Study Report SR349 [2016]

New Zealand whole-building whole-of-life framework: An overview

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Preface

In April 2013, BRANZ commenced research into development of a New Zealand whole-building whole-of-life framework. The purpose of the framework is to establish a level playing field for evaluation and reporting of the environmental impacts of building designs in comparison with an appropriate reference building, based on life cycle assessment (LCA). Initial focus is on offices.

This report has been developed to provide an introduction to the framework and the resources available within it. These resources have been developed with the aim of facilitating greater use of LCA, particularly with respect to building design.

Other reports published for the framework research are available on the BRANZ website at www.branz.co.nz/study_reports and include the following:

Berg, B. Dowdell, D. & Curtis, M. (2016). *New Zealand whole-building whole-of-life framework: Development of reference office buildings for use in early design*. BRANZ Study Report SR350. Judgeford, New Zealand: BRANZ Ltd.

Dowdell, D., Berg, B., Marston, N., Shaw, P., Burgess, J., Roberti, J. & White, B. (2016). *New Zealand whole-building whole-of-life framework: Development of datasheets to support building life cycle assessment*. BRANZ Study Report SR351. Judgeford, New Zealand: BRANZ Ltd.

Dowdell, D. (2014). *New Zealand whole building whole of life framework: Life cycle assessment-based indicators*. BRANZ Study Report SR293. Judgeford, New Zealand: BRANZ Ltd.

Dowdell, D. (2013). *Application of environmental profiling to whole building whole of life assessment – key features*. BRANZ Study Report SR276. Judgeford, New Zealand: BRANZ Ltd.

Dowdell, D. (2013). *Application of environmental profiling to whole building whole of life assessment – a plan for New Zealand*. BRANZ Study Report SR275. Judgeford, New Zealand: BRANZ Ltd.

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Dowdell, D. (2012). *Evaluation of Environmental Choice New Zealand as a best practice ecolabel and comparison with the GBCA Framework*. BRANZ Study Report SR271. Judgeford, New Zealand: BRANZ Ltd.

Jaques, R., McLaren, J. & Nebel, B. (2011). *Environmental profiling of New Zealand building material products: Where to for the New Zealand building sector* BRANZ Discussion Paper. Judgeford, New Zealand: BRANZ Ltd.

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Stuart Ng, Standards New Zealand

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Finally, BRANZ would like to thank Massey University, in particular Sarah McLaren of the New Zealand Life Cycle Management Centre, and the Victoria University of Wellington, in particular Mike Donn of the School of Architecture, for their valuable contributions to this project.

Note

This report is intended for stakeholders with an interest in understanding the environmental impacts of the built environment through application of life cycle assessment (LCA), including government, architects, designers, engineers, quantity surveyors, specifiers, construction product manufacturers, importers, design and building information model (BIM) tool providers, LCA practitioners and researchers.

It has been developed primarily for application to the design of new offices in New Zealand but may be helpful for other applications of building LCA.

New Zealand whole-building whole-of-life framework: An overview

BRANZ Study Report SR349

Authors

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Reference

Dowdell, D. & Berg, B. (2016). *New Zealand whole-building whole-of-life framework: An overview*. BRANZ Study Report SR349. Judgeford, New Zealand. BRANZ Ltd.

Abstract

BRANZ, with industry and research partners, has developed the New Zealand whole-building whole-of-life framework, which aims to provide resources to facilitate more consistent use of life cycle assessment (LCA) applied to buildings. This is especially important now that building LCA is recognised within the Innovation category of the Green Star building environmental rating tool.

Initial resources available in the framework are focused on the concept and preliminary design of new-build offices with a gross floor area of 1500 m^2 or more, located in Auckland, Wellington or Christchurch.

The framework provides information and data for use when carrying out building LCA, environmental indicators for reporting and calculated life cycle environmental indicators for 10 New Zealand reference office buildings which can be used for comparison with building designs. The framework is underpinned by international building sustainability standards.

In addition, an awareness raising/education building LCA tool called *LCAQuick – Office* has been developed to help stakeholders involved in design to better understand what LCA is, what its outputs are and how to incorporate it into design, without the need to incur significant cost or time. *LCAQuick – Office* is supported by YouTube training videos and a Help facility.

All resources developed to date are available for download from the BRANZ website at www.branz.co.nz/buildingLCA.

Keywords

Design, environment, LCA, LCAQuick, life cycle analysis, life cycle assessment, office, reference building, whole building, whole of life.

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Acronyms and terms

ALCAS	Australian Life Cycle Assessment Society (www.alcas.asn.au)
API	Australian Property Institute (www.api.org.au)
Australasian EPD® Programme	EPD scheme across Australia and New Zealand set up by LCANZ and ALCAS for the purposes of acting as an EPD Programme Operator. The programme is based on The International EPD® System. Further information about the Australasian EPD® Programme can be found at www.epd-australasia.com and the International EPD® System at www.environdec.com.
BEES	Building Energy End-use Study (www.branz.co.nz/BEES)
BIM	building information model
BRANZ	Building Research Association of New Zealand (www.branz.co.nz)
BRE	Building Research Establishment (www.bre.co.uk)
BREEAM	BRE Environmental Assessment Method
BSi	The British Standards Institution
building information model	A digital representation of the physical and functional characteristics of a building. As such, it serves as a shared knowledge resource for information about a building, forming a reliable basis for decisions during its life cycle from inception onward (Building and Construction Productivity Partnership, 2014).
carbon footprint	Sum of greenhouse gas emissions and removals in a product system, expressed as CO_2 equivalent and based on a life cycle assessment (ISO, 2013).
CBI	Co-ordinated Building Information
characterisation	Process of assigning characterisation factors – see 'midpoint characterisation factor'.
CEN	European Committee for Standardisation (www.cen.eu)
CIC	Construction Industry Council (http://nzcic.co.nz/)
constructed asset	Anything of value that is constructed or results from construction operations (ISO, 2011a).
co-ordinated building information	A classification system designed by and for members of the construction industry to co-ordinate the five main information sources – drawings, specifications, quantities, technical and research information, and trade information and publications. CBI is based on the European CAWS (Common Arrangement of Work Sections) system and the ISO-sponsored Uniclass project.[1]

[1] Taken from the Masterspec website. For further information, visit www.masterspec.co.nz/industry-resource/cbi-classification-and-coding-overview-1130.htm.

co-product	Any of two or more marketable materials, products or fuels from the same unit process, but which is not the object of the assessment (CEN, 2013). Also called a by-product. A waste from a process that, with or without subsequent processing, provides another function, is also considered a co-product.
datasheet	Collection of data for a stage or module in the life cycle of a building for use in scenario development when conducting building LCA in New Zealand. Datasheets developed by BRANZ are for application to new-build offices in New Zealand, with emphasis on early design stages, but may be useful (with care) for other stages of design and other applications of LCA. All available datasheets can be downloaded from the BRANZ website at www.branz.co.nz/buildingLCA.
DBH	Department of Building and Housing (now part of the Ministry of Business, Innovation and Employment [MBIE]).
EcoInvent	Proprietary LCA database of unit processes developed and maintained by the EcoInvent Centre (www.ecoinvent.org).
EcoSpold	Data exchange format used for life cycle inventory data and life cycle impact assessment methods.
embodied carbon	Total carbon dioxide (or greenhouse gas emissions) required for the extraction, processing, manufacture and (sometimes) delivery of building materials to the building site and installation in the building. Usually expressed in units of kg CO_2 equivalents when considering all significant greenhouse gases or kg CO_2 when just considering carbon dioxide emissions.
embodied energy	Total energy required for the extraction, processing, manufacture and (sometimes) delivery of building materials to the building site and installation in the building. Usually expressed in units of MJ or kWh.
end-of-waste state	Point at which a waste becomes a useful material and defines the boundary between first use (which generated the waste) and a second, subsequent use (which uses the secondary output derived from the waste).
environmental product declaration	A voluntary declaration providing quantified environmental data using predetermined parameters and, where relevant, additional quantitative or qualitative environmental information. Also known as a Type III environmental declaration or Type III ecolabel.
EPD	environmental product declaration
estimated service life	Service life that a building or parts of a building would be expected to have in a set of specific in-use conditions, determined from reference service life data after taking into account any differences from the reference in use conditions (ISO, 2011a).
GBCA	Green Building Council of Australia (www.gbca.org.au)

generic data	Data that depicts typical characteristics of products in a sector but is not necessarily representative of a specific named product in that sector. Data may be sourced or adapted from databases or derive from literature or other sources. Also known as secondary data.
GFA	gross floor area – usually measured in square metres (m^2)
global warming potential	Midpoint characterisation factor assigned to different greenhouse gases for the purpose of calculating global warming impacts (see 'midpoint characterisation factor').
Green Star	The NZGBC's voluntary environmental rating tool for buildings which assesses a building at the design and as-built phases in the following areas: management, indoor environment quality, energy, water, transport, land use and ecology, emissions and innovation.
gross floor area	Sum of the area of all floors of a building, including mezzanines and balconies. The gross floor area is measured from the exterior faces of the exterior walls or from the centrelines of walls separating two uses within a building, including all voids and unused parts of buildings (MfE, 2008).
GWP	global warming potential
hazardous waste	Unwanted materials that exhibit hazardous characteristics to humans and/or the environment.
IEA	International Energy Agency
ILCD	International Reference Life Cycle Data System, which was developed to provide a common basis for consistent, robust and quality-assured data, methods and assessments (http://eplca.jrc.ec.europa.eu/?page_id=86).
IMPACT	specification and database for software developers to incorporate into their tools for application of LCA and life cycle costing.
IPCC	Intergovernmental Panel on Climate Change (www.ipcc.ch)
ISO	International Organization for Standardization (www.iso.org)
LCA	life cycle assessment
LCANZ	Life Cycle Association of New Zealand (www.lcanz.org.nz/)
LCAQuick – Office	Excel-based early design support tool developed by BRANZ to help architects and other professionals involved in design to better understand what LCA is, how to incorporate it into workflows and how to use LCA outputs to inform design decisions. It performs an evaluation of a design and compares it to one or more reference New Zealand office buildings.
LCI	life cycle inventory
LCIA	life cycle impact assessment
LEED	Leadership in Energy and Environmental Design

life cycle assessment	Compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle (ISO, 2006a).
life cycle impact assessment	Phase of the life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system (ISO, 2006a).
life cycle inventory	Outcome of a life cycle inventory analysis that catalogues the flows across the system boundary and provides the starting point for life cycle impact assessment (ISO, 2006a).
maintenance	Combination of all technical and associated administrative actions during the service life to retain a building or its parts in a state in which it can perform its required functions (ISO, 2011a).
MAF	Ministry of Agriculture and Forestry (now part of the Ministry for Primary Industries).
MBIE	Ministry of Business, Innovation and Employment (www.mbie.govt.nz).
MfE	Ministry for the Environment (www.mfe.govt.nz).
midpoint characterisation factor	Factor derived from a characterisation model which is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator (ISO, 2006b). For example, global warming potentials are midpoint characterisation factors derived from a characterisation model used to convert emissions of different greenhouse gases into a common unit of midpoint impact (in this case, kg eq. CO_2 to represent radiative forcing).
Monte Carlo simulation	Technique that converts uncertainties in input variables of a model into probability distributions. This is achieved by randomly selecting values from distributions for variables and recalculating the simulated model many times in order to produce the probability distribution for an output.
net floor area	Sum of the floors of a building measured from the exterior faces of the exterior walls or from the centrelines of walls separating two uses within a building, excluding all common areas such as hallways, elevators, voids and unused parts of buildings (MfE, 2008).
net lettable area	See net floor area– usually measured in square metres (m^2).
New Zealand Life Cycle Management Centre	Based at Massey University and established to provide education, training and research to life cycle management professionals to meet increasing consumer demand for green metrics on products (www.lcm.org.nz).
NLA	net lettable area
NZGBC	New Zealand Green Building Council (www.nzgbc.org.nz)
NZIQS	New Zealand Institute of Quantity Surveyors (www.nziqs.co.nz)
PAS	publicly available specification
PCR	product category rules

PEF	product environmental footprint
PFA	Property Funds Association (www.propertyfunds.org.au)
product category	Group of construction products that can fulfil equivalent functions (CEN, 2013).
product category rules	Set of specific rules, requirements and guidelines for developing EPDs or footprints for one or more product categories (adapted from CEN, 2013).
product system	Collection of materially and energetically-connected unit processes which performs one or more defined functions (ISO, 2006a). Includes services.
reference service life	Service life of a product/component/assembly/system which is known to be expected under a particular set, i.e. a reference set, of in-use conditions and which may form the basis of estimating the service life under other in-use conditions (ISO, 2011a).
refurbishment	Modification and improvements to an existing building in order to bring it up to an acceptable condition (CEN, 2011b).
repair	Returning an item to an acceptable condition through the renewal, replacement or mending of worn, damaged and degraded parts (CEN, 2011b).
replacement	Change of parts of an existing item to regain its functionality.
RS	research stream (within the New Zealand whole-building whole-of-life framework research)
scenario	A collection of assumptions and information concerning an expected sequence of possible future events (CEN, 2013).
secondary fuel	Fuel recovered from previous use or from waste which substitutes primary fuels (CEN, 2013). Examples include used solvents, wood, tyres and oil.
secondary material	Material recovered from previous use or from waste which substitutes primary materials (CEN, 2013). Examples include recycled scrap metal, crushed concrete, glass cullet, recycled wood chips and recycled plastic.
secondary output	A secondary material or secondary fuel.
service life	Period of time after installation during which a facility or its component parts meets or exceeds the performance requirements (ISO, 2011a).
SETAC	Society of Environmental Toxicology and Chemistry (www.setac.org)
SME	Small-to-medium-sized enterprise
unit process	Smallest portion of a product system for which data is collected when performing an LCA (ISO, 2006a).
USGBC	United States Green Building Council (www.usgbc.org)

WGBC	World Green Building Council (www.worldgbc.org)
waste	A substance or object that the holder discards or intends or is required to discard (CEN, 2013).
water footprint	metric or metrics for quantifying potential environmental impacts related to water.

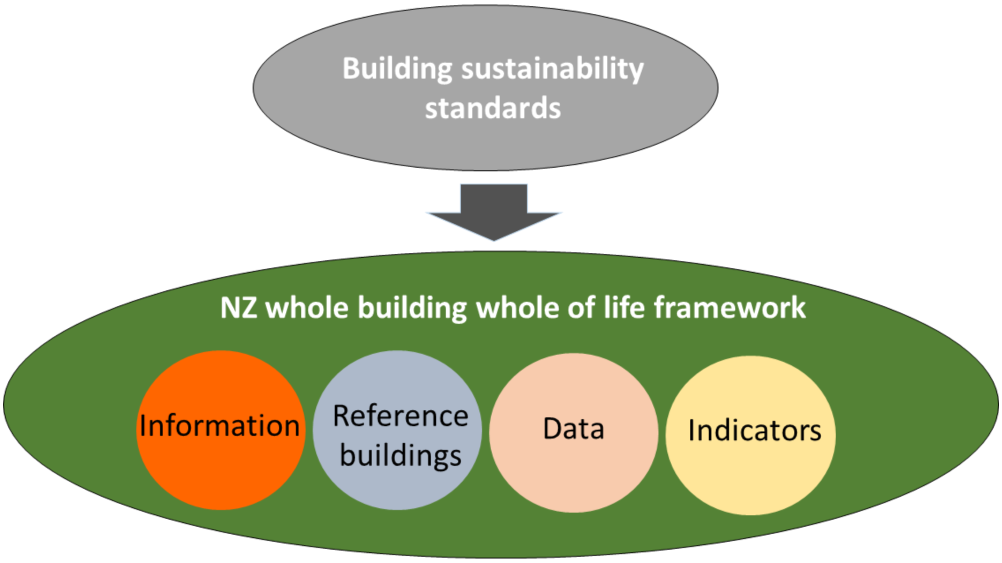
1. Executive summary

BRANZ, with industry and research partners, has developed the New Zealand whole-building whole-of-life framework ('framework') which aims to provide information and resources to facilitate more consistent use of building life cycle assessment (LCA) in New Zealand. Initial focus has been on early design of new-build offices.

This report identifies three stakeholder groups who can, primarily, engage with the framework and also how they can engage. The three stakeholder groups are:

- Group 1: Manufacturers and importers of construction materials and products, and their sector bodies/trade associations.
- Group 2: Architects, designers, structural engineers, specifiers, quantity surveyors, other design professionals and LCA practitioners involved in evaluating design of buildings using LCA.
- Group 3: Building rating tool providers (the New Zealand Green Building Council).

The framework is based on international building sustainability standards, with resources structured as shown below.



Resources developed to date are:

- Information: Includes this study report and Study Report SR351 (Dowdell et al., 2016). The reports provide information about the framework and how supporting data has been developed.
- Reference buildings: 10 recently-constructed reference office buildings (1500 m^2 gross floor area or more) have been modelled (using a building information model [BIM]) in terms of their structure and thermal envelope, as well as energy modelled using New Zealand template energy models (developed as an output of the Building Energy End-use Study [BEES][2]) and information in consent documentation. These reference buildings reflect actual material use in the buildings and designed (rather than measured, actual) energy use. Study Report SR350 (Berg et al, 2016) provides information on the derivation of the reference buildings and results in terms of environmental indicators.

[2] www.branz.co.nz/BEES

- Data: Includes datasheets covering transport of materials to construction sites in Auckland, Wellington and Christchurch, construction site waste, office building service life, maintenance and replacement of materials during the building service life, energy modelling, water-use benchmarks, and materials end-of-life routes at building end of life. A summary of environmental indicators and life cycle inventory (LCI) for low voltage New Zealand grid electricity is also provided, based on work undertaken at the New Zealand Life Cycle Management Centre supported by BRANZ (Sacayon Madrigal, 2016).
- Indicators: Currently-recommended indicators are provided in BRANZ Study Report SR293 (Dowdell, 2014), which additionally sets out methods for calculation of impacts and characterisation factors. Current indicators are in line with international standards. Indicators proposed for future inclusion in the framework are also set out.

Further Masters and Doctorate level research is being undertaken at the New Zealand Life Cycle Management Centre, the outputs of which will be referenced or made available on the BRANZ website as they are completed. This research includes an LCA-based analysis of energy efficient refurbishment of New Zealand offices, an evaluation of barriers and enablers to help small-to-medium-sized construction product manufacturers develop LCA-based environmental data and development of water scarcity characterisation factors for New Zealand.

Additionally, and with specific application to early design of office buildings, an awareness-raising tool called *LCAQuick – Office* has been developed. The aim of *LCAQuick – Office* is to provide a resource to help Group 2 stakeholders involved in early stages of building design to better understand LCA, in particular:

- what building LCA is
- how to incorporate LCA into existing workflows
- what the outputs of LCA look like, how to use and interpret them
- how decisions taken at early design are likely to lead to environmental impacts during the building life, where these occur and how to reduce them
- how the environmental impacts of early designs compare to environmental impacts calculated for reference New Zealand office buildings.

LCAQuick – Office can be downloaded from the BRANZ website at www.branz.co.nz/buildingLCA and is accompanied by YouTube video tutorials (see the LCA playlist at www.youtube.com/user/BRANZmedia/playlists).

