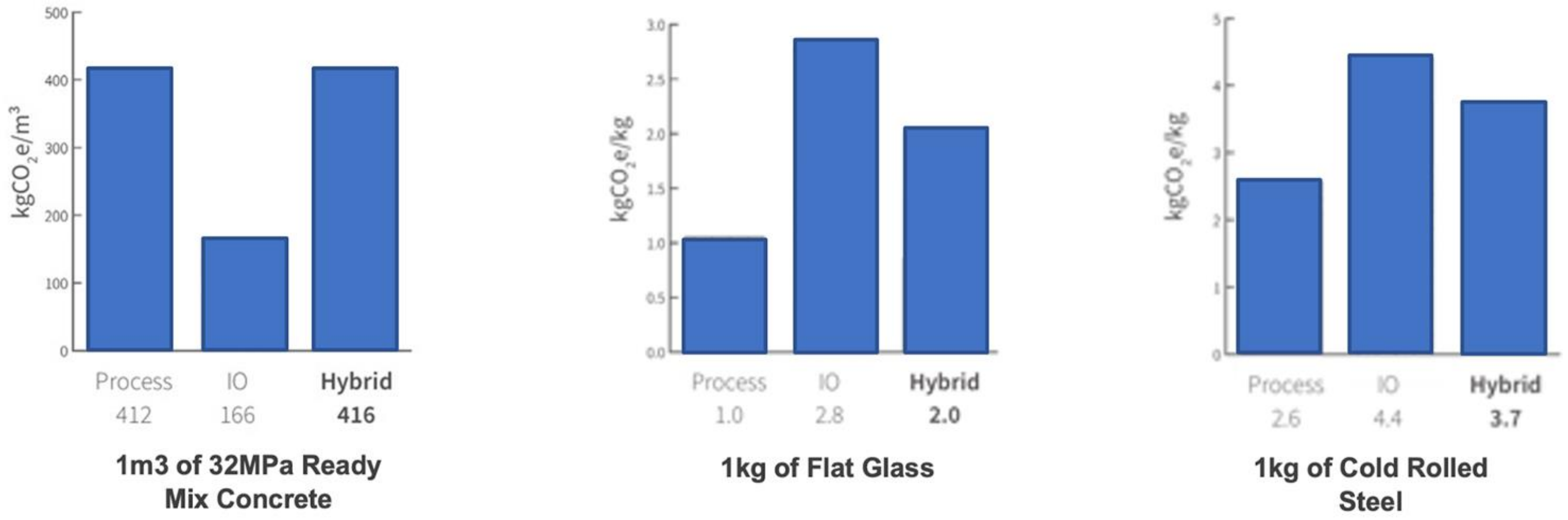
Differences in Methods - Material Level

The graphs presented on this page are reproduced from the EPiC database to illustrate the implications, at the "material" scale on the **completeness and comparability for the three quantification methods** discussed above. What this set of graphs demonstrates is that is **inconsistency and variability across the three methods** and none is currently perfect or sufficiently accurate to support comparability to a sufficiently tight standard. More investment in research and development is desirable. The objective of this comparison is to highlight the **importance in understanding the differences amongst methods, when utilising and comparing** different databases and the impact this may have on the results or assessment.

The 2019 version of the EPiC database encompasses a collaboration between AUSLCI and IE Lab, with the goal of progressing the integration of methods and reducing error. Variances in material level carbon intensity will be magnified at the whole building level. http://www.epicdatabase.com.au/. Please refer to the website for all open-source resources associated with the data, methods and computational code for the Epic database.

Further research to pursue increasing accuracy of material level inventory data would be beneficial to the industry.

Figure 4 – Example of comparison of Material CO2-e Intensity / Unit by Measurement Method taken from EPiC Database



Quantification Methods – Summary and Survey

The purpose of this section of the paper has been to provide a **high level overview of the three approaches to quantification** of upfront carbon at each scale and the issues to consider for comparability by the user.

- There is extensive literature on all the quantification methods and issues of comparability. Overall, the literature on the subject demonstrates that the construction sector **would benefit from further specifically focused research** on reducing limitations and improving comparability and benchmarking consistency at all scales. A shared goal for the industry is to have the means by which to account for the upfront carbon footprint of materials and buildings to the highest and greatest completeness possible. Understanding that 95% of the carbon footprint is captured with 95% accuracy ensure that carbon mitigation and Net Zero commitments are achieved in real terms. This is a goal which MECLA is well positioned to support and champion.
- **Access to data that is as complete, accurate, reliable and updated as often as possible is a shared goal** for all industry stakeholders. As is the evolution of whole building quantification approaches.
- Accelerating action should consider the options to leverage prevailing cost management standards and property classification norms more generally, to assist with the goal of reliable benchmarking. The approach to "benchmarking" (defining the average) must consider the level of "accuracy" suitable within the context of the limitations of all methods outlined and the best available data at the time.
- If Upfront Carbon is to be "controlled" in any manner, (akin to approaches being explored in EU) then further research is warranted with an aim of reducing the variance challenges outlined. **These are key areas MECLA could champion for the industry going forward.**

Section 3 Survey Questions

1. Were you aware that there are three different quantification methodologies? Y/N
2. Were you aware of the objectives, strengths and limits in application of the different methods? Y/N
3. Were you aware of the differences in measurement methods to achieve 95% completeness at the a) material and b) building scale? Y/N
4. At which stage/s of construction do you think that the quantification of embodied carbon should occur? Select options: Planning, concept, detailed design, construction, as built
5. What could MECLA do to improve the quantification methods and their application? Select options: research, nothing, other (please state)
6. Do you have specific suggestions for work or questions and opportunities for MECLA to consider? Y/N (if Y - then provide Text response)
7. The UK is investing in a [government supported materials inventory] to improve access and quality. Is this an initiative you consider suitable for Australia? Y/N and Why (text response).
8. Do you support the concept of independent body to outline an assembly level/ typology carbon inventory? Y/N
9. Please provide any additional comments/feedback on Section 3 . (text response)
10. Was the content in this section clear to you? Y/N

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SECTION 4

FUNCTIONAL / DECLARED UNITS

Functional/ Declared Units - Purpose

The purpose of this section is to understand from stakeholders what "units of comparison" they would find most useful in day-to-day application. It is common to find a disconnect between the declared unit and the construction ready unit of product (e.g. 1kg clay brick declared vs 1 m2 76mm brick wall – functional).

A **"Functional Unit"** is a quantified performance of a product system for use as a reference unit (ISO 14067). It is a physical measure of a product which describes, a unit of measure (e.g. kg, m2 etc), a description of measure (e.g. ready mix concrete or floor area) and a quality aspect, (e.g. 32Mpa concrete or Class 5 office building) etc.

At the "material" scale, the term "declared unit" is also used.

A **"Declared unit"** is a quantity of a construction product for use as a reference unit in an EPD for an environmental declaration based on one or more information modules (EN 15804). A declared unit is used when the function of the product is not known or stated. (e.g. 1 kg of clay brick; 1kg of glass)

Ideally, units are framed to **enable meaningful comparisons** for Stakeholders needs (i.e. comparing an individual material / complex assembly of many materials or building or infrastructure). The end user of the information needs to be considered. A question for the industry is **who is the primary stakeholder and what difference in needs exists** across the different stakeholder groups? What an architect may find of most use, an LCA specialist may not. This is a key issue identified in this section.

It is also an important first step in the process of comparability is whether **it be a material or a building**. That is, providing sufficient description of scope, unit and quality definition to support robust comparison.

What follows are a **sample** of functional and declared units for a ***sample*** of materials and buildings. Infrastructure is a work in progress. **Please note, this is not exhaustive,** rather a selection to act as the basis for **input from Stakeholders on the sorts of unit** expression that aligns to their practical application needs in an efficient and practical manner.

The material list only includes a small sample of commonly used materials. A limited sample of 'composite' materials are included. Outside of the scope of this paper, but an area for further work by WG2 is more complex construction assemblies (e.g., a window, an upper floor assembly; external wall or a service element e.g. chiller).

For some materials there may be a difference between the declared units identified (e.g. most here are drawn from product declarations) and those used by designers and cost planners. An objective of this section is to seek feedback from Stakeholders on the "best fit / preferred expression of functional unit based on their User type. This feedback will support further MECLA work flows.

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Declared Units - Materials

The tables on this page and the next page summarise the functional / declared units used for key material types, noting this list is not exhaustive.

