BUILDING PERFORMANCE

Whole-of-Life Embodied Carbon Assessment: Technical Methodology

Building for Climate Change Programme

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Te Kāwanatanga o Aotearoa
New Zealand Government

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
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1. Context

1.1. Background

New Zealand has committed to achieving net zero greenhouse gas (GHG) emissions, excluding biogenic methane, by 2050. Achieving this goal will require transformative change in many sectors of the economy – including building and construction, which is responsible for a significant proportion of New Zealand's total GHG emissions.

Government's approach to reduce emissions in the building and construction sector will be laid out in the first Emissions Reduction Plan, to be released by 31 May 2022.

The Building for Climate Change programme has been established to reduce emissions from the building and construction sector. It is expected that introducing regulatory requirements to reduce buildings' whole-of-life embodied carbon will be a key part of the approach.

In 2020 MBIE consulted with the building and construction sector on proposals to introduce mandatory reporting requirements and eventually caps for the whole-of-life embodied carbon of buildings. Sector feedback indicated support for these proposals. Feedback also identified that the biggest barrier to undertaking embodied carbon assessments was the lack of an agreed methodology for doing this.

1.2. Purpose of this document

This document sets out a proposed methodology for assessing the embodied carbon of new buildings in New Zealand, as will be required if proposals to implement the regulation of embodied carbon proceed.

Prior to the implementation of these proposals, this document is intended to support the consistency of embodied carbon assessments of buildings in New Zealand while they are not mandatory, enabling early adopters to incorporate the methodology in their own processes. It is also intended to introduce embodied carbon assessments to those parts of the sector that may be less familiar with the concepts.

1.3. Status of this document

This document represents MBIE's thinking to date on what might form the basis of a technical methodology to facilitate future regulatory changes, incorporating requirements to report and then meet caps on the embodied carbon of buildings in New Zealand.

This document has been refined based on technical feedback received in 2021 from experts and key stakeholders in this area. However, embodied carbon is a new concept for building regulatory systems internationally, and this methodology will be subject to change as our (and the sector's) understanding of embodied carbon, and how it should be regulated, progresses.

2. Objective & Principles

The primary objective of this methodology is to establish a consistent method of assessing the embodied carbon emissions of buildings in New Zealand, with the ultimate aim of making significant reductions to these emissions.

Four key principles have guided the formation of this methodology:

CONSISTENT Using the methodology provides consistent assessments of embodied carbon, so their results can be compared with each other, and used to make informed decisions.	**TRANSPARENT** Assessments can be traced back to reliable sources, and assumptions are made clear, so their results can be trusted. Methods can be improved in future, to capture the most up-to-date information and best practice data & tools available.
ACCESSIBLE & UNDERSTANDABLE Assessments are simple and clear to understand by users across all areas of the sector, supporting carbon literacy.	**OUTCOME-DRIVEN** Results of assessments lead to reductions in embodied carbon emissions across the building and construction sector.

2.1. Intended audience for the methodology

This methodology is intended to be able to be used by anyone involved in the design, construction, operation and management of buildings in New Zealand. This includes:

- **Designers & building professionals:** e.g. architects, engineers, quantity surveyors, building control officials,
- **Building owners/clients:** e.g. property developers, homeowners, property managers,
- **Builders:** e.g. main contractors, house builders, subcontractors,
- **Construction supply chain**: e.g. suppliers of building materials and products, waste contractors.

We expect these audiences will use the methodology in different ways. Additional guidance and support may be required to ensure a baseline level of understanding is achieved across all audiences, and support a gradual growth in carbon literacy prior to the introduction of proposed regulation.

2.2. What stage of the building process should the methodology be used?

This methodology is intended to be used at any stage of the design and construction process for a new building. Assessments carried out at early design and concept stage are likely to have the biggest impact on embodied carbon emissions.

We have proposed to regulate the embodied emissions of buildings by requiring an embodied carbon assessment to be submitted with a building consent application. Further work and consultation are required to develop these proposed regulations, but it is expected that these will be based on this methodology.