All framework resources can be accessed from the BRANZ website at www.branz.co.nz/buildingLCA.

2. Introduction

2.1 Background

BRANZ commenced research into environmental profiling and whole-building whole-of-life assessment in 2010 to help answer questions raised by the construction industry about evaluation of environmental performance on the construction product and building scale. The initial research focused on how environmental product declarations (EPDs) underpinned by life cycle assessment (LCA) can provide a robust source of information for a more consistent evaluation of the environmental performance of construction products, which, in turn, can be incorporated in the assessment of New Zealand buildings across the life cycle.

Development of such a framework is important for the New Zealand construction industry because it:

- provides more of a level playing field for assessment, with a focus on environmental performance of buildings across the life cycle
- enables evaluation of the environmental performance of buildings according to their function
- provides a basis for comparing building designs in order to better understand the sources and scale of environmental impacts across the life of a building
- aligns with ongoing developments in building environmental assessment according to international standards
- provides a holistic assessment that does not focus on single issues or specific parts of the life cycle of a building, both of which risk problem shifting from one impact to another or one stage of the life cycle to another or one medium to another
- provides a basis for measuring continuous improvement through recognition of innovation based on reduced environmental impacts – this can be at the construction product level through to the building level
- facilitates a stronger connection between supply and demand for construction products – architects and designers that use LCA to evaluate their building designs rely on LCA-based data for construction products, which can be provided by manufacturers and importers. By making data about their products publicly available, manufacturers and importers can ensure data for their products is accurate and representative of current production as well as demonstrating a willingness for robustness and transparency
- with increasing use of quantitative design tools such as building information models (BIM) and energy models, opportunities for linking LCA-based data into the design process become quicker and easier. For example, provision of LCA-based indicators as metadata in freely-downloadable BIM objects of construction products provides opportunities for direct calculation of environmental impacts of building designs in BIM – this will increasingly facilitate more rapid assessment of building environmental performance during the design process.

In February 2013, BRANZ published BRANZ Study Report SR275 *Application of environmental profiling to whole building whole of life assessment – a plan for New Zealand* (Dowdell, 2013), which set out a vision and plan for how LCA and EPDs of construction products could be integrated with LCA-based building assessment in order to derive quantitative impacts for buildings across the life cycle. The plan was developed with existing New Zealand initiatives, structures and organisations in mind so as not to 'reinvent wheels' and to take account of developments in international standards concerning evaluation of the environmental performance of buildings.

Following a consultation with the New Zealand construction industry, the plan provided the basis for a 3-year Building Research Levy funded research programme to develop a New Zealand whole-building whole-of-life framework.

2.2 Organisation and focus of research streams

The framework aim is to provide information and resources to encourage and facilitate more consistent use of building LCA, with an initial focus on application to early design of new-build offices.

To achieve this aim, the research was divided into three research streams. A stakeholder group and industry interest groups were established in order to receive input to and feedback on the research from interested stakeholders.

The three research streams (RS) were organised as follows:

- *RS1 Establish LCA-based indicators to underpin the reporting basis of the framework:* This research completed in 2014 and resulted in publication of BRANZ Study Report SR293 (Dowdell, 2014). The report sets out currently recommended environmental indicators for reporting and environmental indicators highlighted for potential future incorporation into the framework. The report includes calculation methodologies and characterisation factors for use in calculating potential environmental impacts.
- *RS2 Develop calculated environmental impacts for a set of reference New Zealand office buildings, in order to provide an initial basis for comparison:* A simple matrix for categorising office buildings has been developed, and 10 New Zealand office buildings each with a gross floor area (GFA) of 1500 m^2 or more have been modelled according to materials used in the structure and thermal envelope and designed energy use according to location in Auckland, Wellington and Christchurch. This work has resulted in BRANZ Study Report SR350 (Berg, Dowdell & Curtis, 2016).
- *RS3 Develop default data for use when conducting building LCAs in the absence of specific data*. Excel datasheets have been developed that provide reference data for use in building LCAs of offices during early design. While the information has been developed for application to early-stage design, it may also be useful for other building LCA applications. These resources can be downloaded from the BRANZ website at www.branz.co.nz/buildingLCA and are supported by information in BRANZ Study Report SR351 (Dowdell et al, 2016).

BRANZ has supported other research being conducted at the New Zealand Life Cycle Management Centre at Massey University as part of the framework. Outputs of this research will be made available on the BRANZ website as it is completed during 2016 and 2017. This research includes the following:

- An LCA-based evaluation of energy-efficient refurbishment in New Zealand offices to ascertain and recommend refurbishment options that yield the largest potential environmental gains. This research is due to complete in early 2017.
- An evaluation of the barriers faced by small to medium-sized enterprises (SMEs) that want to engage with LCA and what opportunities exist to help overcome these barriers. This research is due to complete in late 2016.

- Assessment of methods for calculating water scarcity impacts in New Zealand. The outputs of this research will be reported later in 2016.
- Development of an LCA-based model for New Zealand grid electricity generation and distribution in order to produce a life cycle inventory (LCI) for 1 kWh of low-voltage New Zealand grid electricity delivered to a building. The outputs of this work have been used in the framework.

Additionally, and with specific application to early design of office buildings, an awareness-raising tool called *LCAQuick – Office* has been developed by BRANZ. The aim of the tool is to provide a resource to help stakeholders involved in the early stages of building design to better understand LCA, in particular:

- what building LCA is
- how to incorporate LCA into existing workflows
- what the outputs of LCA look like and how to use and interpret them
- how decisions taken at early design are likely to lead to environmental impacts during the building life, where these occur and how to reduce them
- how the environmental impacts of early designs compare to environmental impacts calculated for reference New Zealand office buildings.

LCAQuick – Office is available for download from the BRANZ website at www.branz.co.nz/buildingLCA and is accompanied by YouTube video tutorials (see the LCA playlist at www.youtube.com/user/BRANZmedia/playlists).

2.3 Organisation of this report

This report is organised as follows:

- Section 3 sets out the key stakeholders who can use the framework.
- Section 4 provides a brief introduction to LCA and the building life cycle.
- Section 5 sets out the framework focus and architecture.
- Section 6 details the scope of the framework currently.
- Section 7 provides an introduction to *LCAQuick – Office*.
- Section 8 sets out how you can add data and information to the resources available on the framework.

3. Key framework stakeholder groups

There are three main stakeholder groups for whom the framework has been developed which are mapped out in Figure 1. The ways that these groups can use the framework are different and set out further below.

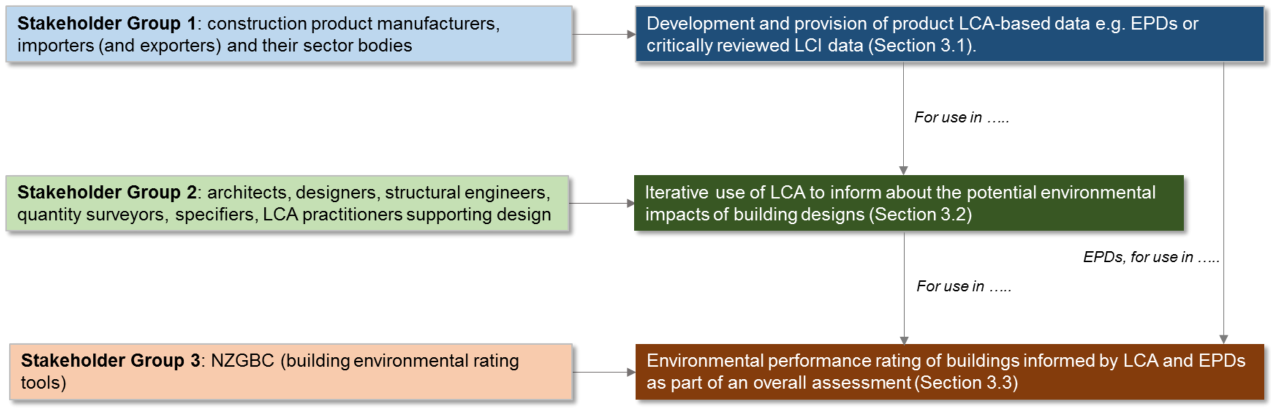


Figure 1. How construction industry stakeholders can engage with the framework.

3.1 Stakeholder Group 1

Manufacturers, importers and exporters of construction products and their sector bodies may interact with the framework primarily through development and publication of LCA-based data. There are two main options open to this stakeholder group which are mapped out in the flowchart in Figure 2.

Other ways that Stakeholder Group 1 can interact and contribute to the framework are set out in Section 3.1.3.

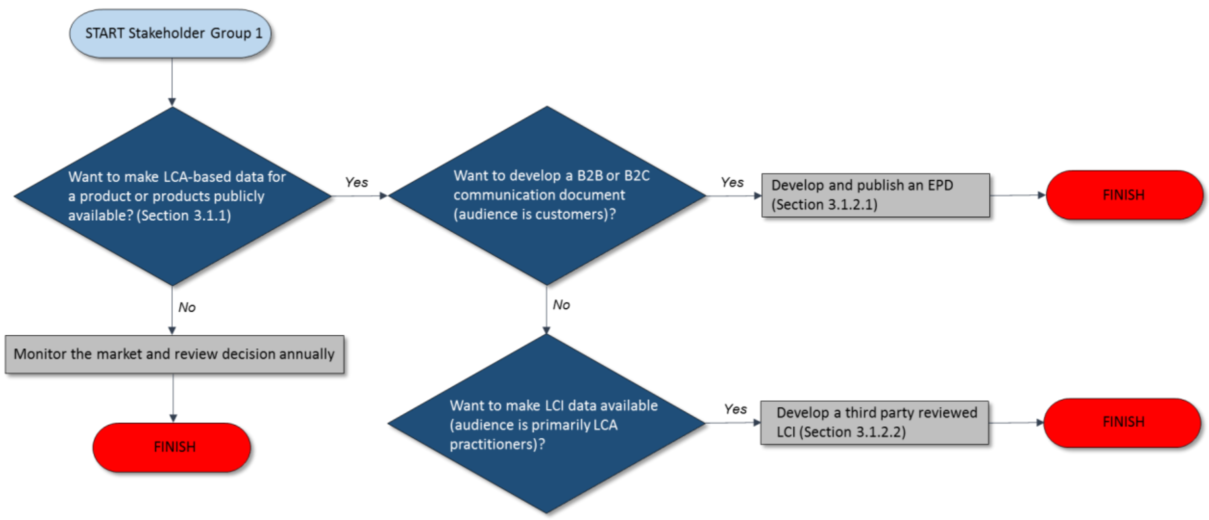


Figure 2. Flowchart for Stakeholder Group 1 engagement.

3.1.1 The choice to make available product-LCA-based data

Firstly, this stakeholder group must consider whether to make product-LCA-based data publicly available. Potential reasons for choosing to do so are to:

- Demonstrate transparency to customers.
- Showcase environmental attributes of products using a robust, science-based approach and facilitate evaluation of building environmental impacts using LCA (see Section 3.2).
- Lead the competition and through provision of LCA-based data, show potential customers how your products can contribute to their environmental goals.
- Raise environmental performance higher up the corporate agenda by benchmarking performance and using this as a basis for implementing environmental improvements. Continuous improvement is a key attribute of quality management.
- Look for opportunities for efficiency gains and cost savings, by assessing products and processes from an LCA perspective.
- Input to research and development activities, by evaluating and better understanding associated environmental implications.
- Help a building project to achieve points within the building environmental rating tool Green Star through the Innovation Challenge for EPDs.
- Ensure that available data for your products is representative and current. During early stage building design (concept and preliminary design) building design decisions focus on aspects such as form, orientation, window-to-wall ratios and type of structure. At this stage, generic LCA data, in the absence of specific product data, can be sufficient to iteratively inform early design decisions towards environmentally-preferable options. Later in the design process, when specific products are being evaluated and specified, access to product-specific LCA-based data becomes increasingly important to inform choice. If product-specific LCA-based data does exist, it is preferred to generic data during early design.

LCA is a robust, science-based approach and its application to construction products is enshrined in international standards. LCA studies are not small undertakings and require data collection (sometimes additionally requiring data from suppliers) which can be costly and take time. Options for carrying out an LCA are to:

- engage external expertise. Examples of specialists that provide LCA services are available on the Life Cycle Association of New Zealand (LCANZ) website (www.lcanz.org.nz)
- develop internal expertise by supporting a staff member to undertake postgraduate study in life cycle management and life cycle assessment at Massey University's Life Cycle Management Centre (www.massey.ac.nz).

Due to the data intensive nature of LCA, it is usually conducted in specialist software tools with supporting databases. The two main LCA software tools used in New Zealand are GaBi provided by thinkstep and SimaPro provided by lifecycles. Both softwares require purchase of a licence to use and annual maintenance. Both organisations provide training. Costs depend on the type and number of licences and supporting data required. Further information is available at:

- lifecycles (www.lifecycles.com.au) for SimaPro.
- thinkstep (www.thinkstep.com) for GaBi.

There is, additionally, an initiative that has developed a free open-source LCA software tool called openLCA available at www.openlca.org.

3.1.2 Formats for publicly available LCA-based data

Having made a decision to make LCA-based data available in the public domain, the next choice is the form of the data that is to be made available.

There are two, not mutually exclusive, choices which have quite different audiences:

- An EPD, which is a third-party-verified LCA-based marketing document for Business 2 Business (B2B) or Business 2 Customer (B2C) communications. More information about EPDs is provided in Section 3.1.2.1.
- An LCI, which is essentially a long list of quantified environmental inputs and outputs, used by practitioners when undertaking LCAs. More information about LCIs is provided in Section 3.1.2.2.

3.1.2.1 Environmental product declarations (EPDs)

EPDs or Type III environmental declarations to use ISO terminology, are concise, readable, third-party-verified marketing documents that include the reporting of LCA-based results in addition to other environmental information. They are primarily aimed at B2B communication but are also useful for B2C communications.

At the time of writing this report, products with EPDs used in buildings attract points in Green Star through the Innovation Challenge for EPDs, making products with EPDs attractive to building design projects aiming for a Green Star building environmental rating. Further information is provided in Section 3.3.

EPDs must comply with ISO 14025 (ISO, 2010a) which sets out the principles and procedures for their development. For construction products (which includes services) in particular, the European standard EN 15804 (CEN, 2013) provides more specific rules for EPD development and what must be reported. Currently, this should (ideally) be used as the basis for construction product EPDs in New Zealand.

Construction product EPDs compliant with EN 15804 have a life of five years, during which time regular review is necessary to ensure that reported environmental indicators remain valid and representative of the product being supplied. If the reported environmental indicators change significantly during this period, e.g. due to changes in manufacturing location or suppliers, then the EPD must be updated. This is to ensure it remains representative during the period of EPD registration.

EPDs are based on product category rules (PCR) which provide more detailed product or sector specific rules for carrying out LCAs. PCR exist for many products already and more are being developed all the time. The process for PCR development involves stakeholder consultation and, for construction products, has a life of five years for EN 15804-compliant PCR.

At the time of writing, ISO 21930 (which was originally published in 2007) is being updated. This is the international standard equivalent of the European standard EN 15804. The new ISO 21930 standard appears to be developing in line with EN 15804, providing more specific requirements and guidance where experience of using EN 15804 has shown this is necessary or advantageous.

The first EN 15804-compliant EPD for a New Zealand construction product was published by Allied Concrete in 2014 based on 2013 annual production of concrete made with Holcim-supplied cement at 28 batching plants across the North and South Islands[3].

Since September 2014, an EPD programme for products used in New Zealand and Australia has existed called the Australasian EPD® Programme (www.epd-australasia.com/). This provides a local platform for development and registration of verified EPDs compliant with ISO 14025 (ISO, 2010a) and EN 15804 (CEN, 2013) for construction products.

The Australasian EPD® Programme was established as a joint initiative of LCANZ and ALCAS and is affiliated with the International EPD® System, one of the largest and oldest EPD programme operators globally. Further information about the International EPD® System can be found at www.environdec.com.

Construction product manufacturers with products that are primarily for export rather than use in New Zealand or Australia may wish to consider registering their EPDs in local EPD schemes where their products are sold. Given the global scope of the International EPD® System with which the Australasian EPD® Programme is affiliated, this may be suitable.

3.1.2.2 Life cycle inventories (LCIs)

The first output of an LCA model is an LCI. This consists of a list of quantified environmental inputs and outputs (or flows) that cross the boundary between the system being modelled and the wider environment. Environmental inputs typically consist of non-renewable and renewable resources, and environmental outputs typically consist of emissions to air, water and soil. All are scaled according to the quantity of product or products that provide the basis for the study.

An LCI is difficult to use and interpret, and may typically run to hundreds of lines of flows. However, if made available in a format that may be downloaded into LCA software, LCIs can be used by LCA practitioners in their modelling. Therefore, by providing LCI data, Stakeholder Group 1 members can ensure that the data used in LCA studies that includes their products is current, accurate and representative.

An LCI may be used to calculate indicators that are reported in an EPD. However, indicators in an EPD cannot be reliably converted back into an LCI by users of an EPD. LCIs which are freely available, methodologically consistent and well maintained can make the process of EPD development cheaper and verification of EPDs easier.

LCIs are likely to be cheaper to produce than EPDs, but have a more limited audience and are not suitable for communication to customers. LCIs of construction products should be developed using the same methodological standards as used for EPDs, i.e. EN 15804 (CEN, 2013) as well as more detailed requirements set out in relevant PCR. The LCA work should also be independently critically reviewed to these same standards.

Having developed an LCI, the data should be reviewed periodically to ensure it remains representative and is updated if necessary. Consideration should be given to updating the data at least every five years.

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[3] The latest version of the Allied Concrete EPD is available at http://gryphon.environdec.com/data/files/6/10204/epd555%20Allied%20Concrete%20Ready%20mixed%20concrete.pdf

3.1.3 Other ways Stakeholder Group 1 can input to the framework

Resources have been developed which are available for download at www.branz.co.nz/buildingLCA, which may be useful for scoping and carrying out an LCA.

These resources, which include default information for use in the absence of more specific information (called datasheets), are intended to be updated periodically. Therefore, BRANZ welcomes information and data from members of Stakeholder Group 1 which can be incorporated during envisaged future updates.

More information about how the reference information in the datasheets has been developed is provided in Section 6.3 and how to submit data and information to BRANZ for inclusion in future updates in Section 8.

3.2 Stakeholder Group 2

Use of LCA in building design is not currently well developed in New Zealand. This is in contrast to peer regions such as Australia, Europe, Japan and North America where its application is growing or already established. The information, data and other resources that have been developed for this framework are aimed at achieving a more consistent application of LCA at the building level so that Stakeholder Group 2 members can make design decisions supported by robust environmental information.

Some traditional barriers to use of LCA in building design are summarised in Figure 3, together with framework and other resources that have been developed to reduce these.

It is intended that framework resources will be added to and updated in the future, as more and better data becomes available (for example, through development of EPDs and/or LCIs by construction product manufacturers and importers and their trade associations – see Section 3.1) or with any significant changes that may be required by future international standards.

