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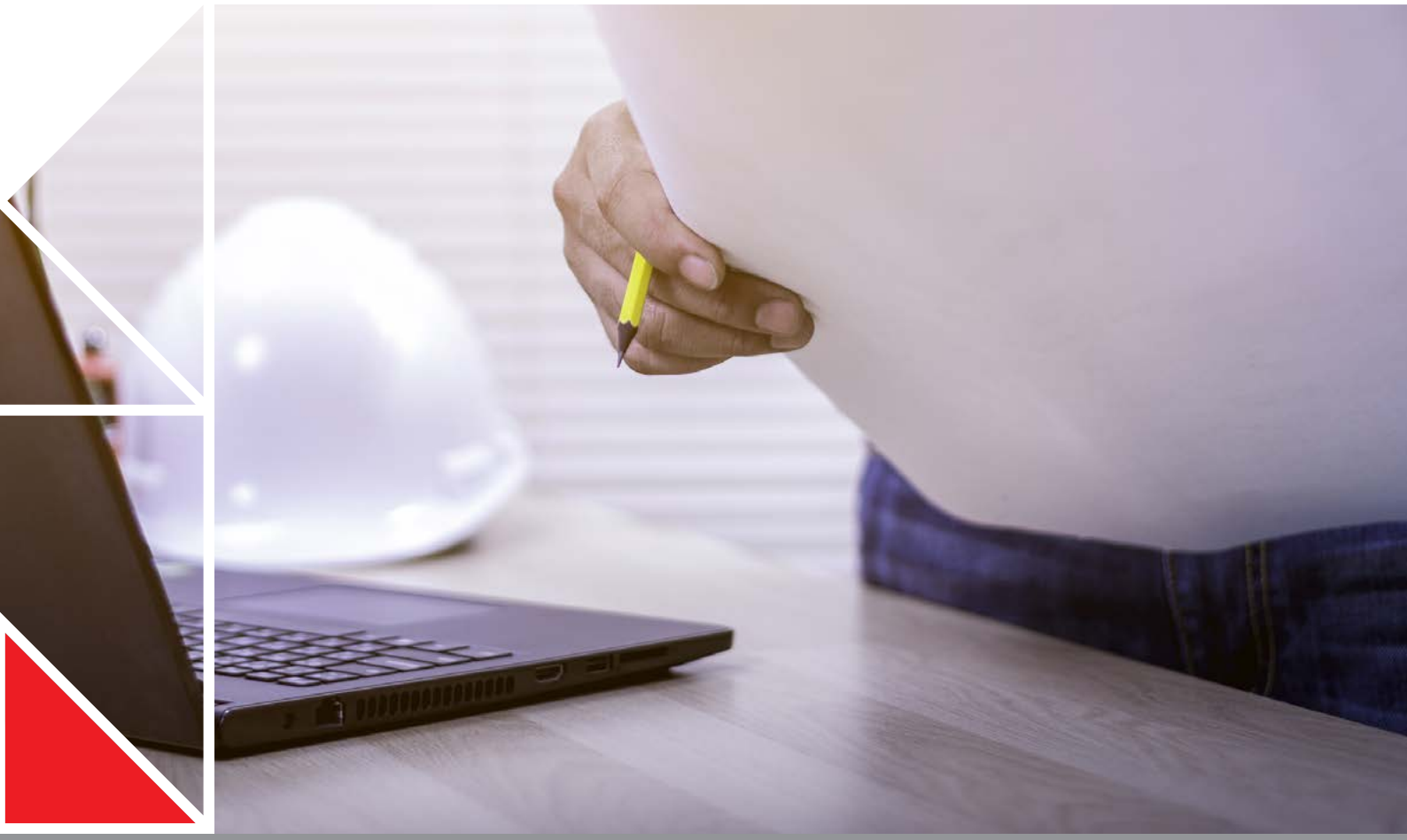

TOOLS FOR MEASURING CARBON IN NEW-BUILD HOUSES

February 2022

- New house construction must produce far fewer greenhouse gas emissions if the industry is to help New Zealand meet its net-zero carbon target by 2050.
- A large part of the reduction in emissions will be achieved from decisions made at the design stage of a new house.
- This bulletin outlines the BRANZ tools available to architects, designers and engineers to produce houses that have lower carbon footprints.

