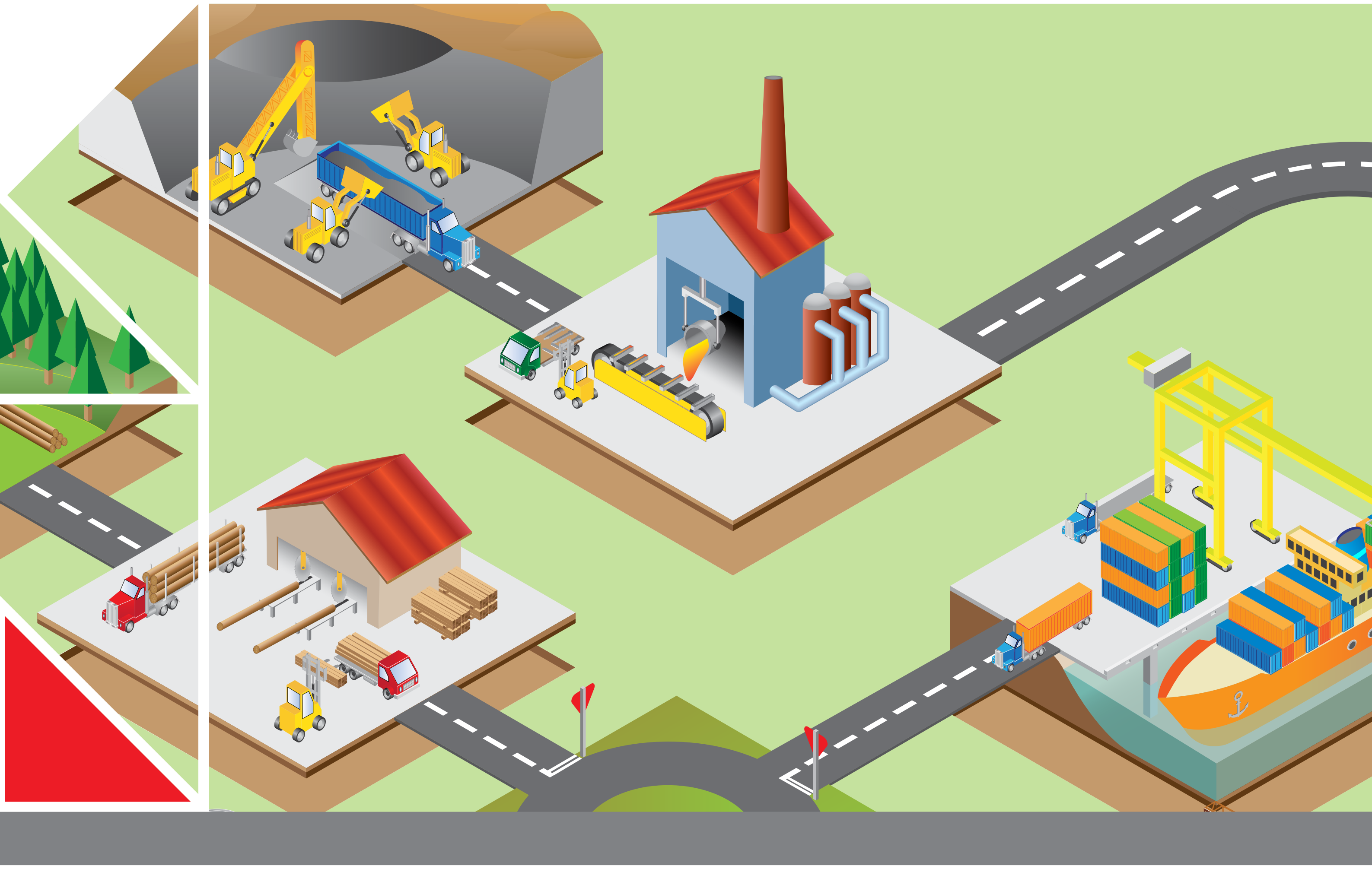
BRANZ

ISSUE608 BULLETIN



BUILDING LIFE CYCLE ASSESSMENT

April 2017

- Buildings can leave a significant legacy of unwanted environmental impacts.
- A building life cycle assessment provides quantified information on building environmental performance that can be compared to targets set by the client.
- This bulletin complements Bulletin 596 *An introduction to life cycle assessment*.

1.0 WHAT IS BUILDING LIFE CYCLE ASSESSMENT?

1.0.1 Building life cycle assessment (LCA) is a tool for calculating potential environmental impacts of buildings. It is particularly useful when applied early and iteratively during building design, so that environmental consequences of design choices can be tested, understood and refined.

1.0.2 LCA may be used in other applications as well. Facilities managers may use it to evaluate alternative options for plant and equipment, product manufacturers to understand their products' environmental impacts or tenants to understand the environmental impacts of alternative fit-out options. This bulletin focuses on application of building LCA in design only.

1.0.3 To carry out a building LCA, the building life cycle is divided into stages and modules (Figure 1). Within each module, key processes are identified where material and energy inputs and outputs such as wastes and emissions to air, water and soil are quantified. Based on these results, potential environmental impacts are then calculated.