Stakeholder Group 2 members can also contribute to the framework through provision of the following:

- Feedback on the resources that have been provided, requests for further information and resources on specific aspects of the framework. This may be used to prioritise research in the future.
- Reference buildings (with client permission), which will allow BRANZ to develop a larger database of designed buildings from which to compile more reference buildings. The identity of buildings can remain confidential if desired.

Lack of understanding of what LCA is and how to use it.	*LCAQuick – Office* is a free resource developed to help Stakeholder Group 2 members better understand LCA and how it can be used. This is complemented with information and resources developed for the framework available for download and a BRANZ Bulletin on "Introduction to LCA" (requires purchase).
Don't have any LCA capability and it's expensive and time consuming to do.	YouTube video tutorials will enable you to quickly get started with *LCAQuick – Office*. Different versions have been created for flexibility. Commercial design-support tools featuring LCA are becoming increasingly available.
Clients aren't interested.	There is a clear business case for greener office buildings (API/PFA, 2011; NZGBC, 2010; WGBC, 2013), Green Star NZ now recognises building LCA and use of products with EPDs, its time to act on climate change (IPCC, 2014)!
Requires a lot of data which are difficult to get.	Generic materials and other data have been developed for the framework to get things started. The Australasian EPD® Programme has been set up to provide a consistent mechanism for Stakeholder Group 1 members to provide data.

Figure 3. Barriers and enablers for use of building LCA in design.

Information about how to provide feedback and reference buildings is available in Section 8.

3.3 Stakeholder Group 3

Potential environmental impacts calculated at the building level using LCA arise as a result of the myriad decisions taken during design. These take into account how passive design features can lead to lower energy demand, where energy is obtained and in what form, what materials are used and how durable they are, how they are manufactured and from where they are obtained. A building LCA is therefore a holistic form of assessment, that draws together issues that are traditionally considered separately, such as energy, materials, waste, transport and water, and reflects their contributions to overall building environmental impacts using the same indicators.

The New Zealand Green Building Council (NZGBC) introduced new Innovation Challenges in its Green Star building environmental rating tool in 2015. Two of these Innovation Challenges include:

- **Material Life Cycle Impacts**, which recognises use of building LCA in design (by Stakeholder Group 2) and aims "to encourage a project team to perform whole-of-building, whole-of-life cycle assessments of their project and to demonstrate that their project performs better in most impact categories without negative trade-offs. This challenge also aims to increase demand and availability of life cycle data, and to build the capacity of industry to perform life cycle comparisons of projects"[4], and;

[4] www.nzgbc.org.nz/Attachment?Action=Download&Attachment_id=349

- **Environmental Product Declarations**, which recognises use of products with EPDs (produced by Stakeholder Group 1) in the design and aims "to encourage the use of products and materials for which life cycle information is available".[5]

Information, guidance and resources developed as part of this framework can assist with the process of rating buildings based on LCA results by improving consistency with respect to methodology, data and assumptions. Further information on these is provided in Section 6.

Recognition of building LCA and EPDs in Green Star in New Zealand is an important incentive and follows trends in other building environmental rating tools globally, some examples of which are provided below. Further examples are provided in BRANZ Study Report SR272 (Dowdell, 2012) available for download from www.branz.co.nz/study_reports.

3.3.1 Green Star (Australia)

The Green Building Council of Australia (GBCA) began investigating the addition of credits for use of building LCA in its Green Star building environmental rating tool in 2012 which led to incorporation as an Innovation Challenge credit. The credit was devised to reward a building design with mainly lower environmental impacts in comparison with a reference building.

The reference building may be a hypothetical building representing standard contemporary construction practice or a real building recently constructed that is similar in use, construction and operation. Where the reference is based on a real building, the LCA should be based on as-built drawings[6].

With the launch of the latest version of Green Star – Design & As-built v1 – in 2014, building LCA is now a core credit.

Additional points are awarded for use of products with an EPD.

3.3.2 BREEAM/IMPACT (UK/global)

BREEAM was the first building environmental rating tool to feature inclusion of LCA, developed based on BRE's Environmental Profiles methodology (BRE, 1999). Today, BREEAM is used globally and recognises use of LCA at the building level through its MAT01 Life Cycle Impacts credits[7]. Office building elements included in the assessment are:

- external walls
- windows
- roof
- upper floor slab
- floor finishes/coverings.

[5] www.nzgbc.org.nz/Attachment?Action=Download&Attachment_id=351
[6] www.gbca.org.au/uploads/78/34894/Materials_Life_Cycle%20Impacts_FINAL_JUNE2014.pdf
[7] www.breeam.org/BREEAM2011SchemeDocument/content/09_material/mat01_general.htm

Where data about materials used in any of the above elements is based on EPDs, this has the effect of increasing the contribution the element makes to the building's MAT01 performance.

BRE, with partners, has also developed a BIM-based approach called IMPACT for carrying out building-level LCA in comparison with a building benchmark. For each building use type a sample of typical buildings, known as archetypes, are assessed and combined into a single benchmark representing average performance. The performance of a building design can then be compared to the benchmark in order to assess performance based on LCA outputs.

3.3.3 LEED (USA/global)

LEED was developed by the United States Green Building Council (USGBC). In the latest version, v4, LCA is recognised in the Building Life Cycle Impact Reduction credit. In this credit, an LCA of the building structure and enclosure must be carried out that demonstrates at least a 10% reduction for three selected environmental indicators out of six, compared to a baseline building. One of the environmental indicators must be climate change and no indicator should increase by more than 5% compared to the baseline.

Other criteria include:

- The baseline and designed buildings must be of comparable size, function, orientation and operating energy performance.
- The building service life must be the same and at least 60 years.
- The same LCA software tool and data must be used for the evaluation.
- Data used must be compliant with ISO 14044 (ISO, 2006b).

4. Background and basis for the framework

This section provides a short introduction to LCA and its development as a tool for assessing environmental performance.

A description of the standards basis for the framework is also provided.

4.1 What is LCA?

LCA is an environmental systems analysis and accounting tool for quantifying the inputs and outputs of an option, whether a product, service or organisation[8] and relating these to potential environmental impacts. LCA is a systematic approach, where the system of interest comprises the operations that collectively produce the product or service being investigated. The system being assessed is linked to other industrial systems supplying and transporting inputs and carrying away outputs (Figure 4), all of which is considered within the assessment.

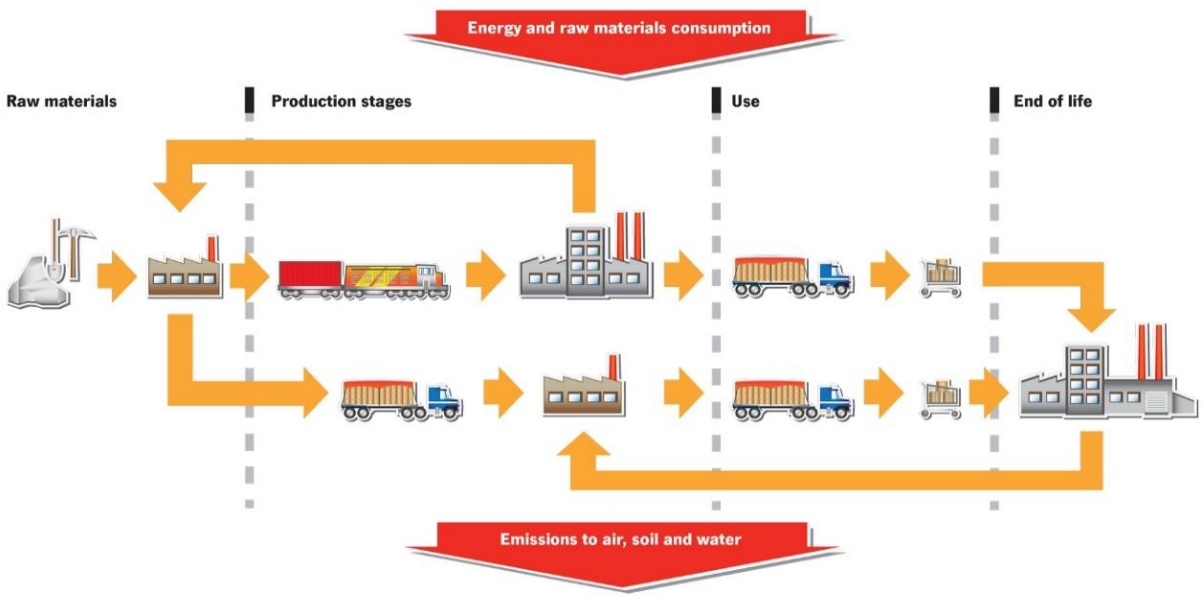

Figure 4. Example of a product life cycle.

An LCA offers a clear and comprehensive picture of the flows of energy and materials through a system and gives a holistic and objective basis for comparisons. Results are presented in terms of the system function so that the value of the function can be balanced against the environmental effects with which it is associated.

The results of an LCA quantify the potential environmental impacts of a product or service over the life cycle, to help identify opportunities for improvement and to indicate more environmentally-preferable options, for example, through comparison of alternative building designs.

[8] LCA of organisations is covered by ISO/TS 14072 (ISO, 2014c) and is not specifically covered by this framework.

4.2 A brief history of LCA

LCA as a tool for providing information about the environmental implications of decisions is not new. In fact, Coca-Cola in 1969 is reportedly the first company to commission an analysis of the energy, material and environmental consequences of alternative options – in this case, different types of packaging (Hunt & Franklin, 1996).

The methodology, application and communication of LCA has developed enormously since that time, including the creation of LCA-based methods or 'footprints' that typically focus on specific environmental issues. Current examples of these include carbon footprints, water footprints and in Europe, product environmental footprints[9].

LCA is a quantitative assessment approach and, as such, the quality of its outputs are a function of the robustness of the methodology and the quality of the data used in an assessment. When the assessment involves a comparison of alternatives to deduce the more favourable environmental option, a consistent application of methodology and use of data of similar, high quality is essential. Producing results for alternative options that are based on application of different methodologies, or that are based on different data quality between alternatives, means that decisions can be taken with less confidence.

To begin to address these issues, the Society of Environmental Toxicology and Chemistry (SETAC) published a Code of Practice in 1993 (SETAC, 1993), which was later followed with publication of four founding LCA standards between 1997 and 2000[10]. These four standards were subsequently consolidated and republished as ISO 14040 (ISO, 2006a) and ISO 14044 (ISO, 2006b).

In the 2000s, application-specific international standards were also published, notably ISO 14025 (ISO, 2010a) covering communication of LCA in EPDs (first published in 2006) and ISO 21930 (ISO, 2007), covering LCA applied to construction products.

Buildings are particularly challenging products to evaluate in comparison to other products. This is because they are diverse in terms of their function, form, size, structure, location and longevity. They typically contain a wide range of products which are often used in combination to form assemblies or construction systems (or constructed assets), the performance of which can significantly contribute to the overall performance of the building.

The building industry itself presents a challenge to use due to its disaggregated nature, with complex supply chains and input from numerous parties including architects, designers, engineers (e.g. structural, mechanical and electrical, and fire), quantity surveyors, construction managers, material suppliers, builders, electricians, plumbers, installers, conformance bodies and facilities managers (for example).

Recognition of these challenges led to the development of international standards concerning the application of LCA to building construction. This has, in turn, led to development of European standards that have built on these international standards, summarised in Table 1.

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[9] http://ec.europa.eu/environment/eussd/smgp/dev_pef.htm

[10] The four founding standards were ISO 14040 (first published in 1997), ISO 14041 (first published in 1998), ISO 14042 (first published in 2000) and ISO 14043 (also first published in 2000).

Table 1. Summary of International and European Standards for LCA of buildings.

Level	ISO Standards (version at time of writing)	European Standards[11] (version at time of writing)
Framework standards	ISO 15392: Sustainability in building construction – General principles (ISO, 2008)	EN 15643-1: Sustainability of construction works – Sustainability assessment of buildings – Part 1: General framework (CEN, 2010)
	ISO 21929-1: Sustainability indicators – Part 1: Framework for the development of indicators and a core set of indicators for buildings (ISO, 2011b)	EN 15643-2: Sustainability of construction works – Assessment of buildings – Part 2: Framework for the assessment of environmental performance (CEN, 2011a)
Building level standards	ISO 21931-1: Sustainability in building construction – Framework for methods of assessment of the environmental performance of construction works – Part 1: Buildings (ISO, 2010b)	EN 15978: Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method (CEN, 2011b)
Building product level standards	ISO 21930: Sustainability in building construction – Environmental declaration of building products (ISO, 2007[12])	EN 15804: Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products; 2012 + A1 (CEN, 2013)

These standards provide requirements and guidance for building level assessment using LCA and provide the basis upon which this framework has been developed.

4.3 The building life cycle

Figure 5 depicts the life cycle of any building divided into four key stages, these being:

- Product stage: Includes processes prior to building handover including raw material supply, transport and manufacture of products up to the manufacturer's gates.
- Construction stage: Includes processes prior to building handover including transport from the manufacturers' gates to the construction site and activities on the construction site up to the point the building is ready for handover. This stage includes transport and any onward processing, if necessary, of wastes or landfilling of wastes that are generated during transport and installation. The manufacture of materials and products that become waste is also included here, rather than in the product stage.

[11] Listed standards concern use of LCA. Other standards are EN 15643-3 (CEN, 2012a) which provides a framework for assessment of social performance of buildings and EN 15643-4 (CEN, 2012b) which provides a framework for assessment of economic performance of buildings

[12] At the time of writing, this standard is being updated. See Section 3.1.2.1.

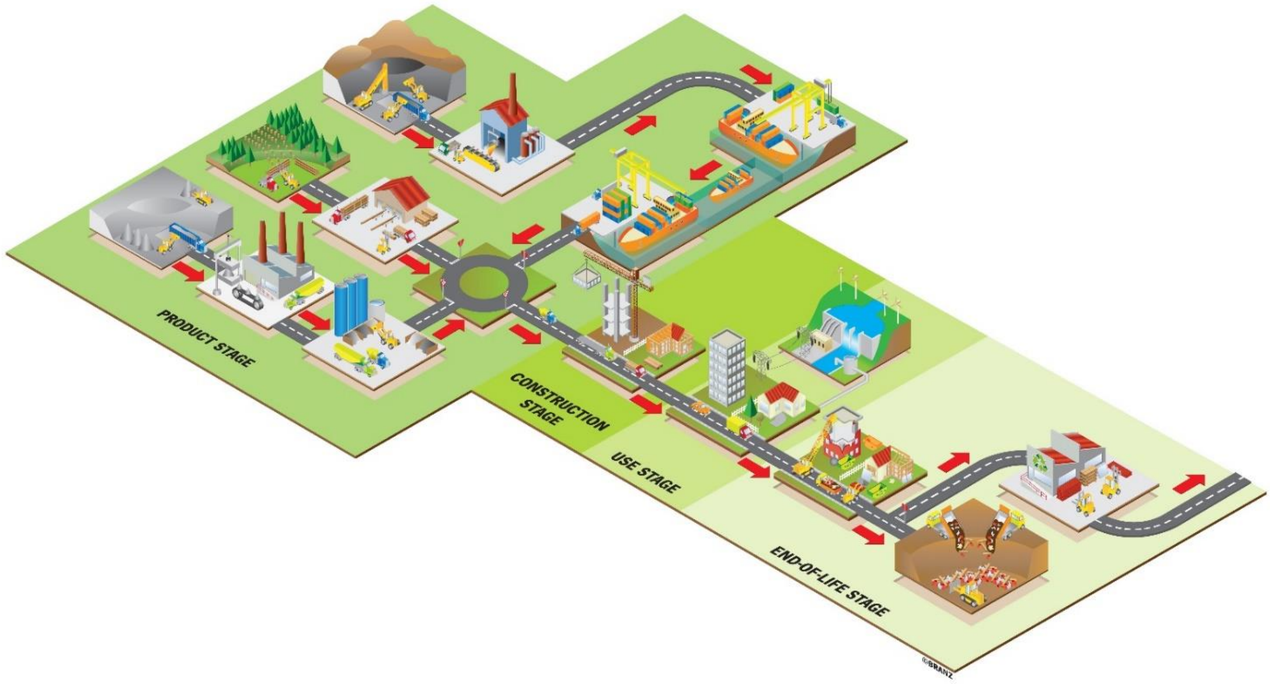


Figure 5. Depiction of a building life cycle.

- Use stage: Includes activities required to enable the building to maintain its level of function including maintenance, repair, replacement and refurbishment. This also includes supply of water and treatment of wastewater, and supply and use of energy.
- End-of-life stage: Including deconstruction or demolition of a building, transport of materials and processes necessary for recycling or disposal.

EN 15643-2 (CEN, 2011a) divides these four stages into discrete, numbered modules that contribute to each stage, illustrated in Figure 6. It also includes a separate information module (module D) which represents net benefits and loads beyond the life cycle of the building (for example, through availability of recycled material that may be used for other purposes once the building has been deconstructed).

A building level assessment using the framework should typically consider the stages in Figure 6, but there may be underlying reasons why all modules are not included. Inclusion of module D is optional. If module D is included it must not be aggregated with results for modules A1 to C4. Instead, it must be provided separately and is provided for information only.

Modules may be excluded if they are not relevant to a specific application or it can be demonstrated that they do not make a significant contribution to environmental indicators.

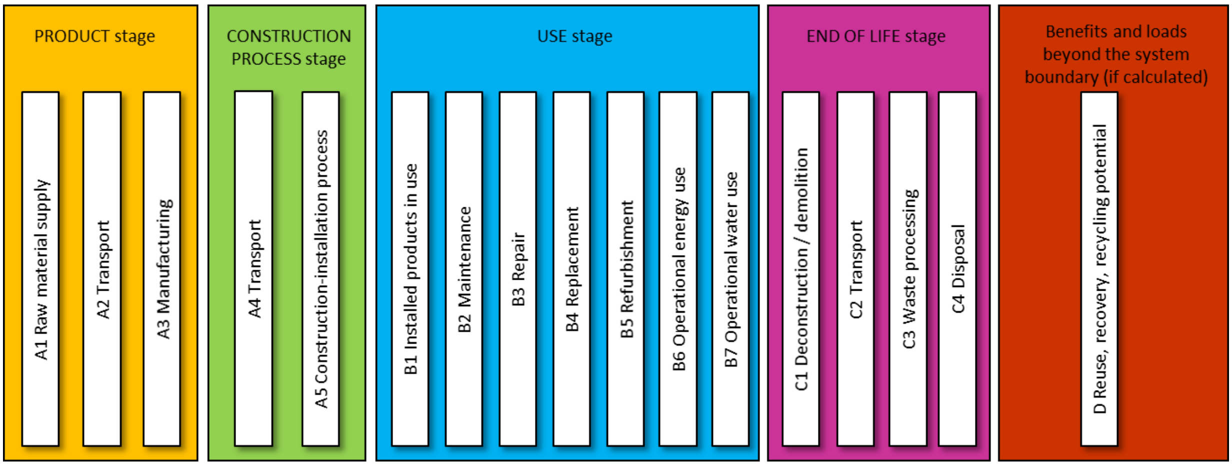


Figure 6. Stages and modules of the building life cycle.