This methodology can also be used at other stages of the building life cycle (e.g. during operation, at end-of-life) to assess the carbon impact of repair, replacement and demolition activities. It can also be used to quantify the embodied carbon of existing buildings, so

decisions around whether to retain and renovate existing buildings, as opposed to demolish and rebuild, can be better informed.

3. Overview of Methodology

3.1. Definitions and Scope

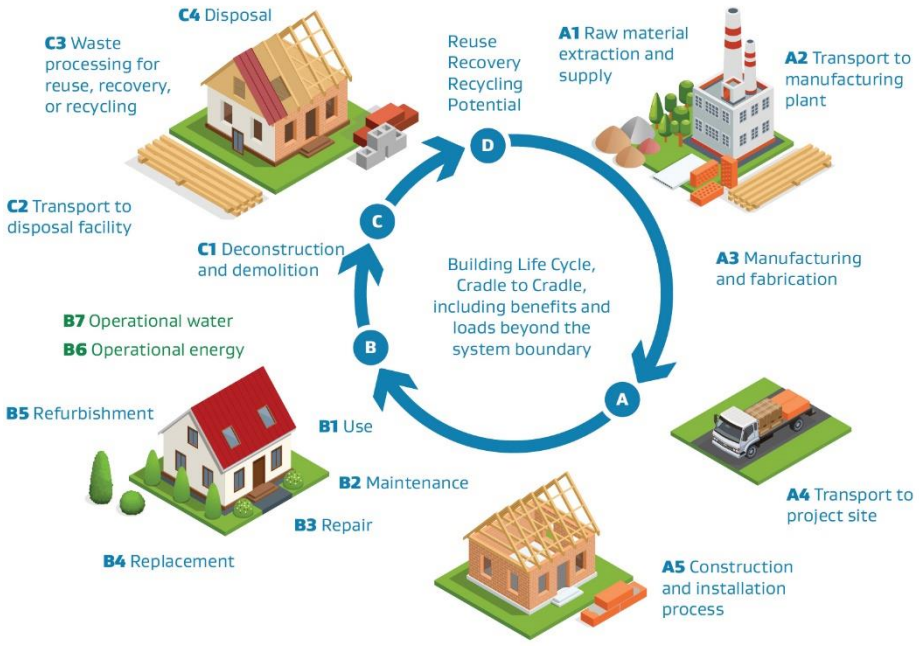
This methodology uses a Life Cycle Assessment (LCA) approach to assess embodied carbon across the life cycle of a building.

The embodied carbon of an entity is the sum of all the greenhouse gas emissions[1] that occur at each stage of its life cycle. Emissions are measured in units of kg CO_2-e[2]. In LCA studies, they are reported in the environmental impact category known as 'Global Warming Potential' (GWP).

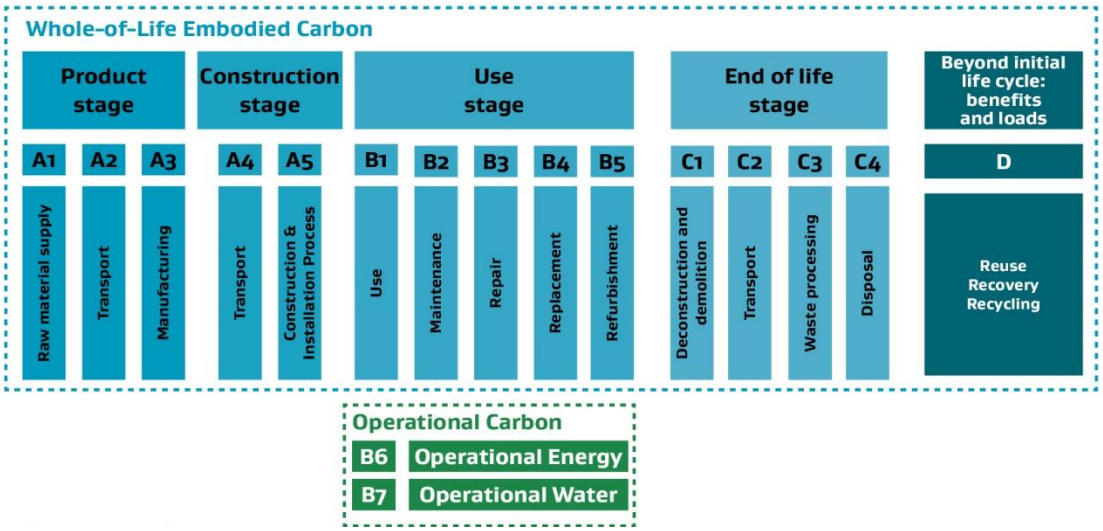
For the purposes of this methodology, a building's whole-of-life embodied carbon:

- is the sum of the embodied carbon of the constituent materials and products in the building, to the extent that it includes those elements that make the most significant contribution to the total embodied carbon of the building,
- includes all the emissions associated with these materials and products that occur right across their lifecycle, namely production and manufacture, transportation and construction processes, maintenance activities, and what happens when the building is no longer used (end-of-life),
- excludes emissions associated with the operation of the building, typically from energy used for heating, cooling, lighting, and water consumption.

The diagrams below illustrate this using the module framework for life cycle stages. Emissions occurring at each life cycle stage are accounted for in a 'module', e.g. A1, B3, C4 etc.



[1] Including CO_2, methane and other gases that have a warming effect.
[2] The equivalent quantity of CO_2 that has the same warming effect as that amount of greenhouse gases



Emissions in all modules fall within the scope of this methodology, with the exception of modules *B6 Operational energy* and *B7 Operational water,* as shown above.

These two modules relate to the operation of buildings and so fall within the scope of the work to improve the operational efficiency of buildings within the Building for Climate Change programme.

3.2. Technical Basis

This methodology is based on international standards which set out rules for LCA in construction works[3]. The module framework for life cycle stages introduced above is defined and referenced extensively in these international standards. These standards have been developed over many years and are widely used around the world.

These same standards are typically used to verify Environmental Product Declarations (EPDs) for construction materials and products, both in New Zealand and overseas. An EPD records the results of an LCA across a number of impact categories, including embodied carbon emissions. Much of the available data for the embodied carbon of construction materials and products in New Zealand are recorded in EPDs, and so are presented in the module framework format. To ensure compatibility with this data, the same international standards are used as the basis of this methodology.

[3] EN 15978: Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method;
EN 15804: Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products;
ISO 21930: Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services.

4. Scope of Assessment Methodology

The following model has been proposed for the assessment of embodied carbon of buildings:

kg Co_2 -e = **m^2** × **kg material/ m^2** × **kg Co_2 e / kg material**

Whole-of-life embodied carbon	New building efficiency	Material efficiency	Carbon intensity

Emissions reductions at a national level are achieved by reducing some, or all, of these factors:

- **New building efficiency**: how much we build new,
- **Material efficiency**: how much material we use to do that, and
- **Carbon intensity**: how much GHG is emitted to supply those materials.

The data required to complete the calculations involved in an embodied carbon assessment are typically the quantity of materials used in the building, and the carbon emissions associated with those materials throughout their life cycle. Multiplying these values together for each material and adding up the results will give the embodied carbon of the building.

While these calculations are relatively simple, decisions around the scope of the assessment, or the choice of data sources, introduce complexities that need to be addressed in a standardised manner. This methodology describes how to address these complexities that are not specified within the international standards.

We acknowledge that proposals to quantify, report and cap emissions in kg CO_2-e/m^2 will not directly incentivise greater new building efficiency (i.e. make people more inclined to build fewer new buildings, or buildings with smaller footprints). However, we anticipate other drivers will have an effect on this, including:

- construction costs,
- current trends towards denser urban planning (highlighted by the National Policy Statement on Urban Development),
- support and requirements being explored through the Building for Climate Change programme to renovate or repurpose existing buildings, and to improve the durability and resilience of new buildings.