Table 4: Declared unit options

Category	Material	Benchmark Definition and relevant Standard Classification	Reference Unit (options)
Aluminium	• **Bar** • **Extruded** • **Sheet**	• **Bar flat** (by thickness properties are defined by AS1865) • **Extruded, Extruded powder coated, Extruded angle** (AS/NZS 1866) • **Sheet** (properties are defined by AS/NZS 1865)	**kg or T**
	Composite panel **Sheet**	**Composite panel** (in 4 mm thickness panel) **Sheet** (by various mm thickness; properties are defined by AS/NZS 1865)	**m^2**
	Round tube	**Round tube** (by various mm thickness and diameter; properties are defined by AS 1867)	**kg or m by dia**
Cement	**Portland Cement** **Blended cement**	**Portland Cement** shall comply with AS 3972 **Blended cement** (including Supplementary Cementitious materials such as Fly ash, Ground Slang, Amorphous Silica) shall comply with AS 3582 series.	**kg or T**
Concrete	**Readymix Concrete**	**Grades of concrete:** 20MPa, 25MPa, 32MPa, 40MPa, 50MPa, 65MPa, 80MPa, 100MPa (Properties of concrete are defined by AS 1379 and AS 3600) Also geopolymer draft Standard	**m^3** **(volume of concrete)**
Glass	**Float**	By common thickness e.g. 6mm, 8mm, 10mm, 12mm	**m^2**
	Performance Coated	By common thickness e.g. 6mm, 8mm	**m^2**
	Laminated	By common thickness, including interlayer ; 6.38mm, 8.38mm, 10.38mm	**m^2**
	Toughened (including heat soaking process)	As above 6mm, 8mm, 10mm, 12mm	**m^2**
	Heat Strengthened	6mm, 8mm, 10mm, 12mm	**m^2**

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Declared Units - Materials

Table 4 cont.

Category	Material	Benchmark Characterisation and relevant Standard Classification	Reference Unit
Steel	Re-Bar	• **Bar plain** (strength 250 MPa and Normal ductility class as defined by AS/NZS 4671). • **Bar deformed** (strength 500 MPa in Low or Normal ductility class as defined by AS/NZS 4671) • **Stainless steel plain bar or ribbed bar** (strength 200 or 500 MPa in Normal ductility class as defined by BS 6744)	**Tonnes or kg**
	Mesh	**Welded mesh, plain, deformed or indented** (strength 500 MPa in Low and Normal ductility class as defined by AS/NZS 4671 and welding shall confirm with AS/NZS 1554)	**Tonnes / m^2 or / m^2 cover**
	Organic coated steel products	**Flat panels for roofing or cladding applications** (AS1397:2021 and AS/NZS 2728:2013) (per mm thickness)	**m^2 by cover OR net m^2**
	Plate / Structural	• **Hollow section** (Steel grades 250, 350, 450MPa with range of thickness as defined by AS/NZS 1163) • **Plate, Strip, sheet floorplate** (strength ranges from 250, 300, 340, 350 and 380, 480 MPa with range of thickness as defined by AS/NZS 1594) • **Plate and floorplate** (strength 200 to 450 MPa as defined by AS/NZS 3678) • **Flats and sections** (strength 280 to 360 MPa with range of thickness as defined by AS/NZS 3679) • **Plate** (strength 500 to 690 MPa with range of thickness as defined by AS 3597)	**Tonnes**
Timber	Softwood	Softwood (sequestration excluded) (AS 2858)	**m^3 or by thickness m^2**
	Hardwood	Hardwood (sequestration excluded) (AS 2082)	**m^3 or m^2**
	Engineered	By Variant (CLT (no Aus. Standard), DLT (no Aus. Standard), Glulam (AS/NZS 1328.1-1998 and AS 5068-2006)) (sequestration excluded)	**m^3 or m^2**

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Functional Units - Buildings

This table has been compiled with reference to the Australian National Construction Code (to align with operating carbon performance); planning processes as well as Property & Shopping Centre council for quality classifications.

Table 5: Functional units buildings

				Sub-Classifications (metadata)	
NCC Class	Building Type NCC	Description	Functional Unit (m2) - IPMS*** (and PCA)	Sub-type	Construction
1a	Residential - single domestic	Single dwelling or one of a group of attached dwellings,	Gross Floor Area (GFA) AND OR Net Conditioned space	Standard* Quality* Prestige*	Type A, B or C Construction New build, major refurbishment, minor refurbishment Whole building, base building (shell & core), fitout (FF&E) Climate Zone
1b	Residential - small hostel	Boarding house, guest house or hostel < 300m2	Gross Floor Area (GFA) AND OR Net Conditioned space	TBA	
2	Residential - apartments	Multi-unit residential (domestic) dwellings	Gross Floor Area (GFA) AND OR Net Conditioned space	1-2 storey block 3 storey block 4-8 storey block 9+ storey block	
3	Residential - large hostel	Residential building providing long-term or transient accommodation for a number of unrelated persons.	Gross Floor Area (GFA) AND OR Net Conditioned space	Boarding house Hotel, motel or guest house Hostel or backpackers Student accommodation or workers' quarters Residential care building.	Hotel star rating
4	Residential - Other	Single domestic dwelling within a building of non-residential nature (that is, a Class 5 to Class 9 building). For example, a caretaker's residence within a hospital.	Gross Floor Area (GFA) AND OR Net Conditioned space		Type A, B or C Construction New build, major refurbishment, minor refurbishment Whole building, base building (shell & core), fitout (FF&E)
5	Office	Commercial or professional use buildings	GFA / ABS GFA Useable / Net Lettable Area (NLA)	Premium A Grade B Grade C & D Grade	
6	Retail	Buildings where retail goods are sold or services are supplied to the public, such as shops or restaurants.	GFA / ABS GFA Useable / GLAR	Neighbourhood Regional / sub-regional CBD	

Functional Units - Buildings

Table 5 cont.

				Sub-Classifications (metadata)	
NCC Class	Building Type NCC	Description	Functional Unit (m2)	Sub-type	Construction
7a	Carpark	Carparking (underground / multi-storey)	GFA /ABS GFA / NFA	Ongrade, above ground, basement	Type A, B or C Construction New build, major refurbishment, minor refurbishment Whole building, base building (shell & core), fitout (FF&E)
7b	Storage	Warehouses, storage buildings or buildings for the display of wholesale goods.		Specify type/use	
8	Industrial	Factories – buildings used for production, assembling, altering, packing, cleaning etc. of goods or produce. Warehouses / large storage buildings	GFA / ABS GFA / NLA	Specify type/use	
9a	Public buildings - Healthcare	Healthcare buildings such as hospitals and day surgery clinics	GFA / ABS GFA / NLA	Teaching/specialist hospital, General hospital, Community/mental health hospital, Clinic/GP surgery **	
9b	Public buildings - Assembly buildings	Buildings where people assemble for social, political, theatrical, religious or civic purposes, e.g. schools, universities, sports facilities, night clubs, childcare centres, pre-schools, or public transport buildings	GFA /ABS GFA / NLA	School - preschool, primary, secondary	
				Higher education - lecture, workshop, studio	
				Transport - train station, airport terminal, ferry terminal	
				Other	
9b	Public buildings - Aged care facilities.	Aged care facilities.	sqm conditioned space		
10 (a, b & c)	Non-habitable structures		GFA /CFA / ABS GFA Useable	Class 10a – sheds, carports, private garages Class 10b – fences, masts, antennas, retaining walls Class 10c – private bushfire shelter.	

Functional/Declared Units – Summary and Survey

- A "**Functional Unit**" is a quantified performance of a **product system** for use as a reference unit (ie to be used as the basis for comparison) (ISO 14067). It is a physical measure of a product which describes, a unit of measure, a description of measure and a quality aspect.
- At the "material" scale, the term "declared unit" is also used but it is the users need to determine a basis for comparability. A "**Declared unit**" is a quantity of a construction product for use as a reference unit in an EPD for an environmental declaration based on one or more information modules (EN 15804). **A declared unit is used when the function of the product is not known or stated**.
- Functional/Declared units are an important first step in the process of being able to **compare or progress to benchmarking** whether it be a material or a building level
- This section has defined potential functional or declared units at a material and building scale.
- **Often units are not in a "design ready" format, needing a User to "convert" the unit to the design format** - a major objective of this section of the paper is to elicit feedback from a broad cross section of stakeholders on what units and measures they would find most useful and immediately applicable to their embodied carbon reduction goals.