5. Framework focus and architecture

Building LCAs may be carried out to answer a range of different questions. Resources currently available in the framework have been developed with a focus on early (concept and preliminary) design of office buildings, but may also be useful for other applications.

The appropriateness of framework resources for other applications will need to be assessed in the context of the goal and scope of the study in which they are intended for use. Examples of other applications may include the following:

- Building owners may want to evaluate different refurbishment options or whether it is better to refurbish the existing office or demolish and build a new office on the same site.
- Building owners, local and national government, may want to understand the environmental implications of going beyond the Building Code.
- Construction companies may want to understand environmental impacts associated with construction and options for how to reduce and manage these.
- Facilities managers may want to quantify the environmental impacts of alternative products or systems which may be incorporated in a building.
- Tenants may want to understand the environmental cost of leasing building alternatives in order to understand how they can help with meeting published environmental goals.
- Researchers may wish to compare New Zealand building environmental performance with environmental performance of buildings in other countries.

5.1 A focus on design (in particular, early design)

The framework focus on design of new office buildings, and in particular concept and preliminary design, is driven by the MacLeamy Concept[13] (Berg, 2014; Donn, Selkowitz, & Bordass, 2012), shown in Figure 7, which illustrates the opportunity to yield maximum environmental gain for minimum additional cost.

The MacLeamy Concept illustrates the relationship between performance effectiveness of a building and cost to implement during the process of design. The environmental impact of a building can be considered as a measure of performance effectiveness, since a poorly-performing building leaves a lasting legacy of environmental impacts over many decades.

According to the MacLeamy Concept, the first stage of design (concept design) represents the stage in the process when decisions taken by the designer can have the greatest effect on the eventual performance of the designed building, while the cost of implementing these decisions is also the lowest.

However, the potential cost to the architect or engineer of factoring LCA into the design process can be potentially expensive, requiring either external specialist support or purchase and training in the use of specialist software. In order to provide Stakeholder Group 2 members with an opportunity to better understand how to use LCA, BRANZ has developed *LCAQuick – Office*. Its aim is to provide a free, easy-to-use,

[13] Whilst not named as such, a paper by Paulson Jr (1976) graphically illustrates the relationship between the level of influence and project cost.

easy-to-access platform to help Stakeholder Group 2 members during concept and preliminary design, providing an opportunity to raise awareness and become more comfortable with LCA without the need for significant investment. Further information about *LCAQuick – Office* is in Section 7.

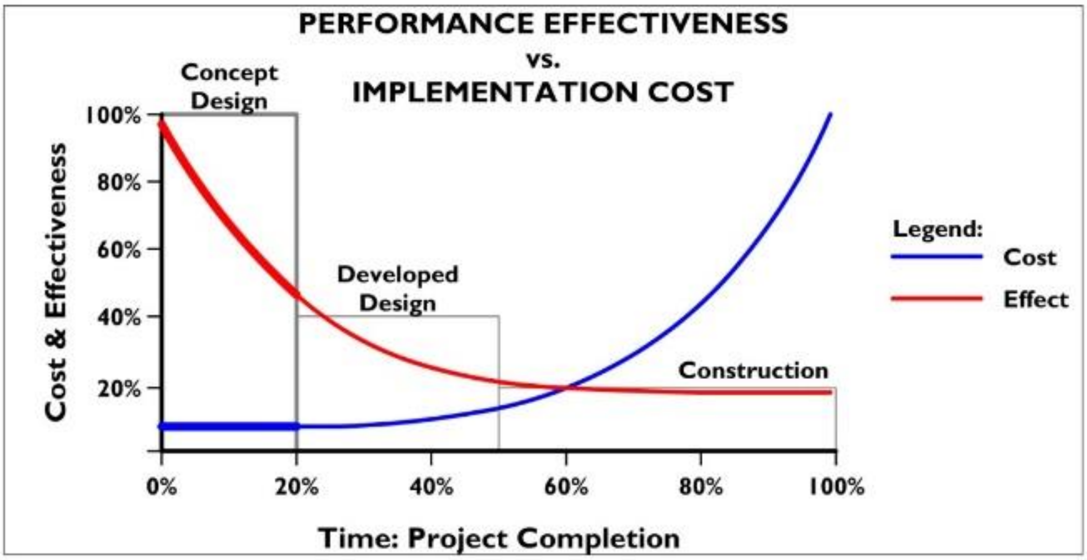


Figure 7. The MacLeamy Concept (from Berg, 2014).

During concept design, architects typically commence by 'sketching' initial ideas aimed at fulfilling a client's brief, whether through use of pen and paper or design-support tools such as Sketch Up[14], Revit or ArchiCad. This process is iterative, resulting in rejection of some ideas in favour of others, and combines features of ideas towards a design concept. By its nature, this stage of design lacks data, meaning there are challenges to use of a data-intensive technique such as LCA.

However, this is also the stage of the design process when decisions taken about the building mean that future environmental consequences are also locked in. Historically, the scale of these environmental consequences has been unknown or poorly understood and often not considered important by clients who engage the services of an architect.

The framework has been created in order to seek to change this.

5.2 Architecture of the framework

The framework has been developed to facilitate use of LCA applied to buildings and building design. It is informed by current international standards on building sustainability, which set out how LCA should be applied to buildings and building products, and provides additional interpretation and information from a New Zealand perspective. It also draws on findings from previous research undertaken on New Zealand commercial buildings, such as the Building Energy End-use Study (BEES)[15], Bint (2012) and Berg (2014).

[14] www.sketchup.com/products/sketchup-pro
[15] www.branz.co.nz/cms_display.php?sn=126&st=1&pg=14152

The framework provides support in four ways, illustrated in Figure 8:

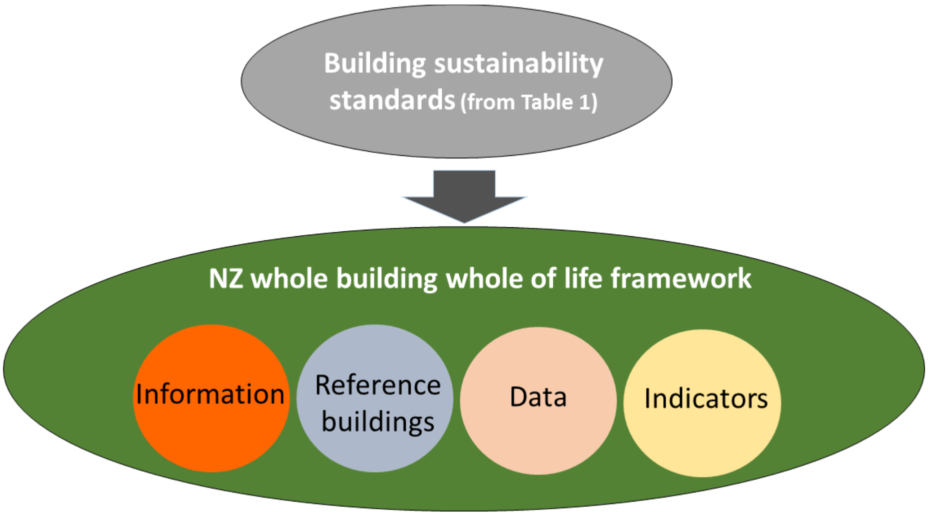


Figure 8. The NZ whole-building whole-of-life framework.

- **Information**: This and accompanying reports provide information about building LCA from a New Zealand perspective. It is recommended that building-level LCAs carried out for New Zealand are developed in accordance with this information to provide better comparability between different building assessments. Updates and additional information may be developed in the future.
- **Reference Buildings**: The structure and thermal envelope of 10 New Zealand office buildings have been modelled in BIM (for materials quantities) and EnergyPlus (for designed energy demand) using consent documentation obtained from Auckland, Wellington and Christchurch Councils. Environmental impacts for these buildings have been calculated using data developed for the framework. Further information about the reference buildings is provided in the accompanying BRANZ Study Report SR350 (Berg, Dowdell & Curtis, 2016). Reference buildings are recent examples of office buildings constructed in New Zealand which have been developed to provide a basis for comparison during early design. The specific identity of the buildings is not disclosed.
- **Data**: This provides generic data for use in building-level LCA during early design of offices and in the absence of specific data. The following datasheets have been developed according to modules in Figure 6:
    - Module A4: Generic transport distances, by mode, of construction products from the last manufacturer, fabricator or assembler to a construction site in Auckland, Wellington and Christchurch.
    - Module A5: Waste generation during construction and subsequent transport and fate of site construction waste.
    - Module B1 to B7 (use stage): Office building service life.
    - Module B2: Maintenance of constructed assets during the building service life.
    - Module B4: Replacement of constructed assets during the building service life.
    - Module B6: Defaults for energy modelling of offices obtained from BEES and other sources.
    - Module B7: Benchmark water consumption in offices obtained from Bint (2012).
    - Module C1: Fate of wastes produced during deconstruction/demolition of buildings.

The methods used for development of these datasheets is set out in the BRANZ Study Report SR351 (Dowdell et al, 2016). The intention is to add to and improve these datasheets as feedback is received, and further data and information is provided by the New Zealand construction industry. The process for providing feedback, data and information is set out in Section 8.

- **Indicators**: Environmental indicators for calculation when conducting building LCA in New Zealand are set out in the accompanying BRANZ Study Report SR293 (Dowdell, 2014). The initial set of indicators listed in Section 6.4 are based on those in international standards in Table 1. Other indicators, proposed for future inclusion in the framework, are also set out in Study Report SR293. Furthermore, research being conducted at Massey University as part of the framework aims to facilitate the calculation of water scarcity impacts in the future. Results of this research will be made available on the BRANZ website on completion.

Production data for products that may be commonly considered in commercial buildings during concept and preliminary design have also been developed, based on a range of sources including EPDs, LCIs and an LCA database called EcoInvent. These data underpin calculations in *LCAQuick – Office* and have been independently reviewed for appropriateness of use at concept and preliminary design. They are used to contribute to calculations of reference building environmental impacts presented in the accompanying BRANZ Study Report SR350 (Berg, Dowdell & Curtis, 2016), together with supporting information about the data.

All the above data has been embedded in *LCAQuick – Office* as a practical application of the framework (illustrated in Figure 9). *LCAQuick – Office* uses this data with other inputs – primarily material quantities and modelled energy use – to calculate building environmental impacts. Further information about *LCAQuick – Office* is provided in Section 7.

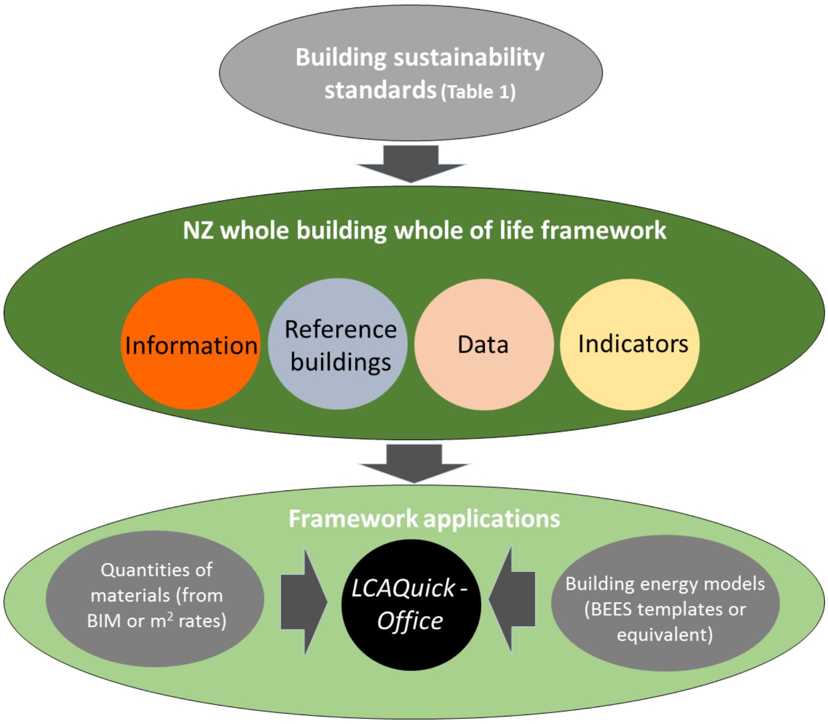


Figure 9. *LCAQuick – Office* as an application of the framework.

In summary, framework outputs are listed in Figure 10.

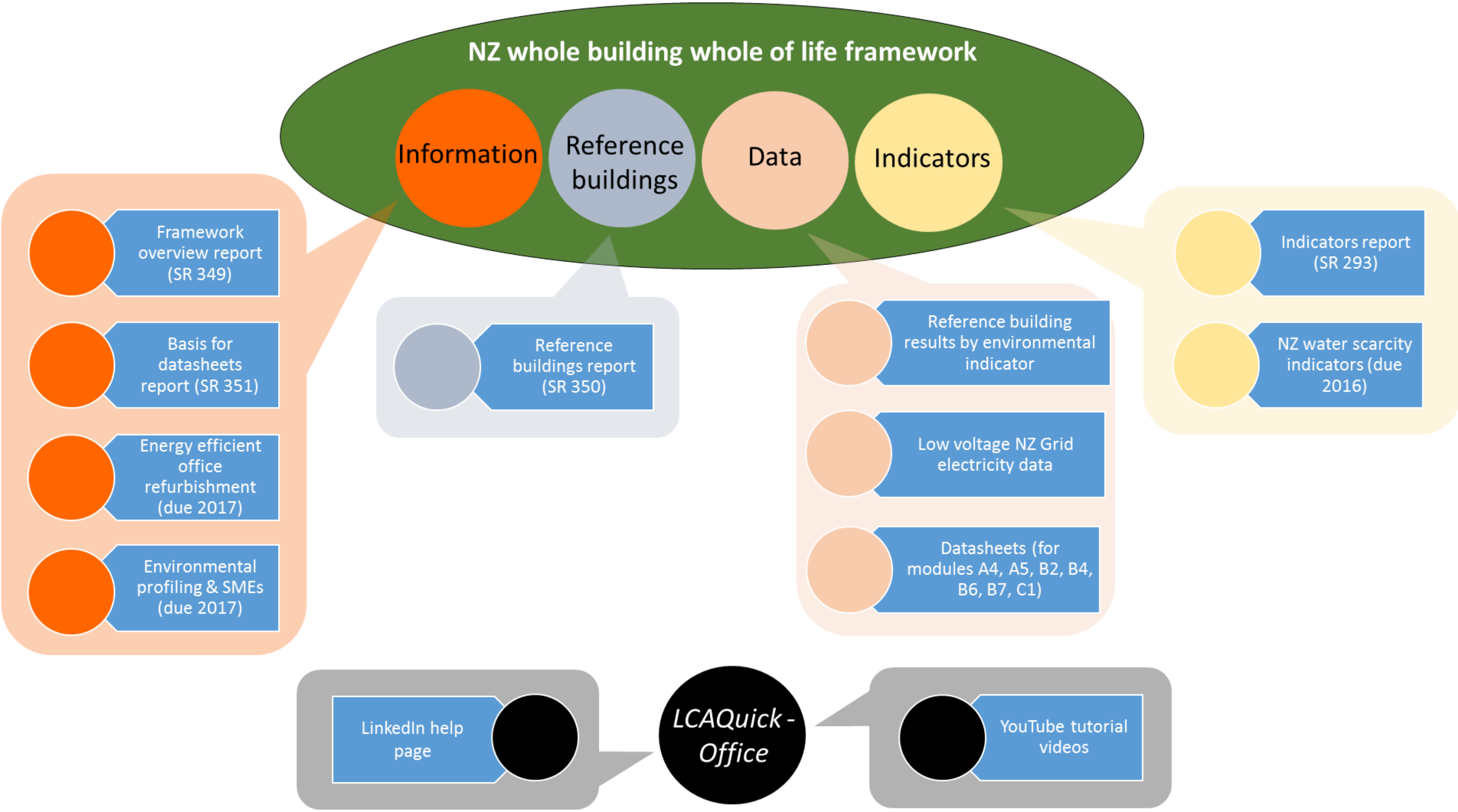


Figure 10. Summary of current framework resources.

6. Framework scope

Figure 11 sets out the scope of how building LCA may be applied to building design according to:

- building type
- stage in the design process
- stages of the building life cycle included for evaluation
- environmental indicators considered.

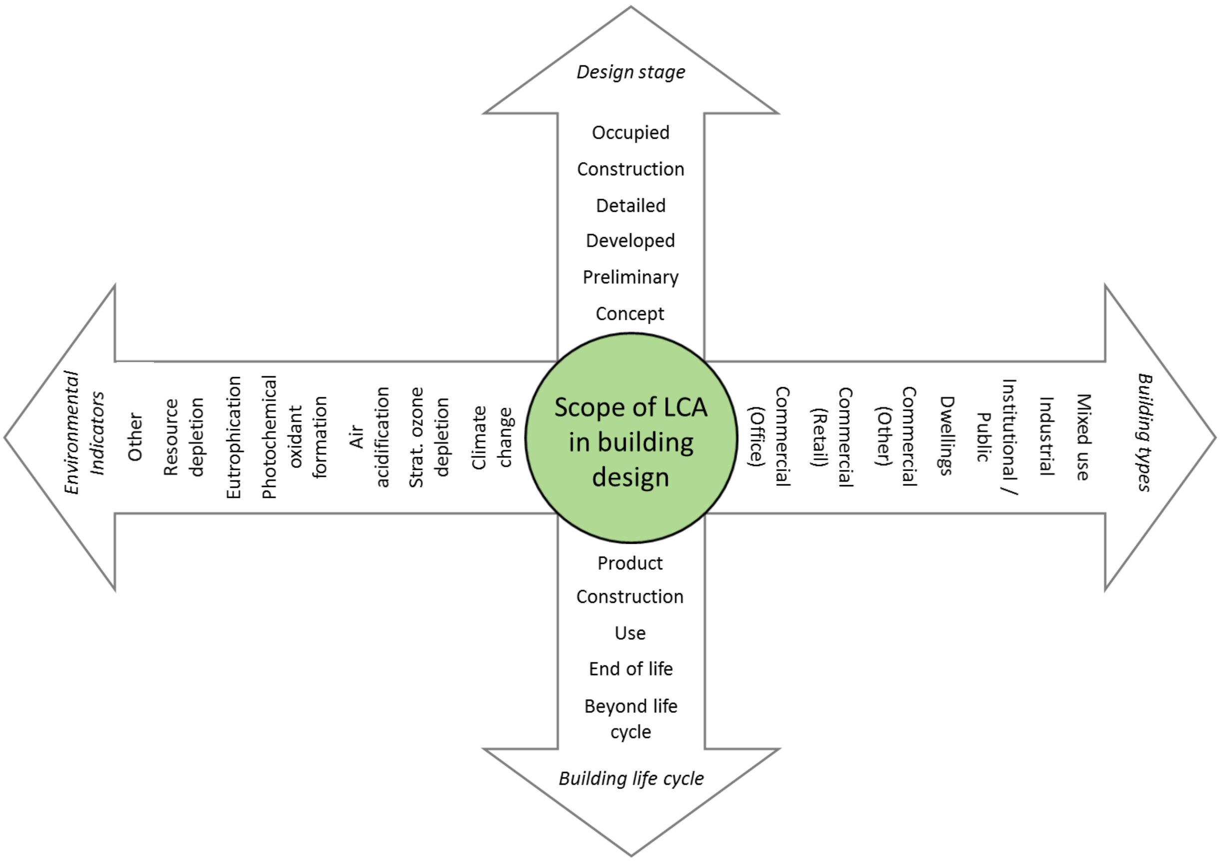


Figure 11. How LCA can be applied during building design.