1 INTRODUCTION

1.0.1 The building sector is a significant contributor to greenhouse gas emissions from the materials used in constructing buildings and the energy and water used in operating them. The sector has an important role in helping New Zealand achieve its target, set in law, of a net-zero carbon economy by 2050.

1.0.2 Scientists from BRANZ and Massey University developed a carbon budget, calculating the greenhouse gas emissions a new house can be responsible for while the country is moving towards the 2050 net-zero carbon goal. They then compared this to the carbon emissions in typical new-build houses of varying sizes. The average new home (including stand-alone houses, medium-density housing and apartments) is multiple times over budget – producing far too many emissions in its construction and operation. The evidence shows that we need to change the way we build and operate housing so our homes account for fewer greenhouse gas emissions.

1.0.3 Emissions fall into two main types:
- Embodied carbon emissions are caused when greenhouse gases, frequently from non-renewable energy sources, are released into the atmosphere from manufacture and transporting materials, constructing and maintaining buildings and then deconstructing or demolishing them.
- Operational carbon emissions come from all the energy that building occupants use, for example in heating, cooling and ventilation, as well as their use of water.

1.0.4 Embodied carbon and operational carbon can be measured as a building's carbon footprint – the sum of all greenhouse gas emissions produced as a result of its construction, occupation and deconstruction/demolition.

1.0.5 In coming years, the requirement for lower-carbon construction will become a mandatory part of building law. On 29 November 2021, the Ministry for Business, Innovation and Employment (MBIE) published *Outcome of consultation: Building Code update 2021*. In this document, MBIE sets out some intended timeframes (subject to Government signoff) as part of its Building for Climate Change programme:
- 2021–2023: MBIE will finalise methodologies for carbon mitigation.
- 2024–2029: MBIE will introduce mandatory disclosure of embodied carbon for new buildings and bring in a phased introduction of embodied carbon caps for new buildings.
- From 2030 onwards: Progress towards final emissions-reduction caps. Carbon calculation tools, resources and other technical infrastructure will be fully in place.

1.0.6 While measuring the carbon footprint of a new house is not yet a legal requirement, it is something that many designers and clients have already chosen to carry out.

1.0.7 This bulletin outlines the BRANZ tools that architects, designers and engineers can use to reduce the carbon emissions of houses and other building types. The tools are being continually upgraded – the details here apply as of the first half of 2022.

1.0.8 Tools focusing just on thermal performance or energy modelling in houses are covered in BRANZ Bulletin 602 *Thermal modelling tools for houses* and are not described here. BRANZ recommends that energy modelling is used as a tool when developing a house design so that location, site and design-specific parameters can be considered.

2 EMBODIED CARBON EMISSIONS IN CONSTRUCTION

2.0.1 Embodied carbon emissions are assessed over the life cycle of a building (Figure 1). (For a more detailed explanation of life cycle assessment, see BRANZ Bulletin 596 *An introduction to life cycle assessment* and BRANZ Bulletin 608 *Building life cycle assessment*.)

2.0.2 Embodied carbon can be assessed over different periods (Figure 2), such as:
- cradle to gate – resource extraction and material manufacture up to the factory gate
- cradle to site – all a material's emissions up to the point it reaches a building site
- cradle to grave – a whole-of-life measure from manufacture and installation through maintenance to demolition/disposal.

2.0.3 A building's carbon footprint, including both embodied carbon and operational carbon, should be considered as early as possible in the design process. Decisions made as part of concept and preliminary design can have a significant impact on a building's carbon footprint. Carbon footprinting after this stage is a lost opportunity – changes can be time-consuming and expensive to implement, which makes improvements less likely to happen.