Section 4 Survey Questions

1. **Please indicate what type of User of information you are:** (select: Architect / engineer / builder / procurement / specifier / supplier / quantity surveyor / other)
2. **Are the examples of "materials" declared units applicable to you in your practice?** Y/N. If N – please explain
3. **Are the examples of "building" functional units applicable to you in your practice?** Y/N. If N – please explain.**Do you have any further or alternative suggestions for functional units of materials?** Text response
4. **Do you have any different suggestions for functional units of buildings?** Text response
5. **In this paper we have not covered functional units for infrastructure. Do you have suggestions for functional units for infrastructure assets?** Text response
6. **What role should MECLA play in supporting Australian practice for functional unit definition at BOTH the material and building scale to improve useability and support comparability?** Text response
7. **Please provide any additional comments/feedback on Section 4 .** (text response)
8. **Was the content in this section clear to you?** Y/N

SECTION 5

BENCHMARKING APPROACHES

Benchmarking Methods - Purpose

Introduction

Benchmarking methods allow the embodied carbon performance of materials/building/infrastructure to be compared to a theoretical 'typical' performance on an empirical basis. A range of benchmarking methods are presented in this section which were compiled by MECLA WG2 through:

1. Literature review and desktop research
2. Working Group and Project Control Group discussions
3. Limited stakeholder engagement

This Discussion Paper forms part of the process of **more extensive stakeholder engagement**. This is a **preliminary list** of benchmarking methods, and **we welcome feedback on their appropriateness as well as suggestions of additional methods**.

It is **not MECLA's intention in this Discussion Paper to identify a preferred benchmarking method**. Rather the aim is to provide a review of the range of options available to a user to benchmark performance. The method that is preferred by a user will depend on the information they have available, the stage of design of a project and consistency with other embodied carbon calculation methods in use by the individual/organisation.

Users may find that there is no single method that suits their needs and where data is readily available in all instances. It therefore may be appropriate to develop a hierarchy of methods **specific to the organisation's requirements**.

To make it easier for users to assess these methods we have included information on the following areas:

- Type of Data: there are three primary types of LCA data – process analysis (PLCA), hybrid analysis (HLCA) and input output (IOLCA) data. Further explanation of these 3 data types can be found in Section 2.
- Opportunities and limitations of different methods
- Alignment with relevant rating schemes or standards: there are existing (and emerging) schemes that reward reductions in embodied carbon in buildings and infrastructure. We have also noted alignment with standards (both Australian and International) – **standards are discussed further in Section 2 of this Paper**.

1. https://carbonleadershipforum.org/material-baselines/

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Benchmarking Methods - Materials A1-A3

Table 6: Note this is at the material level

Method Name	Data Type	Description	Potential Strengths	Potential Limitations	Standards & Rating Tools Alignment
1- All Life Cycle Inventory (LCI) Data	PLCA, HA & IOLCA	Mathematical average of all available data sources.	Data availability is not reliant on published EPDs. Recognises all data sources and includes data relevant to the organisation beyond that directly associated with the product*. Particularly helpful when EPDs are limited.	Aggregates data with different sources and scopes. This limits its ability to be used for a benchmark for any one material/product that is produced with a single data source (i.e. EEIO data benchmarks may not be a relevant comparison point for process based data from an EPD). The inclusion of all data types (EEIO, HA & PA) would mean the average value is higher, potentially advantaging 'laggards'.	ISO 14067; GHG Protocol; Climate Active; GreenStar; RiCS
2- All Process LCI data and EPDs	PLCA	Median value of all process based LCI data as well as EPD data sources	Method is consistent with LCA guidelines on use of data sources. Some data sources are available and maintained by third parties. Median value is robust against outlying data points.	There may be limitations on publishing the database values from each database that sit within these calculations (some of these databases are under paid licenses). Process based data may estimate a smaller carbon impact than other data sources. Reliability and quality of material product declarations may vary significantly.	ISO 14067, EN 15804, Green Star, Infrastructure Sustainability (IS) Ratings
3- Published EPDs	PLCA	Mathematical average of published EPDs: i) BAU values only ii) Including BAU and 'improved performance' options	Reflects data of actual products. Development of EPDs allows manufacturers to identify specific processes to target for improvements to carbon/environmental outcomes. Encourages publishing of EPDs as this would influence benchmark values.	Lack of available data points within Australia for some materials/ products. Cost burden on suppliers (particularly small suppliers who then may be under-represented in data points). Comparability of EPDs undertaken under different Programs or Product Category Rules (variability is being addressed by widespread adoption of PCRs aligned with EN15804 and/or ISO21930:2017). Limit of regional data in background datasets. BAU may be unclear for some product categories.	ISO 14067, EN 15804, Green Star, Infrastructure Sustainability (IS) Ratings
4- Industry Pathways (QM)	Various	Ensure materials are sourced from organisations who are committed to industry decarbonisation initiatives (e.g. Decarbonisation Pathways Australian Cement and Concrete Sector).	Likely industry support for their agreed pathways.	Specific benchmark values are unlikely to be defined – this method would serve as a proxy for quantitative benchmarks. Not all industries have developed pathways. 'Benchmarking' methods would be different between industries and potentially incomparable.	None.
5- Organisation Pathways (QM)	Various	Ensure materials are sourced from companies that have verified decarbonisation targets (e.g. through the Science Based Target Initiative).	Organisations can define their own trajectories towards decarbonisation that are independently verified to align with the Paris Agreement.	Specific benchmark values are not defined – this method would serve as a proxy for quantitative benchmarks. Organisational level targets (such as an SBT) do not ensure that specific products are 'low carbon'. Relies on the strength of external programs verification methods.	GHG Protocol Corporate Standard.

The term "EPD" in this represents all declarations prepared using Type III 3rd party (I, II or III) by ISO 14067 or 14025 (not restricted to any declaration label).

Benchmarking Methods for Materials – Worked Example 1

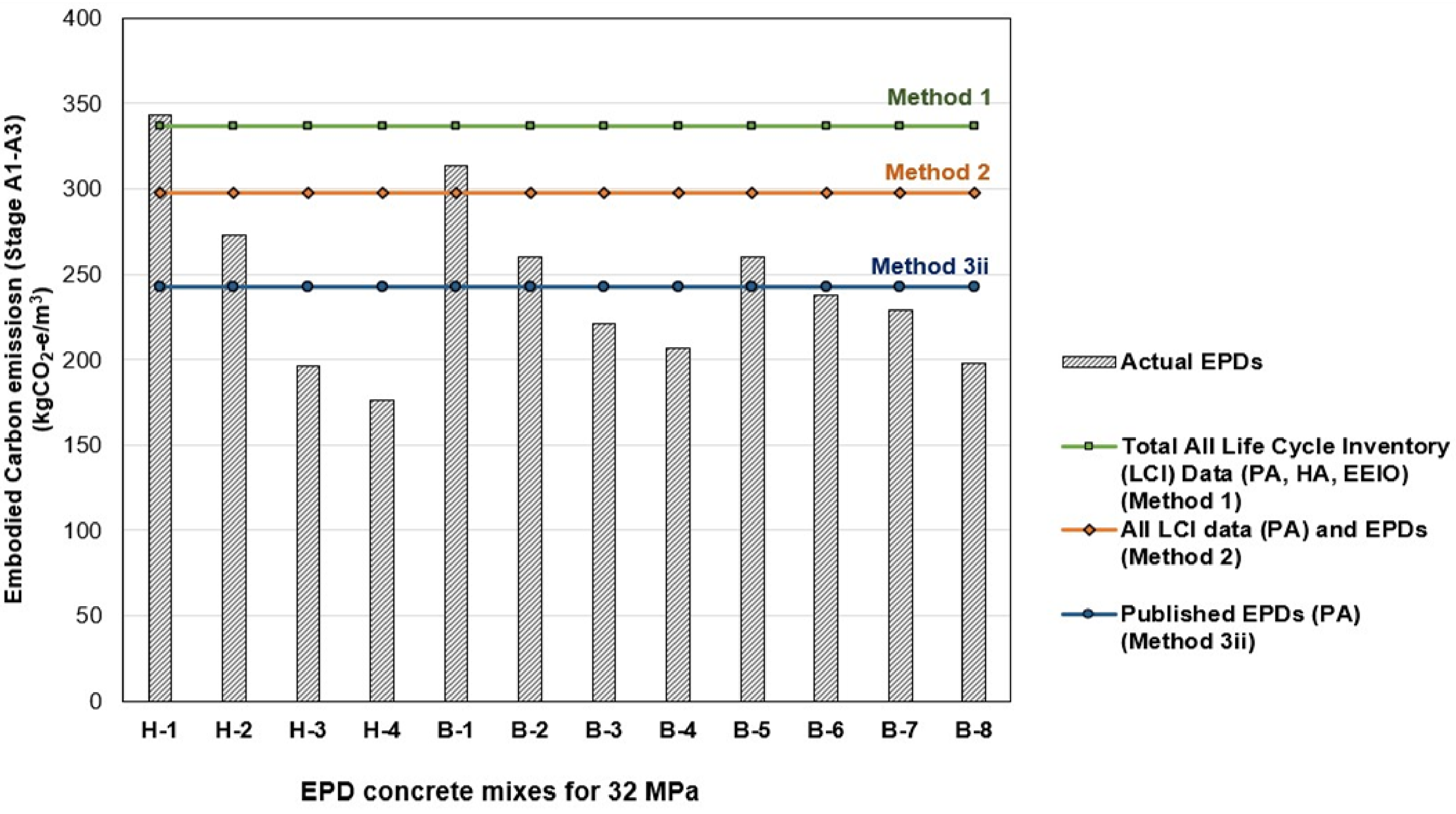
This page **provides examples** of the results from calculating different benchmarking methods for a particular material - in this case **1m^3 of 32MPa concrete** (Stage A1-A3). It compares the benchmarking methods (marked as horizontal lines) to the available Australian EPD data for 1 m3 of 32MPa concrete (represented by the columns in the graph).