Figure 12 highlights how the resources, including the *LCAQuick – Office* tool, developed for the framework currently map to the scope in Figure 11. Whilst resources developed to date specifically address highlighted areas, they may also be useful for other building LCA applications. In these instances, care should be taken to ensure that the resources are appropriate in the context of the goal and scope of these studies. Where framework resources are being considered for use in other building LCA applications, consideration should be given to information in Table 2.

Further information about the scope of the framework is provided in the following sections.

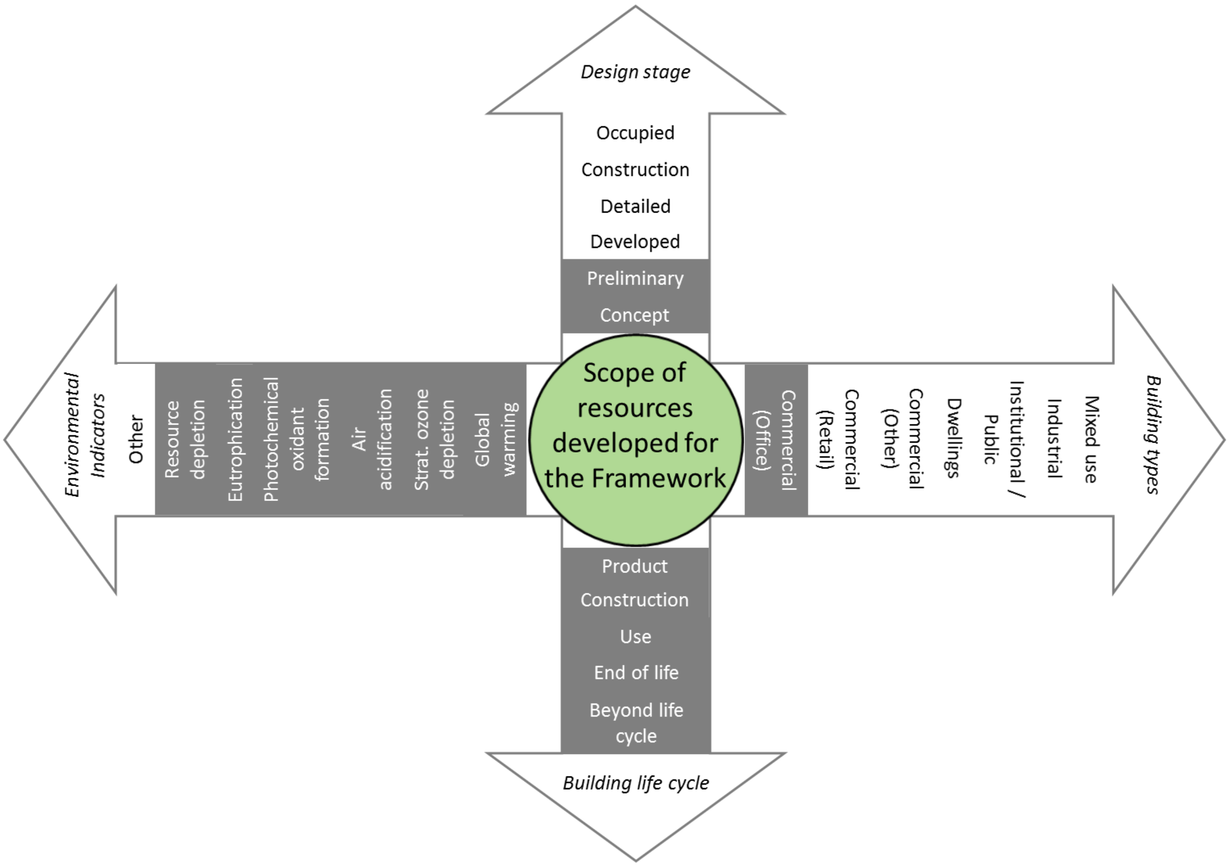


Figure 12. Scope of the framework resources developed for this project.

Table 2. How framework resources may be useful for other building LCAs.

Resource	Application
Reference buildings	Currently developed for 10 office buildings, some with other uses, with a GFA of 1500 m^2 or more. Therefore, no other building types yet developed for comparison.
Data	Developed for application to early design. May be useful for later stages of design where there are data gaps. Where use of the data shows a potentially significant contribution, consideration should be given to obtaining specific data.
Indicators	Applicable to other building types.
LCAQuick – Office	Calculates environmental impacts of concept/preliminary office building designs and compares with reference office buildings. May additionally be used to look at other building types with the same materials as are typically used in New Zealand offices to calculate environmental impacts, but comparison with New Zealand office reference buildings will be of limited value. Building service life set to 60 years.

6.1 Scope by building type

The framework currently focuses on office buildings over 1500 m^2 GFA. Reference buildings for offices less than 1500 m^2 and other building types have not yet been developed for comparison.

The accompanying Study Report SR350 (Berg, Dowdell & Curtis, 2016) provides information about reference office buildings that have been developed for comparative purposes during early design.

An aim is that more reference buildings can be made available in the future with increased use of building LCA. This would facilitate a more comprehensive listing of reference buildings for use during design from which, over time, trends may be obtained about potential environmental impacts associated with designs.

6.2 Scope in the design process

New Zealand Construction Industry Council (CIC) Guidelines set out the stages of design as follows[16]:

- Concept
- Preliminary (often combined with concept design on less complex projects)
- Developed
- Detailed
- Construction

Based on this guidance, Table 3 provides a list of building elements[17] that may be typically considered by design stage.

During concept and preliminary design, early consideration may be given to massing, orientation, window-to-wall ratio, structure and thermal performance. Focus is therefore on structure, roof and external walls.

As design progresses through developed and on to detailed design, the building LCA can develop in tandem, providing input on the likely environmental impacts of options being considered at each stage. With development of greater detail about the building, the building LCA model can be refined and outcomes tested as quantities of materials become more certain as well as the internal layout, heating and cooling requirements, and detailing of the building.

In the current absence of specific data (for example, from published EPDs), generic data for products used in the structure and thermal envelope have been developed and externally reviewed for application during concept and preliminary design. Reference building models (embedded in *LCAQuick – Office*) use this data and therefore focus on structure and enclosure only.

As more LCA-based product specific data is made available by Stakeholder Group 1 members, so generic data can be increasingly replaced. Also, at later stages in the design process, provision of product-specific data allows design teams to more easily evaluate alternatives.

[16] A description of each stage, taken from the NZCIC Guidelines (NZCIC, 2004), is provided in Appendix A.
[17] Definitions of building elements are provided in Appendix B based on NZIQS (2012).

Table 3. Building elements by stage of design (based on NZCIC, 2004).

Building element		Inclusions by design stage			
		Concept/ preliminary	Developed	Detailed	Construction
Structure	Substructure	✓	✓	✓	✓
	Frame	✓	✓	✓	✓
	Structural walls	✓	✓	✓	✓
Exterior fabric	Roof	✓	✓	✓	✓
	Exterior walls	✓	✓	✓	✓
	Windows and exterior doors	✓	✓	✓	✓
Interior finishing	Stairs and balustrades			✓	✓
	Partitions		✓	✓	✓
	Interior doors			✓	✓
	Floor finishes		✓	✓	✓
	Wall finishes		✓	✓	✓
	Ceiling finishes		✓	✓	✓
	Fittings			✓	✓
Services	Sanitary plumbing		✓	✓	✓
	Heating and ventilation (mechanical services)		✓	✓	✓
	Fire services		✓	✓	✓
	Electrical services		✓	✓	✓
	Vertical and horizontal transportation		✓	✓	✓
	Special services		✓	✓	✓
	Drainage		✓	✓	✓
External works and sundries	External works		✓	✓	✓
	Sundries		✓	✓	✓

Quantities of materials required for a building-level assessment may be obtained based on a Schedule of Quantities prepared by a quantity surveyor. Alternatively, they may be generated from a BIM model if one is available during early design.

Two versions of *LCAQuick – Office* are available. The first takes an input of square metre rates while the second takes outputs of material quantities from a BIM model (developed in Revit or ArchiCad).

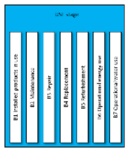
6.3 Scope in the building life cycle

The building life cycle should be considered in order to obtain a meaningful comparison of alternative designs. The division of the building life cycle into stages and modules is provided in Figure 6, with further information provided in the following sections:

- Section 6.3.1 Product stage (modules A1 to A3)

- Section ▪ Construction process stage (modules A4 and A5)

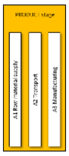
- Section 6.3.3 Use stage (modules B1 to B7)



- Section 6.3.4 End-of-life stage (modules C1 to C4)

- Section 6.3.5 Benefits and loads beyond the system boundary (module D)

6.3.1 Product stage (modules A1 to A3)



The product stage consists of three modules, these being:

- Module A1: Raw material supply
- Module A2: Transport (from suppliers to main manufacturer/tier 1 supplier)
- Module A3: Manufacturing (by main manufacturer/tier 1 supplier)

Construction product data may be available which presents the results of modules A1, A2 and A3 separately. Other construction product data may be presented which sums the results of modules A1, A2 and A3.

Care should be taken to ensure that all significant process stages in manufacture are included.

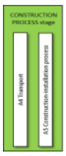
Data used to represent construction products must include all significant processes from extraction of raw materials or following achievement of the end-of-waste state (Appendix D) if derived from recycling to the factory gate, prior to dispatch of the finished product.

Available data for construction products is likely to vary in terms of quality. During early stages of design when design concepts are being explored, generic data can be sufficient in the absence of product-specific data. As more product-specific data becomes available in New Zealand, generic data can be replaced.

In order of preference, sources of data can be based on:

- Independently verified EN 15804 compliant EPDs for New Zealand manufactured or imported products (for example, EPDs of construction products registered on The Australasian EPD® Programme[18]) or published critically reviewed life cycle inventories (LCIs) developed in accordance with and reviewed for compliance with EN 15804 and relevant PCR (if available);
- Independently verified EPDs or published critically reviewed LCIs developed to LCA standards other than EN 15804 for New Zealand manufactured or imported products.
- Independently verified EN 15804 compliant EPDs for products manufactured in other geographical locations (for example, EPDs registered on The International EPD® System[19] or IBU[20]) or published critically reviewed LCIs developed in accordance with and reviewed for compliance with EN 15804 and relevant PCR (if available). Selection should ideally be based on similarity with New Zealand processes.
- Independently verified EPDs or published critically reviewed LCIs developed to standards other than EN 15804 for products manufactured in other geographical locations. Selection should ideally be based on similarity with New Zealand processes.
- Modelled processes based on generic data, adapted where possible for location of manufacture (e.g. including use of New Zealand grid electricity for processes in New Zealand).
- Modelled processes based on generic data in an unadapted form.

6.3.2 Construction process stage (modules A4 and A5)



The construction process stage consists of two modules, these being:

- A4 Transport (to the construction site)
- A5 Construction-installation process

6.3.2.1 Transport to the construction site (module A4)

Data representing transport of construction products to the construction site should, ideally, be based on real data where the environmental impacts of transport are significant when considered in the context of the building life cycle. However, this is complicated by three factors:

- An LCA practitioner does not know if transport to the construction site makes a significant contribution to an LCA until data has been collected. However, effort may be spent collecting data to find that it does not make a significant contribution.
- During design, especially early design, the specific source(s) of construction products is unlikely to be known.

18 www.epd-australasia.com/
19 www.environdec.com
20 http://ibu-epd.com/en/epd-program/published-epds/

- Distance will vary depending on the location of the building in relation to manufacturers of construction products, which may have more than one plant located in New Zealand or overseas.

In the absence of specific data, default transport data for delivery of construction products to construction sites located in Auckland, Christchurch or Wellington[21] have been developed, on the basis these cities are most likely to feature new-build offices over 1500 m^2 GFA.

This generic transport data has been developed to support consideration of transport of construction products during early design when use of specific products is less certain. They may also be useful for other applications, such as supporting the definition of scenarios as set out in Section 7.3.2.1 of EN 15804 (CEN, 2013).

The generic transport data is available in an accompanying datasheet entitled 'NZWBWLF – Module A4 transport datasheet v1' ('A4 transport datasheet') which can be downloaded from the BRANZ website (www.branz.co.nz/buildingLCA). The A4 transport datasheet provides generic transport distances by mode for construction products according to their Co-ordinated Building Information (CBI) classification. Information about how the A4 transport datasheet was developed is provided in the accompanying BRANZ Study Report SR351 (Dowdell et al*,* 2016).

Module A4 represents transport of products to the construction site, whether the product being transported is already (or nearly) completed, e.g. prefabricated panels, curtain walls and windows, or a product that is cut or shaped on the construction site, e.g. timber framing and plasterboard linings.

It is intended that the A4 transport datasheet will be reviewed and updated in the future as more data becomes available. Future updates will be made available on the BRANZ website.

Data in the A4 transport datasheet has been used in the calculation of environmental impacts for the reference buildings embedded in *LCAQuick – Office*.

6.3.2.2 Construction-installation process (module A5)

Default data about waste generation at construction sites has also been developed to support modelling of module A5. This data is contained in the accompanying datasheet entitled 'NZWBWLF – Module A5 site waste datasheet v1' ('A5 site waste datasheet') which can be downloaded from the BRANZ website (www.branz.co.nz/buildingLCA). It may be used in support of development of scenarios according to Section 7.3.2.2 of EN 15804 (CEN, 2013) or for other applications.

The data contained in the A5 site waste datasheet is provided according to material or product name, or by CBI code, and includes:

- Waste, as a percentage by mass of material or product that is typically generated at construction sites. For an example of how to use this (for Product X), see below.
- The proportion of this waste which is typically reused, recycled, recovered or goes to landfill or cleanfill.
- Additional information and notes.

[21] For office developments in Tauranga or Hamilton, Auckland defaults may be used. For offices in Palmerston North or Masterton, Wellington defaults may be used. For offices in Dunedin, Christchurch defaults may be used.

- Source(s) of information.

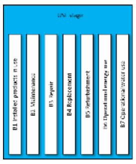
The A5 site waste datasheet sets out waste as a percentage by mass of product used in the building. For example, if Product X has a waste percentage of 4%, this means that 4% more of Product X needs to be transported to the construction site than is used in the building. Thus if 10,000 kg of Product X will be incorporated in the building, 10,400 kg of the product will need to be transported to the construction site and the environmental impacts of this calculated (based on distances and modes provided in the A4 transport datasheet or more specific available data).

Taking this example of Product X further:

- Whilst the environmental impacts of manufacture of the 10,000 kg of Product X used in the building are accounted for in modules A1 – A3, the environmental impacts arising from manufacture of Product X that becomes waste (i.e. the 4% or 400 kg) are accounted for in module A5.
- The transport and fate of the 400 kg of Product X that becomes waste at the construction site is also accounted for in module A5. If some or all of Product X is recycled or recovered, then all processes up to the point where an end-of-waste state is achieved are accounted here. For more information about the end-of-waste" state, see Appendix D.

Information about how the A5 site waste datasheet has been developed is contained in BRANZ Study Report SR351 (Dowdell et al, 2016).

6.3.3 Use stage (modules B1 to B7)



Based on EN 15643-2 (CEN, 2011a), the use stage of a building is divided into seven modules, these being:

- B1 Installed products in use
- B2 Maintenance
- B3 Repair
- B4 Replacement
- B5 Refurbishment
- B6 Operational energy use
- B7 Operational water use

A further important consideration is the required service life of the building.

6.3.3.1 Required service life

In the absence of specific information, e.g. a service life requirement specified by a client, the required service life for offices should be considered as 60 years, as set out in the accompanying datasheet 'NZWBWLF – Module B1 to B7 required service life datasheet v1' ('B service life datasheet'), downloadable from the BRANZ website (at www.branz.co.nz/buildingLCA).

The basis for this required service life is set out in Study Report SR351 (Dowdell et al, 2016).

This default of 60 years is embedded in the *LCAQuick – Office* tool.

6.3.3.2 Installed products in use (module B1)

ISO 21931-1 (ISO, 2010b) does not provide much information about what should be included in this module. However EN 15978 (CEN, 2011b) provides some further detail. Based on this and for the purposes of the framework, this module should contain emissions, where known to occur, from materials or construction systems to air (including indoor air) and water and/or soil arising as a result of normal use of a building, e.g. due to leaching or out gassing.

This information may be provided in EPDs where relevant to a particular product and required by PCR.

There is currently work ongoing internationally to develop consistent testing regimes for emissions to air, water and soil from construction products. The International Energy Agency (IEA) has developed Annex 68[22] as part of its Energy in Buildings and Communities Programme which is looking at indoor air quality design and control in low-energy residential buildings. BRANZ, together with research partners, is currently undertaking a project which aims to map the knowledge that exists about the indoor air quality of New Zealand homes. It will also establish an approach on how to conduct a contaminant survey of the New Zealand housing stock.

Materials data in *LCAQuick – Office*, used to calculate potential environmental impacts of reference office buildings, does not currently account for module B1 due to a lack of data.

6.3.3.3 Maintenance, repair, replacement and refurbishment (modules B2 to B5)

Maintenance, repair, replacement and refurbishment correspond with modules B2, B3, B4 and B5 respectively in Figure 6.

Maintenance (module B2)

Maintenance requires an activity or activities over a specified frequency or frequencies, to ensure a constructed asset maintains its functionality.

This means that a constructed asset should, at least, achieve the durability requirement according to Clause B2 of the New Zealand Building Code (reproduced in Appendix C) provided adequate maintenance is carried out, before replacement may be necessary. Constructed assets in New Zealand should frequently last longer than this durability requirement provided appropriate and timely maintenance is carried out.

Default generic maintenance data is provided in the accompanying datasheet 'NZWBWLF – Module B2 maintenance datasheet v1' ('B2 maintenance datasheet') which can be downloaded from the BRANZ website (at www.branz.co.nz/buildingLCA).

In the B2 maintenance datasheet, maintenance activities are listed by CBI classification. Each listed activity is quantified where possible. It assumes that required building maintenance is carried out. Persistent failure to carry out required maintenance may eventually result in the need for repair or premature replacement of materials.

The data is appropriate for use:

[22] http://www.iea-ebc-annex68.org/About_Annex-68

- in early stages of design, when product-specific decisions have not been taken – once specific products are being considered during later stages of design, then manufacturer-specific maintenance instructions can be used
- in the absence of product-specific data when the impacts of any of these activities are not significant.

Sources of information that have been used to define maintenance activities are also provided in the B2 maintenance datasheet. Supporting information concerning the development of the B2 maintenance datasheet is provided in Study Report SR351 (Dowdell et al, 2016).