This methodology sets out an approach in five areas:

- **Scope of building elements** to include in assessments,
- **Scope of life cycle stages** to include in assessments,
- How to report **carbon emissions and carbon benefits** in assessments,
- How to use **data sources** in assessments,
- The **format of results** of assessments.

4.1. Scope of building elements

For the purposes of this methodology, the mandatory scope of an embodied carbon assessment shall initially include the significant elements of a new building that perform the primary functions of the building.

Assessors may voluntarily choose to include additional elements, such as internal fixtures and fittings, ceilings, and temporary works in the assessment. Including these elements will help provide a more holistic understanding of whole-of-life embodied emissions, but will involve extra time and effort, so a balance is needed. The embodied carbon of these non-mandatory elements is reported separately to that of mandatory elements. This helps fair comparisons to be made and helps ensure consistency between the outputs of the mandatory part of assessments.

The level of detail to which the components in each element are considered in the assessment should be such that the effort involved is not excessively onerous, but captures the bulk of the embodied emissions.

The table below outlines the split between mandatory and voluntary building elements to be included in embodied carbon assessments.

Building System	Mandatory: must be included in the assessment	Voluntary: may be reported independently within the assessment
Ground work	• Substructure/foundations • Earth retaining structures • Basements	• Vegetation • Hard landscaping • Ancillary buildings • External services, including drainage
Structure	• Ground floor structure • Upper floor(s) structure • Load bearing systems: gravity and lateral structural frames and walls • Roof structure	• Temporary works (formwork, scaffold etc.) used during construction that are not reused • Stairs • Lifts and escalators
External envelope	• Cladding/façade primary elements (weather exposed layer, structural support system) • External wall insulation • Roof covering and insulation • External windows and doors	• Cladding/façade secondary elements (seals, brackets etc.)
Non-structural internal elements	• Non-loadbearing walls • Internal doors • Floor and wall finishes	• Ceilings • Fixtures, fittings and furniture
Building services	• HVAC[4] equipment	• Water, drainage, electrical services • Other building systems such as fire and security systems

[4] Heating Ventilation Air Conditioning

Rationale

This is a pragmatic approach – we consider that the mandatory elements are responsible for the bulk of the embodied emissions of a building over its life and are comparatively simple to calculate.

To enable the regulation of embodied carbon, further detail will be provided to reduce inconsistency arising from different interpretations of what each element comprises. The mandatory and voluntary split will be reviewed as more research and data becomes available, to ensure the mandatory scope captures the bulk of emissions with the least additional effort, and as the practice of embodied carbon assessment becomes more common.

4.2. Scope of life cycle stages

For the purposes of this methodology, the scope of an embodied carbon assessment shall include all stages of the building's life cycle, namely all modules in A, B (excluding B6 & B7), C and D in the LCA module framework.

An alternative approach is to limit the scope to initial stages only, i.e. modules A1-A5, sometimes referred to as 'up-front embodied carbon'. However, by including all life cycle stages within the scope, assessments will give a fuller picture of all emissions driven by the building.

There is additional complexity and effort required to assess emissions across all modules, potentially reducing the accessibility of assessments. To mitigate this, the assessment results will differentiate between emissions that will occur up to the operation/use stage, and those that are estimated from future life cycle stages. Although there is greater uncertainty for future emissions, there is the expectation that reasonable efforts will be made to account for these, in putting forward plausible scenarios and corresponding estimates of emissions for modules B, C and D. A greater degree of approximation will be expected for the quantities of emissions in these modules (compared to emissions in module A1-A5) in the assessment. Correspondingly, a greater degree of robustness and level of detail will be expected for the quantities of emissions in modules A1-A5 in the assessment.