3 THE DEVELOPMENT OF CARBON TOOLS IN NEW ZEALAND

3.0.1 Carbon tools are created within an international framework of standards and protocols including European (EN) and international (ISO) standards. As these documents change, the tools are refined and updated.

3.0.2 Another key element in the development of carbon tools is the growing number of environmental product declarations (EPDs) that manufacturers are having prepared for their products. An EPD is an independently verified document that provides data (including emissions data) around the environmental impact of a product. EPDs allow comparison of products based on their environmental impacts. Some of the emissions data that is used in BRANZ tools such as CO_2NSTRUCT is drawn from product EPDs.

3.0.3 There are a number of New Zealand bodies working in the general area of measuring and assessing carbon emissions connected with buildings, typically with strong working connections and partnerships between them. Universities are one example – work involving Massey University and BRANZ is mentioned above. These are some other examples:

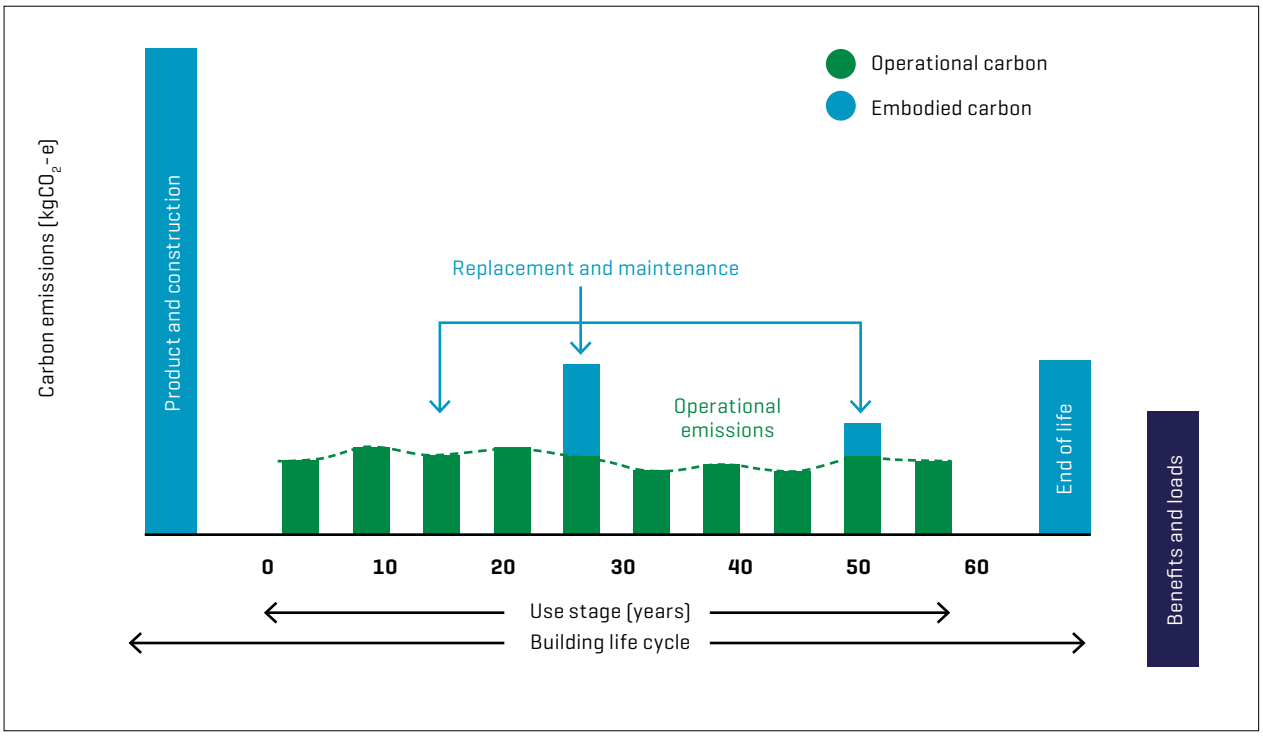

Figure 1. How embodied carbon and operational carbon relate over the building life cycle. (Bar length measurements are broadly indicative only.)
Source: *Procurement guide to reducing carbon emissions in building and construction* (New Zealand Government, June 2021)