These results can be used to understand how using different benchmarking methods will result in different quantitative benchmarks for the same material.

Only **methods 1, 2 and 3** (as defined on the previous page) are provided as worked examples here. This is because methods 4 and 5 are largely qualitative methods and don't result in specific numerical outputs.

Please NOTE – sample size is <N=30 and is subject to sample limits

Figure 5: Carbon emissions of 1m3 32MPa concrete (Methods 1-3)



Benchmarking Methods for Materials – Worked Example 2

This page **provides examples** of the results from calculating different benchmarking methods for a particular material - this time using the example of **1kg of structural steel bar** (Stage A1-A3). An important difference of steel compared with concrete is that the example below uses **international data, rather than Australian data.** This is because while concrete is procured through local suppliers, steel is supplied to the Australian market from both national and international suppliers. The graph on the left only considers Australian data points (3 data points) and the graph on the right includes all the accessible suppliers datapoints (90 data points) grouped by geographical region.

As with the concrete example, only **methods 1, 2 and 3** are provided as worked examples here. This is because methods 4 and 5 are largely qualitative methods and don't result in specific numerical outputs.

Figure 6: **Carbon emissions of 1 kg of structural steel bar (Methods 1-3)**
Only Australian **EPD's data**

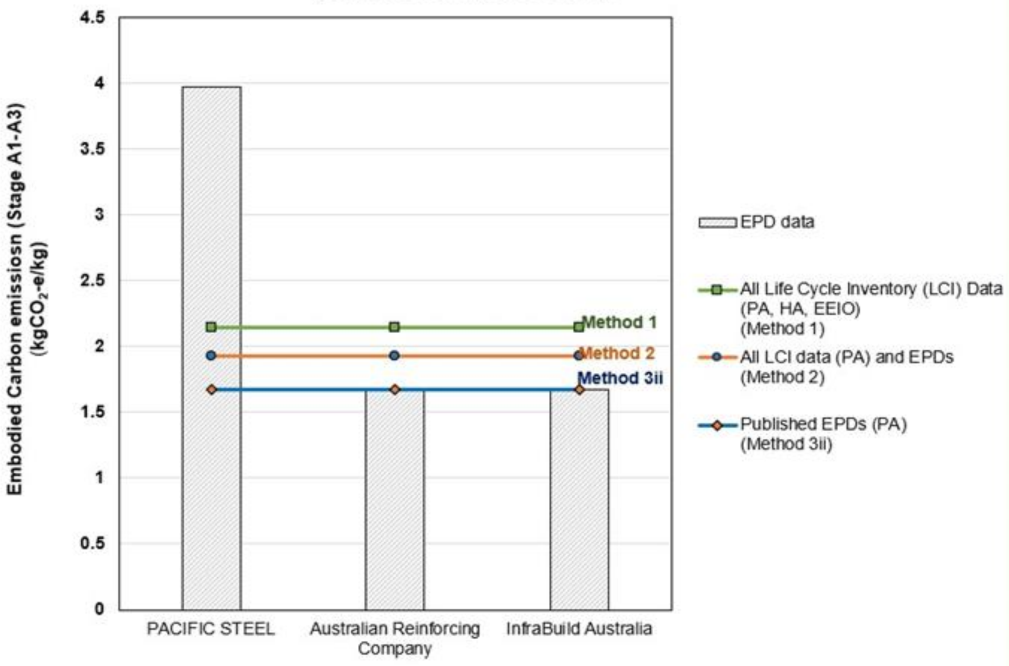
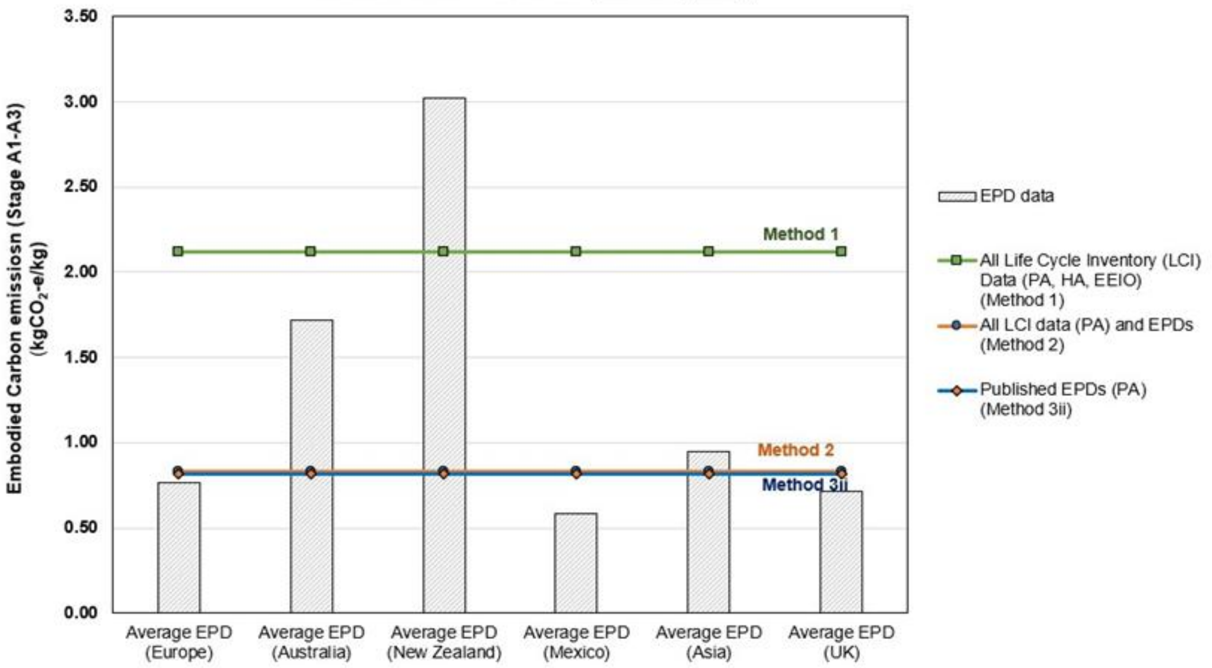


Figure 7: **Carbon emissions of 1 kg of structural steel bar (Methods 1-3)**
All available EPD's data (*across globe*)



Benchmarking Methods for Materials – Worked Example 3

This page provides additional information **that helps a reader to understand how selecting a specific geography** may influence the outcome of the benchmarking methods. The graph shows the distribution of carbon emissions for **1 kg of reinforcement bar** across different regions (combination of 90 EPDs and 5 Australian LCI data points- Stage A1-A3).

The spread of values could arise due to the use of different LCI sources (e.g. Aus LCI; Gabi; Ecoinvent etC); the software used; the assumptions of the assessor; differences in background data or product category rules.

This also highlights the risk to whole building assessment where one specific product declaration is selected for a product which may not be finally used and may have an impact on the result.

The graph shows that embodied carbon performance is **clustered in the various countries/regions which leads to different regional 'average'** performance. It also shows that the number of data points varies widely between regions.

In Australia, the properties of reinforcement bar are defined by AS/NZS 4671.