Repair (module B3)

Repair is an activity that may be necessary to maintain functional performance of constructed assets for two reasons:

- Random or deliberate events may damage constructed assets, such as storms, floods, accidents or acts of terrorism.
- Recommended maintenance at a recommended frequency is not carried out, meaning that constructed assets may degrade, become excessively worn or damaged as a result.

Designing buildings that are compliant with the New Zealand Building Code provides a level of accepted resilience to certain events, such as earthquakes or fires. Other potential events, such as an act of terrorism, may be required for consideration on specific building design projects.

Repair required as a result of random or deliberate events is not considered in the reference buildings in *LCAQuick – Office*. All reference office buildings have been designed to be at least compliant with the New Zealand Building Code.

Repair may also be necessary where appropriate maintenance has not been carried out. Provided maintenance is carried out (for example, using defaults in the B2 maintenance datasheet and B4 replacement datasheet or based on specific manufacturer data), then no repair should be necessary and the product should at least achieve the durability requirement of the New Zealand Building Code.

For the purposes of modelling reference buildings in *LCAQuick – Office*, maintenance is included as set out in the B2 maintenance datasheet and B4 replacement datasheet and therefore an assumption is made that no repair is necessary.

There may be other specific LCA studies for which repair should be included in the scope of work, for example, an LCA study that wants to assess the environmental impacts of performing programmed maintenance in comparison with doing the minimum until absolutely necessary.

Replacement (module B4)

Replacement occurs when a constructed asset, or significant parts or sections of a constructed asset, are removed and replaced with an equivalent constructed asset (or part or section) that at least provides the same level of functional performance in the building.

Replacement occurs when the estimated service life of a constructed asset has been reached.

The accompanying datasheet 'NZWBWLF – Module B4 replacement datasheet v1' ('B4 replacement datasheet'), downloadable from the BRANZ website (at www.branz.co.nz/buildingLCA), provides default estimated service life data.

Estimated service life data is organised according to CBI classification. Estimates are provided based on typical, minimum and maximum figures, with sources of data also provided.

For example, '4211 Proprietary curtain walling' shows a typical estimated service life of 42 years, with a minimum life of 30 years and a maximum life of 55 years. This is in contrast to a 15-year life for the building envelope required in Clause B2 of the New Zealand Building Code (Appendix C).

When modelling replacement in the building LCA, the following should be included:

- The (section of) constructed asset being replaced, in terms of the amount being removed using appropriate units, e.g. kg, m^3.
- The manufacture and transport of the replacement (section of) constructed asset, including manufacture and transport of the materials of which it comprises.
- Installation of the new (section of) constructed asset, and removal of the (section of) constructed asset being replaced (if significant to results).
- Transport of the replaced constructed asset and end of life, including whether disposed to landfill or recycled. If recycled, processes should be included until the material or materials comprising the constructed asset reach an end-of-waste state. For more information about the end-of-waste state, see Appendix D.

Estimated service life data in the B4 replacement datasheet:

- Is generic and therefore may not reflect the service life of a specific product. It is appropriate for use in early design and may also be useful for later stages of design. However, where service life of constructed assets of interest make a significant contribution to results, then data for specific products should be used.
- Assumes that appropriate maintenance is carried out in a timely manner.

As a minimum, the typical service life is taken as achieving requirements set out in Clause B2 of the New Zealand Building Code (Appendix C). Minimum and maximum service life data is additionally provided to facilitate sensitivity analysis or as limits for Monte Carlo simulation.

Estimated service life data provided in the B4 replacement datasheet is based on technical reasons for replacement. However, constructed assets may not reach this potential for reasons that are not related to technical performance. Van Nunen et al (2003) summarises the three main reasons that determine when constructed assets need replacing, as follows:

- Technical: Defined when a constructed asset can no longer fulfil its function (for example, a roof begins to leak). This is normally the longest service life.
- Economic: Defined when an alternative can provide the same or better functionality with lesser costs. This may occur when a constructed asset no longer performs satisfactorily due to changes in performance requirements.
- Functional: Defined when the constructed asset no longer meets the function that the occupant demands of it. This may relate or be influenced by individual choice,

perception or behaviour, e.g. colour or style, rather than a technical characteristic. This is often the shortest service life.

Therefore, it may be the building owner and/or occupant that decides when a constructed asset should be replaced, irrespective of technical performance. This will result in a shorter service life than those provided in the B4 replacement datasheet.

Information concerning the derivation of replacement data is provided in the accompanying Study Report SR351 (Dowdell et al, 2016).

The 'typical' estimated service lives in the B4 replacement datasheet provide the basis for modelling of the reference buildings in *LCAQuick – Office*. Modelling of replacement includes the following:

- The production of the new material or product which will be installed (based on module A1–A3).
- Transport and installation of the new material or product (based on module A4–A5).
- Removal of the old material or product, with subsequent transport and end of life.

Refurbishment (module B5)

Refurbishment covers major changes or upgrades to a building which may include changes to fitout, internal layout, building envelope, services and/or structure. Significant refurbishment on a building may result in:

- a change of use, e.g. from warehousing to offices
- an extension to the building service life, instead of demolishing it and building on the same site
- retaining of historical features, e.g. street frontage, whilst upgrading the building to meet modern requirements
- improvement in functionality, including becoming more energy efficient and achieving a better environment for occupants.

Refurbishment of offices in New Zealand is the subject of research at the Life Cycle Management Centre at Massey University, due for completion in 2017.

When evaluating new-build design, future refurbishment activity is unlikely to be known and can therefore be reasonably excluded unless specific requirements are set out in a client's brief. No refurbishment activity is included in the reference buildings in *LCAQuick – Office*.

There may be circumstances where it is appropriate to report on module B5 depending on the purpose and scope of an LCA study. Examples include:

- Where it is already known during design that some future planned refurbishment activity will take place.
- A comparison of refurbishment of an existing building with demolition and new-build on the same site.

6.3.3.4 Operational energy use (module B6)

Module B6 includes energy used by building-integrated systems including heating, cooling, ventilation, humidification, lighting, pumps and control systems and transportation such as elevators and escalators, for example (CEN, 2011b).

The standard additionally requires that energy use for plug-in appliances ('plug loads'), for example, computers, photocopiers and printers, audio, televisions and drinks machines, is reported separately.

Operational energy use due to heating and cooling for reference buildings is calculated based on their location, form, orientation, window-to-wall ratios, insulation levels and products used in a building's thermal envelope using models developed in EnergyPlus.

Default information useful for energy modelling is summarised in the accompanying 'NZ WBWLF – Module B6 operational energy v1' datasheet ('B6 energy datasheet') which summarises findings from BEES research which focused on energy use in New Zealand commercial buildings. It also includes other information and data that may be useful for energy modelling of office buildings.

Defaults required for energy modelling for the purposes of obtaining a Green Star assessment are not provided in the B6 energy datasheet and can be obtained from the NZGBC.

For further information about energy modelling in order to calculate operational energy use, see BRANZ Study Report SR350 (Berg, Dowdell & Curtis, 2016). The method for accounting for energy generated on site which may, at times, be supplemented by energy imported from outside the site boundary (e.g. electricity from the grid) and at other times be exported, is set out in the BRANZ Study Report SR351 (Dowdell et al, 2016).

None of the reference buildings developed to date generate their own energy on site. For the purposes of calculating environmental impacts associated with energy, EN 15978 (CEN, 2011b) requires that any energy generation on the site of the building is assumed to first satisfy demand from building-integrated systems, followed by plug loads.

The magnitude of potential environmental impacts associated with the New Zealand grid can vary yearly according to quantity and location of rainfall, due to the contribution made to the Grid from hydroelectricity. This means that the environmental impacts calculated for office buildings, which primarily use electricity as a source of energy, will also vary depending on the year represented by LCA data for grid electricity. It is therefore important that a consistent grid electricity dataset is used for calculating module B6 impacts of buildings being compared.

The New Zealand Life Cycle Management Centre, with BRANZ support, has developed an LCA model for New Zealand grid electricity on a 'per kWh low voltage electricity delivered' basis. This has been used by BRANZ to develop a low-voltage grid electricity LCI and summary of environmental impacts dataset based on a three-year average (2012–2014). Further information is provided in the BRANZ Study Report SR351 (Dowdell et al, 2016).

This grid electricity dataset is provided to facilitate consistency between different building LCAs and is recommended for use to represent New Zealand grid electricity generation and distribution within the framework. The dataset is called 'NZ WBWLF – Module B6 Grid LCI and impacts v1' and can be downloaded from the BRANZ website (at www.branz.co.nz/buildingLCA). Datasets in other formats are also available.

6.3.3.5 Operational water use (module B7)

EN 15978 (CEN, 2011b) states that module B7 must include all building-integrated water-consuming processes such as drinking water and hot water, water for sanitation, water for irrigation of landscape areas and water for heating, cooling, ventilation and humidification.

Water use associated with appliances, for example dishwashers, should be reported separately.

Bint (2012) developed water consumption benchmarks for New Zealand office buildings based on water use measurements in 93 office buildings across Auckland and Wellington. These measurements comprised total water use in the buildings including water used by appliances.

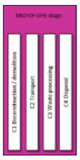
Using these measurements, benchmarks based on net lettable area (NLA) were calculated. Approximate water use in other New Zealand regions was also calculated using the overall sample median for Auckland and Wellington results combined. Resulting benchmarks are summarised in the accompanying 'NZ WBWLF – Module B7 water use v1' datasheet ('B7 water datasheet').

Water use in reference buildings uses these benchmarks. *LCAQuick – Office* additionally provides for a high-level consideration of inclusion of rainwater harvesting and/or greywater recycling within building designs.

Water use in New Zealand is typically considered in terms of consumption, in the absence of the ability to quantify the environmental impact of this demand. The expansion of our towns and cities with increasing population numbers, plus greater demand for productivity from our land, for example, through increased levels of irrigation, are likely to result in increased consumption of water.

Research being undertaken at the New Zealand Life Cycle Management Centre for the framework is seeking to develop and evaluate methods for calculating water scarcity impacts associated with consumption of water in different catchments, regions or water management zones. This will be an important step towards the ability to calculate the impacts of water consumption according to location, rather than focusing purely on the consumption itself. The research is due to be completed later in 2016 and will be available on the BRANZ website.

6.3.4 End-of-life stage (modules C1 to C4)



Based on EN 15643-2 (CEN, 2011a), the end-of-life stage of a building is divided into:

- C1 Deconstruction/demolition
- C2 Transport
- C3 Waste processing
- C4 Disposal

BRANZ has provided default waste data summarising diversion rates from landfill at building end of life. These are expressed as a percentage by mass of material diverted. This generic data is contained in the 'NZWBWLF – Module C1 building end-of-life waste datasheet v1' ('C1 building end-of-life datasheet') available for download from the BRANZ website (at www.branz.co.nz/buildingLCA).

Diversion rates from landfill are provided by material name and by four-digit CBI classification. The basis for the derivation of these landfill diversion figures is provided in the accompanying BRANZ Study Report SR351 (Dowdell et al, 2016).

Other data provided in the C1 building end-of-life datasheet is as follows:

- Fate of waste, in terms of diversion for reuse, recycling or energy recovery. The remainder of material is assumed to go to landfill or cleanfill (or may be left on site, in the ground).
- The recycling or recovery technology used.
- Source(s) of data.

Rates are provided as 'typical' and 'best practice'. When using this data, typical diversion rates should be applied rather than best practice figures.

Typical diversion rates have been used in the development of LCA models for the reference buildings in *LCAQuick – Office*.

Estimates of diversion rates have been used where data was unavailable. Best practice data is largely based on publicly available New Zealand case studies.

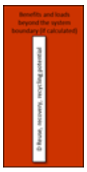
For LCA studies in which the diversion rate from landfill for a construction product at building end of life has a significant influence on results of the LCA, then specific data should be sought.

For the purposes of calculating module C environmental impacts for the reference buildings, a distance of 15 kms was assumed for transport to landfill or cleanfill. Transport distances for building end-of-life waste that goes to recycling facilities varies depending on the location of the recycling operation (which may be overseas).

Consideration of whether waste transport is accounted for in module C2 or module D (if calculated) is dependent on whether the waste being transported has reached an end-of-waste state before transport. If the waste has not reached the end-of-waste state prior to transport, then transport is modelled in module C2. If the waste has already reached the end-of-waste state prior to transport, the transport is modelled in module D (if calculated). For more information about determining the end-of-waste state, see Appendix D.

This module includes processes occurring as a result of containment of a material at its end of life, for example, in a landfill site. Emissions from landfill may occur over long periods after disposal. According to Section 7.4.5.5 of EN 15978 (CEN, 2011b), "a time period of 100 years is considered appropriate for such long-term processes".

6.3.5 Benefits and loads beyond the system boundary (module D)



Modules in the product, construction process, use and end-of-life stages collectively reflect environmental impacts that directly result from a building, through its use of materials, energy and water.

Secondary outputs such as materials and fuels may become available during the life cycle of a building, through reuse, recycling and recovery processes. These may arise at different stages in the life cycle, for example:

- During construction (module A5), materials generated as waste on the construction site may be diverted from landfill. The A5 site waste datasheet provides default data for diversion rates from landfill and end-of-life routes (Section 6.3.2.2).
- During occupation of the building, products may be replaced either individually or as part of constructed assets (module B4) during the building life. The B4 replacement datasheet provides default data to support modelling of replacement during the building life (Section 6.3.3.3).
- During decommissioning/demolition of the building (module C1), materials may be diverted from landfill (or cleanfill) for reuse, recycling and/or recovery. The C1 building end-of-life datasheet provides default data to support modelling of this module (Section 6.3.4).

When diverted from landfill or cleanfill, these can provide further functions, either directly or following additional processing. Functions may be:

- The same or similar to the function intended or provided in the building life cycle from which the material was obtained. This may be through reuse, for example, when concrete blocks leftover at a construction site are reused at another construction site. Or it may be through closed-loop recycling, for example, when scrap steel is used to make steel at an electric arc furnace.
- Different to the function intended or provided in the building life cycle from which the material was obtained and providing material savings. Recycling that results in a material that meets a different function is termed open-loop recycling. An example of open-loop recycling is crushing of concrete to produce secondary aggregate, which may be used instead of primary aggregate.
- Different to the function intended or provided in the building life cycle from which the material was obtained and providing primary energy savings. This is termed recovery. An example is use of timber waste as an energy source in a cement kiln instead of other fuels providing thermal energy.

Similarly, in the case that an occupied building with renewables capacity generates more energy than is used in the building, excess energy may be exported for others outside of the building life cycle to use. An example of this would be where a building with photovoltaic panels generates more electricity than it uses, with the excess being supplied onto the New Zealand grid.

The environmental benefits or loads that may accrue from reuse, recycling, recovery and energy export may be accounted for in module D. Inclusion of module D in a building LCA is optional and is provided for information only. Module D results must not be aggregated with results from modules A1 to C4 as they represent potential benefits and loads outside the system boundary of the building being modelled. It is important to note that, if provided, the benefits or loads reflected in module D:

- May occur as a result of effort to encourage availability of materials for reuse, recycling or energy recovery (or exporting excess energy) when they are no longer required. Actual availability is not necessarily certain and will be dependent on future requirements (e.g. legislation and standards) and processes and technology in the future (in the case of materials derived from the building end of life, this is a long time in the future).
- Are calculated to provide an indication only of broader benefits and loads beyond the building boundary based on current information, practices and technology. They are therefore conservative.

- Are not environmental benefits or loads directly realised within the building boundary but are potential additional benefits or loads that occur in other product systems.

In terms of modelling:

1. Any processing of 'waste' necessary in order for it to reach the end-of-waste state (Appendix D) must be modelled in the module from which the waste derives. For example, if waste concrete blocks in module C3 reach an end-of-waste state following crushing and sorting, then the transport to the recycling yard (module C2) and crushing of the waste concrete blocks (module C3) must be included.
2. The net amount of secondary output is then calculated. This is achieved by subtracting the total of each secondary input from its corresponding secondary output (across all modules in the life cycle of the building). For example, if there is an input of secondary aggregate for use as a base course in module A5 of 10,000 kg and an output of secondary aggregate from crushing concrete in module C3 of 35,000 kg, then the net amount of secondary aggregate generated over the building life cycle is the difference of 25,000 kg.
3. If calculated, module D reflects environmental impacts or benefits arising from processing and transport after reaching the end-of-waste state, *less* the environmental impacts saved through a subsequent use of the secondary output instead of an alternative output that provides the same level of function. Any losses through processing should be modelled and allowance should be made for any differences in functionality delivered by the secondary output in comparison with an alternative. For example, assuming secondary aggregate is a like-for-like substitute for primary aggregate, then the calculated impacts of production of 25,000 kg of primary aggregate can be reflected in module D as a negative figure (which reflects the substitution of 25,000 kg of primary aggregate by 25,000 kg of secondary aggregate).
4. The alternative material or energy that is substituted should be based on current average technology or practice. If this is not available, a conservative approach should be used (Section 6.4.3.3 of EN 15804 [CEN, 2013]).

Figure 13 illustrates the derivation of the net output described above. The net output (n) is calculated by subtracting outputs of materials or fuels (o) from the building life cycle by the inputs of the same materials or fuels to the building life cycle (i).

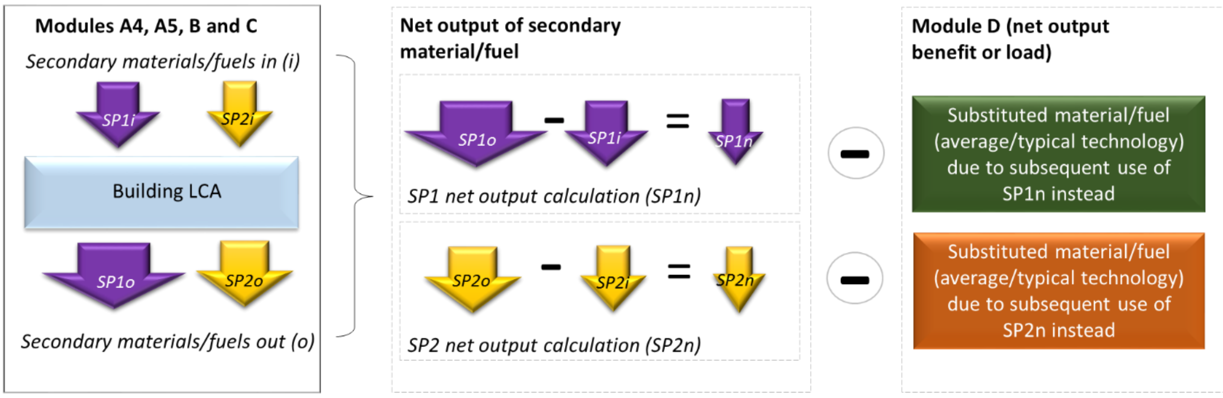


Figure 13. Illustration of net output and module D benefit or load (if calculated).

6.4 Scope of environmental indicators

BRANZ Study Report SR293 (Dowdell, 2014) sets out environmental indicators that are recommended for calculation and the methods and midpoint characterisation factors that should be used. The findings of the report are based on a review of standards, whole-building whole-of-life frameworks, guidance and other information. Characterisation factors provided in the report are based on well-established models.