- The New Zealand Green Building Council engaged BRANZ to develop a tool to assess carbon footprints for use with its rating scheme Homestar version 5 (see 5.0.1).
- Toitū Envirocare (a subsidiary of Crown research institute Manaaki Whenua – Landcare Research) provides information on independent carbon audits and third-party certification through its carbonzero and carbonreduce certification programmes. BRANZ has had its carbon footprint independently verified by Toitū Envirocare for a number of years.

3.0.4 The earliest BRANZ carbon tools have already gone through several versions and been expanded and updated multiple times. BRANZ is keen to hear from building product manufacturers, importers, suppliers and service providers who can provide data that can be added to the tools.

4 BRANZ TOOLS

4.0.1 BRANZ has two life cycle assessment tools:
- LCAQuick calculates environmental impacts of any building designs with a focus on residential and office typologies.
- LCAPlay is a concept-level exploratory LCA tool for commercial buildings.

4.0.2 BRANZ has three carbon footprinting tools:
- CO_2NSTRUCT is a database of embodied carbon and energy figures for building materials and products.
- CO_2RE covers greenhouse gas emissions for residential wall, floor and roof constructions (expressed as per m² of the building element). It allows evaluation based on construction R-value and whole-of-life embodied carbon.
- CO_2MPARE is a database of calculated greenhouse gas emissions for a set of reference residential and office buildings. It also contains carbon budgets for those buildings. It can be used for benchmarking and target setting.

4.1 LCAQUICK

4.1.1 Architects and designers can use LCAQuick to carry out a life cycle assessment of a planned building and understand the potential environmental impacts including greenhouse gas emissions across its life cycle. Using LCAQuick, designers can iteratively reduce or design out carbon and other environmental impacts. The tool was launched in November 2016. Version 3.5 is the latest version (as of early 2022).

4.1.2 The full version of LCAQuick v3.5 is a 57 MB Excel spreadsheet. It can be used with any building information modelling (BIM) tool. Data for this full working version can be entered directly, pasted from LCAQuick Data Entry (see 4.1.3) or loaded from a file saved by LCAQuick Data Entry. As LCAQuick does a number of calculations in the background, users may find that using LCA Data Entry may speed up the process.

4.1.3 LCAQuick v3.5 Data Entry is a lighter version that allows users to enter and organise data but does not contain the functionality to calculate the environmental impacts of a building. Once data is in the correct format in LCAQuick Data Entry, it can be saved into a small file or copied and pasted into the full version of LCAQuick, which will then calculate the environmental impacts.

4.1.4 The tool requires the input of:
- headline information about the project such as building or project name, project number and gross floor area