1.0.4 The benefits of using building LCA in design include the following:

- It calculates potential environmental impacts across different areas of concern (such as environment, human health and natural resources), ensuring the user can make more informed and balanced decisions. Focus on a single environmental impact risks inadvertently increasing other potential environmental impacts.
- It considers the whole building life cycle. This reduces the risk that an environmental saving in one part of the life cycle is made at the expense of an increased impact in another part of the cycle.
- It quantifies potential environmental impacts rather than relying solely on proxy performance measures. For example, calculating energy use (in MJ or kWh) during building occupation provides a measure of energy demand but conveys no information about the potential environmental consequences of how this demand is supplied.

2.0 WHY USE BUILDING LCA WHEN DESIGNING BUILDINGS?

2.0.1 Internationally, there is a positive trend in the uptake of LCA in the construction sector. LCA is gaining popularity as a stand-alone building design aid and as a means of demonstrating environmental performance in building environmental rating schemes. In the Netherlands, it is incorporated as a regulatory tool within the national building code (Scholten & van Ewijk, 2013).

2.1 THE CASE FOR HIGH-PERFORMANCE BUILDINGS WITH LOWER ENVIRONMENTAL IMPACT

2.1.1 Studies in New Zealand and overseas (NZGBC, 2010; Newell, MacFarlane & Kok, 2011; Jones Lang LaSalle, 2011) have considered the benefits of higher-performance buildings with lower environmental impact compared to business as usual (BAU) buildings. Examples of the kinds of benefits that have been reported for office buildings include:

- lower operating and maintenance costs
- increased market value through lower operating cost and more satisfied tenants (up to a 30% increase)
- reduced risk through better coordination of the design-build process required by green design (which may save 2–5% in capital costs)
- increased employee satisfaction and productivity (0–20% productivity improvements in different studies)
- improved public image.

2.1.2 Incorporating building LCA early in the design process provides a means to define clear environmental targets for the design. The client can evaluate quantified, easily costed performance against these environmental targets during the design process.

2.1.3 To be most effective, this will ideally happen before design work starts. For example, in preparation for a first meeting with a potential client, a designer can prepare quantified environmental impacts for a BAU building of a similar size/function to the proposed project.

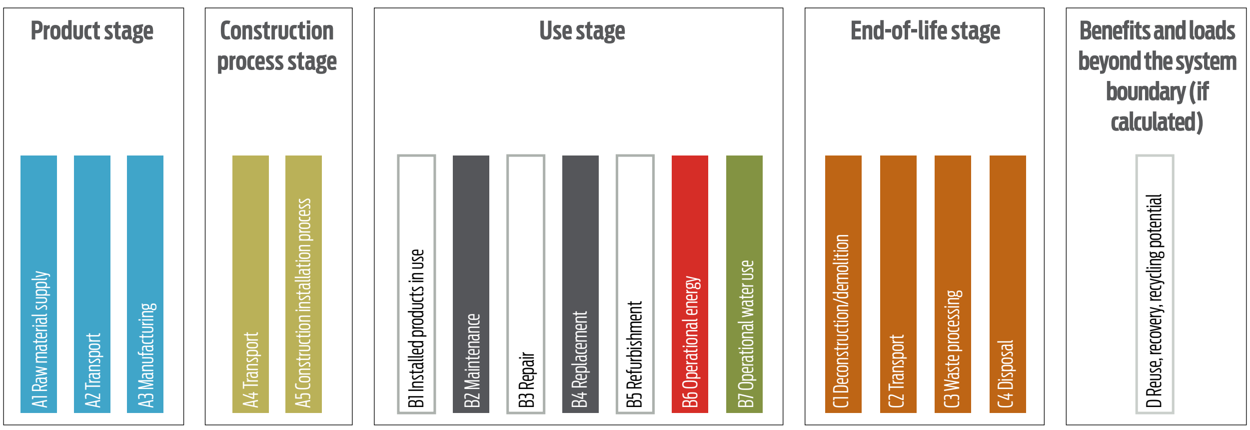


Figure 1. The life cycle of a building (based on EN 15978:2011 *Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method*).

2.1.4 From this early understanding, potential strategies for reducing BAU environmental impacts can be quantified, based on the client's needs and aspirations and any site and planning constraints.

2.1.5 Quantified environmental savings, compared to BAU, can be provided to the client throughout the design process. Together with capital cost and life cycle cost information, this allows the client to understand the implications of decisions and track progress towards targets.

2.2 BUILDING SECTOR NEEDS TO CONTRIBUTE TO PARIS AGREEMENT COMMITMENTS

2.2.1 In 2015, Prime Minister John Key and other world leaders met in Paris and agreed targets for reducing greenhouse gas emissions. New Zealand's ratification of the Paris Agreement committed the country to a 30% reduction in the 2005-level of greenhouse gas emissions by 2030.

2.2.2 The building sector is indirectly responsible for about 20% of New Zealand's energy-related emissions (Sims et al., 2016). These arise from direct consumption of fossil fuels for heating and cooking as well as use of fossil fuels that make up a proportion of grid electricity, used to power appliances and for heating, ventilation and cooling.

2.2.3 The Royal Society report shows a pathway to near and zero-carbon buildings through smart building design and use of low-carbon materials.

2.3 BUILT ENVIRONMENT IMPACTS ON WATER QUALITY

2.3.1 Our buildings and how we use them have environmental consequences in addition to climate change.

2.3.2 Water quality is one example. A study published in the *New Zealand Journal of Marine and Freshwater Research* (Larned et al., 2016) measured water quality at 900 sites around the country according to land use.