To ensure consistency, at the current time, assessments shall assume a building design life of 50 years. This also aligns with the current requirements of section 113 of the Building Act 2004, however longer building lifetimes would be encouraged, as this should avoid future new builds and their associated emissions. Settings that will address the durability and lifespan of buildings are being considered as part of the wider Building for Climate Change programme, and the assumed design life of buildings for embodied carbon assessments will be reviewed accordingly.

Differentiating between estimates of future emissions and those that will occur at or before the time of the assessment assists in making assessment results transparent and understandable. It also allows embodied carbon assessments to be used as part of demonstrating the building sector's contribution to meeting the national emissions budgets for the periods set by the Climate Change Commission. At a high level, emissions will be required to be reported separately as either occurring today or in the future, as indicated in the table below.

Emissions occurring up to the start of the operations/use stage (emissions today)	Emissions that may occur during and beyond the operation/use stage (future emissions)
Modules A1-A5: determined from: material and product quantities at design and construction stage, and their embodied carbon factors, assumptions about transport modes and distances for construction materials and products getting to site, assumptions on the impact of construction activities on site.	Modules B1-B5: estimated on the basis of design life and replacement rate of construction materials and products. Modules C1-C4: estimated based on an assumed end-of-life scenario of the material or product, as provided in EPDs for those materials or products, or elsewhere. Module D: estimated based on assumed scenarios where emissions from one building offset emissions from another in future.

Rationale

Requiring assessments for emissions at all life cycle stages introduces complexity, including the need to estimate emissions that are likely to occur in future from product and material maintenance, replacement and end-of-life. However, it provides a more holistic assessment and helps to avoid perverse incentives, such as using low embodied carbon products that would require frequent replacement or maintenance.

To enable the regulation of embodied carbon, further detail will be provided on appropriate assumptions and approximations for future life cycle stages emissions. This may include tools and other practical support on appropriate data and assumptions to use, that acknowledge the potential nature of future emissions and their inherent uncertainty in the assessment. This will recognise that embodied carbon emissions quantified here will be estimations of emissions that may or may not occur in the future.

4.3. Carbon emissions and carbon removals

For the purpose of this methodology, carbon removals refer to net reductions in atmospheric GHG quantities resulting from activities than are directly attributable to the use of materials or products in a building.

To this end, any inclusion of carbon removals in an embodied carbon assessment must be based on the approach of the relevant internationally agreed standards and best practice at the time, and for these to be referenced accordingly. For example, in the case of biogenic carbon stored in timber, this would be the approach outlined in EN 16485:2014: Product category rules for wood and wood-based products for use in construction.

These removals shall always be reported separately to emissions in the assessment, and in the appropriate life cycle stage, as per the LCA module framework. In the example of carbon that is stored in timber, and then potentially emitted at the end-of-life stage, the carbon removals will be reported in module A1 and the potential emissions will be reported in the appropriate C modules.

The table below outlines how types of emissions and removals will be reported in embodied carbon assessments.

Carbon Impact type	Examples (life cycle stage module that impact occurs)
Carbon Emissions	• Emissions caused by non-renewable energy use, at all life cycle stages (any modules in A, B, C or D) • Emissions caused by processes that emit greenhouse gasses, at all life cycle stages (any modules in A, B, C or D)
Carbon Removals	• Use of natural materials that store sequestered carbon that has been removed from the atmosphere by organic growth (module A1) • Carbonation of concrete during the building's lifetime (module B1) • Potential benefits that may be realised by recycling material after end-of-life, avoiding future emissions from the use of virgin material (module D)

Rationale

This evidence-based approach recognises that assigning a beneficial carbon impact to activities in an embodied carbon assessment is not always straightforward. Their justification is often debated and disputed, and the complexities of the arguments are often beyond most non-LCA professionals.