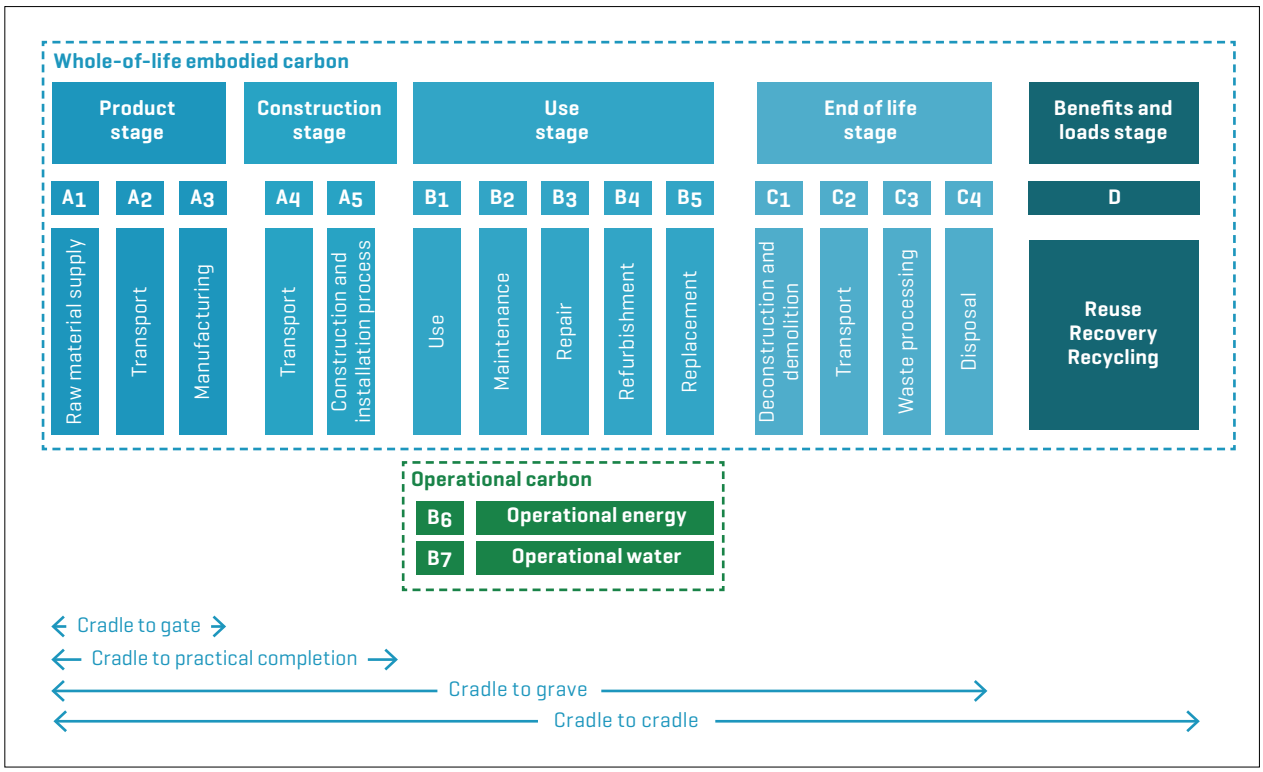

Figure 2. Stages considered in life cycle assessment.
Source: *Procurement guide to reducing carbon emissions in building and construction* (New Zealand Government, June 2021)

- material quantities either as a material take-off from a BIM tool or developed by a quantity surveyor
- results of an energy simulation – default values are available
- an estimate of water consumption – default values are available.

4.1.5 LCAQuick ranks the materials in a design that have the most significant environmental impacts. It allows users to compare alternative constructions based on embodied carbon.

4.1.6 The tool also shows the environmental impacts arising from operational energy and water use.

4.1.7 The tool includes a reference building library, allowing the user's building to be compared with a building in the library. These buildings are case studies and should not be taken to be a statistically representative sample. The buildings include:

- 10 stand-alone houses, one medium-density housing complex and one apartment building
- 10 commercial office buildings
- four school buildings.

4.1.8 The tool gives carbon budget details for a residential or office building, with embodied and operational contributions shown separately. This feature was updated to reflect carbon budget modelling completed in the second half of 2021.

4.1.9 LCAQuick includes a Green Star outputs worksheet that puts LCA results into a format that can be pasted directly into the New Zealand Green Building Council's LCA calculator tool, which calculates potential points.

4.2 LCAPLAY

4.2.1 LCAPlay can quickly provide comparative outputs for different commercial building concept options, helping inform design direction very early in the process. The tool assesses environmental impacts of different building forms, structural systems, façade and HVAC systems. Having tested basic design concepts, users can go on to calculate potential environmental impacts and test options in much more detail using LCAQuick.