2.3.3 Key results are shown in Figure 2. The graphs (a), (b) and (c) show elevated levels of nitrogen, phosphorus and faecal bacteria in lowland streams affected by urban land use. These can affect the water's capacity to support life. Graph (d) provides an indicator of river ecosystem health as measured by the Macroinvertebrate Community Index (which measures the presence of insects, crustaceans, snails and worms based on their tolerance of nutrient enrichment). These and other results led the authors to conclude that "the current state of water quality in New Zealand lowland rivers is generally poor" and that "lowland river water-quality state is strongly influenced by urban land use".

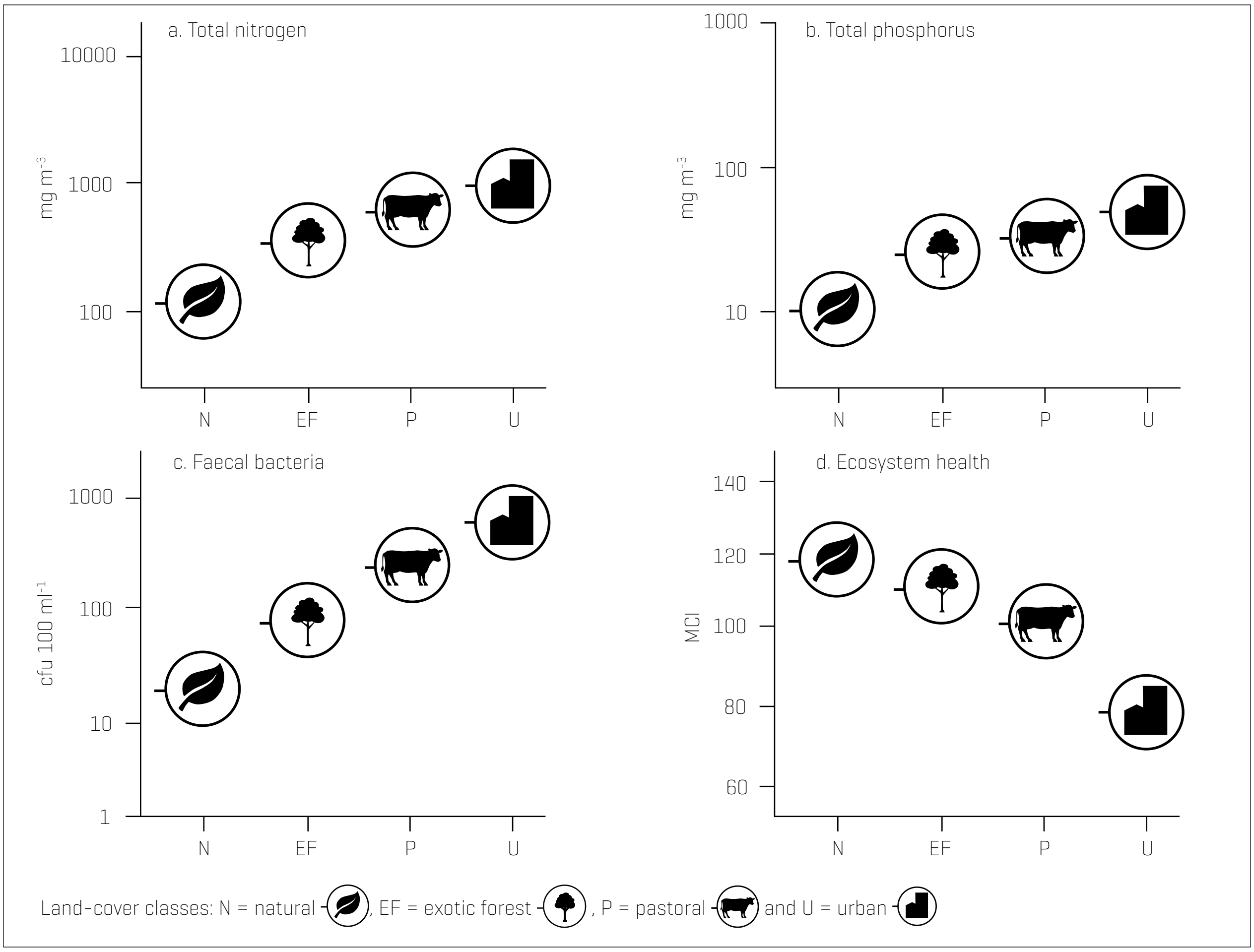


Figure 2. Median measurement of water quality at 900 monitoring points in New Zealand (based on Larned et al., 2016).

3.0 HOW BUILDING LCA CAN BE INCORPORATED INTO DESIGN

3.0.1 A designer proposing better environmental outcomes to a client at the proposal stage can result in:

- few measurable indicators to track environmental performance
- more money from the client and the need to spend this sooner.

3.0.2 However, incorporating building LCA into the design process provides environmental performance indicators that can be agreed with a client and subsequently measured and reported regularly during the design process.

3.0.3 For greatest effect, building LCA must be considered early. Designers using building information modelling (BIM) and building LCA may need to consider their fee structure to reflect more work in early design and less during documentation.