At the time of writing, the LCANZ Best Practice Working Group has commenced work to better understand the underlying models that provide the basis for the characterisation factors used in impact assessment. This is with the intention of obtaining a better understanding of applicability of these models to the New Zealand environment.

Based on the findings of this, and other related work internationally, the methods and characterisations factors recommended for use are reviewable and may be updated in the future. Any future updates will be made available on the BRANZ website at www.branz.co.nz/buildingLCA.

Environmental impacts for future consideration are also listed in BRANZ Study Report SR293. One of these – water scarcity – has provided the focus for a research project at the New Zealand Life Cycle Management Centre (see Section 6.3.3.5).

LCAQuick – Office presents the environmental indicators listed in Sections 6.4.1 to 6.4.6 below plus primary energy resources (total, non renewable and renewable) from Section 6.4.7. Net use of fresh water and total waste from Section 6.4.7 are not presented due to data restrictions.

6.4.1 Global warming (100-year)

Man-made climate change is caused by the emission of greenhouse gases and by other activities influencing their atmospheric concentration. Greenhouse gases are substances with the ability to absorb infrared radiation from the earth (radiative forcing).

Globally, construction is one of the sectors with the greatest impact on the release of greenhouse gas emissions and also has the greatest potential to reduce those emissions. Measures to reduce greenhouse gas emissions from buildings include reducing energy consumption and embodied energy in buildings, switching to low-carbon fuels which also include a higher share of renewable energy and controlling emissions of non-carbon dioxide greenhouse gases.

Modelling the radiative forcing of emissions involves looking at changes in atmospheric concentration, taking into account the residence time of a greenhouse gas. A globally-recognised model, the Bern model, has been developed by the Intergovernmental Panel on Climate Change (IPCC) that calculates the radiative forcing of all greenhouse gases, expressed relative to carbon dioxide. Carbon dioxide therefore has a weighting or global warming potential (GWP) of 1, which provides a reference against which GWPs of other greenhouse gases are expressed.

For policy reasons, GWPs over a 100-year time horizon are most typically used. GWPs for other time horizons, e.g. 20 years and 500 years, are also available.

The IPCC's GWPs are directly used as midpoint characterisation factors for calculation of global warming impacts in LCA. IPCC reports are published regularly (e.g. IPCC, 2014), with updates to GWP values.

6.4.2 Stratospheric ozone depletion

The 'hole' in the ozone layer was detected over Antarctica in 1985. Ozone is continuously formed and destroyed by sunlight and chemical reactions in the stratosphere. Ozone depletion occurs if the rate of ozone destruction is increased due to emissions of ozone-depleting substances such as chlorofluorocarbons which persist in the atmosphere.

Stratospheric ozone, which is 90% of the total ozone in the atmosphere, is vital for life because it hinders harmful solar ultraviolet UV-B radiation from penetrating the lower levels of the atmosphere. If not absorbed, UV-B radiation below 300 nanometres will reach the troposphere and the surface of the Earth, where it can increase the risk of skin cancer and cataracts when appropriate precautions are not taken. It may also cause premature aging and suppression of the immune system. In addition to the increased risk to human health, the UV-B radiation can also damage terrestrial plant life and aquatic ecosystems.

Characterisation factors for ozone depletion account for the destruction of the stratospheric ozone layer. An ozone depletion potential (ODP) of a substance is a relative measure of its potency, relative to CFC 11, according to atmospheric residence time and ability to form Equivalent Effective Stratospheric Chlorine (EESC) which is primarily responsible for ozone depletion.

6.4.3 Eutrophication

This impact category addresses impacts due to addition of nitrogen and phosphorus in bio-available forms in aquatic ecosystems primarily. The addition of nutrients to aquatic systems can act to fertilise plants (algae or macrophytes) with a number of consequences for the ecosystem:

- Composition of the plant community changes to more nutrient-demanding species.
- Algal blooms create shadowing, filtering the light penetrating into the water mass, changing life conditions for macrophytes that need light for photosynthesis, and for predatory fish which need the light to see and catch their prey.
- Oxygen depletion near the bottom of the water body where dead algae deposit and degrade.

There may be seasonal variations in the pattern of limiting nutrients, but as a general rule phosphorus (P) is the limiting nutrient in freshwater systems while nitrogen (N) is the limiting nutrient in marine systems.

6.4.4 Acidification (land and water)

Acidifying pollutants originate primarily from anthropogenic emissions of sulphur dioxide (SO_2), nitrogen oxides (NOx) and ammonia (NH_3). Acidifying emissions arise from combustion of fossil fuels. Road transport, shipping and aircraft are significant sources of NOx emissions. Ammonia emissions are related primarily to agricultural activities.

When emitted to the atmosphere, acidifying pollutants may remain in the air for several days and therefore be dispersed and carried over long distances by winds. They may cause damaging effects far from the source of emission. Acidification can occur when the capacity of the soil or water bodies to neutralise acidifying atmospheric deposition declines.

Acidifying pollutants are removed from the atmosphere by wet ('acid rain') or dry (direct uptake by vegetation and surfaces) deposition. If rates of deposition persist, ecosystems can eventually lose their neutralising or buffering capacity completely.

Acid deposition effects can appear in a number of ways, including acidification of freshwater systems resulting in the loss of fisheries, impoverishment of soils, damage to forests and vegetation, corrosion of buildings, cultural monuments and materials.

6.4.5 Tropospheric ozone formation

This category addresses the impacts from ozone and other reactive oxygen compounds formed as secondary contaminants in the troposphere by the oxidation of primary contaminants volatile organic compounds (VOC) or carbon monoxide in the presence of nitrogen oxides under the influence of light.

Tropospheric ozone can have the following health effects at concentrations that may be present in urban air:

- Irritation of the respiratory system with symptoms such as coughing and throat irritation.
- Reduced lung function, with the potential reduction in a person's ability to undertake more vigorous activities.
- Aggravation of asthma due to greater sensitivity to allergens which can trigger asthma attacks.
- Inflammation and damage to the lung lining.

6.4.6 Abiotic depletion (elements and fossil fuels)

This indicator provides a measure of resource scarcity by considering resources required across the building life cycle, in the context of the availability of those resources globally.

Methods for defining scarcity vary. Scarcity is normally considered at a global level which does not take into account availability at the local level.

6.4.7 Other indicators

Other indicators[23] that may be calculated include:

- primary energy resources (total, non-renewable and renewable)
- net use of fresh water
- waste (total, non-hazardous and hazardous).

[23] These indicators are not measures of potential environmental impact. They focus on providing a measure of a burden but do not provide any indication of whether this burden is significant in terms of its impact or not. The implication is that if the number is large, then it is worse, irrespective of the environment's ability to deal with the burden or not.

6.4.8 Focusing on specific indicators

Since the framework is LCA-based, it provides results for a range of environmental indicators and life cycle stages in accordance with the international building sustainability standards.

However, Stakeholder Group 2 members may choose to use the outputs of the framework to focus on a specific indicator, such as climate change. A study that looks at one indicator is termed a footprint. This may be useful in particular situations, for example, a corporate client may have a published carbon strategy and carbon reduction target. In this case, a focus on greenhouse gas emissions in the design process means that Stakeholder Group 2 members can demonstrate to the client how the design can help contribute to their carbon reduction target (whilst also demonstrating no significant issues in other assessed environmental indicators).

However, the purpose of footprints is primarily as communication tools rather than comparative assessment. This is due to their limited scope (a single issue) which means that implications for other environmental impacts are ignored.

Applications of LCA that deliver footprints are becoming increasingly common. Product (and organisation) carbon footprints are well established, with a number of standards and methodologies now available, examples of which include:

- ISO/TS 14067 Greenhouse gases – carbon footprint of products – requirements for quantification and communication (ISO, 2013).
- ISO/FDIS 16745 Environmental performance of buildings – carbon metric of a building – use stage (ISO, 2014b).
- The GHG Protocol product standard[24].
- PAS 2050 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services (BSi, 2011).

This focus on greenhouse gas emissions is being driven by the global nature and magnitude of climate change and increasing recognition of the economic, social and environmental consequences that result from inaction.

Buildings have been highlighted as a key area where greenhouse gas savings can be made, which is resulting in research into net-zero carbon buildings and net-zero energy buildings[25,26]. Furthermore, acceptance that we will need to live with a level of global warming is stimulating provision of information about adaptation and mitigation measures[27,28,29,30].

Water footprints are likely to gain increasing recognition due to the stress that our activities place on water resources and the need for better consistency around terminology and calculation of water-related impacts. This has resulted in the publication of ISO 14046 (ISO, 2014a) – the water footprint standard.

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24 www.ghgprotocol.org/standards/product-standard
25 http://iea40.buildinggreen.com/
26 www.wbdg.org/resources/netzeroenergybuildings.php
27 www.climatechange.govt.nz/physical-impacts-and-adaptation/
28 www.epa.gov/climatechange/impacts-adaptation/adapt-overview.html
29 http://ec.europa.eu/clima/policies/adaptation/index_en.htm
30 www.royalsociety.org.nz/expert-advice/papers/yr2016/mitigation-options-for-new-zealand/

In Europe, a multi-attribute footprint called a product environmental footprint (PEF) is currently in development[31].

Whilst focusing on specific environmental indicators can be useful for communication, decisions should ideally be taken that do not solve one problem by creating another. Using a holistic assessment approach such as LCA can help make decision makers aware of the wider implications of their decisions and assist them to take steps to monitor, manage or mitigate these, where necessary.

Therefore, where a focus is given to a particular indicator, the user of the framework should ideally check other indicators to ensure no significant implications.

For the purposes of obtaining points under the Material Life Cycle Impacts Innovation Challenge in Green Star, all of the environmental indicators listed in Section 6.4 need to be considered.

6.5 Exclusions

The framework excludes items outlined in the following two sub-sections.

6.5.1 Sustainability

The framework does not calculate sustainability impacts.

The term 'sustainability' has, arguably, become one of the most misused terms in the English language. In 2010, *Advertising Age*[32] listed 'sustainability' as one of the "jargoniest jargon" words of the year due to its frequent misuse and overuse, citing that politicians, businesses and the media use it as an all-encompassing term for "doing the right thing".

Whilst there are a range of definitions (which is largely the problem!) for sustainability what is clear is that it is a mix and balancing of environmental, social and economic considerations. Low energy, less waste and reduced water use are all good environmental outcomes that contribute to sustainability, but they are not sustainability in and of themselves.

LCA primarily calculates environmental impacts, which may have social implications, e.g. VOC emissions and potential health effects. It does not calculate economic or social outcomes, which may be addressed with other tools with a life cycle focus such as whole-life costing and social LCA amongst others.

6.5.2 Other impacts

The framework provides an environmental assessment across a number of potential impacts listed in Section 6.4. There is also the potential to encompass other environmental indicators in the future as set out in BRANZ Study Report SR293 (Dowdell, 2014).

However, it is important to understand that the framework is based on LCA and therefore is limited to indicators that can be calculated using LCA. Other

[31] http://ec.europa.eu/environment/eussd/smgp/product_footprint.htm

[32] www.triplepundit.com/2011/01/ad-age-names-sustainability-one-jargoniest-jargon-words-2010/

considerations, for example, biodiversity impacts, land use change, toxicity and indoor air quality, may also be important for a building project but are not yet calculated in the framework. For now, other information and tools or specialist advice need to be used to consider these kinds of issues, if required.

Examples of complementary information and tools that are available include:

- Declare: A platform for self-declaration of product constituents which has arisen from the Living Building Challenge. Stakeholder Group 1 members can provide Declare labels for their products, which are accessible by Stakeholder Group 2 members. Some New Zealand manufacturers have already obtained Declare labels for some products (for example, Abodo Wood Ltd, Autex Industries Ltd, InZone Industries Ltd, Laminex and T&R Interior Systems). For further information, see www.declareproducts.com.
- Pharos: A United States web-based building product evaluation system developed by the Healthy Building Network. It consists of a database of over 1500 building products from which the user can determine whether ingredients include bio-accumulative toxics, carcinogens, endocrine disruptors or other hazardous constituents. A new volatile ingredients calculator has recently been added. For more information, see www.pharosproject.net.
- The HPD Collaborative: This is a developing initiative for the creation of Health Product Declarations (HPDs). The Collaborative has published an open HPD standard. Further information is available at www.hpd-collaborative.org/.

7. About *LCAQuick – Office*

7.1 Introduction

LCA is currently new to many involved in building design. It is complex, full of new and technical terminology, delivers outputs with which Stakeholder Group 2 members (Section 3.2) may not be familiar and for which benefits are likely to be uncertain.

In order to seek to overcome these and other potential barriers, BRANZ has developed *LCAQuick – Office*, a free resource which has been developed in Microsoft Excel for ease of use, and is supported by YouTube training videos and a Help facility.

The main purpose of *LCAQuick – Office* is to provide a resource that helps Stakeholder Group 2 members (and others, such as students of architecture, building science, engineering and quantity surveying, for example) to better understand what LCA is, what its outputs are, how to incorporate LCA into workflows and how to use it in design. BRANZ has sought to make *LCAQuick – Office* easy to use and provide useful analysis for early design, without the user needing to invest significant time, resource and cost.

However, as with any new tool, BRANZ recommends that potential users watch the YouTube video tutorials that accompany *LCAQuick – Office* before using it.

Two versions are available based on the preferred form of data entry for building products and who in the design team is using the resource:

- A square metre rate version, allowing manual entry of material quantities based on square metre rates (Rates version).
- A BIM version, allowing pasting of a BIM-developed Schedule of Quantities for use where BIM models are available (BIM version). This version can take a Schedule of Quantities produced in Revit or ArchiCad.

LCAQuick – Office has the following scope:

- It is only available in Microsoft Excel.
- If is focused on concept and preliminary design stages (as it considers building structure and thermal envelope only).
- It is focused on office buildings, these being buildings that are entirely offices or are significantly offices with other commercial uses.
- Environmental impacts for New Zealand reference buildings are available in *LCAQuick – Office* for office buildings with a GFA of 1500 m^2 or greater.
- Both the Rates and BIM versions are available for Auckland, Wellington and Christchurch.

7.2 Inputs and outputs

LCAQuick – Office takes the following inputs for a new building design project:

- Headline information about the project, such as building or project name, project number and GFA.
- Material quantities for the structure and thermal envelope, based on two forms of data entry (Rates version or BIM version). It is important that the Schedule of Quantities is as accurate as possible. Accompanying YouTube video tutorials

provide further guidance on how to construct a BIM model in order to obtain accurate material quantities (see the LCA playlist at www.youtube.com/user/BRANZmedia/playlists).

- Results of energy modelling which may be developed using freely-available BEES[33] templates based on EnergyPlus or other energy modelling software. Where other energy modelling software is used, BRANZ recommends using default values contained in the BEES templates and reproduced in the B6 energy datasheet (Section 6.3.3.4) in order that comparisons can be made with reference office buildings.
- An estimate of water consumption (defaults are provided).

LCAQuick – Office contains a database that uses the above inputs to calculate potential environmental impacts of early building designs. This can be used to explore the environmental impacts of different:

- building forms
- building orientation
- window-to-wall ratios and location of windows
- levels of insulation
- type of structure and thermal envelope.

Results can be displayed for seven different environmental impacts (which are recognised in Green Star) plus total primary energy (divided into total, renewable and non-renewable), listed in Section 6.4. *LCAQuick – Office* also provides a comparison of the environmental impacts associated with the building design with a New Zealand reference office building or buildings.

7.3 The database behind *LCAQuick – Office*

Products across different life cycle stages (modules A1–A3, A4–A5, B2, B4, C and D) have been modelled using data from a range of sources, including:

- EN 15804-compliant and some ISO 14025-compliant EPDs.
- Data obtained from a New Zealand study which looked at development of New Zealand construction product data based on LCA (MAF, 2011).
- AusLCI[34], a free life cycle inventory database at the unit process level, developed and maintained by ALCAS.
- The EcoInvent database[35], a proprietary life cycle inventory database of products and processes at the unit process level.

Supporting information about the database is provided in BRANZ Study Report SR350 (Berg et al, 2016).

The data in *LCAQuick – Office* has been reviewed by Tim Grant, director of lifecycles, for appropriateness of use at early design and were found to be acceptable for this application.

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[33] Building Energy End-use Study. Further information available at www.branz.co.nz/cms_display.php?sn=126&st=1

[34] AusLCI is available at http://alcas.asn.au/AusLCI/

[35] EcoInvent version 3.1 data have been used with kind permission of The EcoInvent Centre (www.ecoinvent.com).

7.4 How to use *LCAQuick – Office*

YouTube training videos are available on the BRANZ Media site on a range of topics to assist with using *LCAQuick – Office* (see the LCA playlist at www.youtube.com/user/BRANZmedia/playlists).

If a user of the tool has a query that is not covered by one of these videos or the *LCAQuick* forum (see below), then an email can be sent to LCAQuick.help@branz.co.nz.

Answers to frequently-asked-questions received by BRANZ will be posted on a LinkedIn forum called '*LCAQuick – Office New Zealand* available at www.linkedin.com/groups/8527850.

7.5 Limitations of *LCAQuick – Office*

LCAQuick – Office has been primarily designed to provide a platform to help Stakeholder Group 2 members become more familiar with LCA and how to use it in design, without the need to incur significant cost and time to understand the benefits.

Use of *LCAQuick – Office* beyond this has not been tested. For example, the scope and validity of using *LCAQuick – Office* as a means to obtain Building LCA Innovation Challenge points in Green Star would need to be discussed and agreed with NZGBC prior to use.

Making the tool easier to use (and developing it in Excel) means that there are limitations as follows:

- In order to use the full functionality of the tool, it is most suitable for application to new-build office (or buildings which are mainly offices with other commercial uses) developments with a GFA of 1500 m^2 or more in Auckland, Wellington or Christchurch. This means that in addition to calculating impacts associated with building designs, the comparison with a reference building or buildings is applicable.
- It only covers concept and preliminary design during which focus is on establishing the fundamentals of the building design. To this end, the tool considers products used in the structure and thermal envelope of a building and is limited by the suite of products listed in Study Report SR350 (Berg et al, 2016). It will not take account of other products not listed and there is no current facility for the user to add products.
- It automatically presents results over a 60-year building service life. If a client brief stipulates a different service life, this cannot be manually overridden.
- There is no capacity to change underlying data embedded in the tool. Therefore, default data (in the accompanying datasheets) such as waste rates at construction sites cannot be changed. This is because *LCAQuick – Office* is aimed at assessing fundamental issues of early design (listed in Section 7.2) rather than specific issues such as whether initiatives can be put in place during construction to reduce waste.
- Environmental indicator results are a reflection of the accuracy of the underlying BIM and energy models that may be used to generate the inputs to *LCAQuick – Office*. The tool itself does not assess the accuracy or representativeness of these

underlying models. BRANZ has provided defaults for energy modelling (in the B6 energy datasheet) suggested for use based on the BEES study and other sources which can be downloaded from the BRANZ website (at www.branz.co.nz/buildingLCA). Consistency of approach to energy (and other) modelling is important in order that valid comparisons can be made with the reference buildings.