4.3 CO_2NSTRUCT

4.3.1 CO_2NSTRUCT allows users to calculate the embodied carbon for the materials in a proposed building – part of the assessment of a carbon footprint. It provides values for embodied greenhouse gas (as kg CO_2 equivalent) and energy (MJ) for a range of construction materials including concrete, glass, timber and metals, as well as products such as lifts and fittings for bathrooms and kitchens.

4.3.2 The data is drawn from a range of sources (explained in notes at the bottom of the Excel spreadsheets) and is ranked from good quality to poorer quality. Values besides those with an A data quality rating do not necessarily represent specific products in the New Zealand market.

4.3.3 The materials and products are arranged in different Excel pages following level 2 classes in the Coordinated Building Information (CBI) coding system (Figure 3).

4.3.4 For each material, the total amount of embodied energy is given. This is also split into energy from

Table 1. Building typologies BRANZ tools can be applied to.

	Life cycle assessment tools		Embodied carbon tools		
	LCAQuick	LCAPlay	CO_2NSTRUCT	CO_2RE	CO_2MPARE
Stand-alone houses					
Medium-density housing					
Apartments					
Commercial buildings/offices					
School buildings					

renewable and non-renewable sources. The measure is up to the factory gate, so it does not take account of transport to the building site or wastage on site. For in-situ reinforced concrete, values include both the concrete and reinforcement, even though these are obviously not brought together until construction.

4.3.5 The data for the different materials is collated on the final worksheet, together with data on density, area density and mass/m where it is available.

4.4 CO_2RE

4.4.1 CO_2RE compares the impact and construction R-values of a range of common residential roof, wall and floor constructions. The user can:

- find out the estimated climate change impact and embodied energy for different types of constructions, based on the choice of material and type of system
- compare the carbon performance of alternative constructions according to a desired minimum construction R-value.

4.4.2 The tool includes just over 70% of the construction examples from the BRANZ *House insulation guide* (5th edition) plus some element details from the Passive House *High-performance construction details handbook*. Additional examples may be added over time.

4.4.3 CO_2RE calculates values for:

- greenhouse gas emissions (or removals) – the climate change impact – for different stages of the building's life cycle
- embodied energy used for different stages of the building's life cycle – fixings, including nails, screws and adhesives, are included in the carbon calculations
- construction R-value of each element.

4.4.4 CO_2RE allows:

- exploration of different constructions and the materials used in them
- comparisons of the climate change impact and R-values for different constructions
- options to include biogenic carbon (for example, from use of timber and timber-based materials) in the calculations and potential benefits through reusing or recycling waste
- indicative illustrations (material quantities may not necessarily reflect what is portrayed in each illustration).

4.4.5 These results are given:

- For walls as per m² of wall area in elevation.
- For floors as per m² of floor area. Where the floor area relative to its perimeter length (A/P ratio) can affect the calculated results, CO_2RE shows at least two results (usually for A/P ratios of 2.5 and 4).
- For roofs as per m² of horizontal plan area. This includes raking elements. Roofing materials are calculated on a raking face area basis (allowing for the effects of material laps etc.).

4.4.6 While work is continuing to ensure that the tool accurately reflects common practice, there are certain limitations:

- The framing ratio used for wall framing in the tool is currently 18–24% but research shows ratios are higher in practice.
- Current datasets vary in quality. These will be updated as more and better-quality data becomes available – for example, through publication of more EPDs.
- CO_2RE provides construction R-values based on thermal properties, quantities and locations of component materials. Junctions with other elements that may contribute additional thermal bridging

	Material classes	
Structure	Concrete (in-situ)	
	Concrete (precast)	
	Earth	
	Masonry	
	Steel	
	Timber & engineered woods	
Enclosure	Tanking & precladding	
	Wall cladding	
	Roofing	
	Membrane roofing	
	Windows & doors	
	Glazing	
	Insulation	
	Enclosure sundries	
Interior	Wall & ceiling linings	
	Ceiling systems	
	Floors	
Finish	Tiling	
	Resilient surfacing	
	Carpeting	
	Paint, decor & coatings	
Services	Liquid supply	
	Heating & cooling	
	Electrical	
	Transport	

Figure 3. Material classes set out in CO_2NSTRUCT.