3.1 USING LCA BEFORE DESIGN

3.1.1 In the earliest discussion with a client, the designer can ask about their environmental goals to better understand the level of interest. This is also a time to explore whether the client wants a more formal environmental rating (such as Green Star or Homestar) and, if so, the desired rating.

3.1.2 When responding to a brief, the designer can choose an already developed reference building (see section 6.0) to provide a BAU design, with associated calculated life cycle environmental impacts. Based on information obtained during the initial contact, the designer can begin to develop possible strategies, with savings in environmental impacts compared to BAU. This will show the client how their environmental goals may be met. These should be costed so that the client understands the capital and life cycle costs in addition to the potential environmental savings.

3.2 USING LCA DURING DESIGN

3.2.1 During concept and preliminary design, preferred strategies identified before design can be incorporated and refined. Input from specialists is important to ensure that the appropriate level of simulation detail is used and accuracy achieved. For example, in energy modelling, simple geometry and thermal zoned box energy models that reflect the building geometry are useful for exploring the implications of site constraints. These can include overshadowing, orientation, form, location and size of windows and R-values of external walls.

3.2.2 Similarly, structural engineers can assess structural designs for environmental impacts and investigate alternative materials (for example, cement-replacement concrete instead of concrete made with ordinary Portland cement).

3.2.3 Table 1 shows the results of an analysis of structure and enclosure environmental impacts using concept design information compared with detailed design information for an Auckland office building (from BRANZ Study Report SR350). It shows that more than 90% of environmental impacts calculated at detailed design are covered, even with the imperfect information available at the concept design stage. Total primary energy is an expression of the total energy needed across the life cycle of a building, for example, to make and transport materials and supply energy to meet demand during occupation of the building. It does not reflect the impact of the supply of this energy.

TABLE 1. ENVIRONMENTAL IMPACTS CALCULATED WITH CONCEPT DESIGN INFORMATION COMPARED WITH DETAILED DESIGN INFORMATION.

Indicator (potential environmental impact)	Concept as a % of detailed
Climate change	94
Stratospheric ozone depletion	103*
Acidification	94
Tropospheric ozone formation	91
Eutrophication	93
Natural resources (minerals)	93
Natural resources (fossil fuels)	94
Total primary energy	98

* Implies an overestimation at the concept stage.

3.2.4 At client meetings, the design team can report progress against the client's targets. Other opportunities may be identified, quantitatively evaluated and incorporated into the design. If the project is seeking to use building LCA results in a submission for a building environmental rating such as Green Star (see section 4.0), the potential rating points can be calculated and reported to the client.

3.2.5 This process allows the client and designer to see measurable environmental outcomes during design. Figure 3(a) shows an example for climate change. Together with life cycle costing information in Figure 3(b), this allows the client to mitigate financial risks and allows purposeful decisions with known outcomes.

4.0 RECOGNITION OF BUILDING LCA IN GREEN STAR

4.0.1 The New Zealand Green Building Council's Green Star tool rates a building's performance across nine categories: energy, water, materials, indoor environment quality, transport, land use and ecology, management, emissions and innovation. The output is a star rating, where:

- 4 stars requires 45–59 points and is defined as best practice
- 5 stars requires 60–74 points and is defined as New Zealand excellence
- 6 stars requires 75+ points and is defined as world leadership.

4.0.2 Building life cycle assessment is recognised in the Green Star rating tool as a Materials Life Cycle Impacts Innovation Challenge and is worth up to 6 points (NZGBC, n.d.). A further maximum of 2 points is available for use of building products that have environmental product declarations – see BRANZ Bulletin 603. Points are awarded based on the extent of environmental impact reduction against six environmental impact categories of the designed building relative to a defined BAU building, calculated using building LCA.

5.0 THE NEW ZEALAND WHOLE-BUILDING WHOLE-OF-LIFE FRAMEWORK

5.0.1 The New Zealand whole-building whole-of-life framework has been developed to facilitate use of building LCA in New Zealand. Initial resources focus on assisting early design of office buildings (with residential available in 2018) and are available at www.branz.co.nz/buildingLCA. Resources on the framework may also be useful for evaluating other building types.

5.0.2 Building LCA requires:

- a consistent approach for modelling buildings using LCA
- data for use when modelling the building life cycle
- modelled reference or benchmark buildings for comparison.

5.1 A CONSISTENT APPROACH FOR MODELLING BUILDINGS USING LCA

5.1.1 International and European building sustainability standards provide guidance for building LCA. Building LCA undertaken for the Materials Life Cycle Impact Innovation Challenge in Green Star should be based on the European standard EN 15978:2011. The framework uses the description of the building life cycle in EN 15978:2011 (Figure 1).