For example, the use of natural materials, which store carbon that has been sequestered from the atmosphere during organic growth (referred to as 'biogenic carbon'), can only be considered to offer a net carbon removal if the growth is deemed to be sustainable, resulting in a net decrease in atmospheric greenhouse gas. The use of timber construction products that have been produced from unsustainable deforestation activities does not represent a net carbon benefit and so cannot be accounted for as such in an embodied carbon assessment. The definition of what constitutes 'sustainable' in this context is agreed by consensus among LCA practitioners.

The intention of this approach is to make assessments consistent and transparent, as well as maintaining accessibility, as it does not require assessors to become experts in the

complexities of LCA. It also offers the opportunity for embodied carbon assessments to reflect the best knowledge and evidence available at the time to achieve the best outcomes in terms of reductions.

Recognising that there is a significant level of commercial and academic sensitivity on this topic, this approach requires suppliers or those undertaking the assessment to adhere to the approach of the relevant internationally agreed standards and best practice at the time, and to reference them accordingly. This approach provides straightforward compliance pathways for suppliers and those undertaking assessments, while not disadvantaging any particular material types.

4.4. Data sources

When using this methodology, the data sources used in embodied carbon assessments must be clearly stated and referenced. The embodied carbon factors used for each building material or product are to be recorded, broken down by life cycle modules (in accordance with the LCA module framework), along with the material/product specifications and quantities, accompanied by all the data sources used.

Embodied carbon assessments will be required to use the highest quality data available for each material used in the building that is available at that point of the building design/construction process. The table below sets out a data quality hierarchy for both embodied carbon data and material/product quantity data, going from highest to lowest quality.

Level of Data Quality	Material or product specification and quantity data	Material or product embodied carbon data
Highest (preferred) 5	As-built information for material/product specifications and quantities, that include allowances for site waste	EN 15804 compliant EPD for specific product used in building
4	Detailed Schedule of Quantities, reflecting amounts and specifications of materials included in the building contract	New Zealand sector EN 15804 compliant EPD for product type
3	Quantities take-off from a BIM model used in the design process	Global EN 15804 compliant EPD for product type
2	Rough estimates of material quantities and material types at early stage/concept design	Embodied carbon data for product type from non-EN 15804 compliant EPD, or other databases
1 Lowest (to be avoided)	Benchmarked material quantity data from similar building types	Default values

Wherever possible and appropriate, an allowance for wastage will need to be used when reporting material quantities. This is intended capture the upstream embodied carbon emissions used to manufacture and transport these material quantities which would not be accounted for if the focus was solely on the final quantities of materials used in the completed building.

Rationale

Requiring that data sources be referenced is intended to support transparency and consistency between embodied carbon assessments. It is also intended to ensure robust and repeatable sources and methodologies are used to obtain data.

A data hierarchy provides a pragmatic method of recognising the potential gaps in the data that are required for embodied carbon assessments, especially for the New Zealand context.

As there has been little demand for them in the past, high quality embodied carbon data does not currently exist uniformly across the building and construction sector. It is expected that these embodied carbon assessment requirements will encourage data gaps to be filled, making better quality data more available, which will contribute to increasing certainty and confidence in embodied carbon assessment results.

The use of a data hierarchy is intended to allow data from multiple sources to be used in conjunction with an assessor's preferred assessment tool. The choice of tool used for the assessment can be independent of the data used, but by following this methodology and clearly stating the data sources used, a number of different tools should be able to be used to produce comparable and consistent results.

It is acknowledged that the level of data quality available will change during the building design and construction process. Use of a data hierarchy allows this to be recognised and taken into account when assessing the level of accuracy required of an assessment.

Reporting material quantities and specifications, as well as embodied carbon factors, will increase the transparency of assessments, as well as encourage material efficiency in the building design process.

We have heard feedback from the sector that the current availability and reliability of data for the embodied carbon of construction materials and products is not sufficient to ensure the consistency and robustness of embodied carbon assessments, potentially driving decisions that do not lead to outcomes that reduce emissions. The Building for Climate Change programme is investigating options for establishing robust, transparent and publicly available databases to support embodied carbon calculations, to increase the availability of data at higher levels of the data hierarchy, and providing wider coverage across more products used in construction.