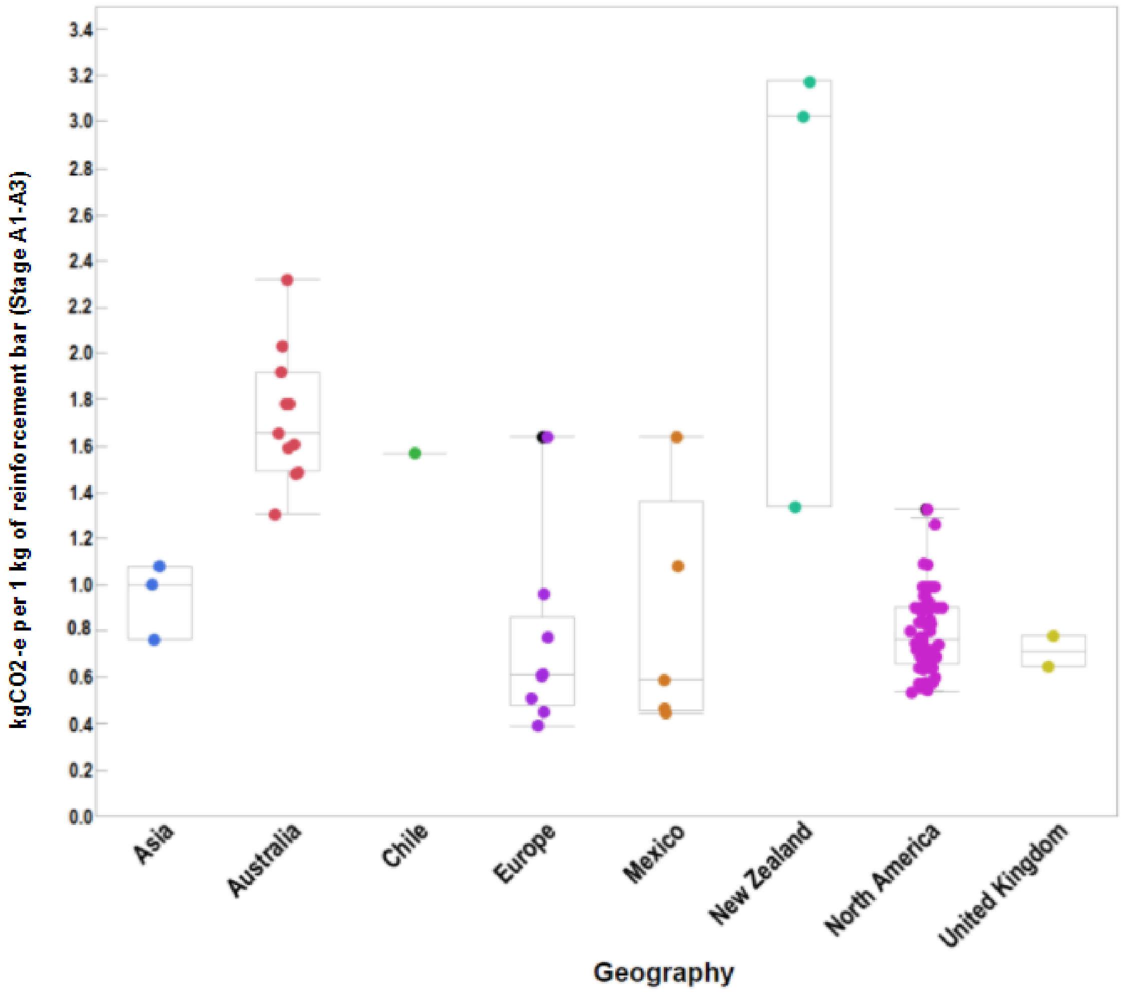


Figure 8: Influence on benchmarking by geography

Benchmarking Methods for Materials - Worked Example Data Sources

Table 7: Source of information for the previous examples on 32 MPa concrete and Steel reinforcement (A1-A3). Note: only Australian data is used for this concrete example as concrete is a material that must be sourced locally)

Name		LCI method	Utilised data points	Access to the data	Note
EC3	Embodied Carbon in Construction Calculator (EC3)	PLCA	Steel bar: 90 data points	Publicly available	Link: https://www.buildingtransparency.org/
ICM	Integrated Carbon Metrics Embodied Carbon Life Cycle Inventory Database	PLCA & HLCA	Steel bar: 2 data points Concrete: 3 data points- ability to model detailed mix design	Publicly available	Link: https://doi.org/10.26190/5df6aa5d5effd Cite: Wiedmann, Thomas ; Teh, Soo Huey ; Yu, Man (2019): ICM Database - Integrated Carbon Metrics Embodied Carbon Life Cycle Inventory Database. University of New South Wales.dataset.
EPiC	Environmental Performance in Construction	PLCA & HLCA & IOLCA	Steel bar: 2 data points Concrete: 3 data points- ability to model detailed mix design	Publicly available	Link:http://doi.org/10.26188/5dc228ef98c5a Cite:Crawford, R.H., Stephan, A. and Prideaux, F. (2019) Environmental Performance in Construction (EPiC) Database, The University of Melbourne, Melbourne.
GaBi	Sphera	PLCA	Steel bar: 2 data points Concrete: 3 data points- ability to model detailed mix design	By use of Lendlease licence	Link: https://gabi.sphera.com/databases/gabi-databases/
CCAA	Cement Concrete & Aggregates Australia	PLCA	Concrete: 1 data point- ability to model detailed mix design	Publicly available	Link: https://link.springer.com/article/10.1007/s11367-017-1266-2 Mohammadi, James, and Warren South. "Life cycle assessment (LCA) of benchmark concrete products in Australia." The International Journal of Life Cycle Assessment 22.10 (2017): 1588-1608.
EPD	Boral and Holcim EPDs	PLCA	Concrete: 12 data points	Publicly available	EPD Australasia Link:https://epd-australasia.com/
eTool	eToolLCD (based on AusLCI data)	PLCA	Steel: 1 data point Concrete: 1 data point	By use of "Open Use" licence	eToolLCD Link: https://etoolglobal.com/
IE Lab	Industrial Ecology Virtual Laboratory	IOLCA	Steel: 1 data point Concrete: 1 data point		These data points provided by the Footprint Company licence (Dr Caroline Noller) – provide link to the IE Lab website.

Benchmarking Methods for Material International Examples

Similar attempts to define embodied carbon benchmarks at a material level have been undertaken internationally. Below are three published examples. Note this is not exhaustive. These have been provided for consideration, but these are not endorsed as approaches to be used. There are many other examples in the academic sphere, as well as those within existing LCI (refer to section 6 for options)

We welcome other examples which could be added for reference for MECLA stakeholders.

Organisation	Data Type	Method Description
Carbon Leadership Forum (https://carbonleadershipforum.org/who-we-are/)	PLCA	The 2021 Carbon Leadership Forum Material Baselines Baseline Report (July 2021) publish three figures per product category (high, median and low) "*to give a rough order of magnitude of embodied carbon impacts per [product] category reflecting the significant variability of product manufacturing and uncertainty of LCA data available.*" Four methods are used depending on the quality of the data available: 1. Industry specific EPDs 2. Product-specific EPDs (where there are more than 20 product specific EPDs) 3. Industry average + uncertainty factor or midpoint between an industry average value and an industry high value as determined by industry EPDs or the ICE database (where less than 20 product specific EPDs exist) 4. Proxy product category (where there are no industry EPDs and very few product EPDs) More information on these methods can be found at: https://carbonleadershipforum.org/2021-material-baselines/
Chartered Institution of Building Services Engineers (CIBSE) - UK	PLCA	Benchmarks were developed for residential heating equipment (TM65.1:2022 0 Embodied carbon in building services: residential heating). CIBSE gathered actual material quantities (and maintenance and refrigerant information) from manufacturers and calculated embodied carbon. Checks and adjustments were made to the data gathered if less than 4 data points were received per equipment category. If no data was received EPDs or generic values (ICE) were used. CIBSE EPDs were not the primary source of data for their benchmarking as there are limited EPDs for heating equipment.
Institute of Structural Engineers (iStructE) - UK	PLCA	iStructE provide benchmark embodied carbon factors (ECF is for modules A1-A3) for common structural materials. The ECFs are taken from EPDs (either manufacturer specific, UK- wide or European-wide averages), worldwide LCI data (such as that provided by Worldsteel) or the ICE database. These are suggested for early project stages and to be substituted by EPDs specific to the project as design develops.

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COLLABORATION FOR CHANGE

Benchmarking Methods for Materials – Summary and Questions

The work completed by the workgroup suggests that there is still room for improvement in the development and production of Materials upfront carbon calculations.