5.2 DATA FOR USE WHEN MODELLING THE BUILDING LIFE CYCLE

5.2.1 There are four types of data required to model the building life cycle:

- Material quantities required as a result of the building design.
- Environmental impact data concerning materials

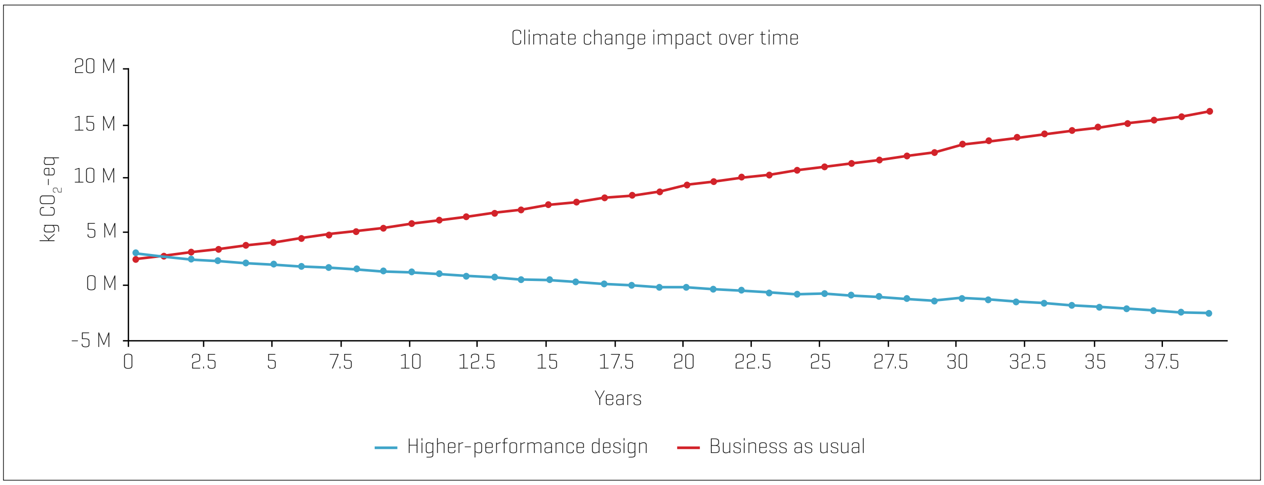


Figure 3(a). Calculated cumulative climate change impact of a building design (blue line) compared to BAU (red line).

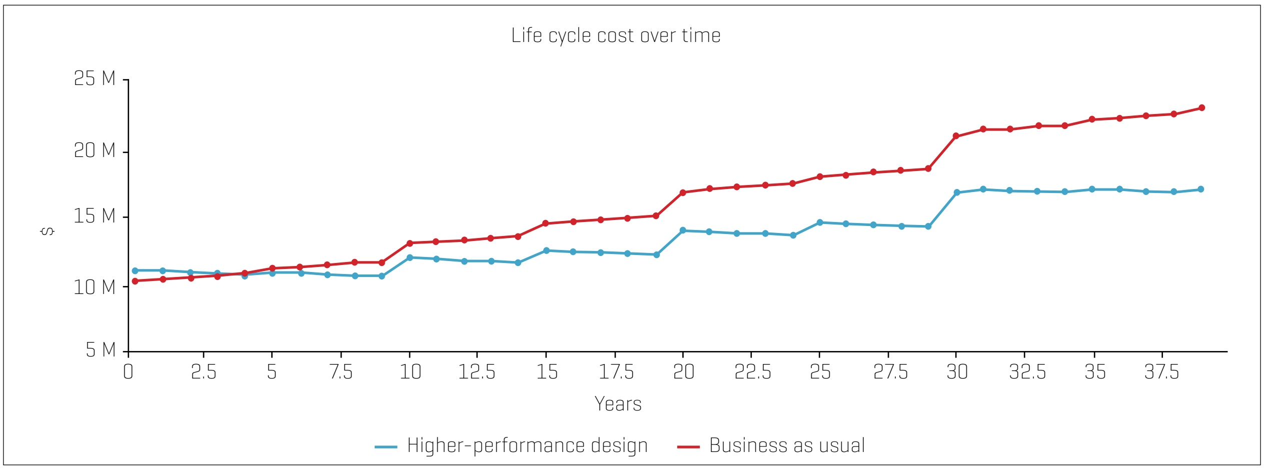


Figure 3(b). Calculated cumulative life cycle cost of a building design (blue line) compared to BAU (red line).

used in the building.
- Default data to inform modelling of the building life cycle.
- A consistent set of environmental impacts and basis for their calculation.

5.2.2 Material quantities may be obtained from a quantity surveyor's schedule of quantities or from a BIM model. When derived from a BIM model, the level of detail of BIM objects used in the BIM model and modelling approach must be sufficient to produce accurate material quantities. BRANZ Study Report SR350 and BRANZ YouTube videos provide information on how to model with BIM to obtain accurate material quantities, based on Berg (2014).

5.2.3 During early design, when branded products are less likely to have been decided, generic material **environmental impact data** can be sufficient to work from. Generic data on environmental impacts of structure and enclosure materials has been developed for the framework (see BRANZ Study Report SR350). Manufacturers can provide specific data for building LCA through development of environmental product declarations (EPDs), which provide robust, third-party verified LCA-based data and other environmental information for manufacture of construction products. The data may also include other life cycle stages. The Australasian EPD® Programme (www.epd-australasia.com) was established in 2014 and provides a means for construction product manufacturers and sector bodies in New Zealand and Australia to produce EPDs for their products. Specific data reported in these EPDs can be used in building LCAs.

5.2.4 Buildings are complex, long-lived products that incorporate multiple materials. For consistency, it is helpful to have **default data** available that can inform the building LCA. This saves time and effort for data collection and can be used to fill data gaps.