4.5. Format of results

This methodology is intended to be accessible and understandable to anyone involved in the design, construction, operation and management of buildings, and these different audiences will use it in different ways. The results of embodied carbon assessments, together with the key information about the building itself, need to be easily understood by those who only have high-level knowledge of the way the assessment itself is carried out. However, the technical basis of the assessments, including assumptions made, and data sources used, as described in other sections of this methodology, must also be able to be traced and scrutinised.

To ensure assessments are accessible, but also lead to better outcomes, it is important that the source information and results produced are presented in a consistent manner, so different buildings or styles of construction can be readily compared.

Mandatory reporting requirements

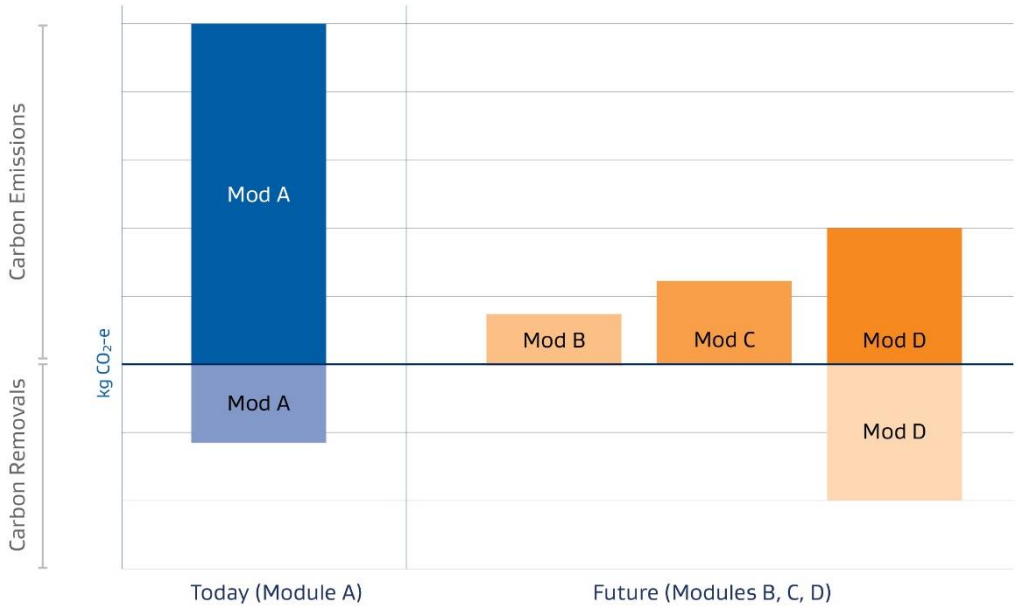
At a minimum, the results of all assessments must report on:

- Building meta-data (size, number of storeys, function & occupancy, type of structural frame and foundations, geographical location),
- Material specifications, quantities and embodied carbon data for each building component declared (mandatory and non-mandatory), together with the sources of the data for each,
- The embodied carbon, total for the building and for each system or material, clearly differentiated by:
    - life cycle stage (demarcated between emissions today and future emissions),
    - carbon emissions and benefits.

Assessments will present results in two different outputs:

- **non-technical output** – providing a high-level summary that can be easily understood by a layperson, compared between buildings, and used to improve the understanding of embodied carbon and carbon literacy in general across the sector,
- **technical output** – including calculations, data sources, references etc. that are intended to provide detailed information to technical experts and improve the quality of assessments over the longer term.

The report needs to include a graphical high level summary of the assessment that clearly differentiates between the carbon emissions and removals, and between emissions up to the start of operation stage (emissions today) and estimates of future life cycle stages (future emissions). A possible example is shown here:



When embodied carbon assessments become part of the building regulatory system, further detail will be supplied to ensure the regulations can be consistently enforced, including template formats and information requirements for the technical and non-technical outputs.

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