The results also leave open the following questions:-

- What performance level defines "suitable" performance in the context of net zero 2040 goals (i.e. 20% less; 40% less; Zero carbon etc)?
- Should a material "average" value be adopted against which % reductions are defined?
- Given the variance evidenced, does this have an impact on credibility and dilute the rationale behind calculation efforts?
- What reduction commitments (if any) is a company obliged after completing an upfront carbon calculation and declaration?
- What is the role of government in funding national inventory development?

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Benchmarking Methods for Buildings

This section presents a discussion of issues of comparability and benchmarking at the whole building scale and how values differ.

Between 2016 and 2020 several important and valuable meta-data studies of whole building lifecycle carbon were carried out based on data collected from studies completed with EN 15978 (IEA, 2016; Simonen et al., 2017; LETI, 2020; Rock et al., 2020). These studies involved the collection of samples from several sources as well as studies published in journals and other literature.

These studies all concluded that the methodological approaches provided by EN 15978 inhibit the comparison of results for the purpose of establishing benchmark (average) values for buildings. They outline the reasons behind many of the differences in the published embodied carbon results including boundary issues, underlying data methods, scope and functional area assumptions (IEA, 2016). The Carbon Leadership Forum concluded that:

"There is an urgent need to standardize general building design data and building life cycle assessment data. Alignment in definitions of building area (gross, internal or exterior), building life cycle stages and scopes are critical for comparison." (Simonen et al., 2017). see slide 42

LETI (2020) further concludes that EN 15978:2011 is "open to interpretation and leads to inconsistency and a lack of comparability between different projects" and, as such, recommended the use of the RICS Whole Life Carbon Assessment for the Built Environment (RICS, 2017) as the preferred approach. The RICS standard critically defines the scope of a building that must be included and the allocation method to meet the definition of "benchmarking" which is fundamental in the discipline of cost consulting. see slide 42

In 2021, the ICMS-3 was published. Its goal is to provide global consistency in classifying, defining, measuring and reporting carbon emissions of construction (& infrastructure) projects and constructed assets to enable performance benchmarking, at regional, state, national or international level (ICMS-3,p1). It builds on RiCS and requires reporting of the total carbon emissions by prescribed element as well as normalizing results to both GFA and NFA basis.

In 2021, the Low Carbon Institute published an approach to measuring upfront carbon for buildings with additional methods to standardize results to improve comparability focusing on the scope of the building included, classification and functional area definition (LCI, 2021)

An example of an empirical benchmarking method for operating carbon for buildings can be found in the NABERS operating energy rating scheme in Australia. The NABERS benchmarking method is an empirical approach which established "bands" of performance wide enough to allow for the range of limitations and possible errors possible within the measurement and validation processes across a complex product of a building. A mathematical "mean" value is established from a valid sample (collected from industry collaboration). Performance steps were then established above and below the mean across a 5 or 6 point scale - where 1 is poor and 6 is good. The performance measure is kgCO2-e / m2 of floor area based on building type and classification. The NABERS approach empirically establishes "best-performance" from data; with adjustment for region and climate. The bands have been subsequently adjusted with continued data point collection.

An alternative benchmarking approach is seen in Sec J of the NCC whereby a "model" building is established, from which a % reduction and or a performance less than is mandated.

International efforts to achieve embodied carbon benchmarking at a whole of building level have been indecisive, but have seen meaningful progression in 2021, as outlined in the research summary documented here. This situation is understandable given the early stage of knowledge.

The strengths of an empirical approach are: quantitative metric aligned to other key building metrics such as cost, rent etc per m2; Agnostic to a particular design vernacular; evidence based. The key weakness is getting a good valid sample of Australian buildings to achieve a statistical sample.

The alternative of a % reduction from a Reference point - such as that within Sec J NCC is that it can reward "high impact" and the question of "reference" is often challenged due to the infinite variability in building design; data collected may not allow for future compatibility;. The strength is ease.

Figure C presents the findings from a variety of studies to demonstrate the problems of comparability with the lack of consensus on alignment of key variables. Further work to test the sensitivity to overall results would be of merit.

Differences in Methods - Building Level

The graphs presented on this page are drawn from Low Carbon Institute "Race to Net Zero; A Climate Emergency guide for new and existing buildings in Australia (figure 15)(1)" to illustrate the implications on completeness and comparability at the building level – for several key measurement variables. The graph attempts to show adjustments to align results to A1-A5 normalised to Net Floor Area to align with operating carbon area normalisation.

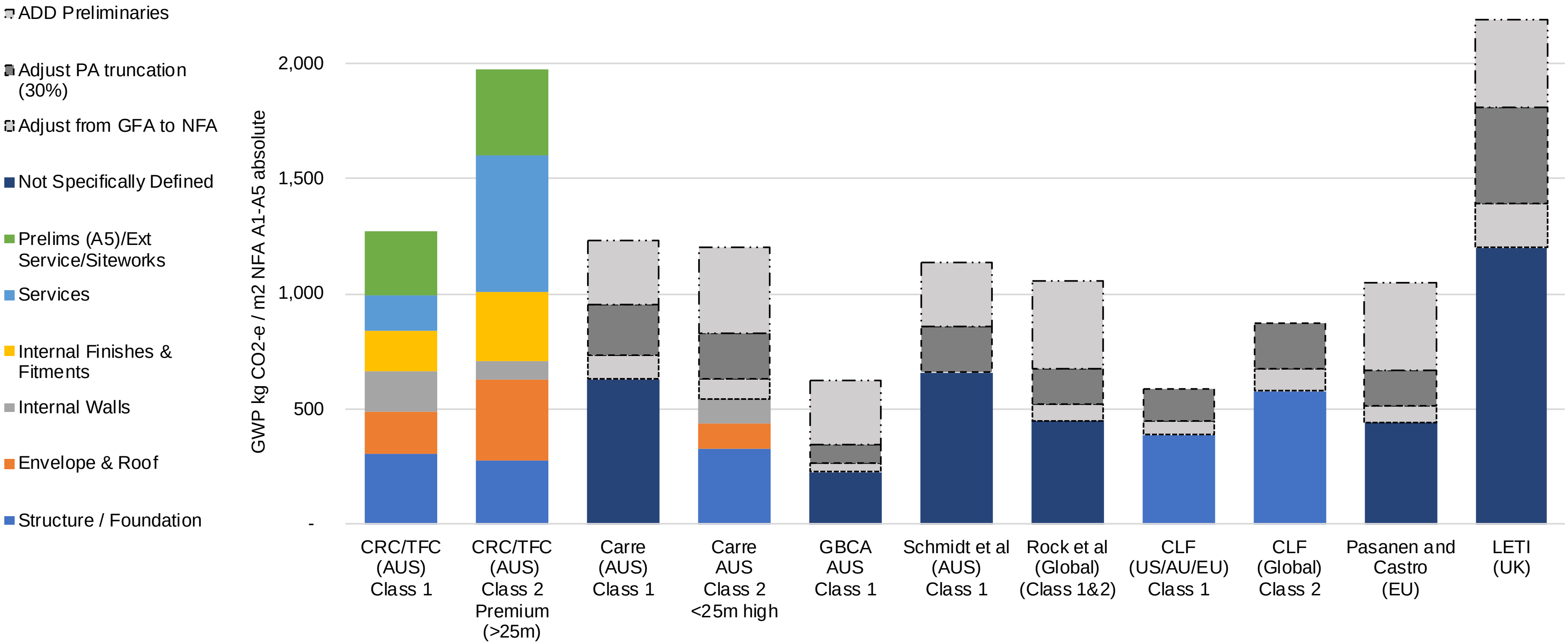
Figure 9 shows a sample of published whole building LCA studies of Class 1 (single house) and Class 2 (apartment) buildings – to achieve "comparability" by adjusting results for key study variables including: area definition (Net vs Gross m2); measurement method (at material and building scale); the addition of AO and A5 – preliminaries and service inputs to achieve the target 95% "completeness".

CLF values are HLCA at both material and building level. Other data points are PLCA. Even within PLCA values the "variance" is significant and support the need for further work necessary in order to progress towards industry background QS measurement norms and an empirical approach to "benchmarking" in order to accommodate background data quality and measurement limitations.

(3) RiCS, (2) ICMS, (4) CLF, (5) LETI and (1)LCI acknowledge that the issues outlined is leading to a general lack of comparability and everyone would gain from further standardization for building classification, floor area measurement definition, building scope inclusion and quantification methods to increase regional and cross-regional comparison.