5.2.5 In early stages of design, these defaults can be sufficient. During the latter stages of design, when specific products are being selected, manufacturer-specific data from EPDs, if available, may replace default data. Specific data from manufacturers, in addition to manufacturing data, may also reflect initiatives at other stages of the life cycle that the manufacturer is involved in such as operation of a product stewardship scheme.

5.2.6 Default data has been developed to inform modelling of office buildings at early design (see BRANZ Study Report SR351). These include (with reference to relevant modules in Figure 1):
- transport of materials to construction sites in Auckland, Wellington or Christchurch (module A4)
- material wastage rates at construction sites, including end-of-life routes (module A5)
- office building service lifetime (use stage)
- maintenance of materials during the office building service life (module B2)
- replacement of materials during the office building service life (module B4)
- energy modelling during the office building service life (module B6)
- office building water consumption benchmarks (module B7)
- building end-of-life and routes for materials (module C1).

5.2.7 To compare and evaluate the environmental performance of buildings using LCA, a **consistent set of environmental impacts** calculated using the same methods needs to be used. Environmental impacts (listed in Table 1) and the methods for their calculation are recommended in BRANZ Study Report SR293. Potential environmental impacts for future inclusion in the framework are also set out.

6.0 MODELLED BUILDINGS FOR USE AS COMPARATORS IN BUILDING LCA

6.0.1 Reference buildings, modelled using building LCA, provide comparators that can be used during the design process to understand how a particular design is likely to perform environmentally.

6.0.2 A reference building may be defined by the design team before design, or a publicly available reference building may be used. The reference building must be carefully selected so that it provides a reasonable basis for comparison.

6.0.3 Ten reference office buildings have been developed as part of the framework. They:
- represent offices or commercial buildings that are mostly offices
- are physically located in either Auckland, Wellington or Christchurch – energy modelling for each building has been carried out for each of the Auckland, Wellington and Christchurch climate zones, providing 30 reference results
- are recently consented and built
- represent a mix of floor areas from 1,500 m^2 gross floor area (GFA) upwards
- represent the base build only, being the structure and enclosure, i.e. the building services and fit-out are not currently included.

6.0.4 Figures 4 and 5 provide example calculated life cycle environmental indicators for the reference office buildings using a 60-year building service life. The Figure 4 example is for climate change, Figure 5 for water quality. The key in each figure refers to modules in Figure 1. For a full set of indicators, see BRANZ Study Report SR350. Each reference office building is given a code made up of:
- Z1 (Auckland), Z2 (Wellington) or Z3 (Christchurch) – the climate zone in which the building is modelled
- Co (commercial office) or Cx (commercial mixed, with the majority of floor space being offices)
- S3 (1,500–<3,500 m^2 GFA), S4 (3,500–<9,000 m^2 GFA) or S5 (9,000 m^2 GFA or more) – the size class of the building
- a or b – different buildings with the same climate zone, use and size class.

6.0.5 Figure 4 reveals the following trends:

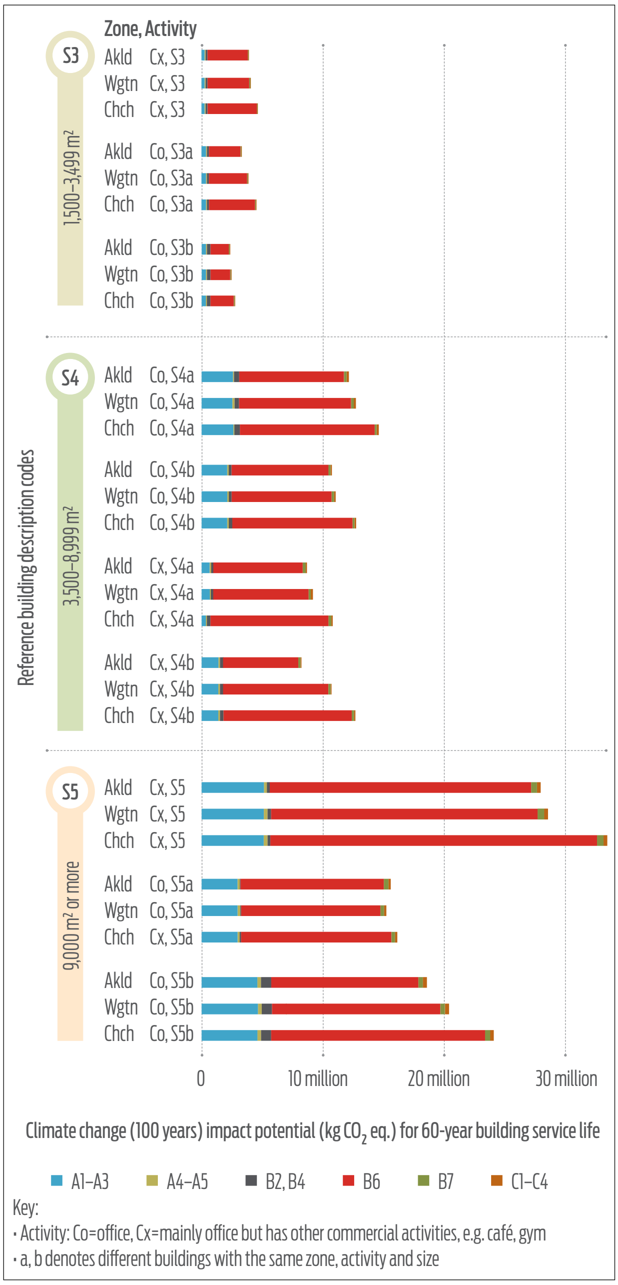


Figure 4. Total calculated potential climate change impact of reference office buildings.