(such as external wall to floor or external wall to roof) are not included.
- For concrete footings, NZS 3604:2011 *Timber-framed buildings* allows for footings as narrow as 165 mm for some types of construction. Digging of wider footings requiring more concrete is not considered.

4.5 CO_2MPARE

4.5.1 CO_2MPARE provides building carbon benchmarks and carbon budgets based on BRANZ analysis of reference buildings. This information can help in setting targets at the start of a new project.

4.5.2 The reference buildings are real buildings that have been constructed in New Zealand but should not be taken to be statistically representative of all residential or office buildings in New Zealand. They are:
- residential – four stand-alone houses ranging from 120 m² to 192 m², an 8-unit medium-density housing complex totalling 887 m² and one apartment building of 108 units
- commercial – six office buildings ranging from 1,800 m² to over 13,000 m² and four mixed-use buildings ranging from 1,900 m² to over 22,000 m².

4.5.3 CO_2MPARE provides summary carbon footprint and other data and information about the reference buildings that BRANZ has assessed using LCAQuick v3.5. For the occupational carbon element (energy use) in the carbon footprinting, it was assumed that comfortable interior temperatures of 18–25°C were maintained all the time in the residential buildings and during office hours in the office buildings. Data is given for Auckland, Wellington and Christchurch locations.

4.5.4 This data is available for comparison with a proposed building:
- Greenhouse gas impacts on a per m² floor area per year basis and per occupant per year (residential only) basis. This includes the mean, low and high ranges. These can be useful for understanding the magnitude and ranges of carbon footprints.
- Estimated carbon budget for the building operating 2022–2050 (on the basis that there is no carbon budget post-2050) on a per m² floor area or per occupant basis.
- Energy use intensity.
- The top five materials contributing to the building carbon footprint broken down by life cycle stage.

4.5.5 The figures provided do not take account of the sequestration of carbon dioxide for timber and engineered timbers such as LVL. They also do not take account of potential benefits from reuse, recycling or recovery of materials at the end of a building's life.

4.5.6 CO_2MPARE is an Excel-based tool that uses macros. It should be used with an up-to-date version of the software.

5 OTHER TOOLS

5.0.1 The New Zealand Green Building Council has the Homestar Embodied Carbon Calculator (HECC) tool. Developed by BRANZ, the HECC tool is based on a CO_2RE tool platform and facilitates calculation of an estimated carbon footprint of a dwelling. Homestar v5 requires calculation of embodied carbon emissions at 8 Homestar or above.

5.0.2 There other tools used in New Zealand to calculate embodied carbon. Some are simple carbon calculators that have been developed locally, while others have been developed overseas.

6 RESOURCES

BRANZ
www.branz.co.nz/calculators-tools

www.branz.co.nz/environment-zero-carbon-research

Bulletin 651 *Climate change, net-zero carbon and the building industry*

Bulletin 608 *Building life cycle assessment*

Bulletin 603 *Environmental product declarations*

Bulletin 596 *An introduction to life cycle assessment*

House insulation guide (5th edition) – a 6th edition is due for publication in 2022.

BRANZ provides free training and support to architects, designers and structural engineers who want to learn more about how to use LCAQuick or how to apply LCA and carbon footprinting to building designs. To arrange training, please email LCAQuick.help@branz.co.nz.

MBIE
www.building.govt.nz/getting-started/building-for-climate-change

www.mbie.govt.nz/dmsdocument/11794-whole-of-life-embodied-carbon-emissions-reduction-framework

Procurement guide to reducing carbon emissions in building and construction – www.procurement.govt.nz/about-us/news/new-guide-to-reducing-carbon-emissions-in-construction

Outcome of consultation: Building Code update 2021 – www.building.govt.nz/assets/Uploads/building-code-compliance/building-code-updates/outcome-consultation-building-code-update-2021.pdf

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