Represents adjustment for "material" level "cut-off" for PLCA inventory data**

Figure 9 – Comparison of Building CO2-e Intensity / Unit by Measurement Method



1. LCI, 2022; The Race to Net Zero – A Climate Emergency Guide for New and Existing Building's in Australia.
2. ICMS-3, 2021; International Cost Management Standard V3 (icms.org)
3. RiCS, (2017); Best practice guide to whole building embodied carbon assessment 1st edition.
4. CLF, 2017; Embodied Carbon Benchmark Study
5. LETI, 2018; London Energy Transformation Leadership Forum

** Note – CLF values are for STRUCTURE only.

Benchmarking Methods for Buildings – International Examples

Below is a short summary of other methods that have been used to develop whole of building benchmarks. This is not a comprehensive list and we are aware of other organisations that have undertaken benchmarking studies and guides including Ramboll, Slattery, The Footprint Company, and Hines.
The Working Group is not aware of benchmarking for infrastructure but welcome input from stakeholders to identify initiatives and will include these in later versions of this paper.

Organisation	Data Type	Method Description
Carbon Leadership Forum - a US based not-for-profit that has a wide variety of corporate sponsors (https://carbonleadershipforum.org/who-we-are/)	PLCA and Unknown	CLF undertook an Embodied Carbon Benchmark Study in 2017. The study gathered 1000 building data points (but used only 325 ultimately) and made the following key findings: Finding A: The data presented represents a reasonable order of magnitude and range of variation of estimates of the embodied carbon footprint of buildings. Finding B: The initial embodied carbon (LCA stage A) of a building's structure, foundation and enclosure is typically less than 1,000 kgCO2e/m2. Finding C: The initial embodied carbon (LCA stage A) of low-rise (less than 7 story) residential building's structure, foundation and enclosure is typically less than 500 kgCO2e/m2 however there is not sufficient data to state ranges with confidence. Finding D: For commercial office buildings, the range of initial embodied carbon (LCA stage A) for building structure, foundation and enclosure is between 200 and 500 kg CO2e/m2 for 50% of buildings in the database. *There is an urgent need to standardize general building design data and building life cycle assessment data. Alignment in definitions of building area (gross, internal or exterior), building life cycle stages and scopes are critical for comparison."* This data was based on a wide variety of sources. A review of the data sources used shows that 42% of these are process based data sources and the rest (58%) use undefined data sources. One of the limitations noted is that the analysis methods used to generate the data were not aligned making it difficult to directly compare LCA results from buildings with different sources of data. These benchmarks have not been widely picked up as part of project specifications or policy.
London Energy Transformation Initiative (LETI)	PLCA	LETI describes embodied carbon reduction strategies and calculation methodologies as well as benchmark bands of performance for embodied carbon per m2 of different building typologies . LETI provides the following guidance regarding data types *"Different life cycle impact assessment methods currently exist: the method used by the tool [*project*] at building level should be consistent with the methods used at the product level (from EPDs, for instance)."* (p42 LETI, Embodied Carbon Primer). They also suggest incorporating EPDs within various stages of development which shows a preference for process based data (see p20 of Embodied Carbon Primer). "*It is noted by one respondent that EPDs would not be possible at Planning stage but RICS methodology supports initially generic and then EPD substitution as the design evolves. Several believe that, unless a specialist product is specified, EPDs could be used by tender stage, when the supply chain is identified.*" (p133 LETI, Embodied Carbon Primer). However, LETI also notes that there are issues regarding age/viability of generic data sets as well as of EPDs themselves. LETI performance benchmarks have been picked up by industry and are actively being written into project specifications in the UK.

Benchmarking Methods – Summary and Survey

Summary

- Benchmarking methods allow the embodied carbon performance of materials/building/infrastructure to be compared to an empirical 'typical/average' performance
- Five potential benchmarking methods at a material level have been outlined and their use demonstrated.
- A comparison of international study results are shown with conclusions all supporting a call for further alignment in method to increase comparability.
- Worked examples are provided to demonstrate how different methods will result in different benchmark values.
- It is acknowledged that a key challenge across many methods may be sufficient data points.
- The comparability problem occurs at the material as well as whole building scale and demonstrates the need for further national and international collaboration on the topic. International cost management and measurement standards maybe a useful body of knowledge to consider – as it demonstrated by the recently published ICMS-3 – Carbon and cost measurement and reporting standard. ICMS-3, 2021; International Cost Management Standard V3 (icms.org)
- Further work to test the sensitivity of the whole building outcome to variance in materials level LCI values is of merit.

See survey questions below

Section 5 Survey Questions

1. In order to help us continue to refine MECLA's role in the next phase of work, please list any organisations that you know of not involved in MECLA who can add value to this work. (Text response)

2. Would it be beneficial to industry to have an agreed benchmarking methods? Yes/No. At which level should it be:
   1. Material level
   2. Whole of building level
   3. Whole of infrastructure level

3. If yes, which organisation is best placed to establish benchmarks at each of the following levels:
   1. Material level
   2. Whole of building level
   3. Whole of infrastructure level

4. Please indicate your order of preference of the 5 materials and building benchmarking method listed below.

   Materials
   - Method 1 – All LCI Data
   - Method 2 – All Process LCI data and EPDs
   - Method 3 – Published EPDs
   - Method 4 – Industry Pathways (qualitative method)
   - Method 5 – Organisation Pathways (qualitative method)

   Buildings
   - % reduction against base case/reference case
   - Performance bands per m2 (similar to NABERS)

5. Do you have any comments on the strengths, limitations and alignment with standards that are provided in this table? Please provide detail.

   Materials
   - Method 1 – All LCI Data
   - Method 2 – All Process LCI data and EPDs
   - Method 3 – Published EPDs
   - Method 4 – Industry Pathways (qualitative method)
   - Method 5 – Organisation Pathways (qualitative method)

   Buildings
   - % reduction against base case/reference case
   - Performance bands per m2 (similar to NABERS)

6. If the ultimate goal is Net Zero materials and buildings by 2040 – is there a role for interim % reduction targets from "benchmark / average" values by certain time frames? (e.g. 20% by 2030; 50% by 2035 etc). Answer Y/N If Y, then what targets and timeframes (open input question)

7. Are there any benchmarking methods that could be added? Yes/No; If Yes, please provide example.

8. Should MECLA seek to align with other organisations internationally who have established embodied carbon benchmarks? If so, which do you think are the most relevant organisations to align with (please include organisations that may not have been listed in this Discussion Paper).

9. Please provide any additional comments or suggestions to further progress alignment on this Section 5 . (text response)

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SECTION 6

EMBODIED CARBON CALCULATION TOOLS AND DATA INVENTORIES

Calculation Tools

The purpose of this section is to compile a list of "LCI data sources" and also "calculators" that are currently available for use to the industry. This list is not exhaustive and we welcome additions to either list. This is simply an attempt to bring resources together in one location.

Carbon Calculation Tool	Description	Use of Australian data?	Access	Form	Sector/asset type or material level	LCA stages calculated	Claimed standards alignment
Asphalt Pavement Embodied Carbon Tool (asPECT)	asPECT provides a methodology to calculate the life cycle greenhouse gas emissions or 'carbon footprint' of asphalt used in highways. Produced in the UK.	N	Open source	Spreadsheet-based	Material level: Asphalt	A-C	PAS 2050 adopted in the development
BCSA & Tata Steel carbon footprint tool for buildings	UK created tool for basic and quick high level assessment of embodied carbon of the superstructure	N	Open source	Web based tool	Asset level: Buildings (limited scope)	A, C, D	EN 15804, EN 15978 adopted in the development
BRE LINA	BRE LINA is an online life cycle assessment tool that gives product manufacturers (and particularly SMEs) access to LCA data and a route to EPD.	N	Licenced	Online platform	Material level: LCA at a product level	A-C	EN15804
Carbon emissions calculation tool: Highways England	A tool to calculate carbon emissions for operational, construction and maintenance activities undertaken on behalf of National Highways, UK. Suppliers must report on the carbon associated with activities undertaken on behalf of National Highways on a quarterly basis.	N	Open source	Spreadsheet-based	Asset level: Specific to Highways industry	A1-A5	Unknown
Embodied Carbon in Construction Calculator (EC3)	Cloud-based tool that allows benchmarking and assessment of embodied carbon, focused on the upfront supply chain emissions of construction materials and collation of digitised EPDs. EC3 is operated by a Washington State nonprofit organisation Building Transparency.	Y (limited)	Open source	Web based tool	Material and asset level	A-C	EPDs developed against ISO 14025, and EN 15804 and/or ISO 21930:2017
Environment Agency Carbon Calculator for Construction	The UK Environment Agency is rolling out a new carbon and cost tool across all of its construction projects to help meet its 2030 net zero ambitions. The new updated tool will soon be launched following the previous spreadsheet based tool.	N	Open source	TBC	TBC	TBC	TBC
eToolLCD	Proprietary web-based tool for whole asset (building or infrastructure), whole of life LCA assessment.	Y	Licenced	Web based tool	Asset level: Buildings and Infrastructure	A-D	EN15978
GaBi	Proprietary LCA modelling software to assess every raw material and process in every phase from extraction to end-of-life across your supply chain. Used by all industries e,g automotive, agriculture etc	Y	Licenced	Web interface or desktop software	Material level	A-D	EN15804
GCCA EPD 3.1 Tool	GCCA's Industry EPD Tool for Cement and Concrete is a web-based calculation tool for EPDs of clinker, cement, concrete and precast elements. Supports manufacturers to prepare EPDs.	Y	Access is free for GCCA members and licenced for other users	Web based tool	Material level: Concrete	A-D	ISO 14025 EN 15804
Green Star Upfront Carbon Emissions Calculator	Tool used for projects seeking to meet the minimum expectation (10% reduction, no points) or credit achievement (20% reduction, 3 points) (uses EPIC data)	Y	Accessed under the Green Star Rating Tool	Web based tool	Asset level: Infrastructure	A1-A3	None