BRANZ welcomes feedback on *LCAQuick – Office,* as well as information, data and more reference buildings. The process for providing feedback is set out in Section 8.

8. How to provide information for future inclusion

BRANZ welcomes provision of information and data to add to and improve the current resources in the framework. By providing data and information, you consent to BRANZ having the option of making the data publicly available.

Please email Dr Dave Dowdell at david.dowdell@branz.co.nz with data or information that you would like to submit for consideration for framework inclusion or to provide notification of data (in the case of large files).

Examples of the sorts of information and data BRANZ is seeking are provided below.

8.1 Stakeholder Group 1

8.1.1 EPDs and LCIs

BRANZ welcomes notification of published EPDs for products used in New Zealand.

Other product data, for example in the form of critically-reviewed LCIs, may be submitted to BRANZ for inclusion as a resource in the framework. LCI data may be submitted to BRANZ in Excel format, as a '.gbx' file (if modelled in GaBi) or a reference to a publicly-available dataset can be provided, e.g. in AusLCI. A critical review statement or critical review report from an independent critical review will also need to be submitted, confirming the scope of the critical review, the standards (and PCR if relevant) against which the review has been carried out, who undertook it and the findings.

8.1.2 Information for datasheets

Data that may be used to add to, improve or update datasheets is welcome. This may include information about construction site waste generation rates by product and end-of-life routes (for waste at the construction site and at building end of life). Data should be supported with information about the underlying study used to obtain the data and source.

8.2 Stakeholder Group 2

8.2.1 Reference buildings

BRANZ would like to develop more reference buildings in order to build up a bigger library of office and other buildings for use in design in the future. To achieve this, BRANZ is seeking to include recent buildings that Stakeholder Group 2 members have designed and had consented. The identity of submitted reference buildings would be treated as confidential unless otherwise notified.

Reference building information can be provided to BRANZ (with client consent) for offices and other building types, e.g. schools, public buildings.

The types of information that BRANZ requires is as follows:

- Completed preliminary design *LCAQuick – Office* model (if used).
- Consent documentation, including specification and drawings.
- Energy modelling report.
- Contact name and details for the architect, structural engineer and energy modeller.
- Confirmation from the client that BRANZ may use the building as a reference.

To submit details of a recently completed reference office or other building, please email Dr Dave Dowdell at david.dowdell@branz.co.nz. On receipt of your email, BRANZ can set up a Dropbox folder and provide you with a unique link for submission of documents about the building.

8.2.2 *LCAQuick – Office* feedback

BRANZ is also seeking feedback from users of *LCAQuick – Office*, in particular, what is good, what is not so good, how it can be improved, has it helped your understanding of LCA and how it can be incorporated in design. To provide feedback, please email david.dowdell@branz.co.nz.

For support with questions about *LCAQuick – Office* not covered in YouTube video tutorials (see the LCA playlist at www.youtube.com/user/BRANZmedia/playlists), please email LCAQuick.help@branz.co.nz. Answers to questions that will be of use to others more widely will also be posted on an *LCAQuick* LinkedIn forum available at www.linkedin.com/groups/8527850.

8.2.3 Information for datasheets

Data that may be used to add to, improve or update datasheets is welcome, e.g. data to support energy modelling of office buildings. Data should be supported with information about the underlying study used to obtain the data or source.

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Appendix A: Description of design phases

The descriptions below are taken from the Appendix to CIC Guidelines (NZCIC, 2004) available at http://www.nzcic.co.nz/design.cfm.

Concept design generally involves the application of a design 'idea' to the practical provision of a facility. It represents a phase where sufficient design concepts are developed for the client to be able to establish the feasibility of the project, the development potential of a site or to be able to select a particular conceptual approach that the client wishes to pursue. The concept design phase may be used to define or verify the brief and may often involve the testing of different approaches/options. During this phase, ideas (concepts) are developed through open interaction by the team of the key elements of the project.

At the end of this phase, the basic building blocks of the project are defined in general terms and co-ordinated between the design disciplines.

Concept and preliminary design phases are often combined on less-complex projects.

Preliminary design generally involves the further refinement of the preferred concept to facilitate testing it against inputs from the team, including cost estimates and regulatory approval. This may provide sufficient information for the communication of the design to a third party for marketing or consultation purposes.

During this phase the project concepts are developed into firm schemes, where the relationship and size of spaces and facilities are defined and co-ordinated between the design disciplines. However, resolution of individual details that do not impact on the key elements is generally left to the next design phase. At the end of this phase, the project should be clearly defined.

Developed design is the phase in which the scope of each component in the design is clearly defined and co-ordinated. This may involve production of detailed information, including sketch details of all significant componentry and their interrelationships. The developed design phase is where the individual technical experts prepare the necessary documentation to define the scope of all building elements. Major input is required from all designers.

The completion of the developed design is a critical point in a project. The scope of the project is fully defined. As a result, cost estimates can be prepared on an elemental basis. Developed design generally provides sufficient information for the client/user to clearly understand the aesthetics and functionality of the building, internal spaces and facilities.

On some projects the developed design documentation is issued for building consent and/or 'guaranteed maximum price' (GMP) tender. Co-ordination between the design disciplines is therefore critically important at the end of this stage.

Detailed design generally provides a level of documentation that clearly defines the design, specification and extent of all building elements. The design should be comprehensively co-ordinated with other disciplines. However, the documents produced in this phase may not be directly able to be 'built' from. Changes to anything but detail at this stage are very disruptive and expensive and often result in further problems as, by now, the project has become very complex and it is hard to identify all ramifications of changes. Detailed design is the phase most commonly used to obtain a tender for the construction of the works.

Construction design is where the requirements defined in detailed design documents are integrated with changes that may occur during the tender and contract process as well as with construction requirements such as site conditions, proprietary and performance design elements, erection requirements and fabricated shop drawings to create drawings that can be directly ‘built’ from. (Note: shop drawings are produced during this stage.)

Appendix B: Definitions of building elements

Building Element		Definition (NZIQS, 2012)
Structure	Substructure	All work below the underside of the lowest floor finish, including all work applicable to the foundations, hardfilling beneath floor slabs, concrete floor slabs, service ducts, lift pits and the like. Includes basement walls between different levels. Excludes excavation above lowest floor level, plumbing, drainage and other services below lowest floor finish.
	Frame	All load-bearing column and beam framework above lowest floor finish, major roof framing members such as rafters and joists. Excludes all profiled finishes and all applied finishes.
	Structural walls	Load-bearing and diaphragm walls together with integral columns. Excludes non-structural spandrel panels, linings and applied finishes and treatments, and profiled finish.
Exterior fabric	Roof	Complete weatherproof covering of all types of roofs. Includes: decks, diaphragm bracing, sarking and screeds; roof support components such as roof purlins, battens; insulation to underside of roof covering, verge and eaves facing and soffit; and secret, parapet and eaves gutters, downpipes, roof lights. Excludes: support beams; in situ or precast concrete roof slabs, parapets and parapet finishes, gable and gable finishes; and canopies, balconies, covered walkways and roof top structures.
	Exterior walls	All work to exterior walls, including applied or in situ finishes. Includes: gable ends, parapets, spandrels and finishes; both skins of exterior cavity walls; and applied exterior finishes to exterior columns, beams, structural spandrels and walls. Excludes curtain walls.
	Windows and exterior doors	All windows and doors in exterior walls, including vertical or near-vertical glazing. Excludes roof lights, interior glazed screens, curtain pelmets, sun screens, curtains, tracks and blinds.
Interior finishing	Stairs and balustrades	Flights and intermediate landings including integral finishings, handrails and balustrades. Excludes applied finishes.
	Partitions	All non-structural internal walls including glazed screens, demountable partitions and sound and fire walls. Excludes fanlights and sidelights, folding or sliding doors forming partitions, wall finishes and fire-stopping and sound barriers in ceiling spaces, where these are a continuation of partitions below the ceiling line.
	Interior doors	All interior doors including frames, architraves, finishes, glazing, fanlights, sidelights, panels over doors, hardware and control systems. Excludes doors to proprietary partition systems, fittings and fixtures.
	Floor finishes	Includes all preparatory work, screeds, surface finishes, matwells, threshold strips and raised floors laid over structural floors.
	Wall finishes	Includes all preparatory work and finishes to interior walls, isolated columns and to interior faces of exterior walls. Excludes fairface finish to concrete and finishes to proprietary partition systems. Includes skirtings, cornices, trims, dado rails and the like.

Building Element		Definition (NZIQS, 2012)
	Ceiling finishes	Includes all preparatory work and finishes, suspended ceilings and framing, soffits of staircases and intermediate landings. Excludes ceiling framing forming part of roof framing.
	Fittings	Joinery fittings, whether built in or fixed in position, includes glass, hardware and finishes. Excludes sanitary fittings, electrical fittings, services to fittings and fixtures.
Services	Sanitary plumbing	Hot and cold water supply, including hot water cylinder, sanitary fittings, soil, waste and vent pipes. Excludes special kitchen equipment, laboratory equipment and services.
	Heating and ventilation (mechanical services)	Heating, ventilation and air conditioning systems, including all associated equipment. Excludes heating source to hot water system.
	Fire services	All fire services within a building, including all associated electrical work.
	Electrical services	All electrical services providing lighting and power. Excludes lighting and power to external works and wiring to equipment and machinery which is covered in other elements.
	Vertical and horizontal transportation	Vertical and horizontal moving equipment, including associated electrical equipment and builders' work.
	Special services	Special services, including associated electrical work and builders' work. Includes gas, liquids, fume extraction systems, pneumatic and vacuum tube systems, refrigeration, disposal systems, kitchen, bar and laboratory equipment and fittings, communication systems, protective systems (excluding fire), building management systems and traffic control systems.
	Drainage	Subsoil drainage, land drains, stormwater drains and soil drains, including excavation, backfill, fittings and the like.
External works and sundries	External works	Site works beyond the line of the exterior face of the building structure. Excludes site preparation.
	Sundries	Items not readily classified under other elements, e.g. verandahs, canopies, swimming pools and small isolated structures such as pump houses.

Appendix C: Clause B2 (Durability), New Zealand Building Code

New Zealand Building Code Clause B2 Durability

This Clause is extracted from the New Zealand Building Code contained in the First Schedule of the Building Regulations 1992 and amended by the Building Regulations 1997.

FIRST SCHEDULE–*continued*

Clause B2–DURABILITY

Provisions	**Limits on application**
OBJECTIVE **B2.1** The objective of this provision is to ensure that a *building* will throughout its life continue to satisfy the other objectives of this code.	
FUNCTIONAL REQUIREMENT **B2.2** *Building* materials, components and construction methods shall be sufficiently durable to ensure that the *building*, without reconstruction or major renovation, satisfies the other functional requirements of this code throughout the life of the *building*.	
PERFORMANCE **B2.3.1** *Building elements* must, with only normal maintenance, continue to satisfy the performance requirements of this code for the lesser of the *specified intended life* of the *building*, if stated, or: (a) The life of the building, being not less than 50 years, if: (i) Those *building elements* (including floors, walls, and fixings) provide structural stability to the building, or (ii) Those *building elements* are difficult to access or replace, or (iii) Failure of those *building elements* to comply with the *building code* would go undetected during both normal use and maintenance of the *building*. (b) 15 years if: (i) Those *building elements* (including the *building* envelope, exposed plumbing in the subfloor space, and in-built chimneys and flues) are moderately difficult to access or replace, or	Performance B2.3.1 applies from the time of issue of the applicable *code compliance certificate*. *Building elements* are not required to satisfy a durability performance which exceeds the *specified intended life* of the *building*.

FIRST SCHEDULE–*continued*

Provisions	Limits on application
(ii) Failure of those *building* elements to comply with the *building code* would go undetected during normal use of the *building*, but would be easily detected during normal maintenance.	
(c) 5 years if:	
(i) The *building elements* (including services, linings, renewable protective coatings, and *fixtures*) are easy to access and replace, and	
(ii) Failure of those *building elements* to comply with the *building code* would be easily detected during normal use of the *building*.	
B2.3.2 Individual *building elements* which are components of a *building* system and are difficult to access or replace must either:	
(a) All have the same durability, or	
(b) Be installed in a manner that permits the replacement of *building elements* of lesser durability without removing *building elements* that have greater durability and are not specifically designed for removal and replacement.	

Appendix D: The end-of-waste state

When waste is generated, it may go to landfill or may be recycled to produce a secondary material or fuel. If recycled, the waste may undergo one or more transport and/or processing stages before producing a secondary output capable of meeting a function or functions that would otherwise be provided by an alternative material or fuel.

For the purposes of modelling environmental impacts of recycling (or reuse or energy recovery) in an LCA, it is important to understand at what point the waste reaches the end-of-waste state. This is because:

- Before a waste reaches the end-of-waste state, transport and processing is modelled in the module in which the waste arises.
- After the end-of-waste state has been reached, any subsequent transport and processing is modelled in module D if it is calculated (in addition to impacts avoided and incurred through substitution of alternative materials by secondary outputs derived from recycling).

For example, following pouring of in-situ concrete at a construction site, a cubic metre of wet concrete remains in the mixer truck. This is returned to the batching plant where it is washed to recover aggregate. In this case, the following needs to be decided before modelling:

- Is the transport of the concrete back to the batching plant modelled in module A5 or module D (if calculated)?
- Is the washing of the concrete at the batching plant modelled in module A5 or module D (if calculated)?

Similarly, for a waste steel sheet separated for recycling during construction:

- Is the transport of the waste steel to an electric arc furnace modelled in module A5 or module D (if calculated)?
- Is the electric arc furnace operation which produces steel ingots from the waste steel modelled in module A5 or module D (if calculated)?
- Is the processing of the ingots in a rolling mill to produce steel bar modelled in module A5 or module D (if calculated)?

In order to answer these questions, the end-of-waste state needs to be determined. EN 15804 (CEN, 2013) provides an informative annex which helps with this decision, interpreted in Figure 14. Applying the criteria in Figure 14 to the concrete and steel cases above, the following may be determined:

- In its plastic form, and assuming it is not able to be reused before it cures or the cured product cannot be used, the returned concrete in module A5 is a waste. However, once washed, the secondary aggregate that is produced may substitute for a primary product (primary aggregate) and may therefore be considered to have reached the end-of-waste state. By choosing to wash the concrete whilst in its plastic state, the batching plant bears the cost of washing (in terms of use of energy and water, for example) but obtains cost savings (through avoidance of disposal costs of the waste concrete and procurement cost of as much primary aggregate) or additional revenue (if sold as secondary aggregate to a third party) which would otherwise not have been obtained. Since the concrete needs washing to realise these savings or revenues, it may be considered to reach its end-of-waste state following washing. In this case, modelling of the washing would take place in module A5 and the associated environmental impacts would be reflected here. Module D, if calculated, would reflect the production of primary aggregate that is substituted by the provision of secondary aggregate. This substitution would be reflected as a negative figure in module D.

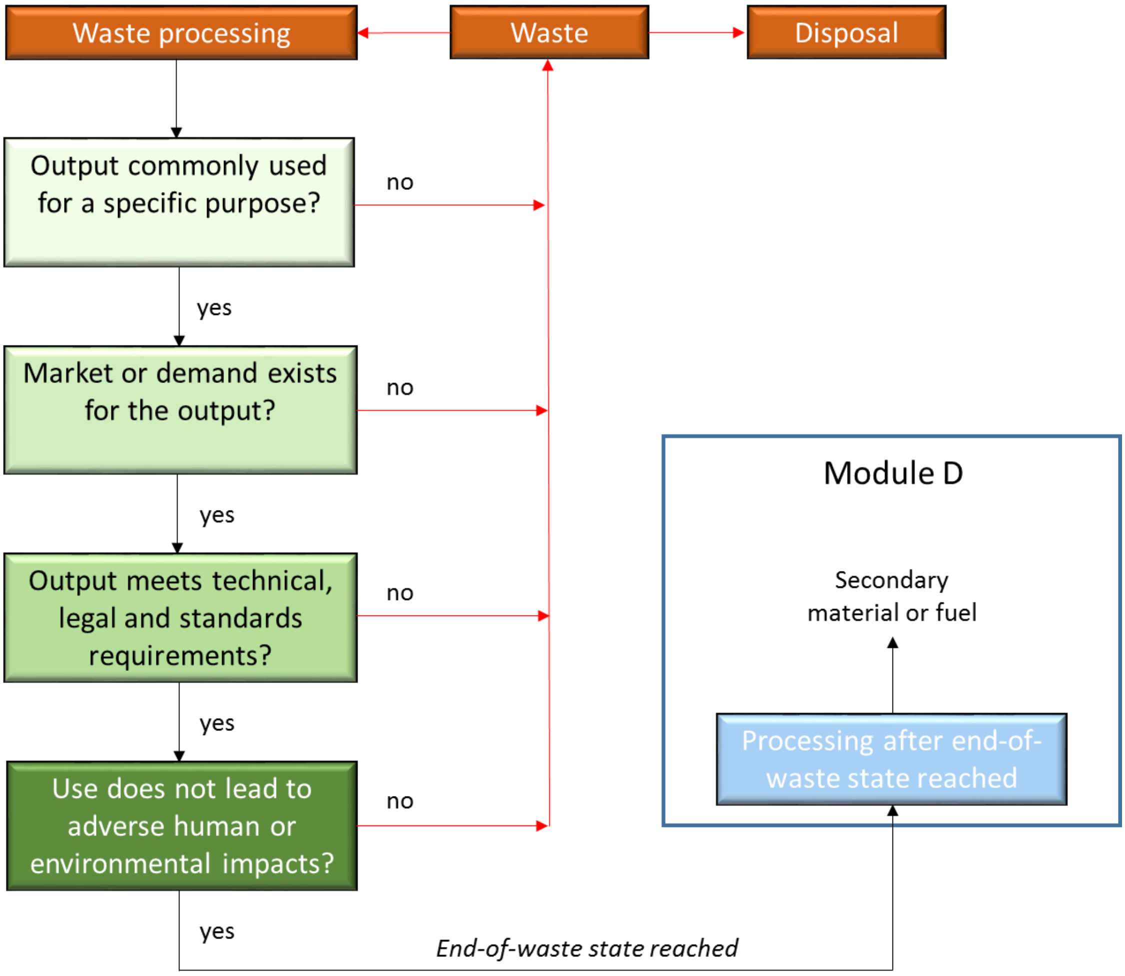

Figure 14. How the end-of-waste state is determined (based on CEN, 2013).

- Waste steel sheet separately sorted into a skip at the construction site (module A5) has a scrap value before it has left the construction site. Based on this, the subsequent transport to and processing of the steel sheet in an electric arc furnace would be modelled in module D (as positive figures), if calculated. The benefit of the provision of steel by this route is calculated according to the substitution of equivalent steel made at a blast furnace, the environmental impacts of which are subtracted.

  Allowance also needs to be given to the amount of scrap in the steel being recycled for which the benefit of recycling at end of life cannot be claimed. Thus if the steel being collected for recycling has a steel scrap content of 10% for example, the benefit of substituted primary steel would be applied to 0.9 kg in every kg collected.