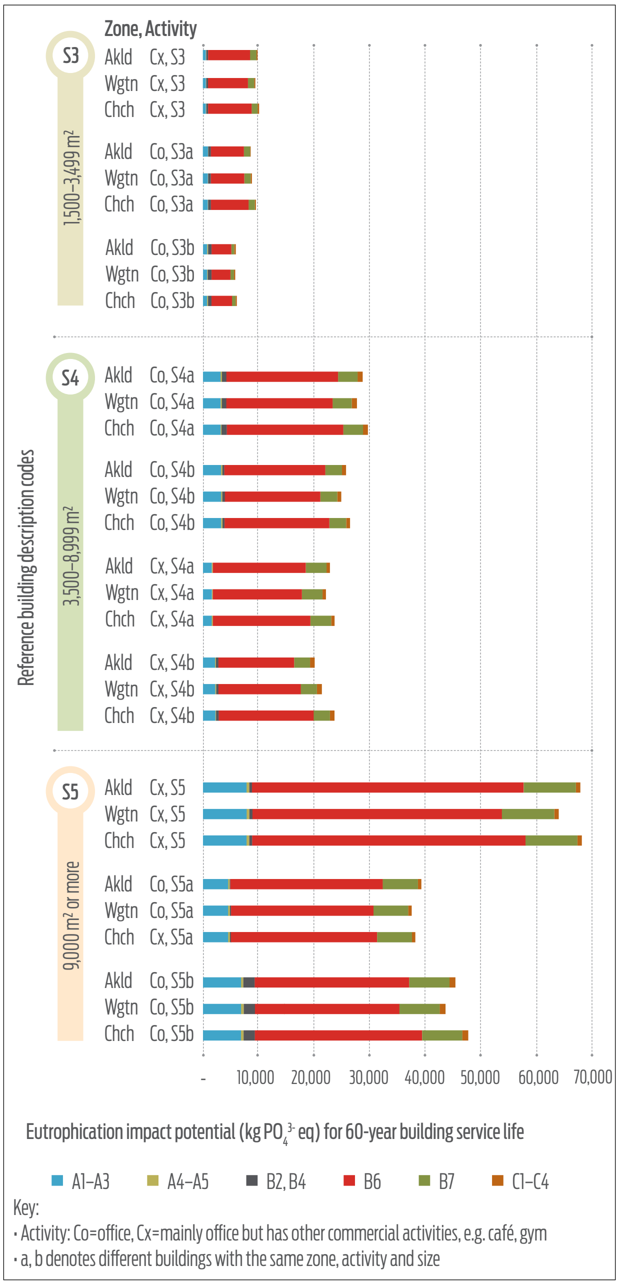


Figure 5. Total calculated potential eutrophication impact of reference office buildings.

- Operational energy use (i.e. the energy required during its use stage – see module B6 from Figure 1) makes the largest contribution (65–87%) to the climate change impact of the buildings. HVAC accounts for almost 40% of this and plug loads a further 28%.
- Materials production (modules A1–A3) also makes a significant contribution (7–25%).
- The calculated potential climate change impact is lower for Auckland office buildings and higher for Christchurch office buildings. This is primarily because of the greater demands for heating and cooling in Christchurch.
- Transport of materials and installation (modules A4–A5) and building end of life (modules C1–C4) make a relatively small contribution.
- The contribution of materials maintenance and replacement (modules B2 and B4) varies.

6.0.6 Figure 5 assesses impacts on water quality. Eutrophication may occur when excess nutrients are added to water (and, to a lesser extent, soil). The figure shows that energy use in occupation dominates this indicator, and materials production makes a significant contribution. Water use (module B7) also makes a significant contribution due to wastewater treatment.

6.0.7 Table 2 provides a summary of average potential environmental impacts calculated for the 10 reference office buildings. For more information about the reference office buildings, see BRANZ Study Report SR350.

7.0 TOOLS FOR CARRYING OUT BUILDING LCA

7.0.1 Undertaking a building LCA usually requires specialist software, due to the amount of data and numbers of calculations involved. Care should be taken when selecting building LCA software to ensure it provides indicators and units shown in Table 2 and contains New Zealand-relevant data. Most software requires licensing. These are some examples of tools available at the time of writing:

- ***LCAQuick – Office*** (New Zealand): *LCAQuick – Office* was developed by BRANZ as a free resource to help design teams better understand and begin to use building LCA. It is provided in Excel, considers office building structure and enclosure and comes with YouTube training videos, a help email address and LinkedIn forum. The tool embeds the framework and includes New Zealand data, as well as the 10 reference office buildings referred to above. It is designed for non-LCA experts who want to better understand building LCA and how to use it and is available for download at www.branz.co.nz/buildingLCA.
- **Athena Impact Estimator for Buildings** (North America): This free building LCA tool was developed and is maintained by the Athena Sustainable Materials Institute (ASMI) in North America. It focuses on the core-and-shell and can model over 1,200 structural and envelope assembly combinations. Data in the tool is focused on North America. ASMI also has other variants including the Athena EcoCalculator for Commercial Assemblies and the Athena EcoCalculator for Residential Assemblies. For more information, see www.athenasmi.org/our-software-data/overview.
- **eToolLCD** (Australia/global): eToolLCD was originally developed by eTool in Australia but is now finding application in Europe. It is an online software tool that is free to access for projects where it is used for non-commercial gain. On projects where the software is used for commercial gain, certification is required (covered by payment of a project fee), which also provides an independent review. eToolLCD can be used to carry out building LCA and life cycle costing using Australian costing data. For more information, see http://etoolglobal.com/.
- **Tally** (USA/global): Tally was developed by KT Innovations, thinkstep and Autodesk as a Revit plug-in application that quantifies the environmental impact of building materials and energy use. It currently reports environmental impacts based on the US TRACI framework. While this is not in line with impact assessment methods recommended in BRANZ Study Report SR293 or recognised in Green Star, it provides an indication of the building LCA results. For more information, see http://choosetally.com/.
- **IMPACT** (UK/global): IMPACT was developed by the Building Research Establishment (BRE) in the UK as a specification and database that is available for software developers to integrate building LCA, life cycle costing and BIM. eToolLCD (see above) is an example of an IMPACT-compliant tool. For more information, see www.IMPACTwba.com.

8.0 FURTHER INFORMATION AND REFERENCES

BRANZ BULLETINS

- Bulletin 596 *An introduction to life cycle assessment* www.branz.co.nz/BU596
- Bulletin 603 *Environmental product declarations* www.branz.co.nz/BU603

BRANZ STUDY REPORTS

The following study reports are available from www.branz.co.nz/study_reports:

- Study Report SR293 *New Zealand whole building whole of life framework: life cycle assessment-based indicators*

TABLE 2. AVERAGE POTENTIAL ENVIRONMENTAL IMPACTS OF ALL 10 NEW ZEALAND REFERENCE OFFICE BUILDINGS.

Indicator (potential environmental impact)	Unit	Value (per m^2 GFA. year)	Value (per m^2 NLA.year)
Climate change	kg CO_2 eq.	27.0	37.8
Stratospheric ozone depletion	kg CFC 11 eq.	0.0000007	0.0000009
Acidification	kg SO_2 eq.	0.12	0.17
Tropospheric ozone formation	kg C_2H_2 eq.	0.011	0.015
Eutrophication	kg PO_4^{3-} eq.	0.061	0.085
Natural resources (minerals)	kg Sb eq.	0.000074	0.000097
Natural resources (fossil fuels)	MJ (NCV)	206	271
Total primary energy	MJ (NCV)	496	651

NLA = net lettable area, NCV = net calorific value

- Study Report SR350 *New Zealand whole-building whole-of-life framework: Development of reference office buildings for use in early design*
- Study Report SR351 *New Zealand whole-building whole-of-life framework: Development of datasheets to support building life cycle assessment*

BRANZ MEDIA

The following videos are available on the Building LCA playlist at www.youtube.com/user/BRANZmedia/playlists.

Building LCA and its application:

- Building LCA: Building Services Applications
- Building Life Cycle Assessment: Introduction
- Building LCA: LCA & EPDs in Green Star NZ

***LCAQuick – Office* training videos:**

- Adapting Existing Revit Models for LCAQuick: Calculating Quantities from BIM Model
- Adapting Existing Revit Models for LCAQuick: Material Object & Classification Parameters
- Adapting Existing Revit Models for LCAQuick: Creating BIM Object Parameter Fields
- Adapting Existing Revit Models for LCAQuick: Adding Data to Fields
- Results Analysis
- Importing Modelling Results
- Modelling Tips and Tricks

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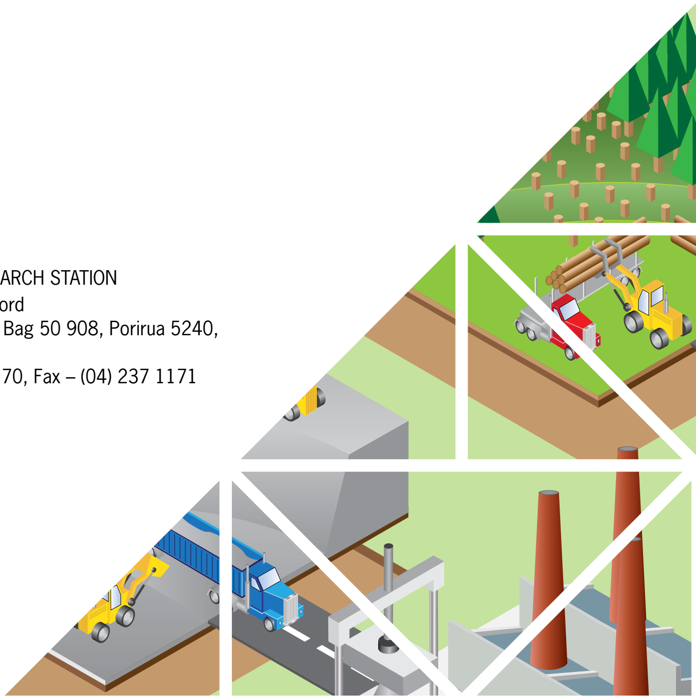
INSPIRING THE INDUSTRY TO PROVIDE BETTER BUILDINGS FOR NEW ZEALANDERS



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