Calculation Tools

Table 8 cont.

Carbon Calculation Tool	Description	Use of Australian data?	Access	Form	Sector/asset type or material level	LCA stages calculated	Standards alignment
IS Materials Calculator	The IS Materials Calculator evaluates environmental impacts in relation to use of materials on infrastructure projects and assets.	Y	Accessed under the IS Rating Tool	Spreadsheet-based	Asset level: Infrastructure	A1-A4 and B2-B5	EN 15804, ISO 14040 ISO 14044
IStructE Structural Carbon Calculator	Tool to help you quickly estimate the embodied carbon in your structures. Primarily for structural materials, database is UK or global. Option to add own data. Incorporates clear guidance for new users with instructions in tool and accompanying manual	N	Open source	Spreadsheet-based	Asset level: Structures only	A-D	
OneClick LCA	Proprietary web-based tool for whole asset (building or infrastructure), whole of life LCA assessment.	Y	Licenced	Web based tool	Asset level: Buildings and Infrastructure	A-D	EN 15978
OpenLCA	Open source and free software for Sustainability and Life Cycle Assessment	Y	Open source	Desktop software	Material level	A-D	ISO 14040, ISO 14044, EN 15804
Pavements - Sustainability Assessment Tool - IN DEVELOPMENT	The National Asset Centre of Excellence (NACOE), user-friendly Sustainability Assessment Tool (SAT) to calculate lifecycle greenhouse gas emissions and lifecycle cost benefits of innovative road pavements designs and rehabilitation treatments.	Y	In development	In development	In development	In development	In development
Rail Carbon Tool	The Rail Carbon Tool is a web-based carbon reduction tool that is provided by the Rail Safety and Standards Board (RSSB) for UK rail industry organisations and companies	N	Open source	Web based tool	Asset level: Rail infrastructure	A1-A4	Unknown
RapidLCA	Streamlined guided tool for LCA of housing	Y	Licenced	Web based tool	Asset level - Small residential only	A-D	
SimaPro	Proprietary LCA tool to analyse and monitor the sustainability performance data of products and services	Y	Licenced	Desktop software	Material and Asset level	A-D	
Tally	Allows designers working in Revit® software to quantify the environmental impact of building materials for whole building directly in Revit.	Tally was transferred to non profit Build Transparency for their EC3 tool in 2021					
The Footprint Calculator	Proprietary web-based tool for whole asset (building, fitout, precinct or infrastructure), whole of life LCA assessment.	Y	Licenced	Web based tool	Asset level: Buildings ; Precincts;	A-D	ISO 14044; ISO 14067; ICMS-3; RiCS

Data Inventories

The below table provides a list of data inventories available, noting this is not exhaustive.

Table 9

Data Inventory	Description	LCA Methodology	Australian Data?	Access
AusLCI	The Australian National Life Cycle Inventory Database (AusLCI)is delivered by the Australian Life Cycle Assessment Society (ALCAS)	PLCA	✓	Open/Licenced
Ecoinvent	The ecoinvent database contains around 18,000 life cycle inventory datasets, covering a range of sectors. Commercial database owned by Swiss Centre for Life Cycle Inventories.	PLCA		Licenced
EU Eco platform	A portal for construction product EPDs verified to EN 15804 and published by established EPD Programme Operators	PLCA		Open
EPD Australasia	Branded program which published ISO 15804 for Australasia.	PLCA	✓	Open
EPiC Database	The Environmental Performance in Construction database is published by the University of Melbourne. The database contains over 850 coefficients.	HLCA	✓	Open
EXIOBASE V3	EXIOBASE is a global, detailed Input-Output Table (MR-IOT). It was developed by a consortium of several research institutes in projects financed by the European research framework programs.	IOLCA		Open
GaBi Datasets	Contains around 15,000 life cycle inventory datasets, covering a range of sectors. Commercial database owned by Sphera Solutions GmbH	PLCA		Licenced
GreenBook	Inventory of materials and design ready omplex assemblies and benchmarks by The Footprint Company. Global data as well as Australia	IOLCA/PLCA/HLCA	✓	Licenced
Global LCA Data Initiative (GLAD)	The Global LCA Data Access network (GLAD) is a directory of LCA datasets, from independent LCA database providers, from around the world. GLAD does not directly host databases. It redirects the users to the data provider website. The directory is open source however some datasets it directs to are from providers that require a licence to access.	-		Open
ICE Database	Inventory of Carbon & Energy database published by the University of Bath, UK. It contains data for over 200 materials.	PLCA		Open
ICM	The Integrated Carbon Metrics (ICM) Embodied Carbon Life Cycle Inventory Database is published by the University of New South Wales. It provides Australian-specific Carbon Footprint Intensities for around 700 construction and building materials.	HLCA & IOLCA	✓	Open
IE Lab	Industrial Ecology Virtual Laboratory (IELab) is a collaborative platform for multi-region input-output modelling and research.	IOLCA	✓	Open/Licenced
USLCI	The USLCI database is published by the NREL for the US.	PLCA		Open

Calculation Tools and Data Inventories – Survey Questions

Calculator Tools

1. Have you used any of the calculation tools listed? Please select which ones.
2. Can you provide any strengths and or limitations with the calculators you have used? Text response against tools
3. Do you have any suggested embodied carbon calculation tools to be added to the list? Please state
4. What other information would you like to know about the tools to inform use? Text response

Data inventories

5. Have you utilised data from any of the inventories listed? Please select which ones.
6. Do you have any suggested data inventories to be added to the list? Please state
7. What other information would you like to know about the data inventories to inform use? Text response
8. Would you support more investment in an industry wide open-access data inventory? Y/N

General

1. Would you like to see the tools and inventories summarized in one location? Y/N. If Yes should this be hosted on the MECLA website? Y/N, If no where would you suggest. An example of this is https://ghgprotocol.org/life-cycle-databases
2. Please provide any general feedback or comments on the collation of calculation tools and inventories. Text response

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SECTION 7

SUMMARY AND SURVEY

Summary and Survey

The Chairs and Committees of WG2 thank all of the participants of WG2 for their input and efforts in constructing this document.

Embodied / Upfront carbon measurement and benchmarking is in a dynamic state, which is evident from the information presented in this document. Although the practices have been developing over the last two decades, the declaration of the Climate Emergency has transformed the environment for this practice and science.

The objective of this paper is to document the dynamic aspects in all parts of the method at the level of materials, whole building and infrastructure. A critical goal for the sector is to evolve measurement approaches that allow for consistent, comparable and reliable benchmarking – or sufficient capacity in the sector to make adjustments to achieve suitable comparability. The goal of “apples for apples” comparability has been central to cost consulting aims for decades. The development of operating carbon measurement and benchmarking also evolved over a decade.

For the industry to succeed in achieving deep reductions in a timely manner, measurement and metrics are essential. It is clear that more investment at all levels of government and industry is of merit - we ask that you consider the questions posed in the survey and provide helpful input - which is framed within the context of MECLA’s core mission of:

- reducing barriers to entry and action
- increasing uptake of embodied carbon mitigation at all scales
- enabling the industry to take action on all fronts.

The survey link is provided below:
https://www.supplychainschool.org.au/mecla/mecla-wg2-upfrontcarbonpaper/

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